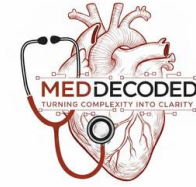


بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ



جانا



PHYSIOLOGY

وَلَقَدْ خَلَقْنَا الْإِنْسَانَ وَنَعَلَهُمَّا تَوْسُوسًا بِهِ نَفْسُهُ وَنَحْنُ أَقْرَبُ إِلَيْهِ مِنْ حَبْلِ الْوَرِيدِ

Physiology | Lecture 10

Neuronal Membrane Potential

Reviewed by :

Jana Sawafta
Amal Al-khatib



As discussed earlier, synapse is a junction between:

- Neuron and another neuron
- Or neuron and an effector cell (muscle or gland)

The **presynaptic** neuron is the sending cell which releases the neurotransmitters.

The **presynaptic** is always **axon terminal**.

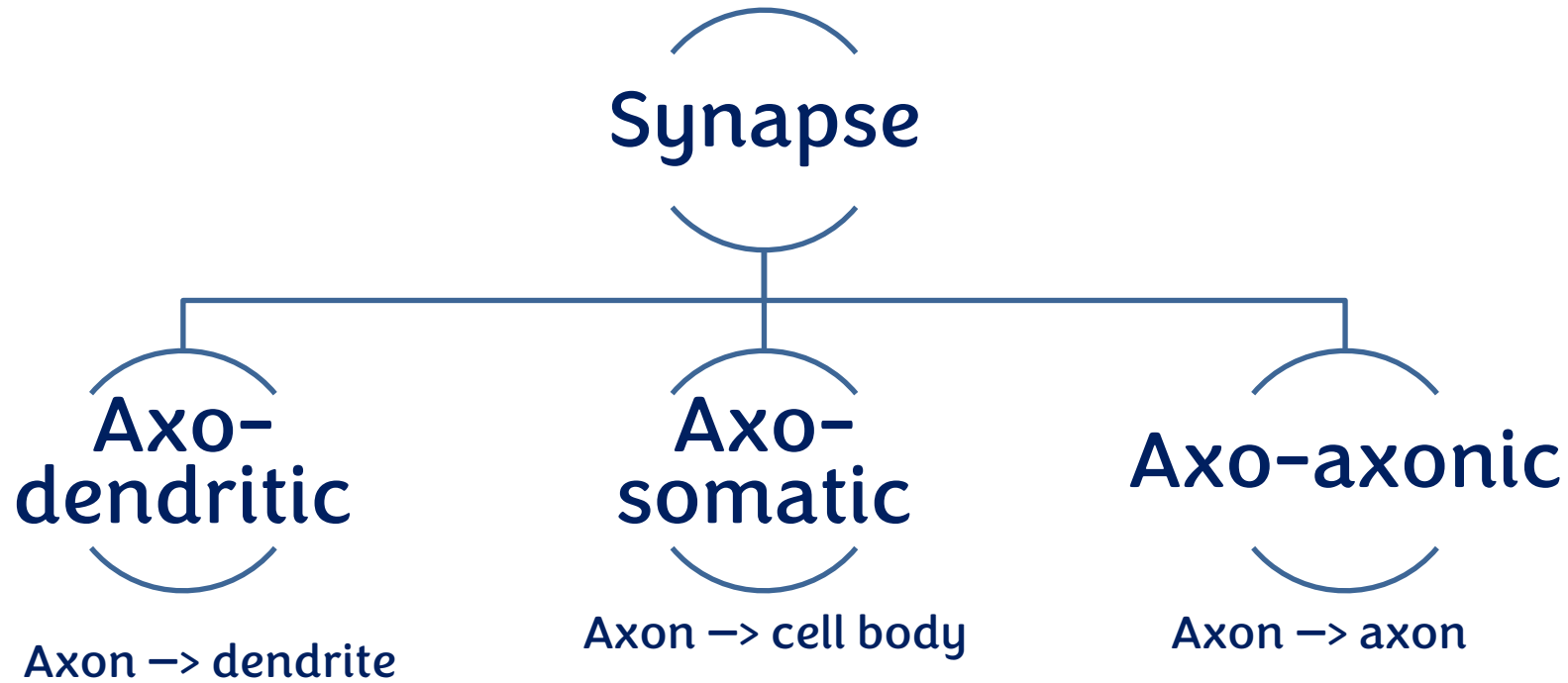
The **postsynaptic** cell is the receiving cell.

It can be:

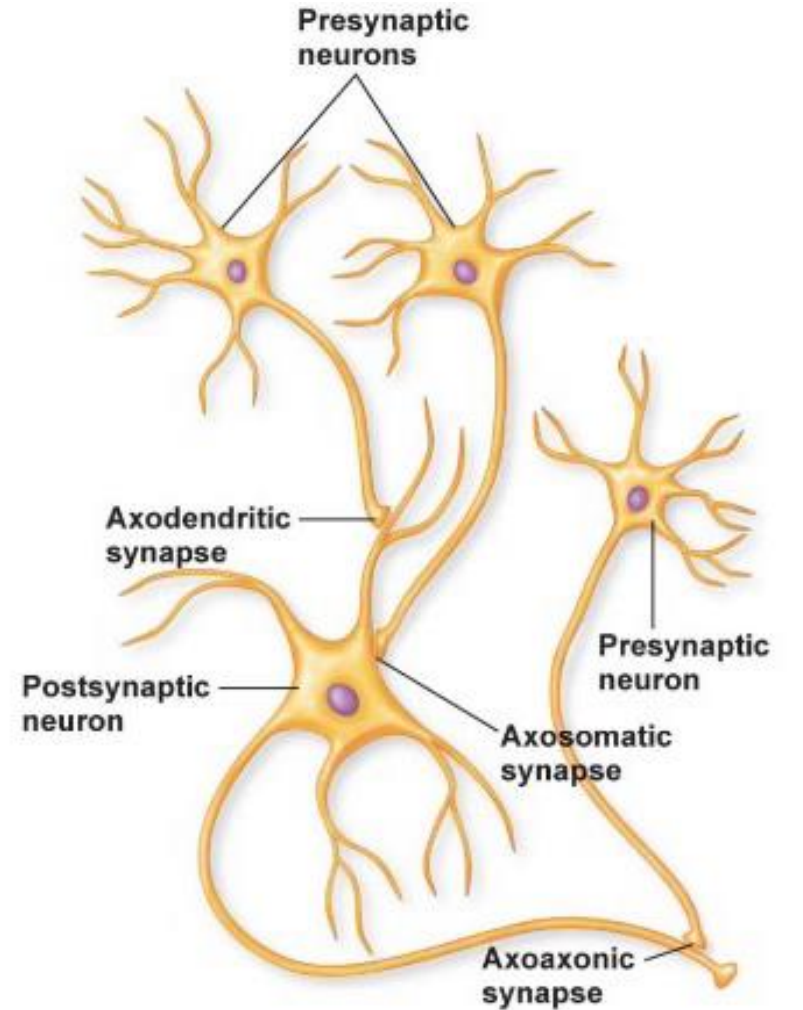
- **Dendrite**
- **Cell body (soma)**
- **Axon**

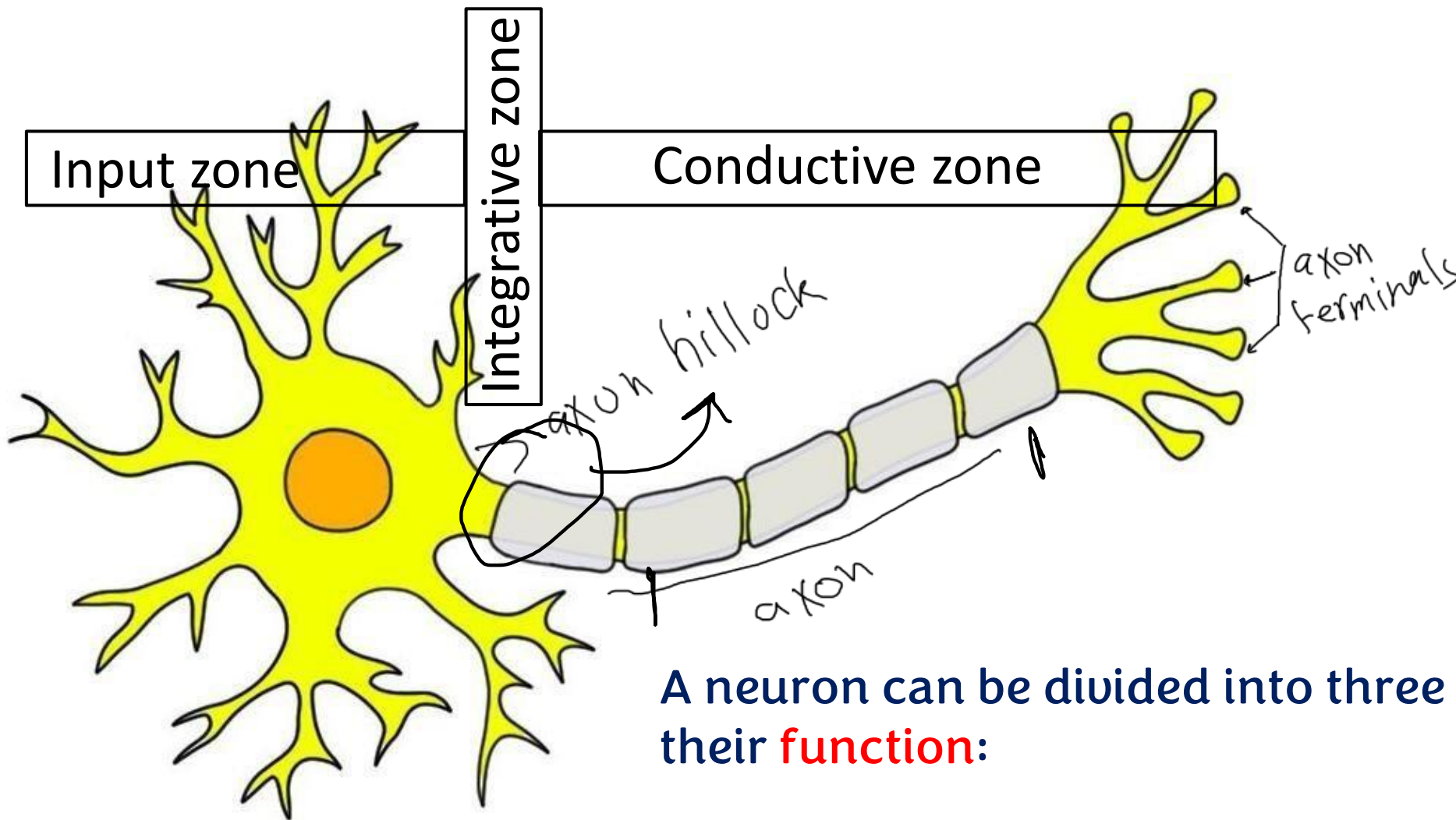
So, the action potential comes through the synapses from presynaptic either through the dendrites or the soma or maybe the axon of postsynaptic then it will propagate all the way through the axon into the axon terminals and now the signals will be transmitted again in the synapses with dendrites or the cell bodies of the postsynaptic neuron.

Synapses are classified based on the postsynaptic structure.



The most common type





A neuron can be divided into three parts based on their **function**:

- whereas the *input zone*, (which are the dendrite and the Soma) are the parts that receive input from other neurons

- Generation** of action potential takes place at the **axon hillock (initial segment of the axon)** that's why it's called **integrative zone**

- after the action potential is generated the conduction (transmission) will be propagated all through the axon until the terminals (conductive zone)

A neuron is an excitable cell that can generate electrical signals; therefore, it has a resting membrane potential.

During the resting state, there is a difference in electrical charge across the cell membrane between the intracellular and extracellular fluids.

If we used a voltmeter to measure the potential difference across the membrane in resting state, it would show a value called the resting potential.

The resting potential is always negative, due to several contributing factors. (Factors like Na^+/K^+ pump, leak channels, and ion concentrations all contribute to this negative potential) “The negative sign indicates that the inside of the neuron is more negative than the outside.”

((When the doctor gives us a value for resting potential, she might not say that it's minus, but I have to know that. So if she says that the resting potential is 65, I have to know that it's minus 65, not positive 65.))

Resting potentials vary among neuron types. For instance, a motor neuron typically has a resting potential of approximately -70 millivolts (mV).

This means that the difference in electrical potential across the cell membrane between the intracellular and extracellular environments is -70 millivolts (mV).

Being excitable means the neuron can respond to stimuli by *changing its membrane potential*. their resting membrane potential can change in two main ways:

- **Depolarization** – membrane potential becomes **less** negative
- **Hyperpolarization** – membrane potential becomes **more** negative.

Changes in the membrane potential happen because **ions flow across the neuron's membrane**. the lipid bilayer of the cell membrane is impermeable to ions. Therefore, ions cannot freely pass through the membrane; instead, they must move via specific ion channels.

The ions involved in generating and maintaining the membrane potential are both cations (positively charged) and anions (negatively charged). The most important ions are:

Sodium (Na^+) – a cation

Potassium (K^+) – a cation

Chloride (Cl^-) – an anion

These ions are distributed **unequally** between the intracellular and extracellular compartments:

Na⁺ (sodium) and Cl⁻ (chloride) are higher outside the neuron.

(Extracellular)

K⁺ (potassium) is higher inside the neuron. **(Intracellular)**

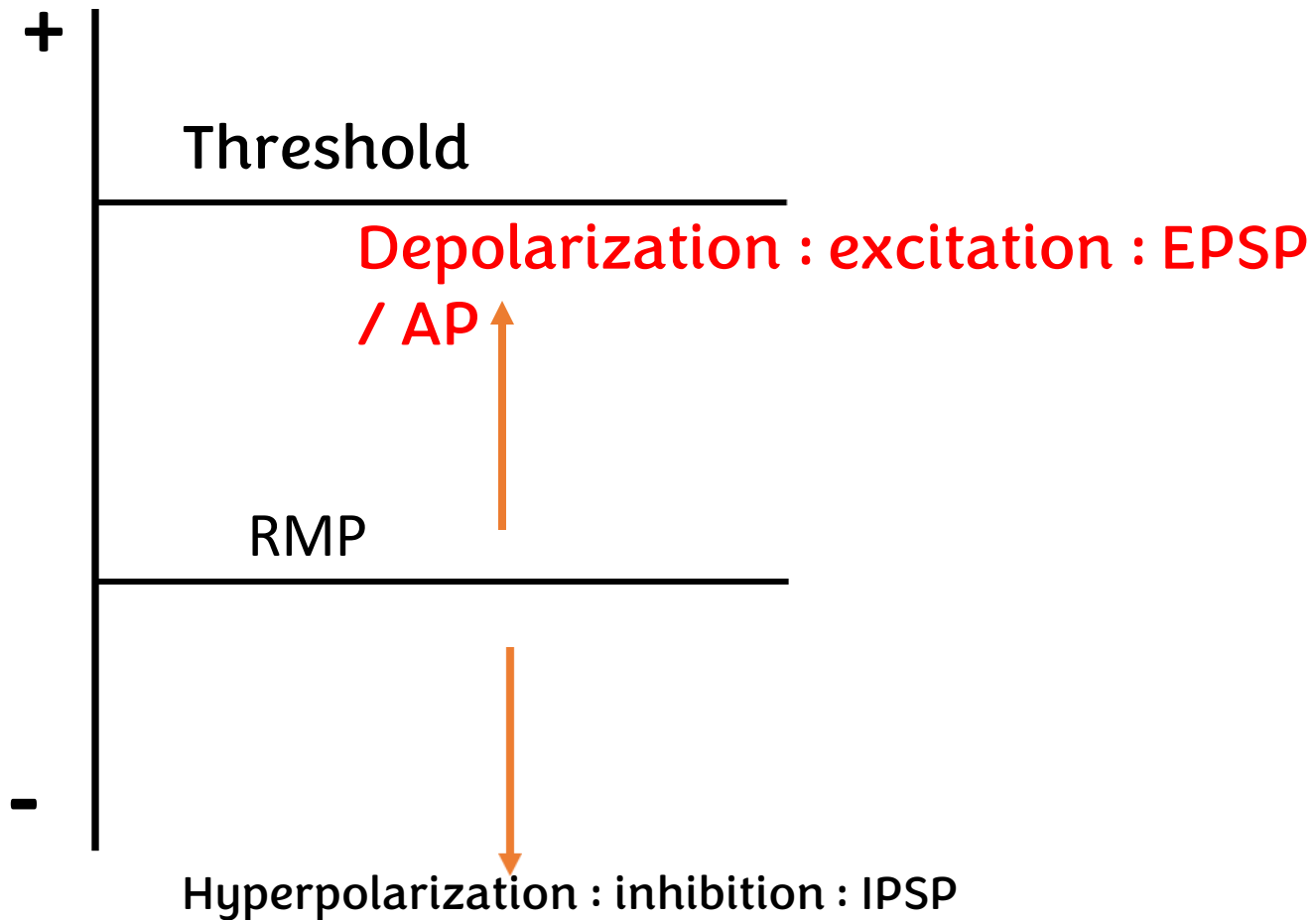
This distribution contributes to the negative resting membrane potential (~-70 mV).

If these ions are allowed to move (if ion channels open), they follow their concentration gradients:

Na⁺ and Cl⁻ → tends to flow into the cell (higher outside) **influx**

K⁺ → tends to flow out of the cell (higher inside) **outflux**

Basics of the membrane potential



Depolarization

is the process in which the membrane potential becomes **less negative** than the *resting potential*.

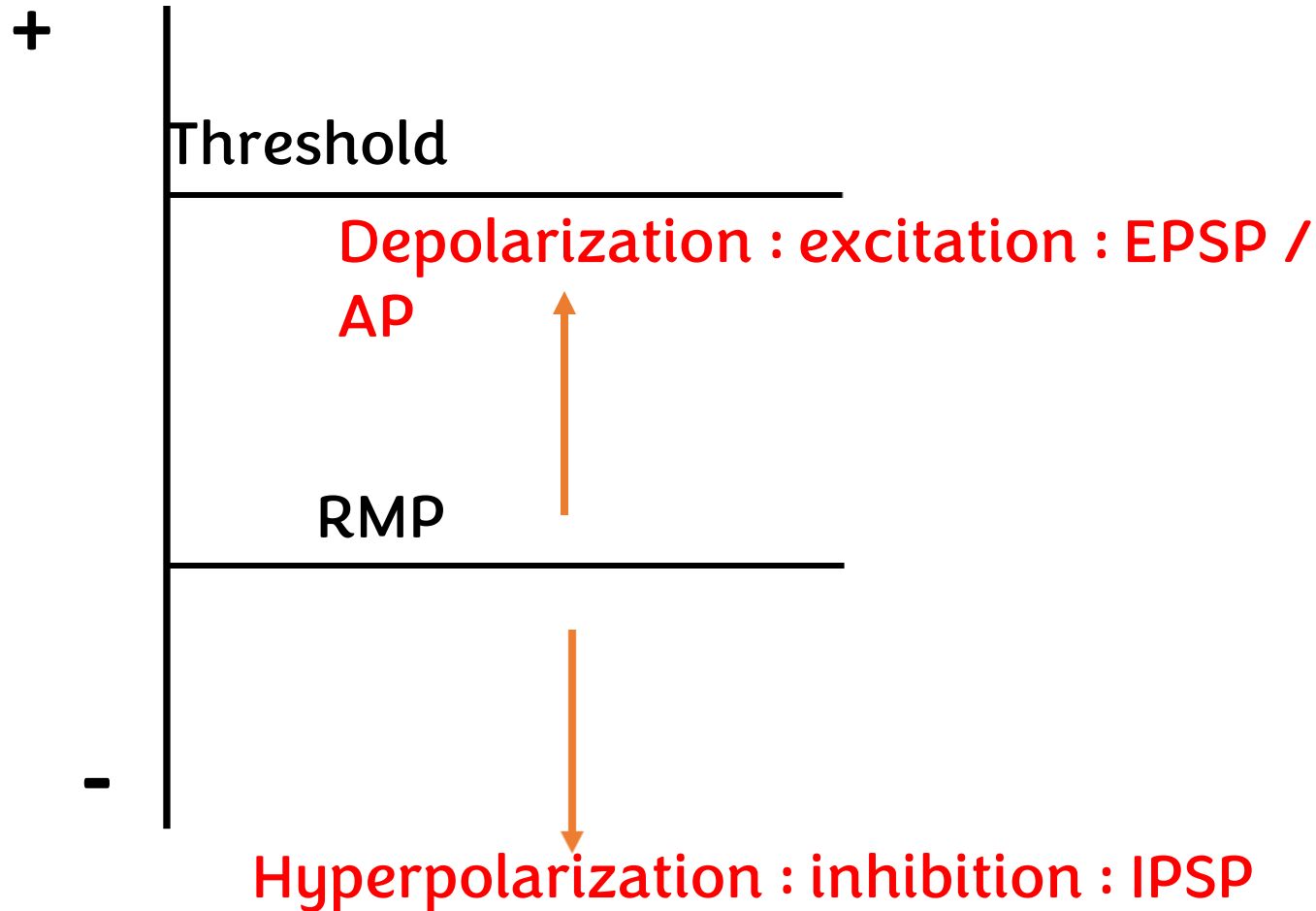
This reduces the difference in charge across the membrane, bringing it closer to zero (***depolarized state***), but not completely equal.

The *main signal* for depolarization is the **influx of sodium (Na^+)**. There are other contributing signals, but sodium influx is the most important.

As positive charges enter, the membrane potential becomes less negative (depolarization).

★ ★ ((The first Step of Action potential is the inflex of Na^+)) ★ ★

Basics of the membrane potential



Hyperpolarization:

Polarization means the difference in charge between the intracellular and extracellular spaces. When the membrane potential reaches zero, it means there is no polarization. That's why any signal that decreases the negativity and moves the membrane potential toward the positive side is called depolarization.

Hyperpolarization is caused by chloride influx and potassium efflux. Both of them increase the negativity inside the cell. This increases the distance from zero, which means it moves the membrane potential away from depolarization, increasing the polarity between the intracellular and extracellular spaces.

Depolarization happens when more positive ions, like sodium, enter the intracellular space. This decreases the negativity, and is mainly caused by sodium influx.

Depolarization leads to excitation of the neuron, while hyperpolarization causes inhibition of the neuron.

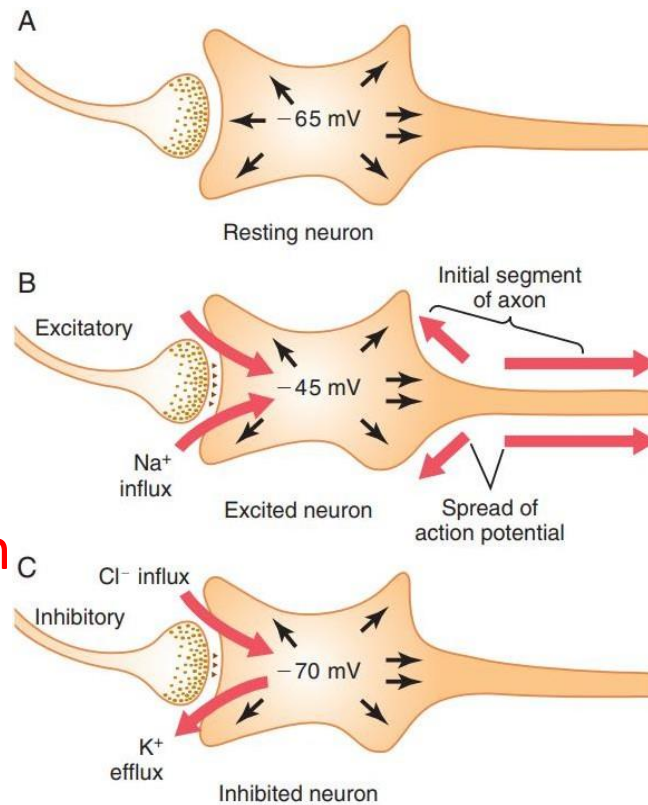
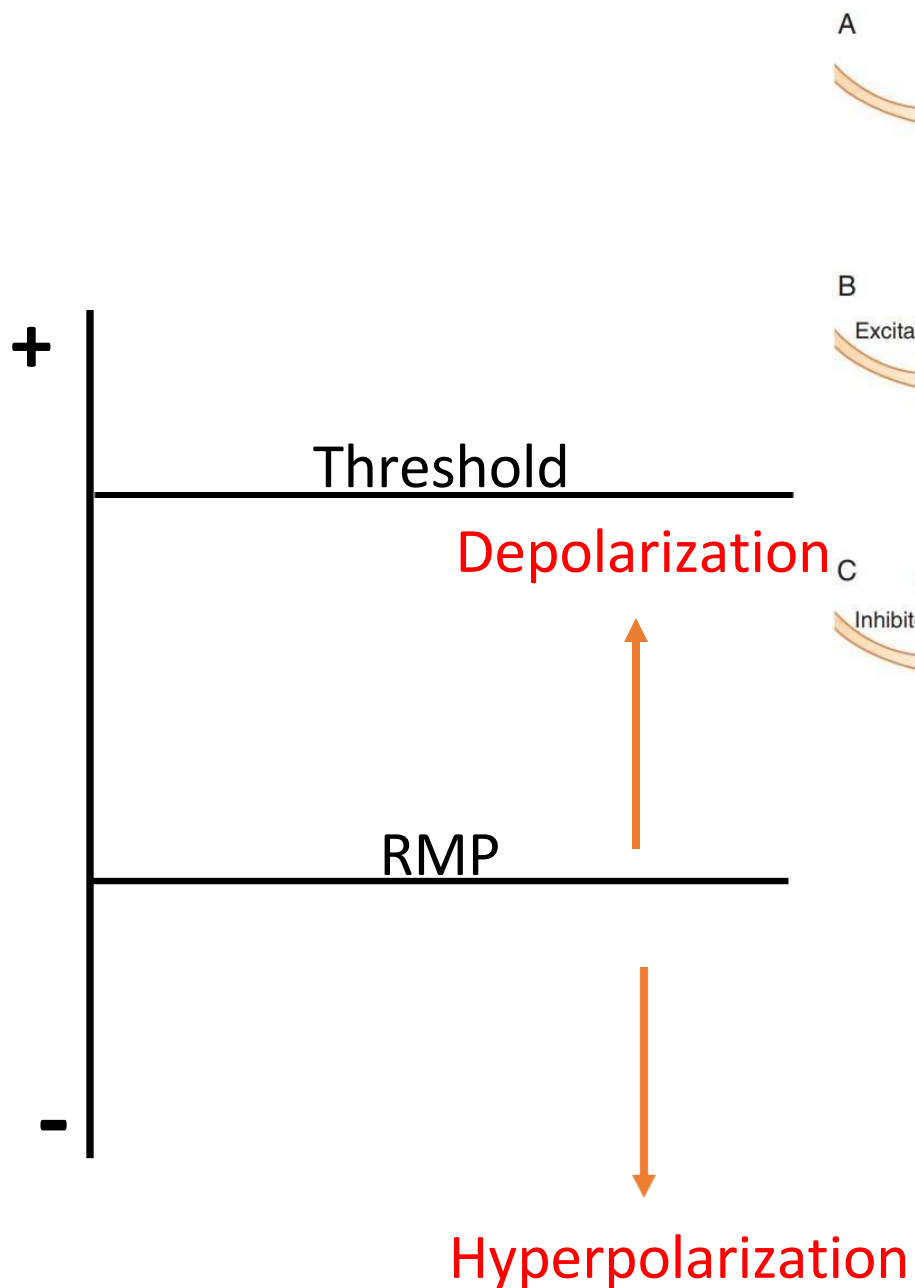
Depolarization effect is called excitation of the neuron because the ultimate goal of the neuronal cell is to fire an action potential. To allow the signal to be transmitted over a longer distance, the action potential is required, as it is propagative and the only type of membrane potential change that can travel over long distances. To make an action potential take place, there must be a threshold, which is a specific membrane potential in a specific neuronal cell. Once the membrane potential reaches this threshold, the action potential will fire. At that point, there will be activation of voltage-gated channels.

When a depolarization occurs – mainly by sodium ion influx – and brings the membrane potential closer to the threshold, this excites the neuron. If the membrane potential does not reach the threshold, it is called a sub-threshold stimulus.

This sub-threshold change still causes excitation in the post-synaptic neuron, producing a change in the membrane potential of the post-synaptic neuron. This change is called an excitatory post-synaptic potential (**EPSP**). If the membrane does reach the threshold, it results in an action potential, which occurs by depolarization of the membrane, mainly due to sodium influx.

On the other hand, if there is chloride influx or potassium efflux, this causes hyperpolarization, which moves the membrane **away** from the threshold, thus inhibiting the membrane. This results in an inhibitory post-synaptic potential (**IPSP**).

These concepts are very important to understand the function and changes within the nervous system.



This neuron, during the resting state, has a resting membrane potential of minus 65 millivolts. Assume there is a trigger that causes an influx of sodium ions (from A to B). This leads to a change in the membrane potential toward depolarization, and the neuron becomes excited. The excitatory potential is the change (the difference) in a neuron's membrane potential which makes it more likely to fire an action potential.

(In this example it is +20 ... from -65 to -45) If this depolarization is strong enough to reach the threshold, then an action potential will fire. If not, the change will stay localized as an excitatory postsynaptic potential (EPSP), which is a type of graded potential.

If the trigger causes an influx of chloride ions or an efflux of potassium ions, this will change the membrane potential as well. In this case, it causes hyperpolarization, making the membrane potential more negative, and inhibiting the neuron. (From A to C)

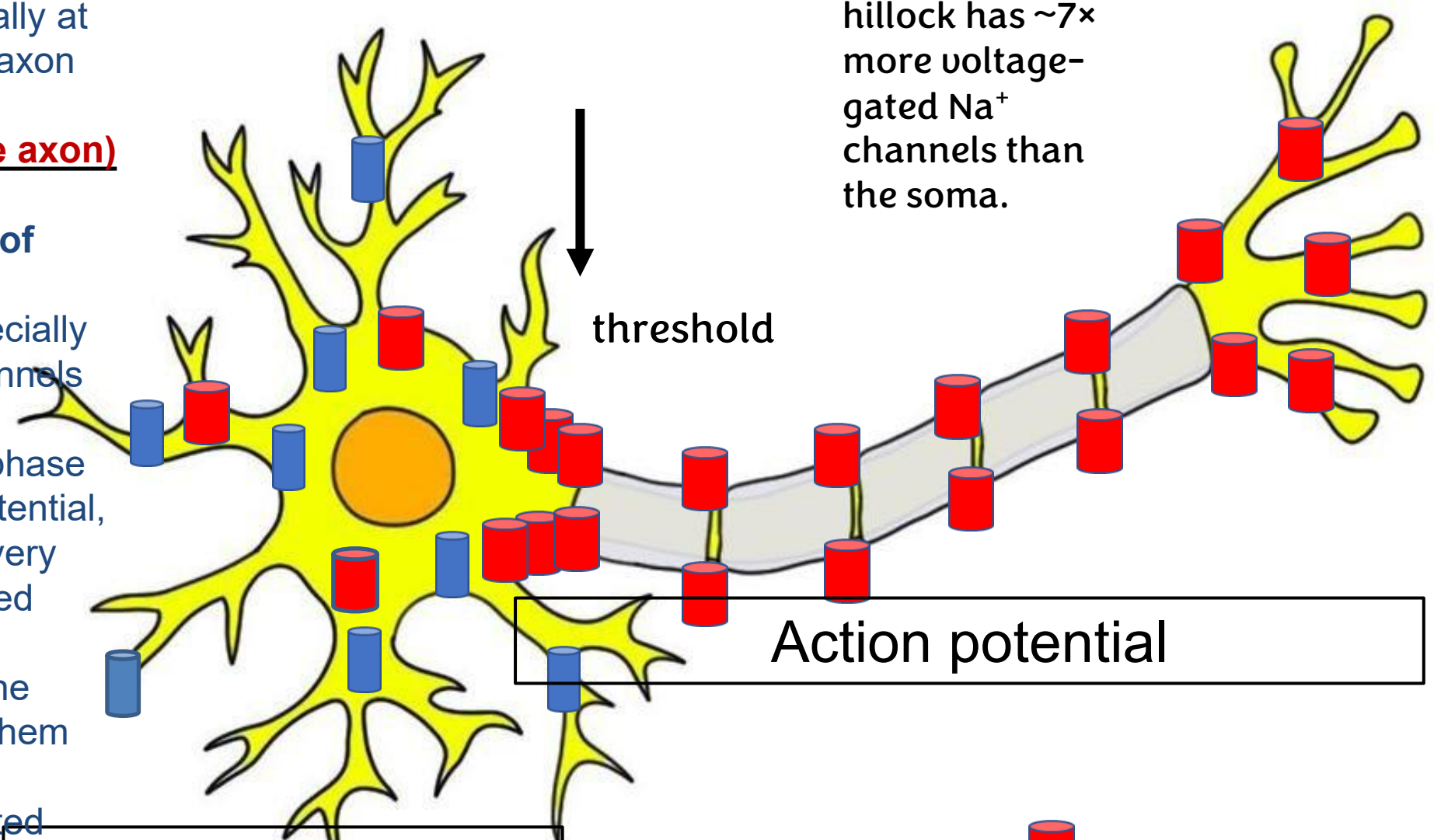
(The inhibitory potential is -5... from -65 to -70)

Resting membrane potential

- The basic cause of the change in membrane potential is a change in membrane permeability of the neuron, which allows ions to diffuse more or less readily through the membrane and thereby to change the membrane potential.

The reason why the generation of action potential is usually at the level of the axon hillock (**initial segment of the axon**) is the **high concentration of voltage gated channels**, especially the sodium channels that will do the depolarization phase of the action potential, while we have very few voltage gated channels in the dendrites and the soma, most of them are ligand or “chemically” gated channels.

The axon hillock has ~7× more voltage-gated Na⁺ channels than the soma.



Postsynaptic potential (PSP)

Action potential

Voltage gated channels
Ligand gated channels

In neurons, graded potentials and action potentials are two types of changes in membrane potential. Graded potentials occur in the dendrites and soma. They do not necessarily reach the threshold, and their magnitude varies depending on the strength of the stimulus. In general, graded potentials can be either depolarization or hyperpolarization.

Graded potentials are named based on their location:

- In sensory receptors, they are called receptor potentials.
- In postsynaptic neurons, they are called postsynaptic potentials (PSPs), which can be:
 1. Excitatory (EPSP) → depolarization
 2. Inhibitory (IPSP) → hyperpolarization

If graded potentials summate and reach the threshold at the axon hillock, an action potential is generated. The action potential is then propagated along the axon toward the axon terminals for long-distance communication. For example, a sensory signal like pain from the skin (e.g., the foot) can travel all the way to the brain through action potentials.

Action potentials propagate through voltage-gated ion channels distributed along the axon.

Unlike graded potentials, action potentials follow the all-or-none principle, which means:

- If the stimulus does not reach threshold → no action potential is generated
- If the stimulus reaches threshold → a full action potential occurs (same strength every time)

So, the strength of the stimulus does not change the size of the action potential, but it can change the frequency of action potentials.

Action potentials are responsible for rapid, long-distance communication in the nervous system.

Graded potential vs Action potential

Comparison of Graded Potentials and Action Potentials in Neurons

CHARACTERISTIC

GRADED POTENTIALS

ACTION POTENTIALS

Origin

Arise mainly in dendrites and cell body.

Arise at trigger zones and propagate along axon.

A graded potential can be called a receptor potential or an end-plate potential, depending on the site in the cell where the change in the electrical signal begins.

In contrast, an action potential is always called an action potential. You may specify it as a neural action potential or a muscular action potential, but it is still referred to as action potential.

because these are the sites where the incoming signals arrive.

AP starts at a specific site in the axon called the trigger zone or the axon hillock, and then propagates through the neuron.

Nerve impulse is the second name of action potential.

Graded potential vs Action potential

Comparison of Graded Potentials and Action Potentials in Neurons

CHARACTERISTIC

GRADED POTENTIALS

ACTION POTENTIALS

Origin

Arise mainly in dendrites and cell body.

Arise at trigger zones and propagate along axon.

Types of channels

Ligand-gated or mechanically-gated ion channels.

Voltage-gated channels for Na⁺ and K⁺.

Channels lead to changes in the membrane potential.

It has few voltage gated channels but they are not enough to generate an action potential.

In the initial phase of the action potential, voltage-gated sodium channels are used first, followed by the activation of potassium channels.

Graded potential vs Action potential

Comparison of Graded Potentials and Action Potentials in Neurons

CHARACTERISTIC	GRADED POTENTIALS	ACTION POTENTIALS
Origin	Arise mainly in dendrites and cell body.	Arise at trigger zones and propagate along axon.
Types of channels	Ligand-gated or mechanically-gated ion channels.	Voltage-gated channels for Na ⁺ and K ⁺ .
Conduction	Decremental (not propagated); permit communication over short distances.	Propagate and thus permit communication over longer distances.

A graded potential can't travel over a long distance; it is localized, so it acts only over a short distance.

For example, if it occurs in the dendrites, it will act there and may reach the soma.

If it occurs in the soma, it will act locally within the soma, but it cannot transmit on its own into the axon or reach the terminal – unless it reaches the threshold and becomes an action potential.

An action potential is called a propagative type of electrical signal, because it can travel long distances. In contrast, conduction in the graded potential is decremental, meaning it decreases and dies out over short distances, whereas the action potential maintains the same change in membrane potential throughout its propagation.

Graded potential vs Action potential

Comparison of Graded Potentials and Action Potentials in Neurons

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Conduction	Decremental (not propagated); permit communication over short distances.	Propagate and thus permit communication over longer distances.
Amplitude (size)	Depending on strength of stimulus, varies from less than 1 mV to more than 50 mV.	All or none; typically about 100 mV.

the stronger the stimulus, the greater the amplitude of the change in the membrane potential.

no matter what the strength of the stimulus is, it follows the all-or-none principle, so it always has the same amplitude.

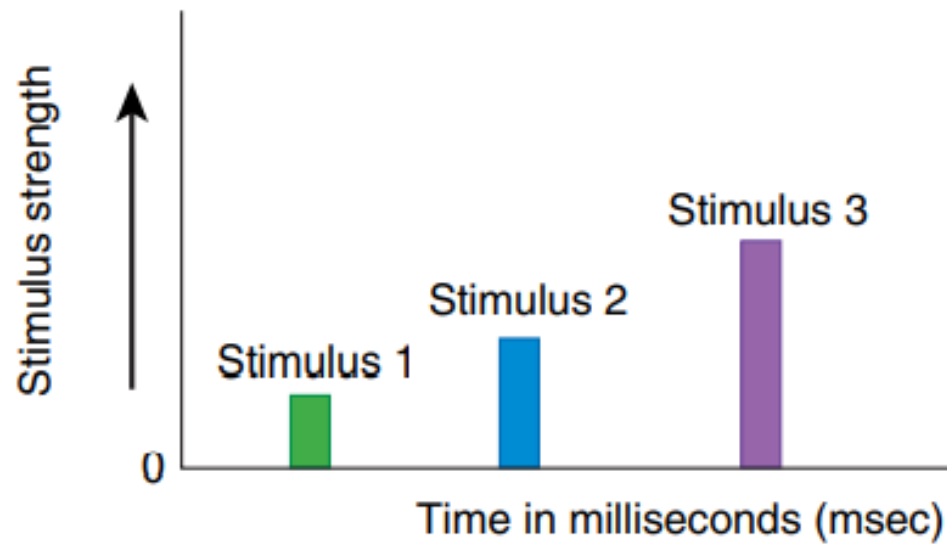
The amplitude of a graded potential depends on the stimulus strength. The greater the stimulus strength, the larger the amplitude of the graded potential.

the stronger the stimulus, the greater the amplitude of the graded potential.

This figure shows the effect on the membrane potential of this neuron resulting from the stimuli.

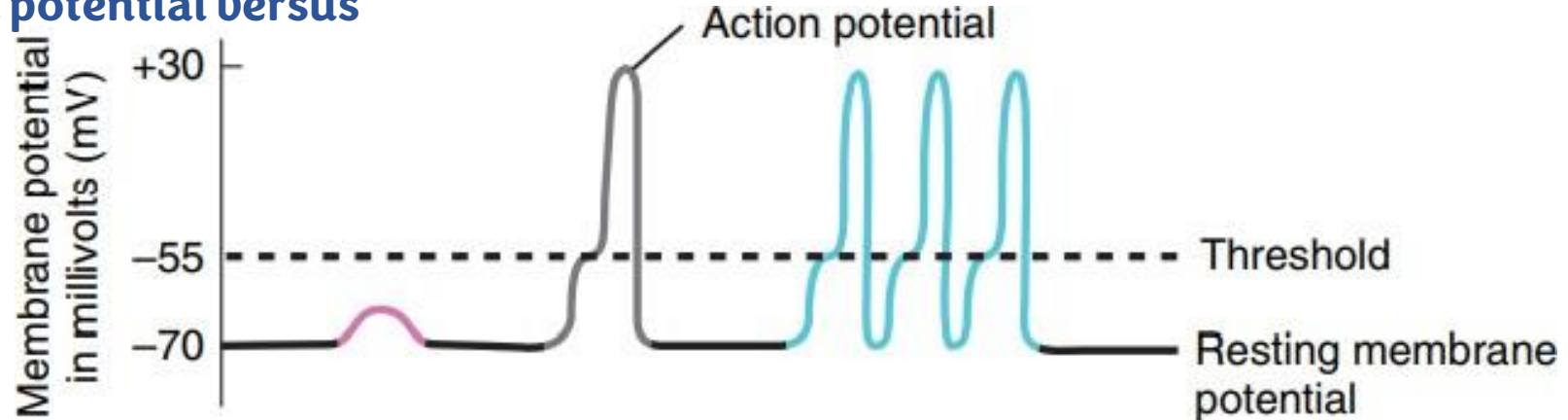


The figure shows three types of stimuli, each with a different strength.

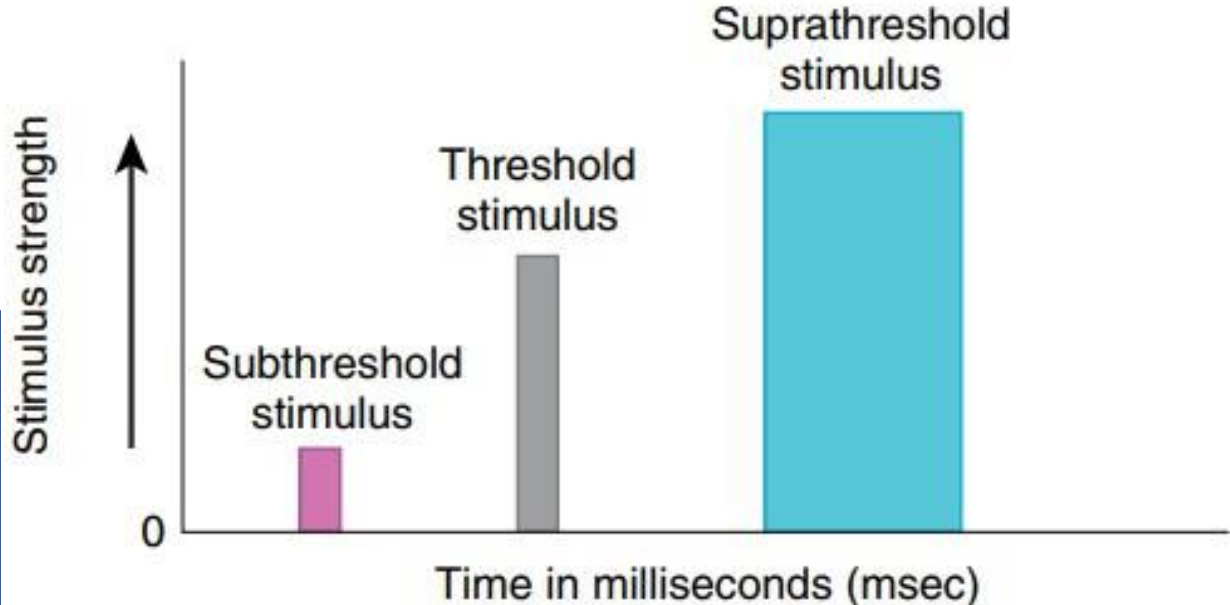


Stimulus 1, the weakest stimulus, changes the membrane potential by, let's say, 5 millivolts.
Stimulus 2 is stronger than stimulus 1, so it increases the amplitude of the change in the membrane potential, let's say, by 10 millivolts.
Stimulus 3, the strongest stimulus, causes a larger change in magnitude, let's say 12 millivolts.

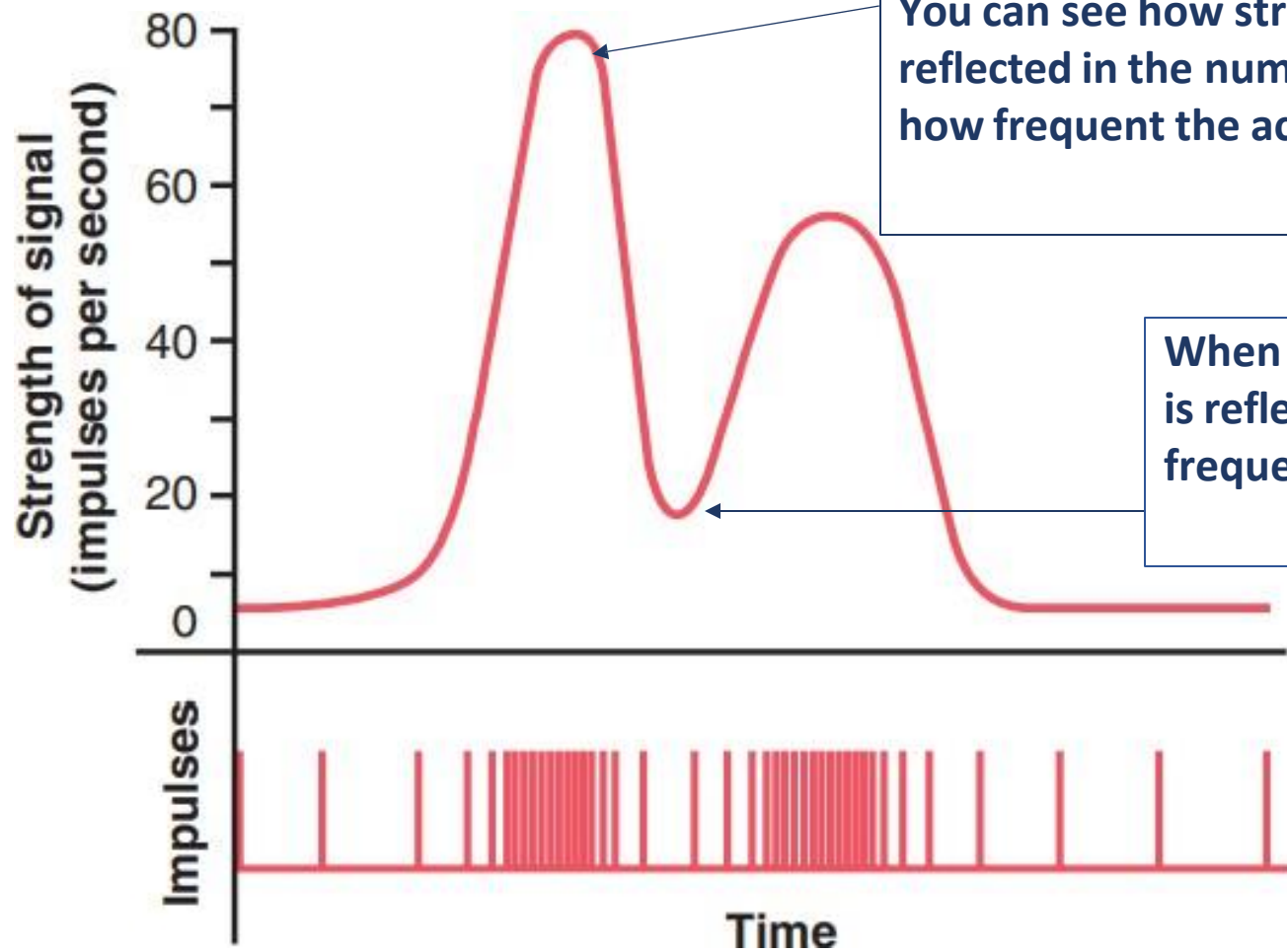
-This shows how the amplitude changes in graded potential versus action potential.



A sub-threshold stimulus is called like this because it does not reach the threshold, so it does not trigger an action potential



A supra-threshold stimulus does not increase the amplitude of the action potential, because the action potential follows the all-or-none principle → it either occurs or it doesn't. However, as you can see, a stronger stimulus – a supra- threshold stimulus – may cause an increase in the frequency of action potential firing(to a limit), but not an increase in its amplitude.



You can see how strong the stimulus is, and this will be reflected in the number of action potentials — that is, how frequent the action potentials are firing.

When the stimulus decreases, this is reflected by a decrease in the frequency of action potential firing.

If you increase the strength of the signal between 40 and 80, still there will be no change in the frequency of firing of action potential since the normal frequency is the frequency founded at the initial and the final state in the diagram, however in the middle state of the diagram, the frequency increases meaning it's a superficial stimuli, so basically after 40 no matter how much the intensity of the stimulus is there will be no increase in the firing of the action potential due to the refractory period

Superficial stimuli : refer to external, often sensory, inputs applied to the surface of the body, such as the skin or mucous membranes. These stimuli are used to trigger specific physiological reflexes, provide sensory feedback, or therapeutically influence bodily functions, particularly in neurological and rehabilitative contexts

Graded potential vs Action potential

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Conduction	Decremental (not propagated); permit communication over short distances.	Propagate and thus permit communication over longer distances.
Amplitude (size)	Depending on strength of stimulus, varies from less than 1 mV to more than 50 mV.	All or none; typically about 100 mV.
Duration	Typically longer, ranging from several milliseconds to several minutes.	Shorter, ranging from 0.5 to 2 msec.

AP is shorter because the voltage-gated channels act very fast. You can see the spike-like shape, and then it returns back within about 0.5 millisecond, up to a maximum of 2 milliseconds.

Graded potential vs Action potential

Comparison of Graded Potentials and Action Potentials in Neurons

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Duration	Typically longer, ranging from several milliseconds to several minutes.	Shorter, ranging from 0.5 to 2 msec.
Polarity	May be hyperpolarizing (inhibitory to generation of action potential) or depolarizing (excitatory to generation of action potential).	Always consist of depolarizing phase followed by repolarizing phase and return to resting membrane potential.

In a graded potential, the stimulus can cause either a depolarization effect or a hyperpolarization effect. This is important when we talk about the sensory nervous system, as certain sensory receptors produce hyperpolarizing potentials, while action potential always cause only depolarizing potentials followed by repolarizing phase

In both cases, these signals are important for the central nervous system, and they will be decoded as different signals.

Graded potential vs Action potential

Comparison of Graded Potentials and Action Potentials in Neurons

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Polarity	May be hyperpolarizing (inhibitory to generation of action potential) or depolarizing (excitatory to generation of action potential).	Always consist of depolarizing phase followed by repolarizing phase and return to resting membrane potential.
Refractory period	Not present; summation can occur.	Present; summation cannot occur.

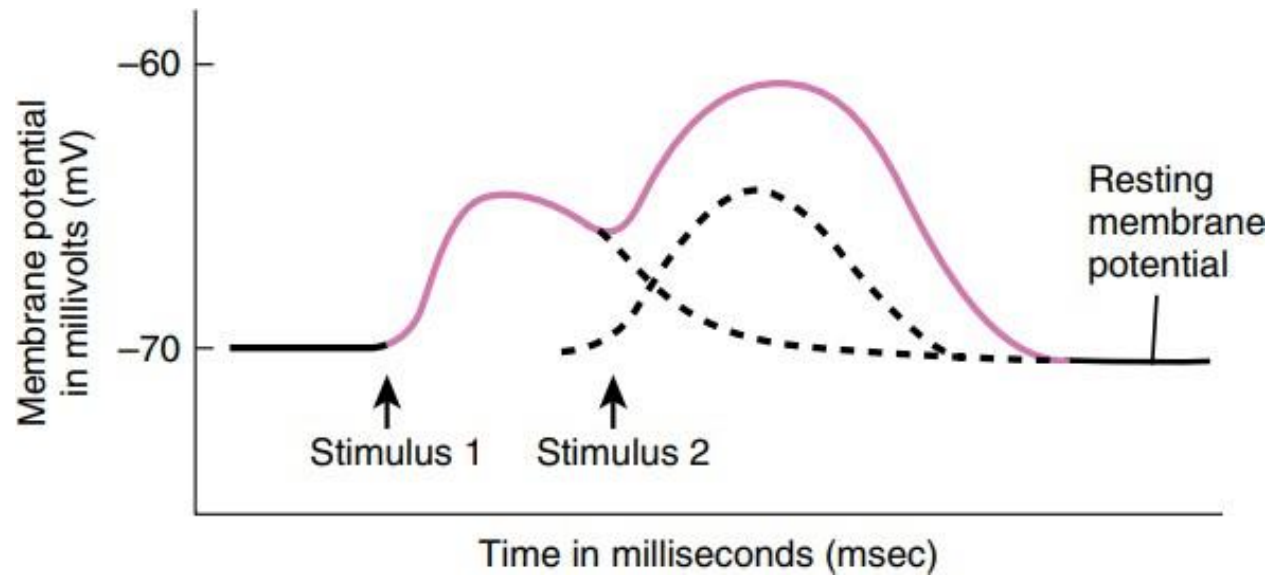
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The more frequent the stimulus, the more summation can happen. This allows the signals to build up on each other, increasing the strength of the stimulus until it reaches the threshold.

↓

there is a refractory period, during which no summation is allowed.

Summation in graded potential



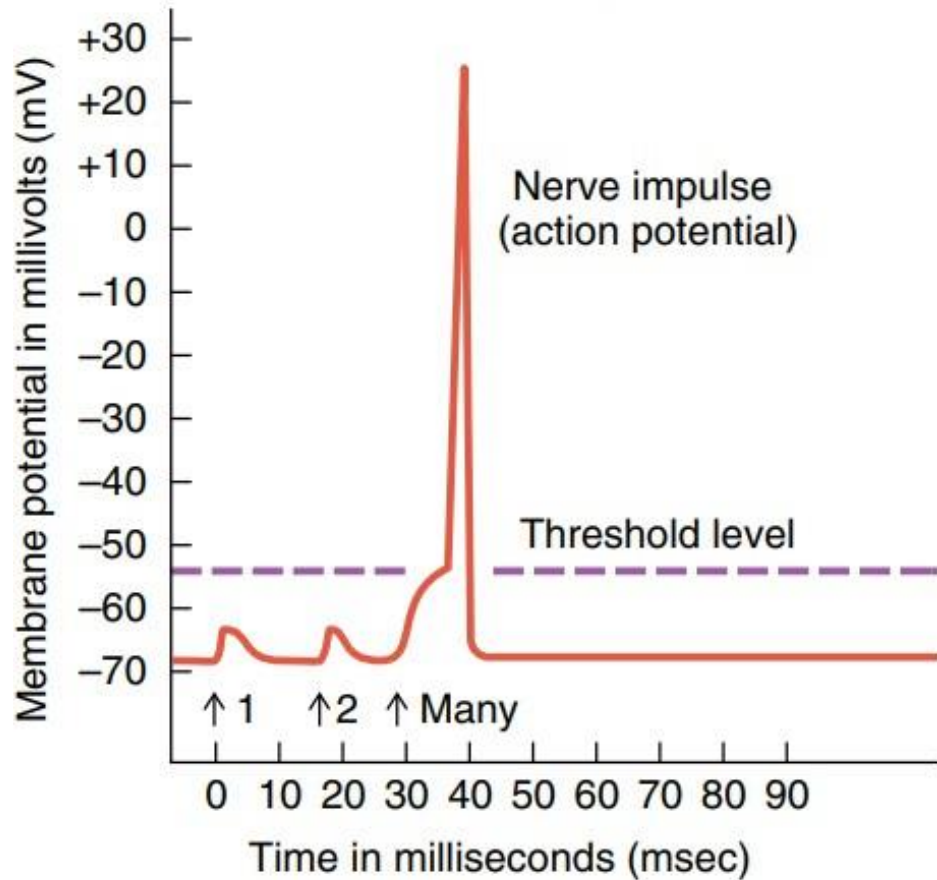
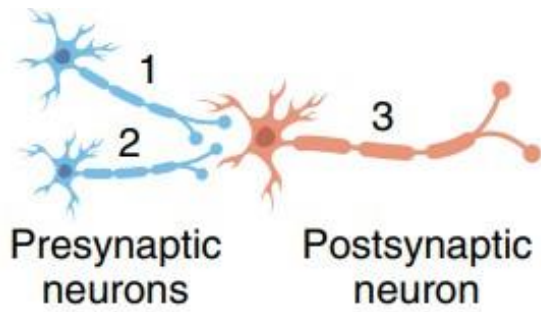
In summation, stimulus 1 causes a change in membrane potential (a graded depolarization). This change is temporary and would normally fade back to the resting membrane potential. However, if stimulus 2 arrives before the membrane fully returns to rest, it adds to the effect of stimulus 1. **Because the membrane is still depolarized, the second stimulus builds on the first, This addition of effects is called summation, and it results in a stronger overall response.**

Keep in mind that summation occurs with graded potentials, which can be either depolarizing (positive) or hyperpolarizing (negative). When adding them together, you must consider their signs, since they can either enhance or reduce each other.

Spatial summation in neurons

two stimuli are different in spatial location, so they are located differently in space, but they come simultaneously to affect the same postsynaptic neuron.

- The effect of summing simultaneous postsynaptic potentials by activating multiple terminals on widely spaced areas of the neuronal membrane is called **spatial summation**.



(a) Spatial summation

In **spatial summation**, signals come from **different neurons at the same time** and affect one neuron together.

For example, **stimulus 1 from neuron 1** causes a depolarization (a positive change in the membrane potential). At the same time, **stimulus 2 from neuron 2** also causes depolarization.

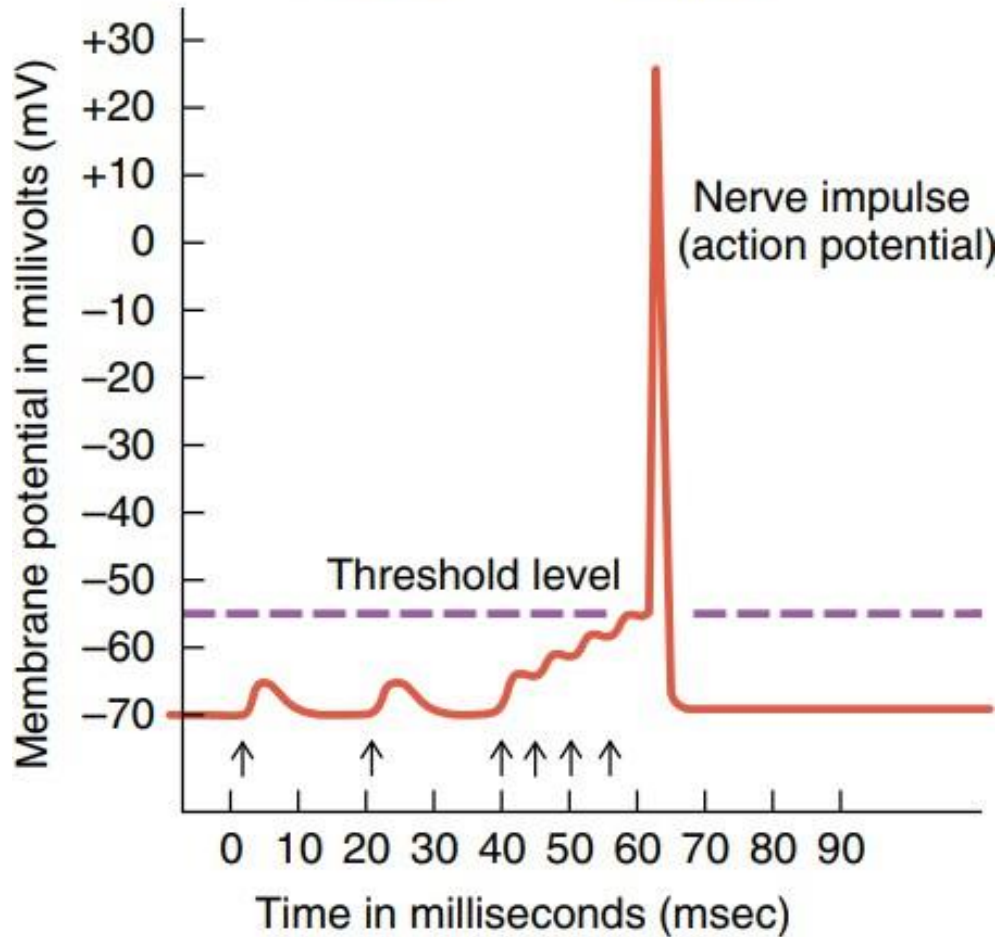
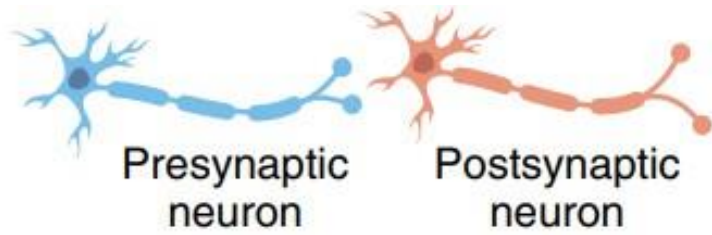
When both of these signals reach **neuron 3 simultaneously**, their effects on the **membrane potential** are combined. Since both are depolarizing, they **add together and make the membrane potential more positive**.

If this combined depolarization is strong enough, it can reach the threshold and **trigger an action potential**. So, instead of one stimulus being enough on its own, the neuron **relies on multiple inputs from different neurons**, and their combined effect allows the neuron to fire.

This process is called **spatial summation**, because the signals are coming from **different locations (different neurons)** but are added together in one neuron.

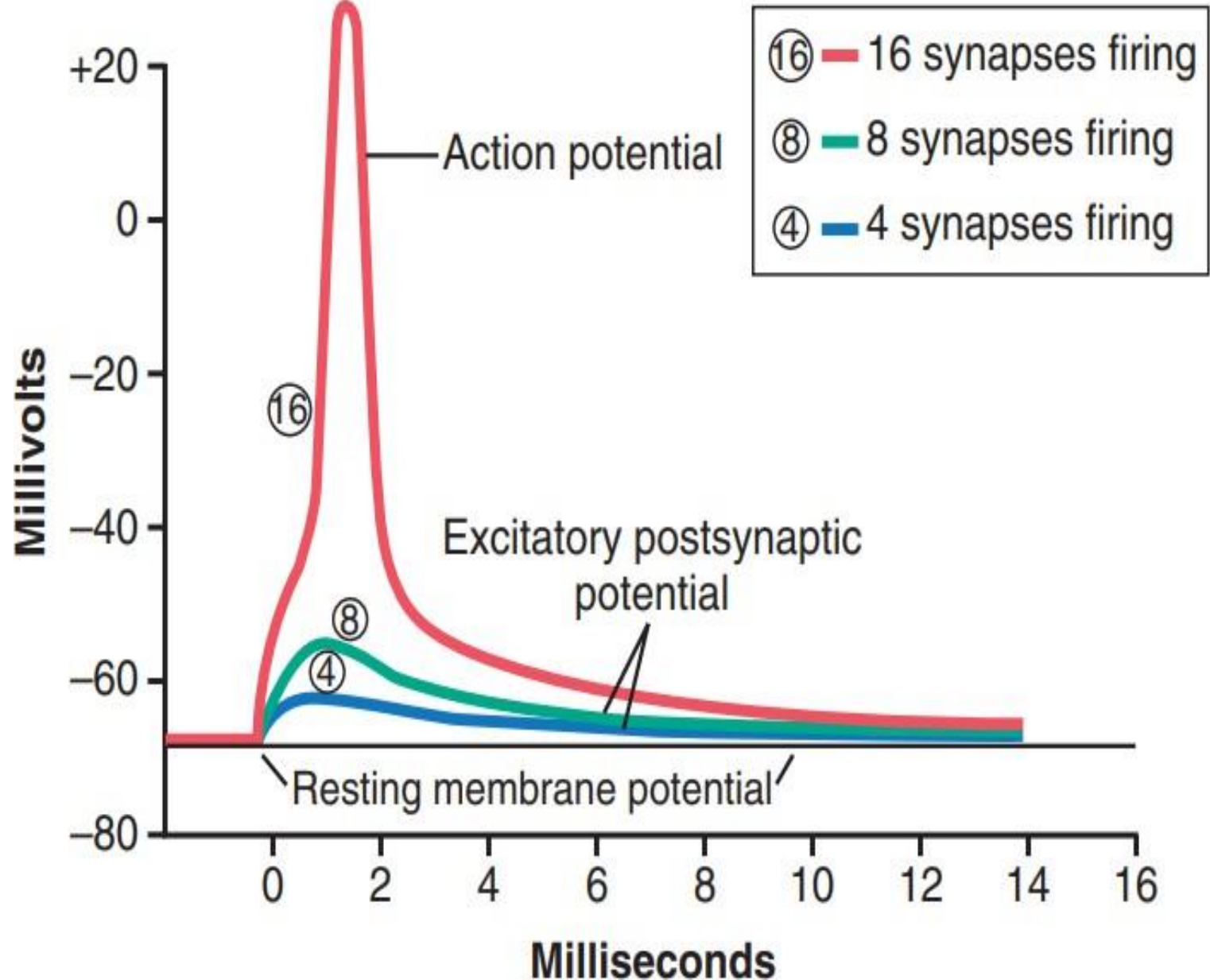
Temporal summation in neurons

- Each time a presynaptic terminal fires, the released transmitter substance opens the membrane channels for at most a millisecond or so. However, the changed postsynaptic potential lasts up to 15 milliseconds after the synaptic membrane channels have already closed.
- Therefore, a second opening of the same channels can increase the postsynaptic potential to a still greater level, and the more rapid the rate of stimulation, the greater the postsynaptic potential becomes. Thus, successive discharges from a single presynaptic terminal, if they occur rapidly enough, can add to one another; that is, they can “summate.” This type of summation is called temporal summation.



(b) Temporal summation

In **temporal summation**, a single pre-synaptic neuron sends signals repeatedly to a post-synaptic neuron in a short period of time, causing changes in the membrane potential. The first signal creates a depolarization that would normally fade back to the resting state, but if another signal arrives before the membrane potential returns to normal, it builds on the first one. Because these signals come very close together in time, their effects add up, and this can eventually bring the membrane potential to the threshold and trigger an action potential, although sometimes the combined effect is still not enough. **This is different from spatial summation, where signals come from different neurons and different synapses at the same time, while in temporal summation it is mostly one synapse but with increasing frequency of signals that allows them to summate**



This graph shows the change in the membrane potential.

See the blue line? It shows 4 excitatory synapses on the same postsynaptic neuron.

You can see the level of change in the membrane potential.

So, if you increase the number of excitatory synapses, you will increase the change in the membrane potential.

Here we have 8 synapses, and if you increase the excitatory synapses to 16, now it reaches the threshold and fires an action potential.

The more excitatory synapses, the more the summation, and the more the chance to reach an action potential.

Time course of postsynaptic potentials

- When an excitatory synapse excites the anterior motor neuron, the neuronal membrane becomes highly permeable to sodium ions for 1 to 2 milliseconds.
- During this very short time, enough sodium ions diffuse rapidly to the interior of the postsynaptic motor neuron to increase its intraneuronal potential by a few millivolts, thus creating the EPSP.
- This potential then slowly declines over the next 15 milliseconds because this is the time required for the excess positive charges to leak out of the excited neuron and to re-establish the normal resting membrane potential.

Time course of postsynaptic potentials

- The opposite effect occurs for an **IPSP**;
- The inhibitory synapse increases the permeability of the membrane to potassium or chloride ions, or both, for 1 to 2 milliseconds, and this action decreases the intraneuronal potential to a more negative value than normal, thereby creating the IPSP.
- This potential also dies away in about 15 milliseconds.

Time course of postsynaptic potentials

- Other types of transmitter substances can excite or inhibit the postsynaptic neuron for much longer periods— for hundreds of milliseconds or even for seconds, minutes, or hours. This is especially true for some of the **neuropeptide transmitters**.

Summation of IPSP and EPSP

- If an IPSP is tending to decrease the membrane potential to a more negative value while an EPSP is tending to increase the potential at the same time, these two effects can either completely or partially nullify each other.

A VERY important tip : when we do the summation its VEEERY important to know how to differentiate whether the summation is HYPERPOLARIZING or DEPolarizing and whether its EPSP or IPSP

To make it easier for you



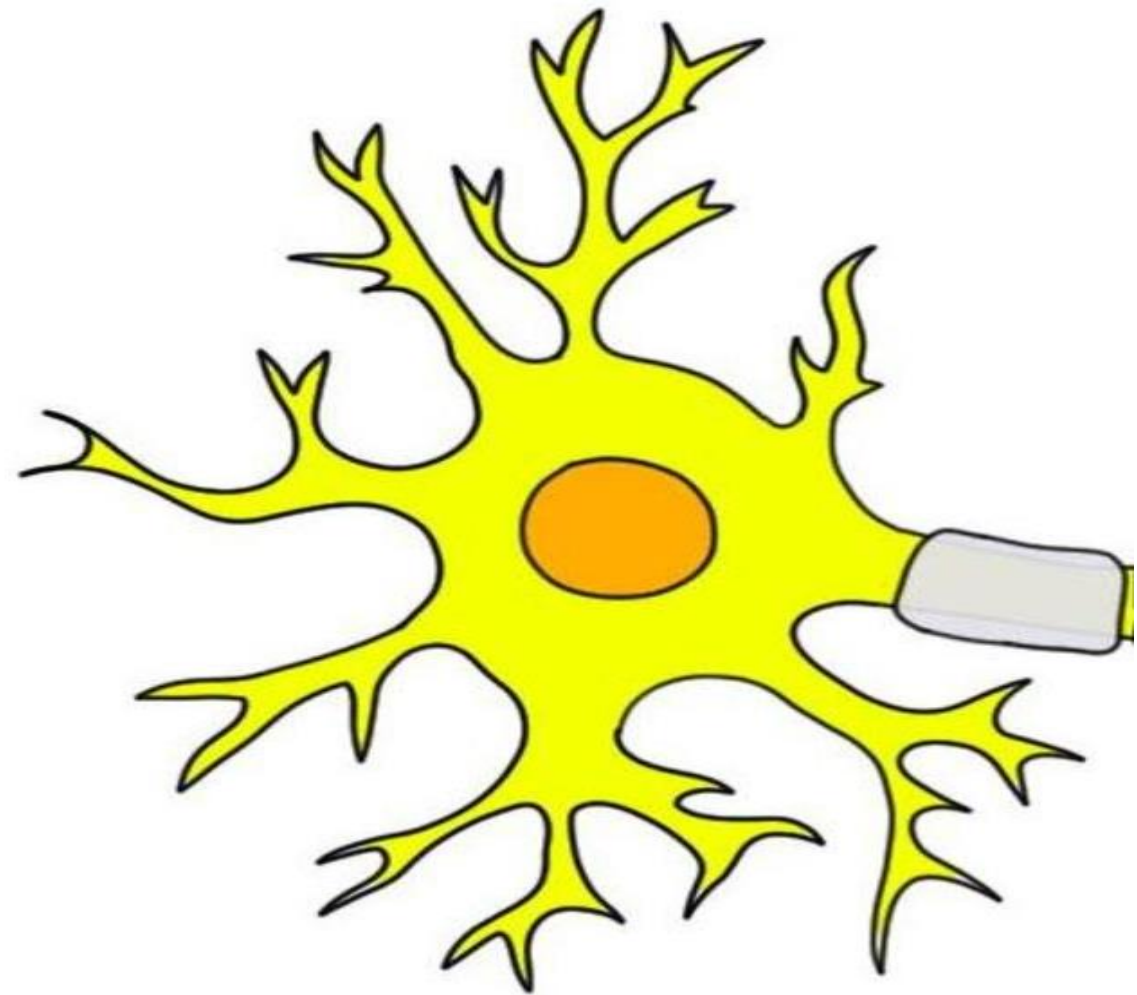
EPSP and IPSP are two types of graded potentials that change the **membrane potential** of a neuron, but they have opposite effects on whether the neuron will fire. An **EPSP (excitatory post-synaptic potential)** causes **depolarization**, which means the inside of the neuron becomes more positive. This moves the membrane potential closer to the threshold, making it **easier for the neuron to generate an action potential**. On the other hand, an **IPSP (inhibitory post-synaptic potential)** causes **hyperpolarization**, which means the inside of the neuron becomes more negative. This moves the membrane potential further away from the threshold, making it **harder for the neuron to fire**. In most cases, a neuron receives both EPSPs and IPSPs at the same time, and the final response depends on their combined effect (summation). If the excitatory signals are stronger, the neuron may reach threshold and fire, but if the inhibitory signals dominate, the neuron will not generate an action potential.

Here the change of the membrane potential in the level of dendrites will be discussed

Dendrites:

Large spatial field of excitation. Because they're branching everywhere

A great opportunity for summation of signals from many neurons.

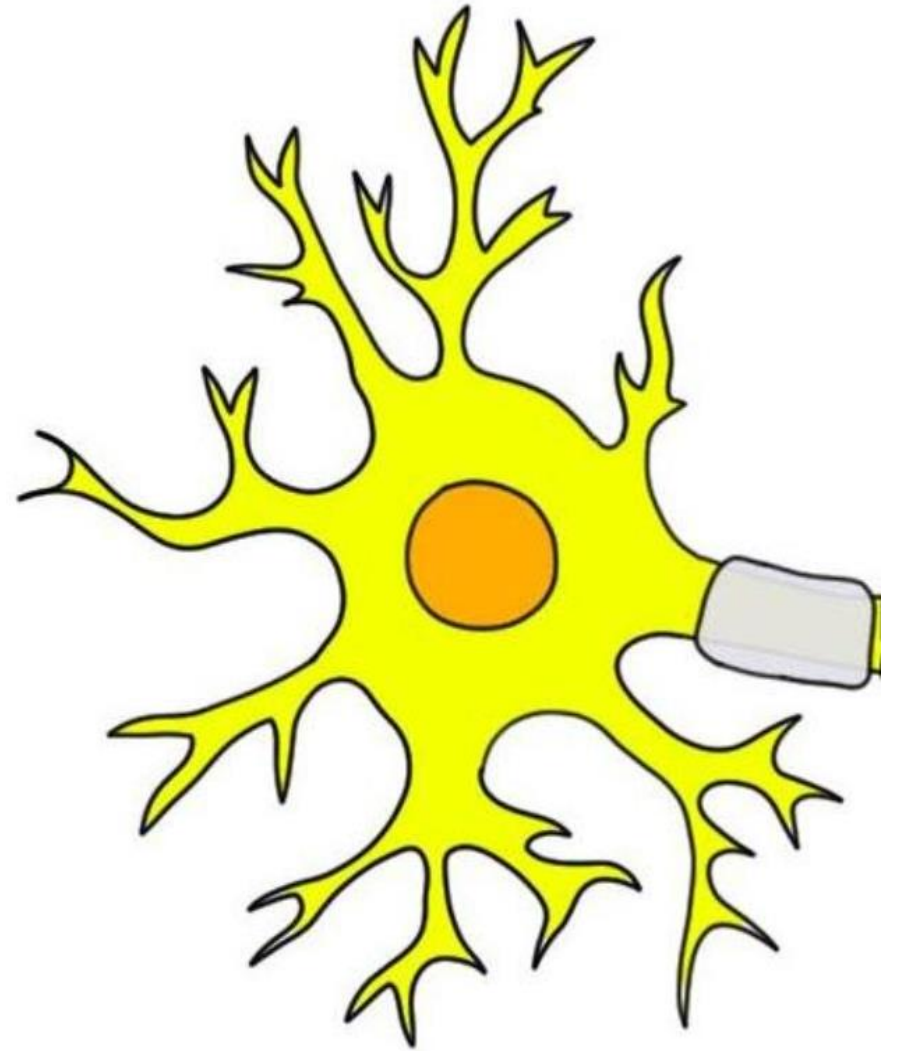


Which increase the number of synapses –increasing the opportunity of firing an action potential (if they are excitatory) or cancel each other if some of them are excitatory and some are inhibitory.

However there is a limitation for dendrites which is :

Most dendrites fail to transmit action potentials because their membranes have relatively few voltage-gated sodium channels, and their thresholds for excitation are too high for action potentials to occur.

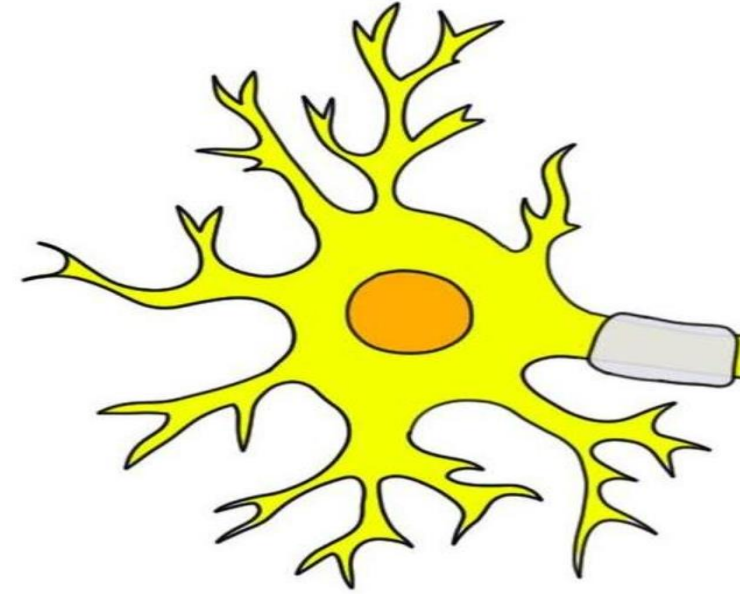
Most common channels in dendrites are ligand gated, which can't generate an action potential



Decremental conduction

The synapses that lie near the soma have far more effect in causing neuron excitation or inhibition than those that lie far away from the soma. (it already started with a graded potential and graded potential is usually used for short distance communication)

That's why its called Decremental Conduction cause the effect will decrease as the signal reaches from the dendrite towards the soma In other words, the same synapse will be more effective if it's nearer to the soma then if it's further away from the Soma (it depends on the distance)



Think of a neuron's dendrite as a long, thin tube designed to receive signals. Its membrane is specially designed to be "leaky," primarily through open, non-gated channels that prefer to let potassium ions pass through. Because the concentration of potassium is much higher inside the cell than outside, Potassium acts like water escaping a leaky hose, constantly leaking out. When these positive potassium ions leave, they take positive charge away from the inside of the cell, which naturally keeps the inside highly negative. This state of having a negative, resting membrane potential that is very close to the natural equilibrium potential of potassium is VERY essential

Here is the opposing effect: While other signals, like sodium, try to rush in and cause depolarization (make the inside positive to fire a signal), the high permeability to potassium (leaky membrane) immediately counteracts this by allowing

to rush out, causing repolarization (pulling the voltage back down to the negative resting state). Consequently, this "leaky" property serves as a stabilizer, preventing the dendrite from depolarizing too easily and setting a strict baseline for how input signals are processed



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Action potential in the axon

Action potential does not begin adjacent to the excitatory synapses. Instead, it begins in the initial segment of the axon.

The main reason is that the soma has relatively few voltage gated sodium channels in its membrane, which makes it difficult for the EPSP to open the required number of sodium channels to elicit an action potential.

Action potential in the axon

The membrane of the initial segment of the axon has 7 times as great a concentration of voltage-gated Na⁺ channels as does the soma and, therefore, can generate an action potential with much greater ease than can the soma.

The threshold is lower in the axon initial segment than the soma.

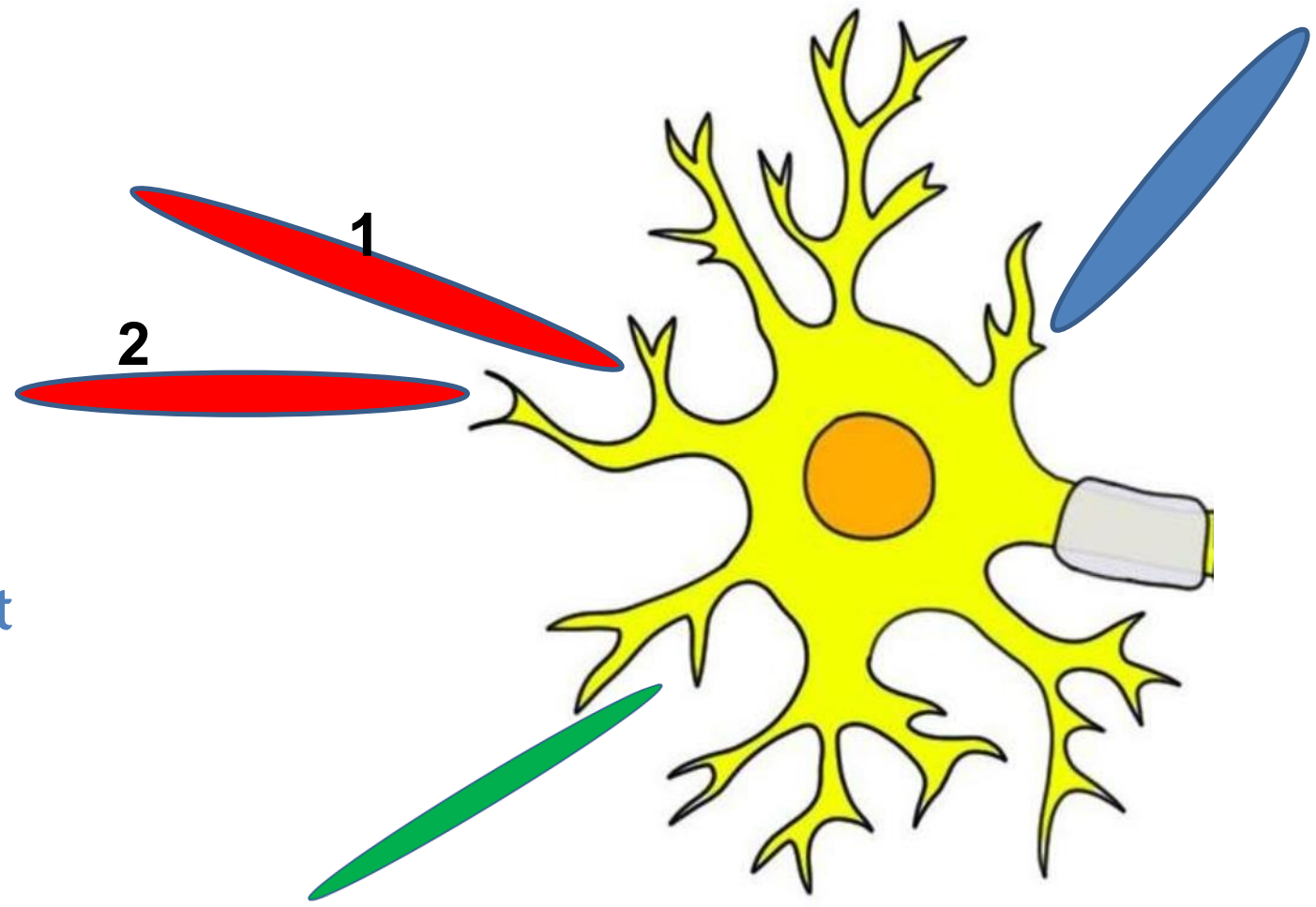
For example/

Let's say $E_1 = +10 \text{ mV}$, (“+” means excitatory potential)

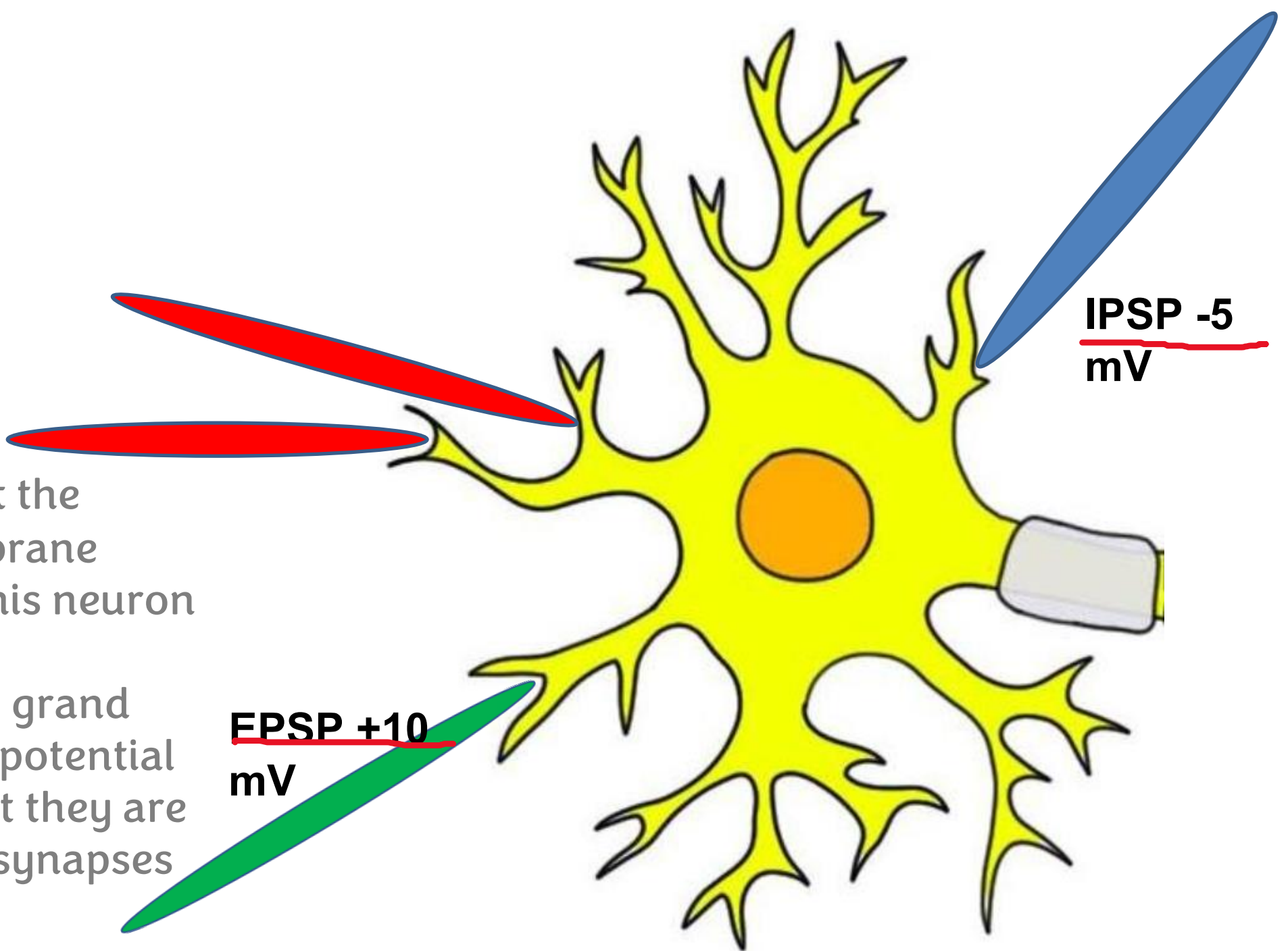
resting state = -70 mV

Threshold = -50 mV .

That means the membrane potential will change from resting = -70 mV to resting potential = -60 mV , but does it mean that the membrane potential in the soma will be -60 mV ? It's very unlikely because the leakage of potassium ions will cause it to be $\sim -65 \text{ mV}$ then again = -70 mV so the strength of the excitatory signal will be decreased toward the soma



* Assume that the resting membrane potential in this neuron = -70 mV, Calculate this grand postsynaptic potential assuming that they are the only two synapses are coming?



Excitatory postsynaptic potential (EPSP)

This positive increase in voltage above the normal resting neuronal potential— that is, to a less negative value—is called the excitatory postsynaptic potential (or **EPSP**), because if this potential rises high enough in the positive direction, it will elicit an action potential in the postsynaptic neuron, thus exciting it.

EPSP is +20 millivolts means 20 millivolts more positive than the resting value.

Opening potassium or chloride channels.

An increase in negativity beyond the normal resting membrane potential level is called an inhibitory postsynaptic potential (IPSP).

IPSP is -20 millivolts means 20 millivolts more negative than the resting value.

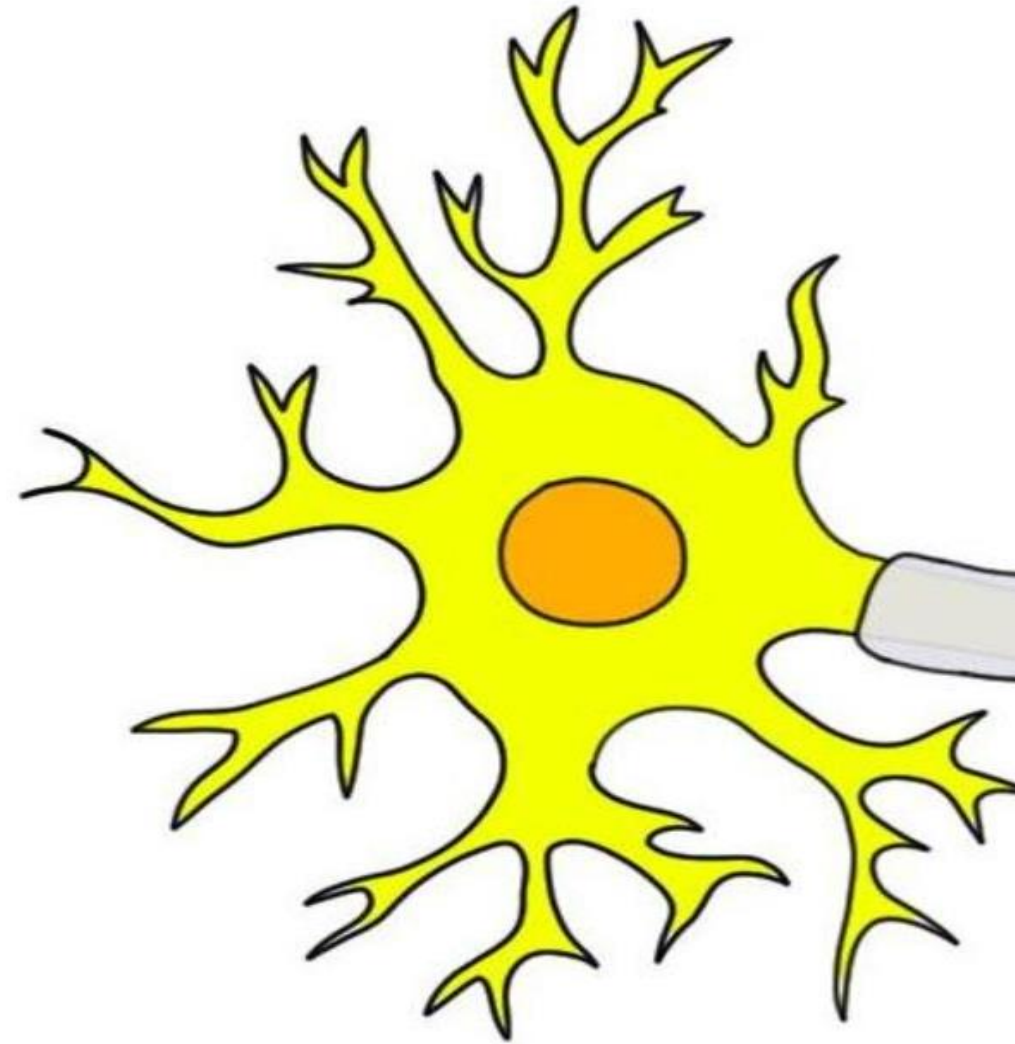
Soma:

uniform distribution of electrical potential

Large diameter (less resistance to conductance).

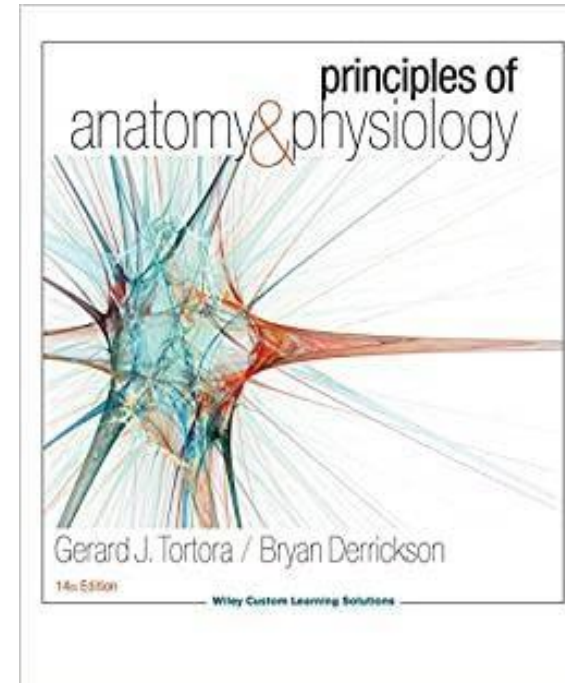
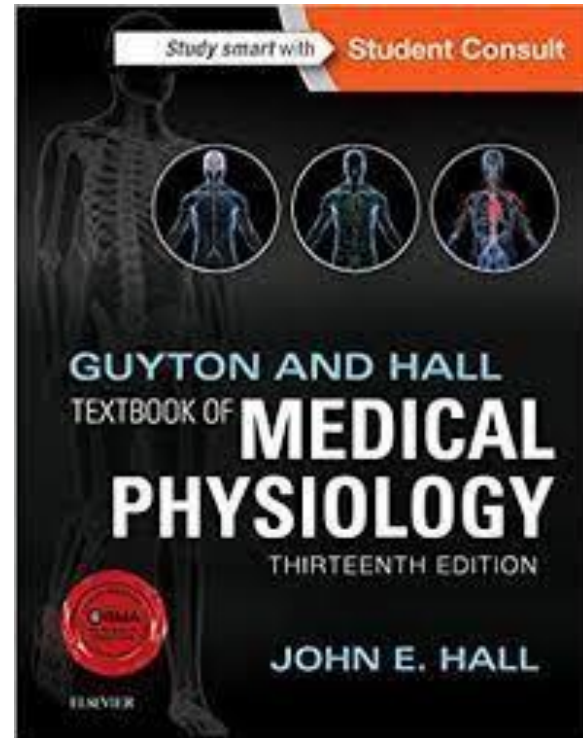
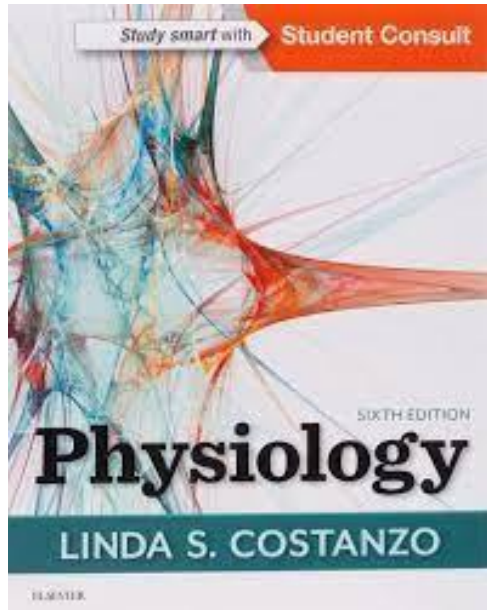
Highly conductive electrolytic fluid.

(change in membrane potential will be transmitted equally to all parts of the soma)



Unless there are other synapses then we will calculate the summation of them

References



9TH
Edition

Human Physiology From Cells to Systems

Lauralee Sherwood
Department of Physiology and Pharmacology
School of Medicine
West Virginia University

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Now , test yourself by this quiz:

<https://forms.gle/VJ5bSSJPA7HjMsHQ6>

For any feedback, scan the code or click on it.



Versions	Slide # and Place of Error	Before Correction	After Correction
V0 → V1			Note added
V1 → V2			

رسالة من الفريق العلمي:

Midterms are
almost here, hoping
we all ace our
exams Good Luck
^ _ ^ everyone

استعن بالله وابدأ في ختمة جديدة
"ختمة شوال"

فالقُرآن لم يُرفع بعد.