Introduction to Physiology for medical students 2021-2022

Sensory receptors

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Learning objectives

- Understand the process of sensation that begins with stimulating sensory receptors.
- Learn about receptor potential and some of its characteristics.
- Distinguish between slowly and rapidly adaptive receptors.
- Recognize different types of summation: spatial and temporal.

there are two conditions for this receptor to be stimulated or activated by this type of stimulus
-it should be appropriate (the receptor is selective for this stimulus) (the receptors have different sensitivity so the thermoreceptor will not respond to a mechanical stimulus, it'll respond to thermo stimulus)
-to be within the receptive field of this receptor

Sensory receptors

- For a sensation to arise, the following events typically occur:

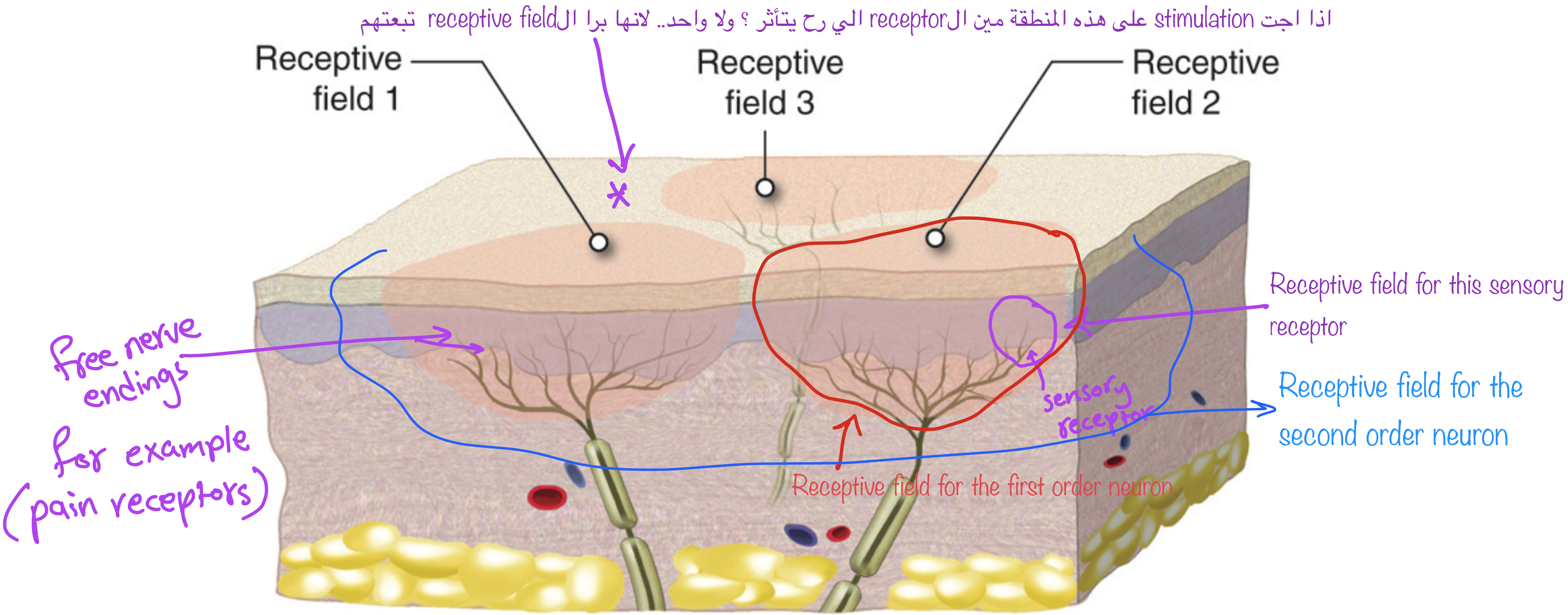
- 1. **Stimulation of the sensory receptor**.

An appropriate stimulus must occur within the sensory **receptor's receptive field**, that is, the body region where stimulation activates the receptor and produces a response.

Each receptor has his own body region that when stimulated it activates this receptor and produces a response

If a stimulation happens in anywhere in the receptive field 1 for example, that will cause an activation (stimulation) for this receptor and what will happen to receptive 2 or 3?? NOTHING

Receptive field



https://psychology.stackexchange.com/

Receptive field

- Receptive fields vary in size. The smaller the receptive field, the more precisely the sensation can be localized or identified.

Higher receptor density—> higher number of receptors—-> smaller receptive field for each of them—-> more precise and localized

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Receptor field

Body regions that will activate this receptor

The sensory pathway all through the way until it reaches CNS

Sensation

function of the sensory receptors

- 2. **Transduction**: A sensory receptor transduces (converts) energy in a stimulus into a graded potential. (receptor potential)

  Whatever the stimulus was, the end point of it is to convert to electrical (receptor potential) this is the language that the CNS understand for the processing

- Each type of sensory receptor exhibits selectivity: It can transduce only one kind of stimulus.

  For example the photoreceptor can transduce the electromagnetic waves to a receptor potential (but they cannot transduce the thermal energy)

Receptor potential

All sensory receptors have one feature in common:

Whatever the type of stimulus that excites the receptor, its immediate effect is to change the membrane electrical potential of the receptor. This change in potential is called a receptor potential.

Receptor potential

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

graded potential

By opening ion channels

Receptor potential is type of graded potential we need some sort of action potential to reach the CNS

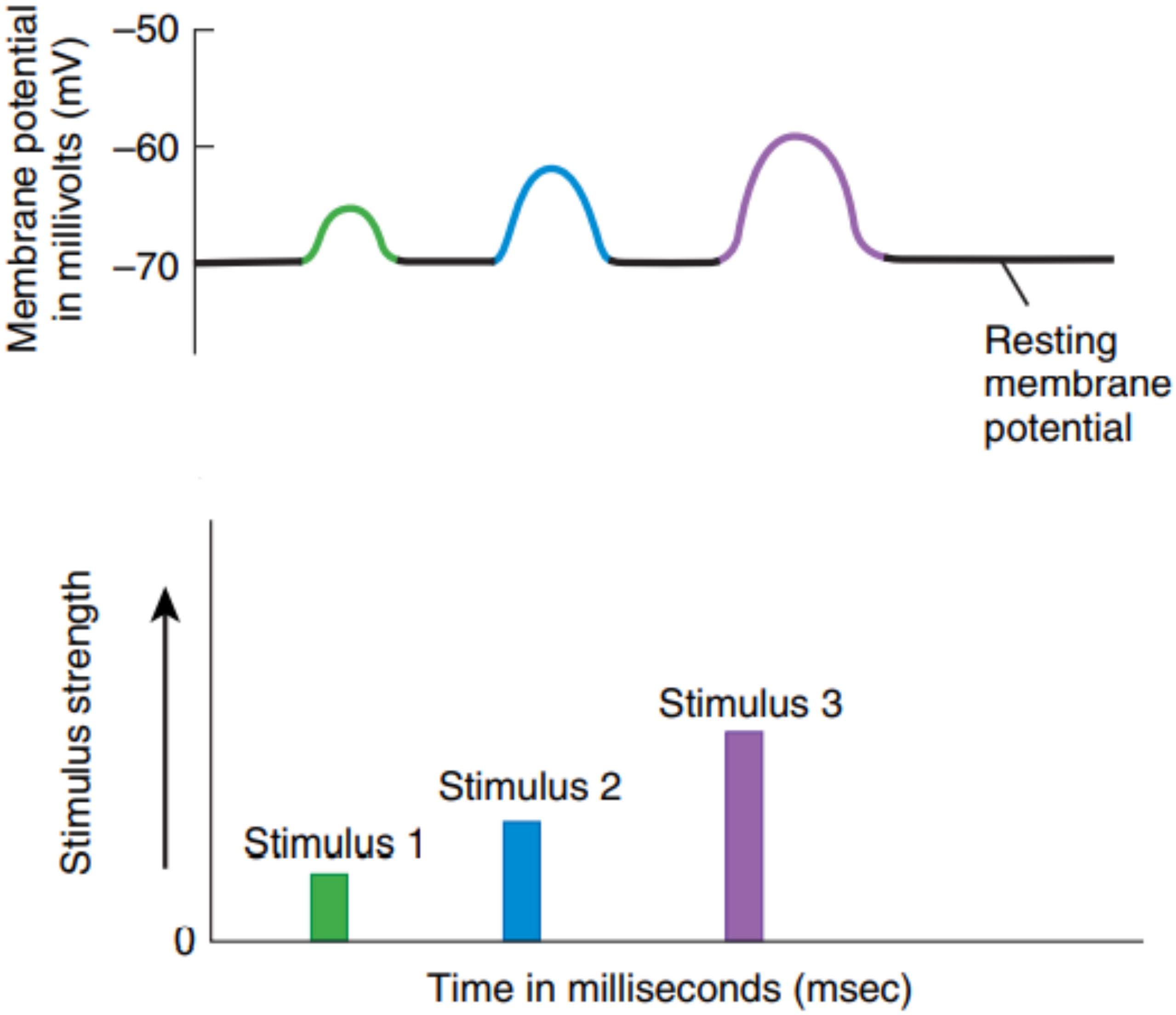
Graded potential vs Action potential

Comparison of Graded Potentials and Action Potentials in Neurons Depends on type of channels

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.
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. → Why 100mV? Because it opens all the Na+ channels and there are no more channels to open
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). Depends on the receptor/cell	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.

The stronger/ more intensity stimulus gives higher amplitude of this receptor potential

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



Stimulus intensity and Receptor potential

We call it plateau
Even if you increase the strength of the stimulus the amplitude will not change

The amplitude increases rapidly at first but then progressively less rapidly at high stimulus strength.

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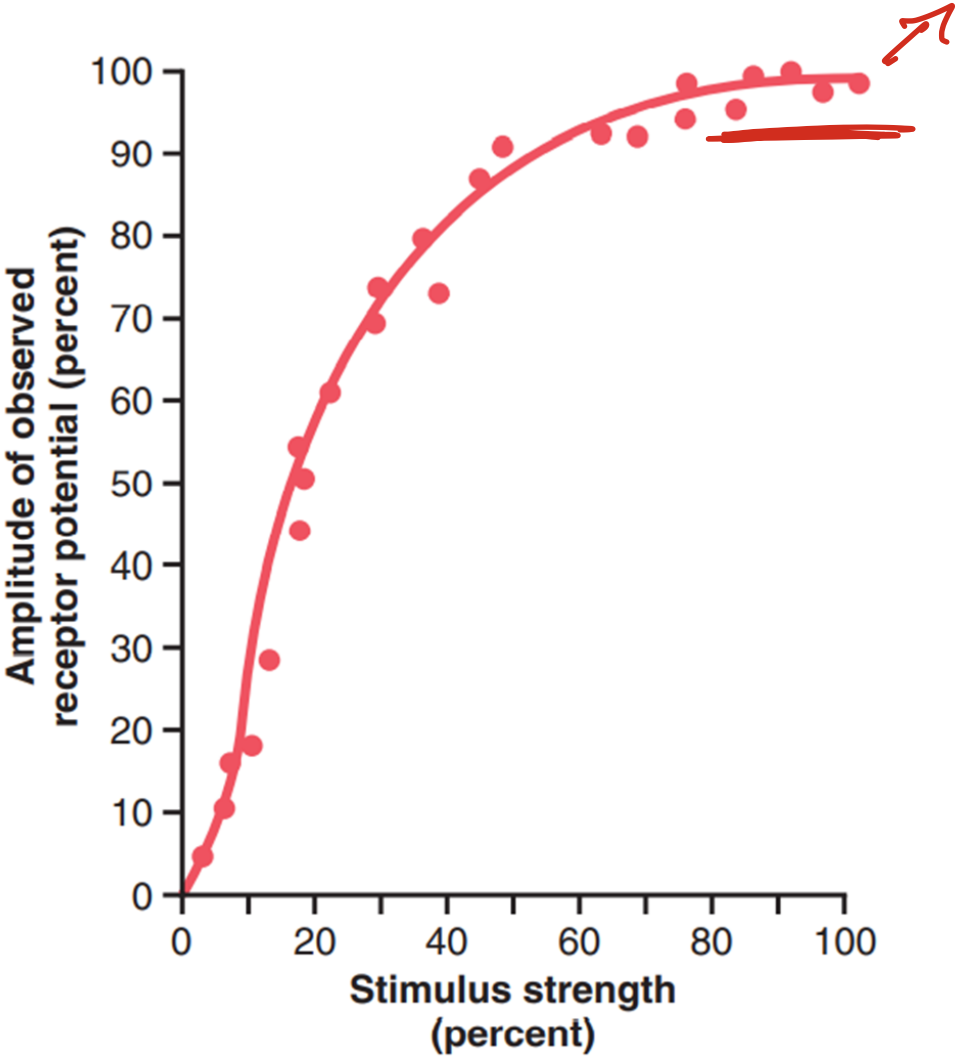


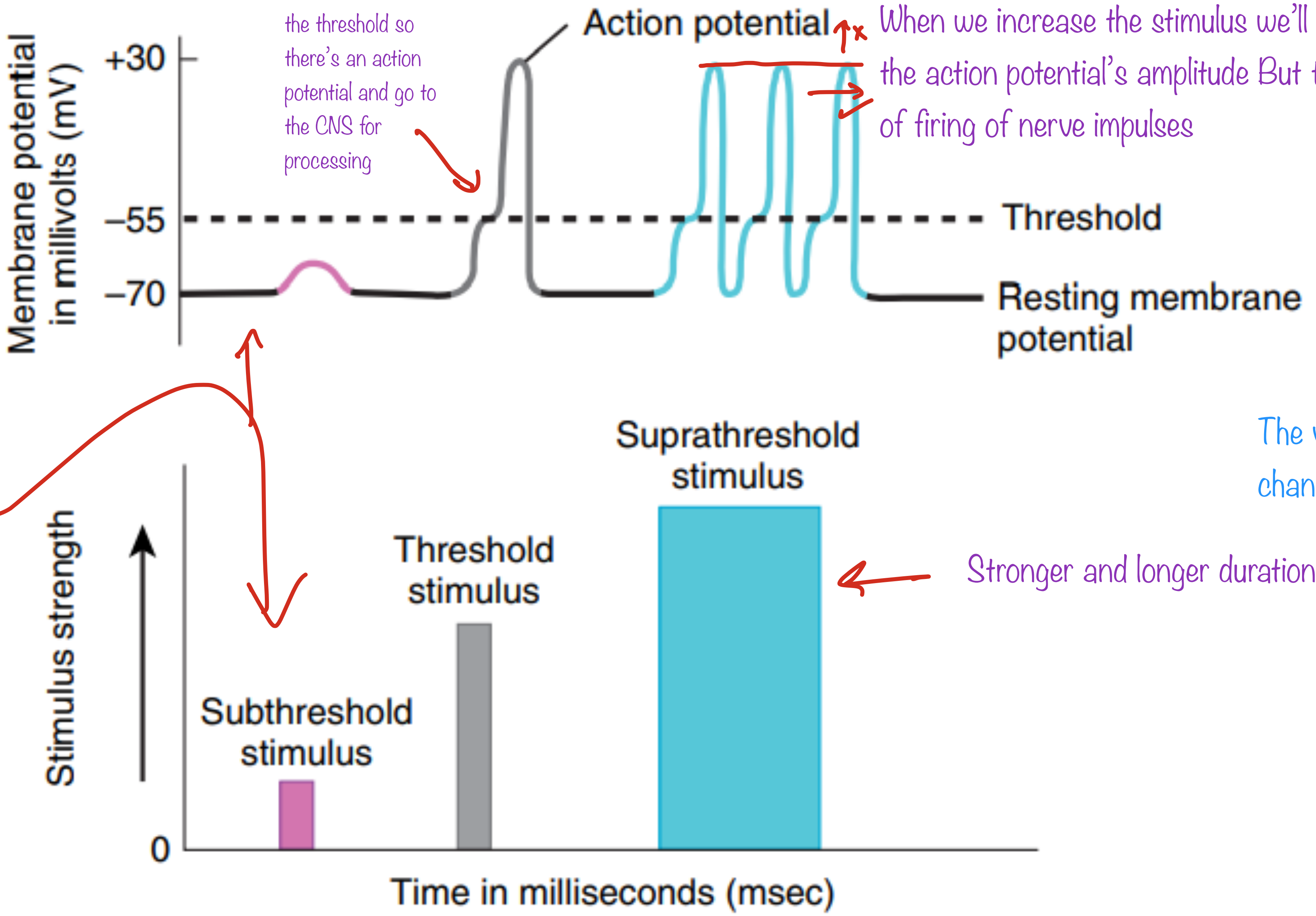
Sensation

- 3. Generation of nerve impulses. When a graded potential in a sensory neuron reaches **threshold**, it triggers one or more nerve impulses, which then propagate toward the CNS.

This stimulus don't reach the threshold so the receptor potential will not reach to the CNS because it happened for short distance and then die out

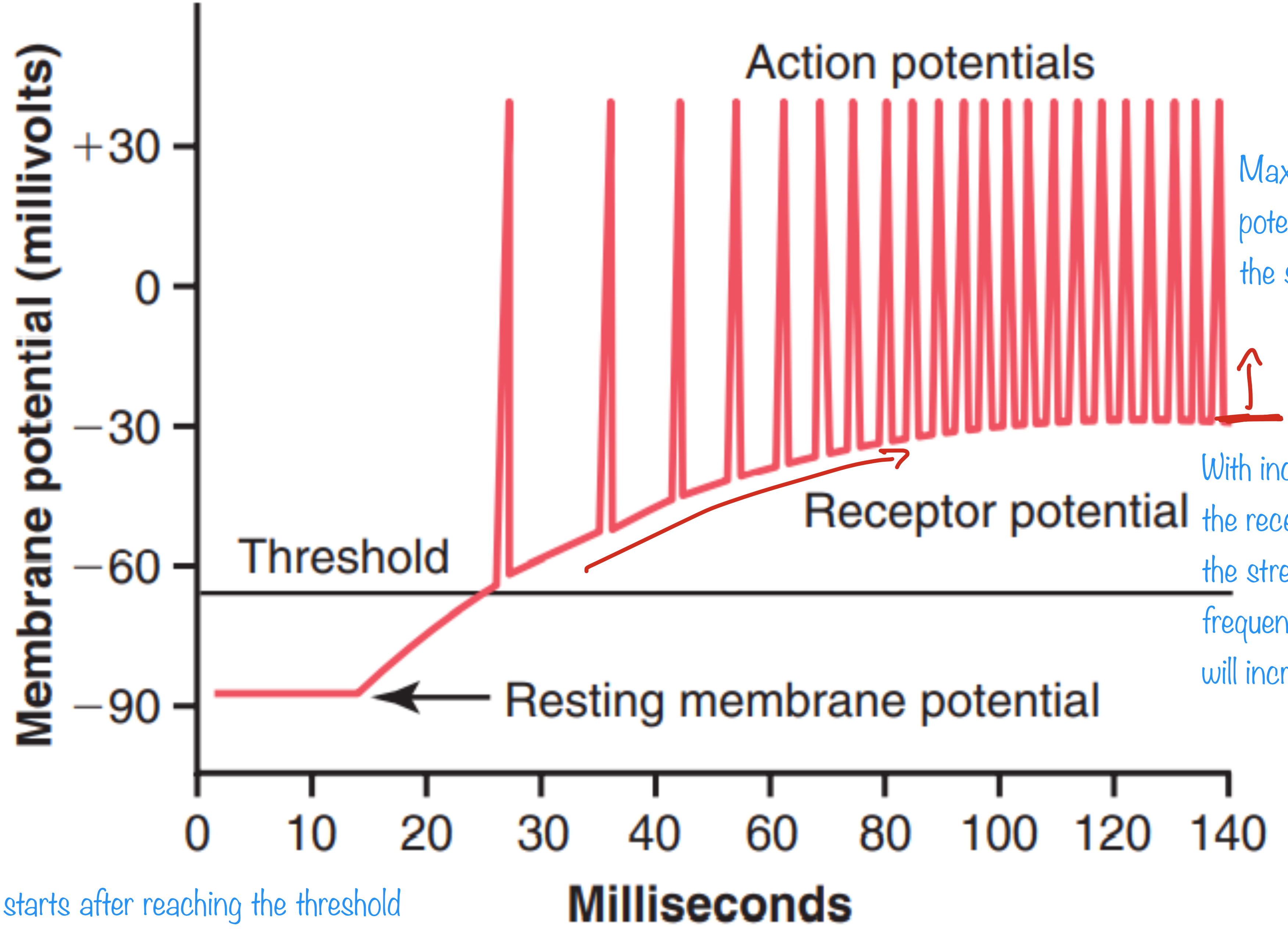
This stimulus reach the threshold so there's an action potential and go to the CNS for processing

When we increase the stimulus we'll not increase the action potential's amplitude But the Frequency of firing of nerve impulses



The voltage gated sodium channels will open

Stronger and longer duration



Maximum frequency of action potential will not increase even the stimulus increases

With increasing the amplitude of the receptor potential (increasing the strength of the stimulus) the frequency of the action potential will increase

The action potential starts after reaching the threshold

Stimulus intensity and Receptor potential

- The frequency of repetitive action potentials transmitted from sensory receptors increases approximately in proportion to the increase in receptor potential.

- The more the receptor potential rises above the threshold level, the greater becomes the action potential frequency.

- Very intense stimulation of the receptor causes progressively less and less additional increase in numbers of action potentials.

Summation in graded potential

We call the increasing in intensity, summation.

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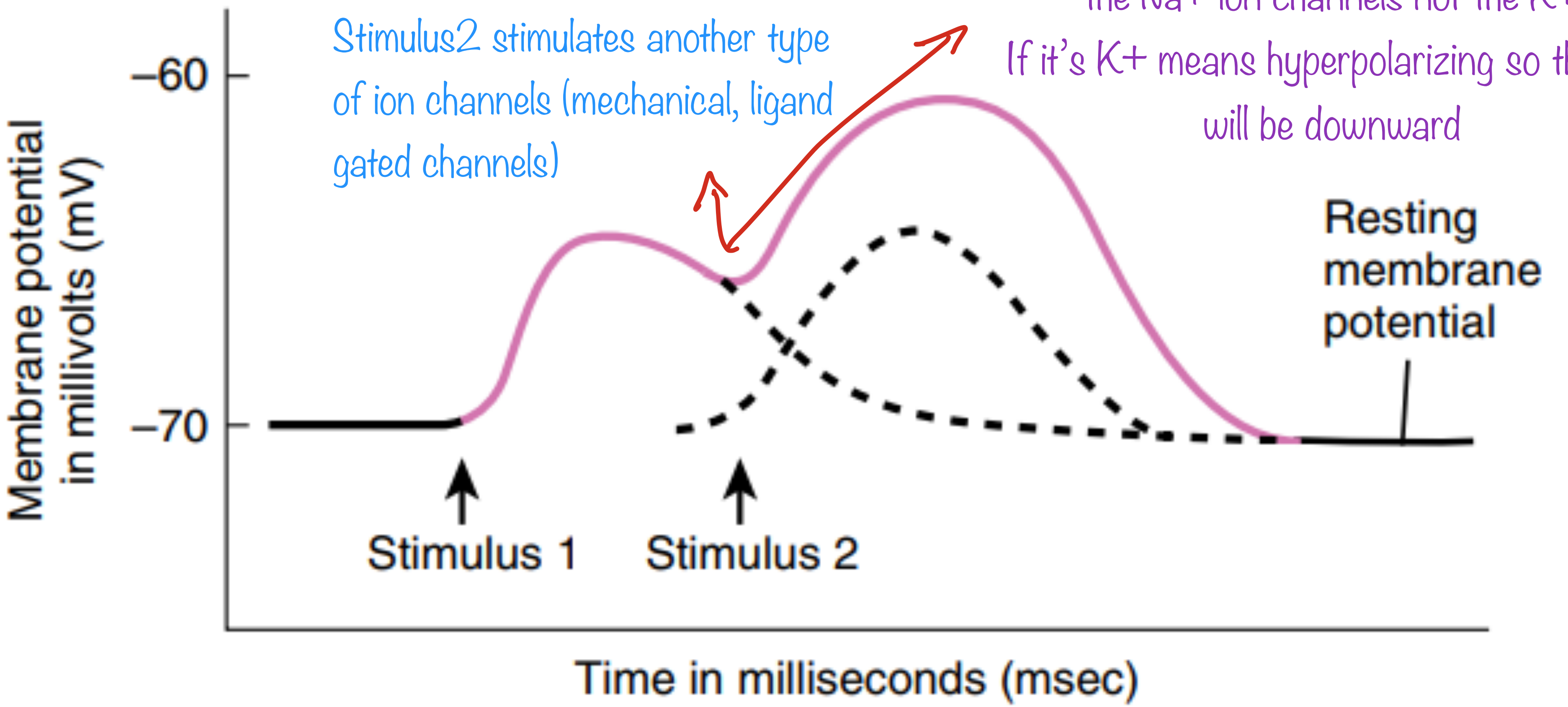
Stimulus2 stimulates another type of ion channels (mechanical, ligand gated channels)

Depolarizing.. the ligand gated channels of the Na+ ion channels not the K+
If it's K+ means hyperpolarizing so the line will be downward



Summation

- One of the characteristics of each signal that always must be conveyed is signal intensity—for instance, the intensity of pain.

Increasing the area that is stimulated

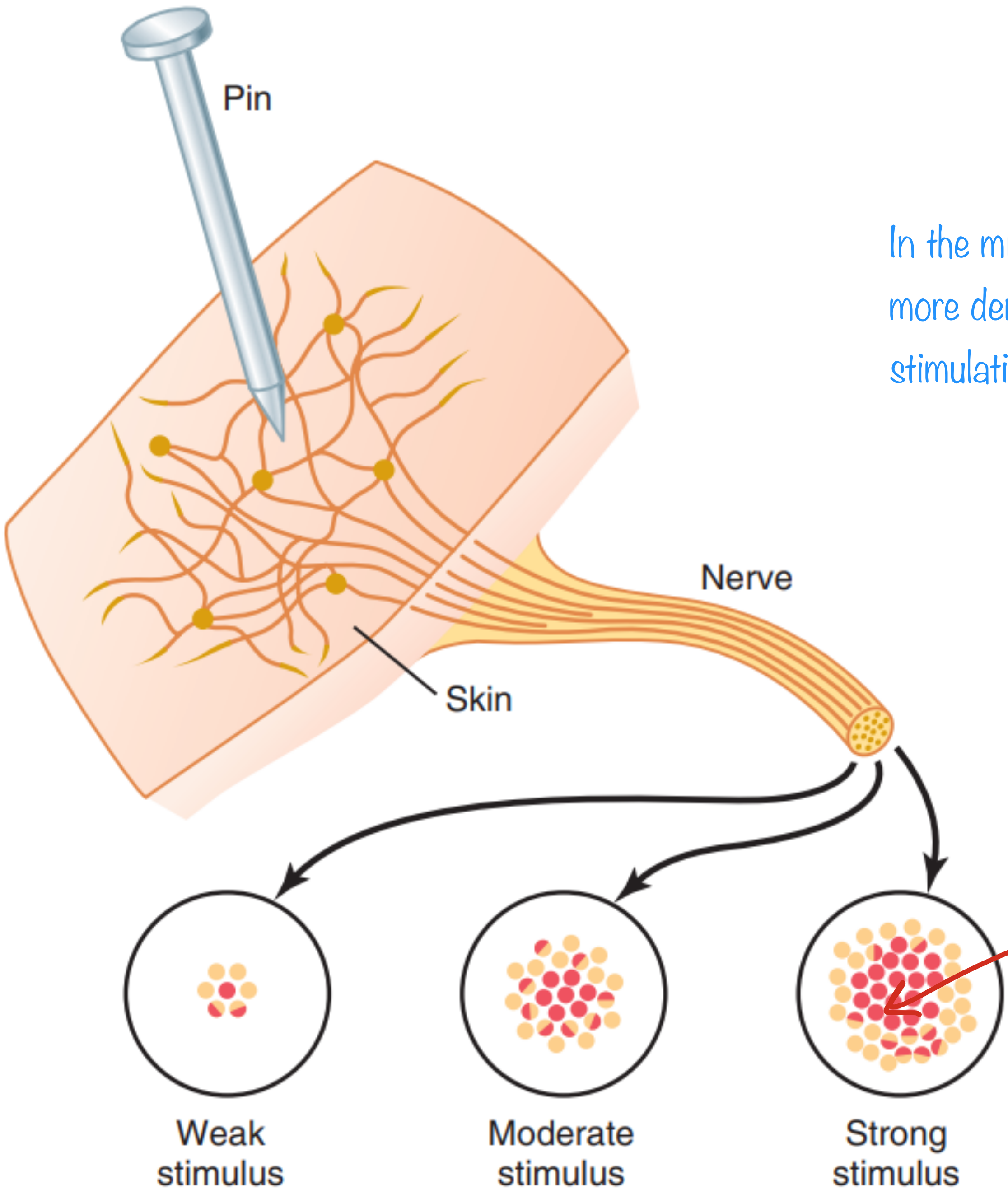
- The different gradations of intensity can be transmitted either by using increasing numbers of parallel fibers or by sending more action potentials along a single fiber. These two mechanisms are called, respectively, spatial summation and temporal summation.

Increasing frequency

Spatial summation

- Increasing signal strength is transmitted by using progressively greater numbers of fibers.

- When the pinprick is in the center of the receptive field of a particular pain fiber, the degree of stimulation of that fiber is far greater than when it is in the periphery of the field because the number of free nerve endings in the middle of the field is much greater than at the periphery.



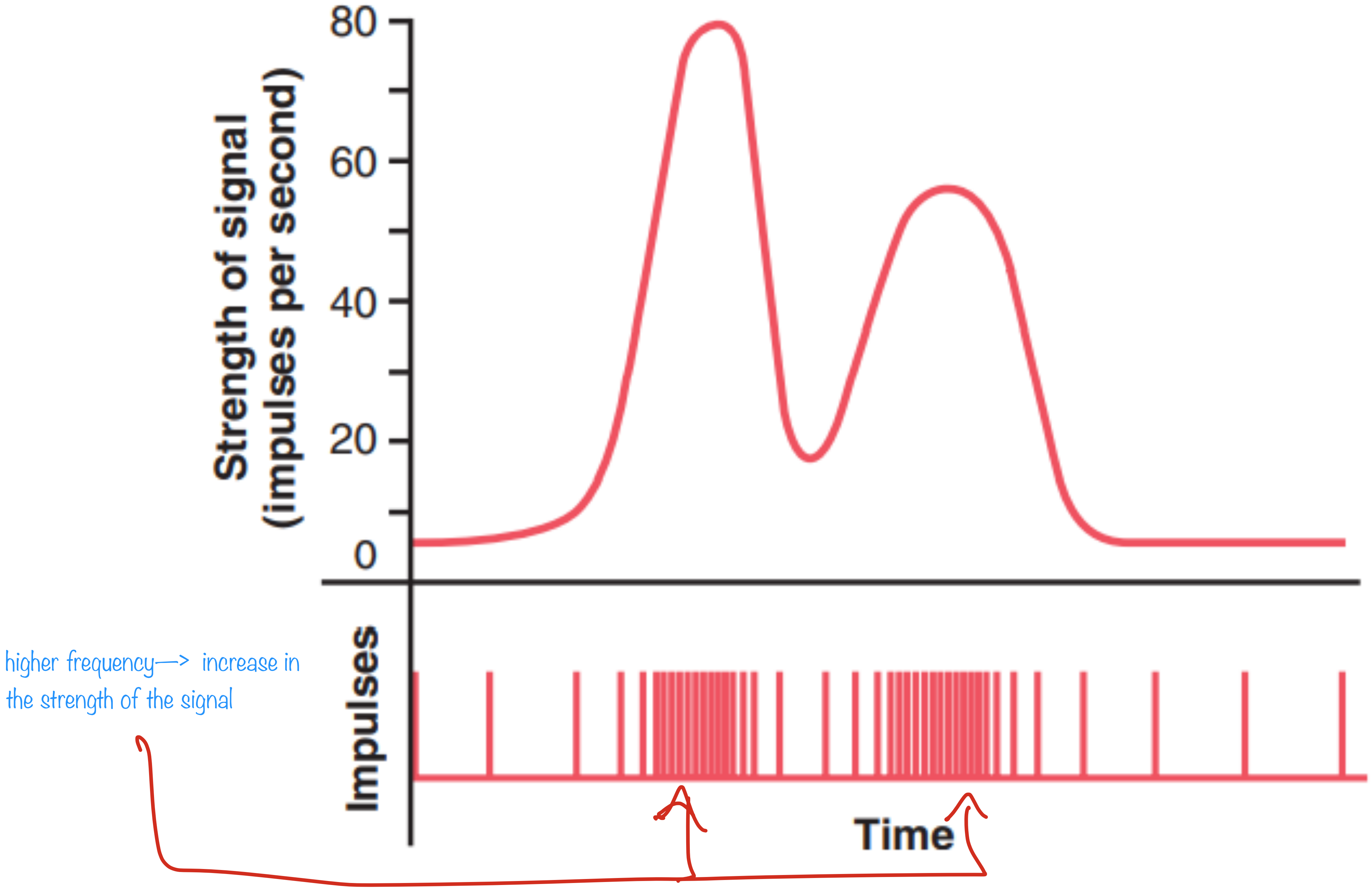
In the middle of the receptor field we have more density—> stronger stimulus than the stimulation in the periphery

Red is stronger
Yellow is weaker

More red -> stronger so it's in the middle

Temporal summation

- A second means for transmitting signals of increasing strength is by increasing the frequency of nerve impulses in each fiber, which is called temporal summation.


80
60
40
20
0
Strength of signal
(impulses per second)
Impulses
Time
higher frequency—> increase in
the strength of the signal

Adaptation

- A characteristic of most sensory receptors is adaptation, in which the receptor potential decreases in amplitude during a maintained, constant stimulus.

Adaption decreases the sensory overload

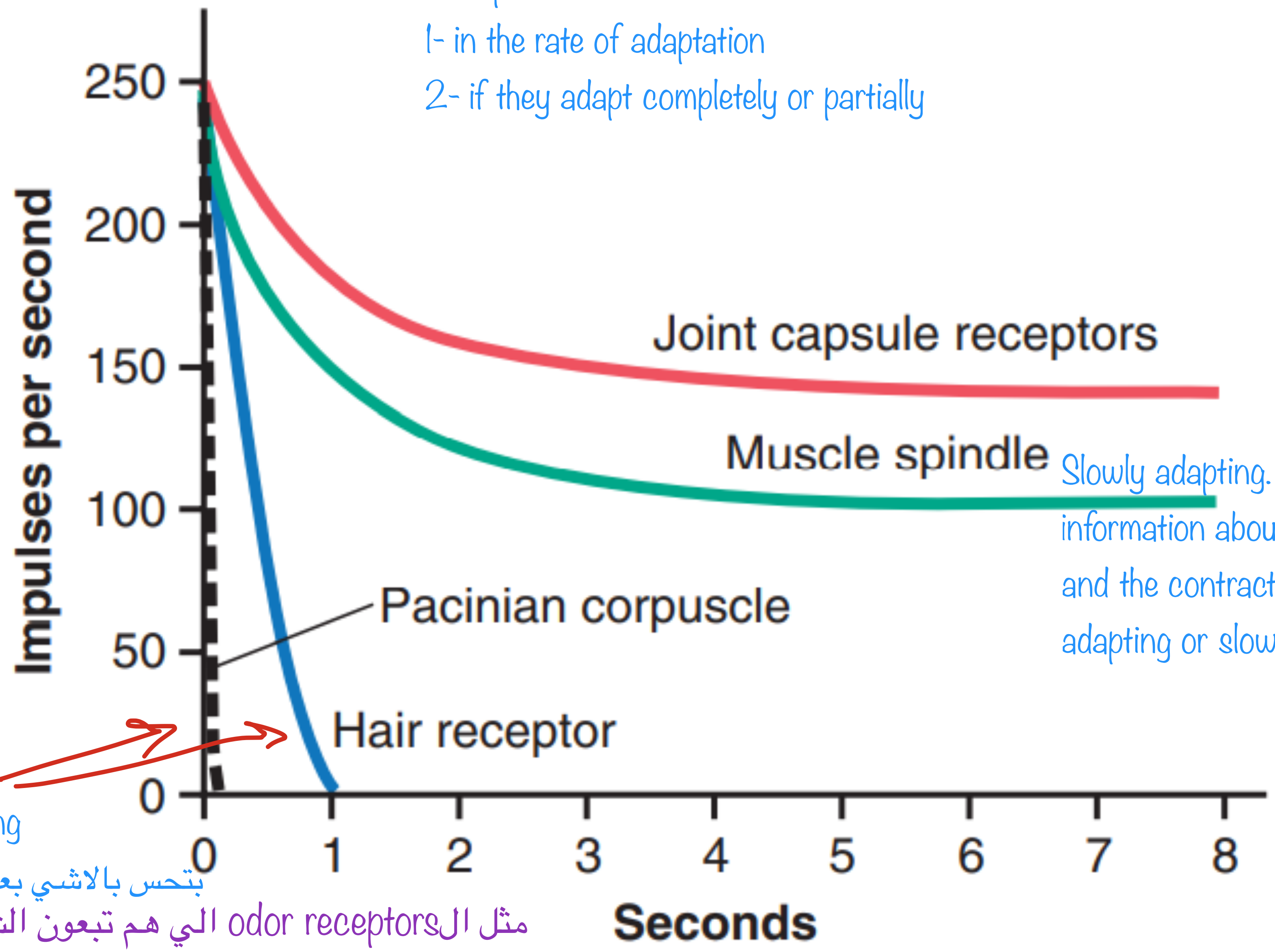
- This causes the frequency of nerve impulses in the first-order neuron to decrease.

- Because of adaptation, the perception of a sensation may fade or disappear even though the stimulus persists.

زي لما تسبح بمي باردة اولها رح تحس بالبرودة بعدين عادي

مع انه المي لساتها باردة

Receptors are difference :
1- in the rate of adaptation
2- if they adapt completely or partially



Slowly adapting.... Muscle spindle Gives us information about the strength of the muscle and the contraction (it could be non-adapting or slowly adapting)

Rapidly adapting
بتحس بالاشي بعدين بروح بسرعة
مثل الodor receptors الي هم تبعون الشم
لما ترش عطر بتشم الريحة اولها بعدين خلص بتبطل تشمها مع انها لسا موجودة

Adaptation of sensory receptors

- When a continuous sensory stimulus is applied, the receptor responds at a high impulse rate at first and then at a progressively slower rate until finally the rate of action potentials decreases to very few or often to none at all.

- Sensory receptors adapt either partially or completely to any constant stimulus after a period of time.

Adaptation

- Receptors vary in how quickly they adapt, and some sensory receptors adapt to a far greater extent than do others.

- Rapidly adapting receptors adapt very quickly. They are specialized for signaling changes in a stimulus.

continuously stimulating the CNS ما بهمني يكونوا

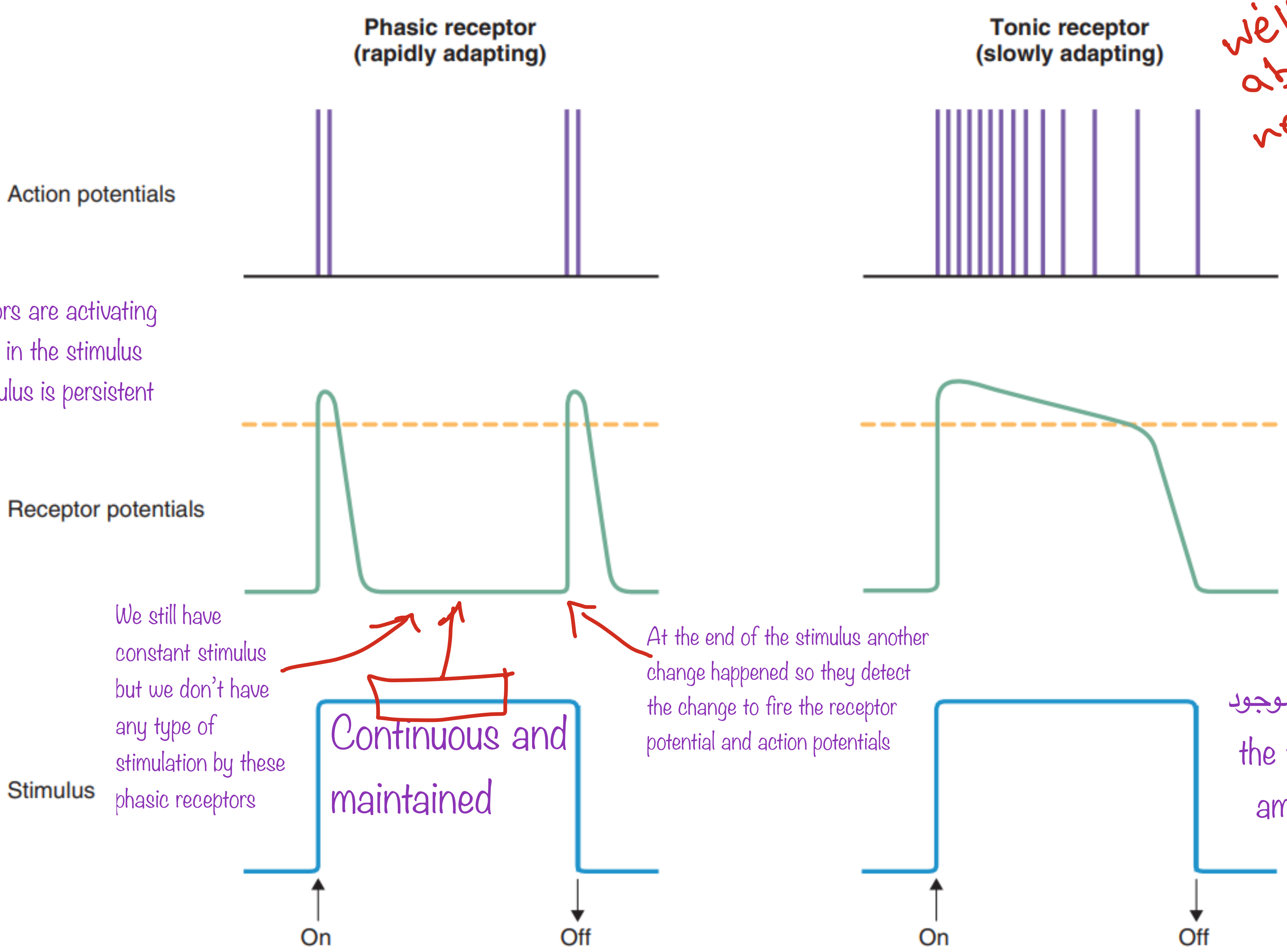
- Receptors associated with pressure, touch, and smell are rapidly adapting.

مثل لما تكون لابس ساعة وحاشرها على ايدك اولها بتحس فيها بعدين بتبطل حاسس انه
الساعة شادة ع ايدك ولما تشلحها يقل الضغط ف تشعر بذلك

Adaptation

- Receptors vary in how quickly they adapt.
- Slowly adapting receptors adapt slowly and may continue to trigger nerve impulses as long as the stimulus persists.
- Slowly adapting receptors monitor stimuli associated with pain, body position, and chemical composition of the blood.

I really care about continuously stimulation for the pain to the CNS to make an action



Costanzo

We'll talk about it in the next slide

Phasic receptors are activating when change in the stimulus not when stimulus is persistent

We still have constant stimulus but we don't have any type of stimulation by these phasic receptors

Continuous and maintained

At the end of the stimulus another change happened so they detect the change to fire the receptor potential and action potentials

The tonic receptor go back to the resting state when the stimulus finish or stop

طول ما الstimulus موجود the frequency and the amplitude decrease

Slowly adapting receptors

- Detect Continuous Stimulus Strength: **Tonic Receptors**.

- Slowly adapting receptors continue to transmit impulses to the brain as long as the stimulus is present (or at least for many minutes or hours). Therefore, they keep the brain constantly apprised of the status of the body and its relation to its surroundings.

Slowly adapting receptors

- Impulses from the muscle spindles and Golgi tendon apparatuses allow the nervous system to know the status of muscle contraction and load on the muscle tendon at each instant.

- Some of the non-mechanoreceptors (the chemoreceptors and pain receptors) probably never adapt completely.

Slowly adapting receptors

- Slowly adapting receptors include:

- (1) receptors of the macula in the vestibular apparatus. Found in the inner ear which detects the position of the head
- (2) pain receptors.
- (3) baroreceptors of the arterial tree.
- (4) chemoreceptors of the carotid and aortic bodies.
- (5) proprioceptors such as muscle spindle and Golgi tendon organ.

Rapidly adapting receptors

- Detect Change in Stimulus Strength. Also called Rate Receptors, Movement Receptors, or Phasic Receptors.

- Receptors that adapt rapidly cannot be used to transmit a continuous signal because they are stimulated only when the stimulus strength changes. Yet, they react strongly while a change is actually taking place.

Predictive function of the rate receptors

- If one knows the rate at which some change in bodily status is taking place, the state of the body a few seconds or even a few minutes later can be predicted.

- For instance, when one is running, information from the joint rate receptors allows the nervous system to predict where the feet will be during any precise fraction of the next second. Therefore, appropriate motor signals can be transmitted to the muscles of the legs to make any necessary anticipatory corrections in position so that the person will not fall.

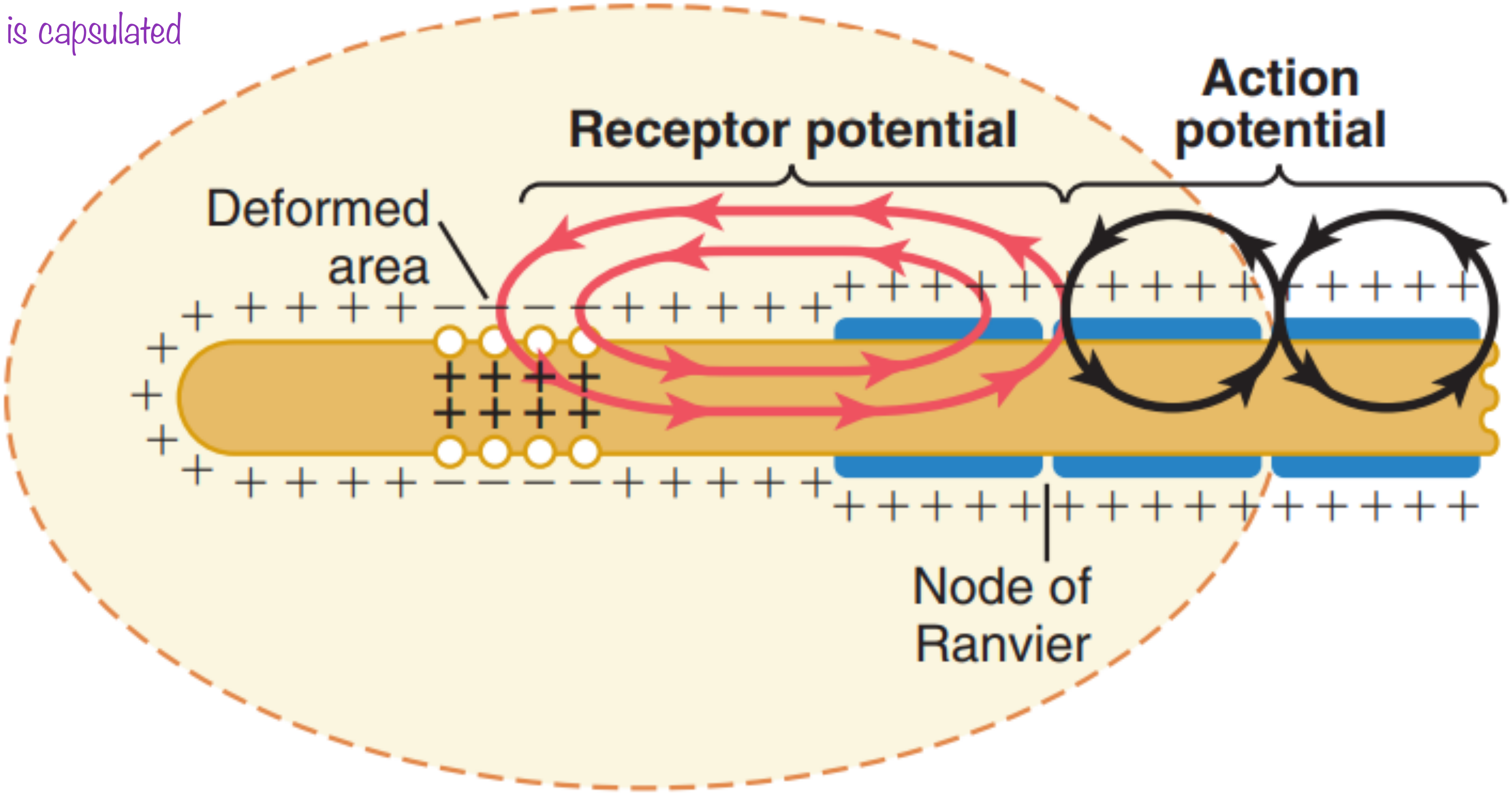
Adaptation of sensory receptors

- The **mechanism** of receptor adaptation is different for each type of receptor, in much the same way that development of a receptor potential is an individual property.

- For instance, in the eye, the rods and cones adapt by changing the concentrations of their light-sensitive chemicals.

Pacinian corpuscle

The nerve ending is capsulated



Rapidly adapting receptors

- In the case of the Pacinian corpuscle, sudden pressure applied to the tissue excites this receptor for a few milliseconds, and then its excitation is over even though the pressure continues. Later, however, it transmits a signal again when the pressure is released.

Rapidly adapting receptors

- Pacinian corpuscle is exceedingly important in apprising the nervous system of rapid tissue deformations, but it is useless for transmitting information about constant conditions in the body.

Adaptation of Pacinian corpuscles

- Adaptation occurs in this receptor in two ways.

- First, the Pacinian corpuscle is a viscoelastic structure, so that when a distorting force is suddenly applied to one side of the corpuscle, this force is instantly transmitted by the viscous component of the corpuscle directly to the same side of the central nerve fiber, thus eliciting a receptor potential.

Adaptation of Pacinian corpuscles

- However, within a few hundredths of a second, the fluid within the corpuscle redistributes and the receptor potential is no longer elicited.

Adaptation of Pacinian corpuscles

- The second, much slower mechanism of adaptation, results from a process called accommodation, which occurs in the nerve fiber itself.

- This probably results from progressive “inactivation” of the sodium channels in the nerve fiber membrane, which means that sodium current flow through the channels causes them gradually to close, an effect that seems to occur for all or most cell membrane sodium channels.

Adaptation of Pacinian corpuscles

- These same two general mechanisms of adaptation may apply also to the other types of mechanoreceptors.
- That is, part of the adaptation results from readjustments in the structure of the receptor, and part results from an electrical type of accommodation in the terminal nerve fibril.

Sensory coding

CNS can distinguish 4 stimulus properties:

- 1. sensory modality: labeled line principle
- 2. location: receptive field
- 3. intensity: spatial and temporal summation
- 4. duration: rapidly vs slowly adapting

Questions? Feedback?

Thank you