Physiology

Modified no.2

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Neurophysiology

Somatic sensation

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Color code

Black	Slides
Dark blue	Doctor
Light blue	Additional info
Red	Important

Welcome to the second physiology lec in the CNS system 🎉

Sensory receptors characteristics:

1- Differential sensitivity. (discussed previously)

2- Unevenly distributed, and different receptive fields. (discussed previously)

3- Lateral inhibition.

4- Adaptation.

Before discussing lateral inhibition, we will discuss the chemical presynaptic inhibition process.

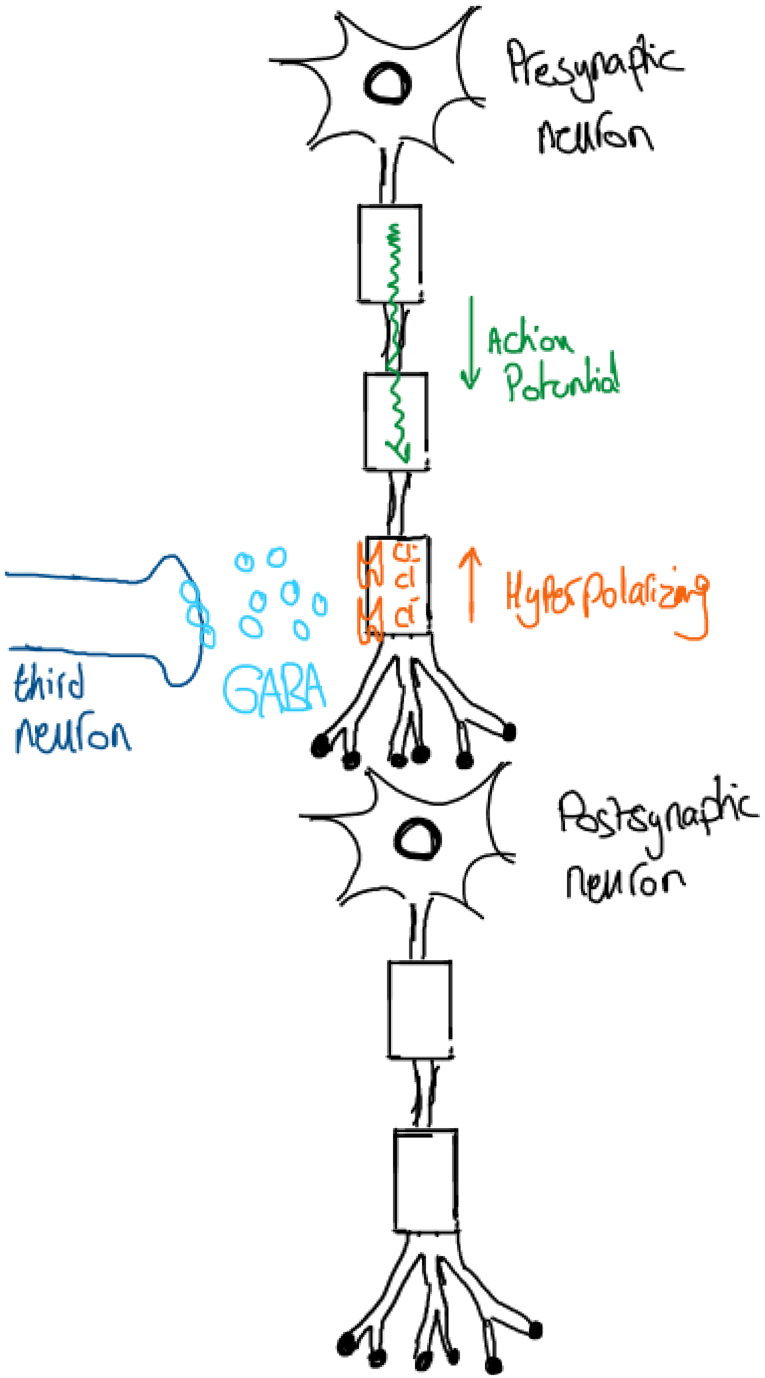
Chemical presynaptic inhibition

- The terminal axons of the presynaptic neuron will synapse with the dendrites or cell body/soma of the postsynaptic neuron.

- Another **third neuron** synapses with the presynaptic neuron before the terminal axon that's why we call it presynaptic.

- The third neuron releases inhibitory neurotransmitters, which make sense because we talk about lateral inhibition.

- This synapse is chemical [the electrical is rare in the CNS]. Neurotransmitters will be released within transporter vesicles, and the receptors waiting for them on the presynaptic neuron.

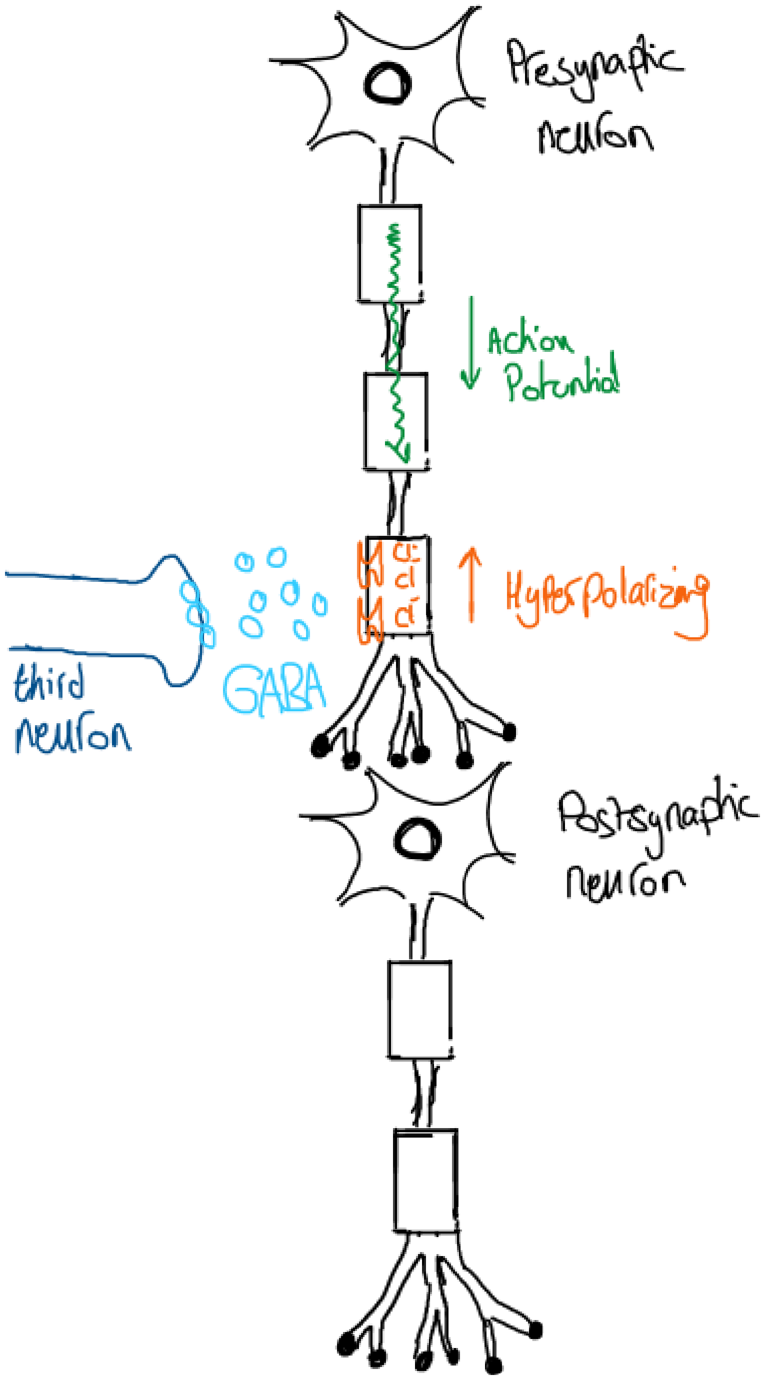


Chemical presynaptic inhibition

- The function of the neuron whether it's inhibitory or excitatory depends on the: 1) Receptors, 2) neurotransmitters, because the neurotransmitter alone can be excitatory and inhibitory, so the receptor also determines the outcome.

- The neurotransmitter that is released here is the most known inhibitory one, GABA!!

- The receptor is usually a chloride channel, allows the influx of cl-, and hyperpolarizes the neuron. However, an action potential already exists in the presynaptic neuron facing the hyperpolarization, and the ions become neutral, reducing the action potential, and the signal transduction gets inhibited.



Lateral inhibition/ surround inhibition

If pressure is applied to the skin with a pencil, many first order neurons will get excited (1,2,3), and they activate many second order neurons by synapsing with each other in any part of the CNS [we're not aware of any synapse in the PNS] reaching the cerebral cortex to be consciously aware of the stimulus (perception).

A sensory receptor converts the stimulus into receptor potential reaching the threshold and generates an action potential.
The stimulus on (1) is stronger than (2 and 3) —-> action potential frequency will increase [not the amplitude] —> the action potential of the first neuron will reach first.

In some cases, like fingertip stimulation, we want to facilitate the localization of the stimulation site, instead of all second order neurons getting activated and transferring the signals, the most intensely activated receptor pathway (1) stops the transmission of impulses in the less intensely stimulated pathways (2 and 3) through branches or collateral process and do "chemical presynaptic inhibition" to (2 and 3) which was discussed previously. Thus, the localization of the stimulus becomes more specific!!!

The lateral inhibition importance becomes clear in the vision to see the contrast between things.

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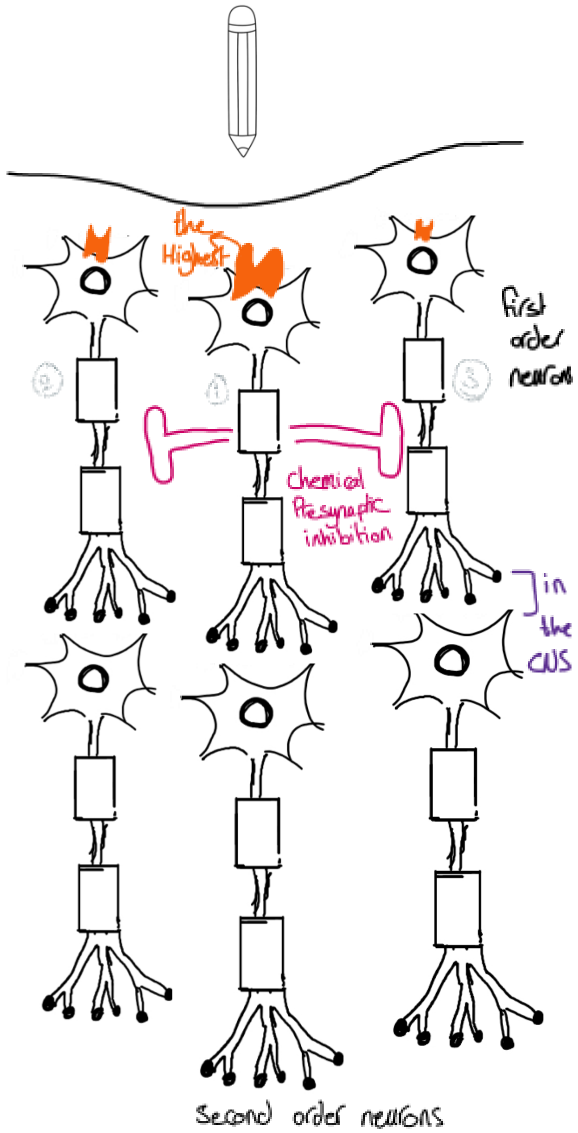


Lateral Inhibition

- Blockage of further transmission in the weaker inputs increases the contrast between wanted and unwanted information so that the stimulus is precisely localized.

- With lateral inhibition, each activated signal pathway inhibits the pathways next to it by stimulating inhibitory interneurons that pass laterally between ascending fibers serving neighboring receptive fields.

- The extent of lateral inhibitory connections within sensory pathways varies for different modalities. Those with the most lateral inhibition: touch and vision

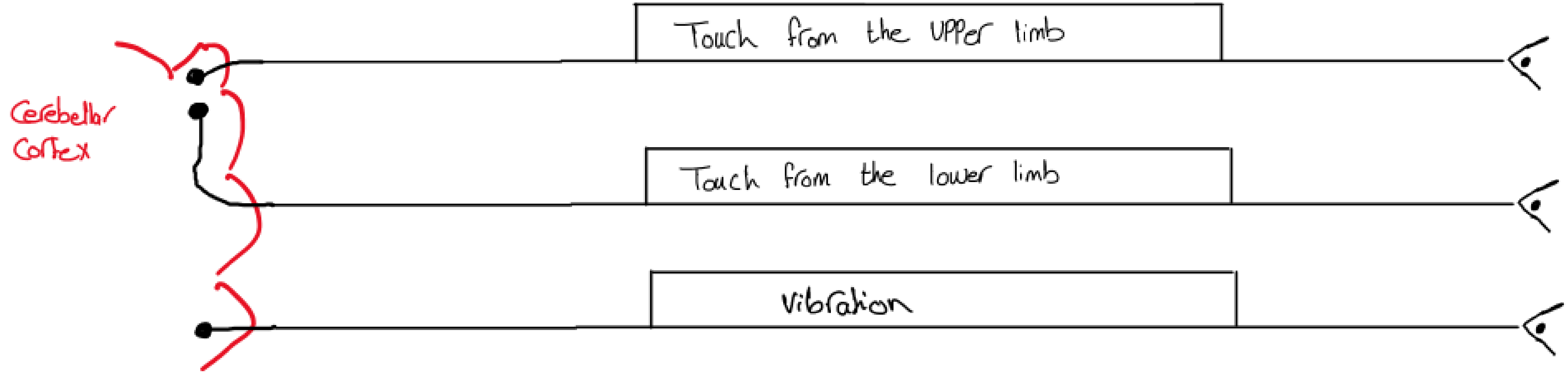
Now, let's boom a question:
How does the brain distinguish between signals, like heat, pain, pressure, or touch, even though all are propagated to the cerebral cortex by electrical signals (action potential)?

The **labeled line principle** is the answer.

Try to resemble it with clothes labels, each label defines its characteristics. Each fiber reaching the cortex is labeled with a certain type of receptor that only responds to a certain type of stimulus , and a certain location.
Ex: the first fiber is labeled by touch on the upper limb.

The same fibers type in different areas reach the cortex close to each other.
Ex: the touch fiber of the upper limb reaches the cortex close to the touch fiber of the lower limb.

بمعنى كل محفز له طريق محدد، له مستقبل خاص فيه مربوط بألياف خاصة فيه، تصل لمكان محدد بالقشرة الدماغية لتحديد نوع المحفز والمكان الذي جاء منه



Labeled Line Principle

- Even though all information is propagated to the CNS via the same type of signal (action potentials), the brain can **decode** the type and location of the stimulus.

- A particular sensory modality detected by a specialized receptor type is sent over a specific afferent and ascending pathway to excite a defined area in the somatosensory cortex.

- Thus, different types of incoming information are kept separated within specific labeled lines between the periphery and the cortex.

Stimulus intensity

- The intensity of the stimulus is reflected by the magnitude of the receptor potential.

- The larger the receptor potential, the greater the frequency of action potentials generated in the afferent neuron.

- A larger receptor potential cannot bring about a larger action potential but it can induce more rapid firing of action potentials.

Stimulus intensity

- Stimulus strength is also reflected by the size of the area stimulated: Stronger stimuli usually affect larger areas, so correspondingly more receptors respond.

- **Temporal (increasing the frequency) and spatial summation (increasing receptors number).**

- So, stimulus intensity reflected by increasing action potential frequency (temporal summation) or increasing activated receptors number (spatial summation), [for example, if 9 receptors transit the signal to the brain, it means the intensity is higher than when only 3 receptors transit the signal].

True or false

- Stimuli of the same intensity always result in receptor potentials of the same magnitude in the same receptor.

This is false because one of the receptor's characteristics is adaptation.

Sensory Adaptation: decreasing the receptor potential despite the constant intensity of the stimulus, leading to decrease our perception about this stimulus.
Ex: When we perfume clothes, we smell it at first, but after a while, we don't, even though the perfume is still there.
Another ex: When we wear a watch for the first time, we feel it, but after a while, we no longer notice it unless something reminds us of it.

The importance of this is to not overload the CNS, only important signals reach the CNS.

Adaptation

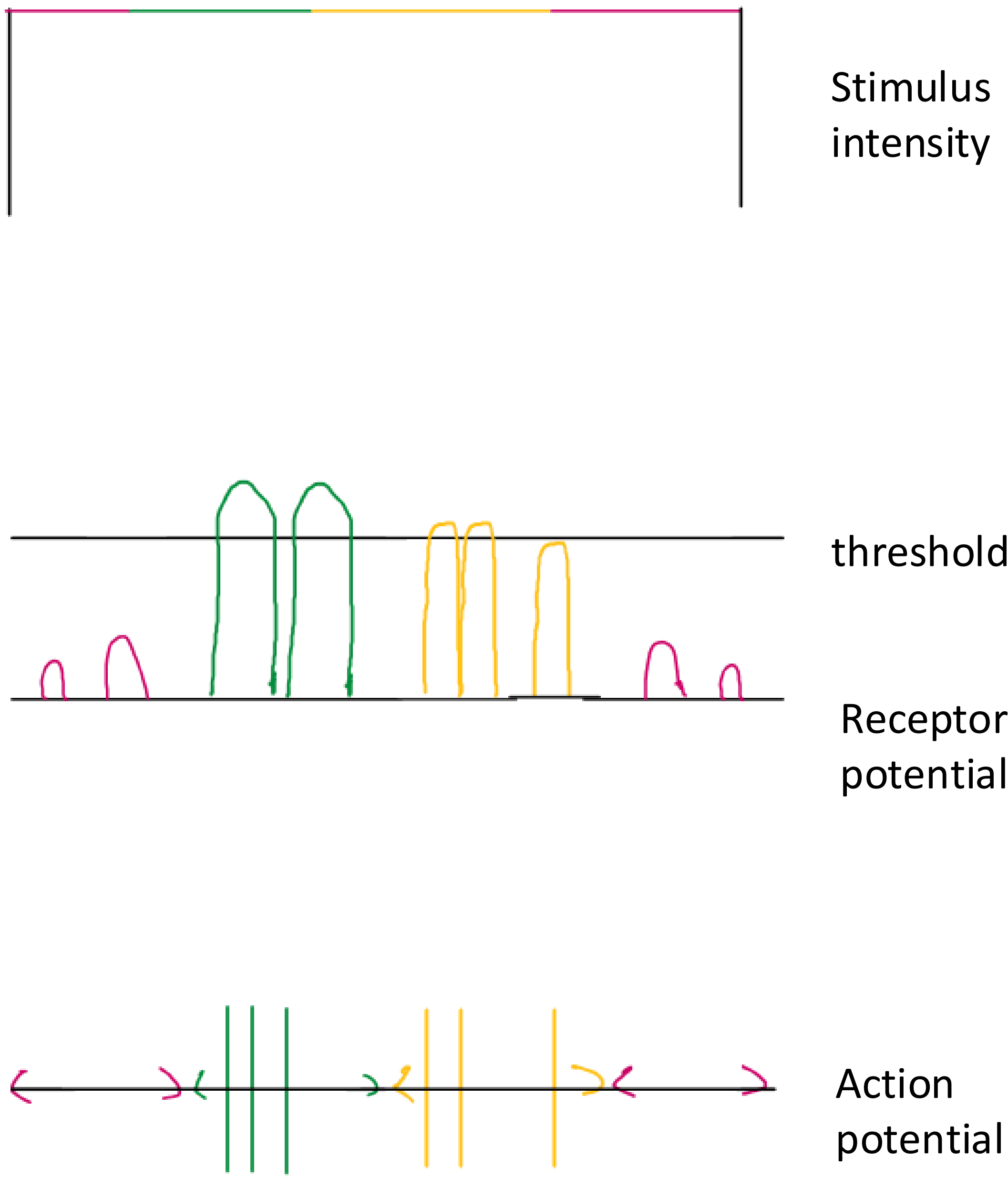
The stimulus intensity is constant.

Phase (1)
The receptor potential doesn't reach the threshold, and there is no action potential.

Phase (2)
The receptor potential is stronger, reaches the threshold, and there is an action potential.

Phase (3)
Despite the existing stimulus the receptor potential and the frequency of the action potential will decrease.

Phase (4)
When the receptor potential is below the threshold, the action potential disappears.



- Almost all sensory receptors are adaptive.

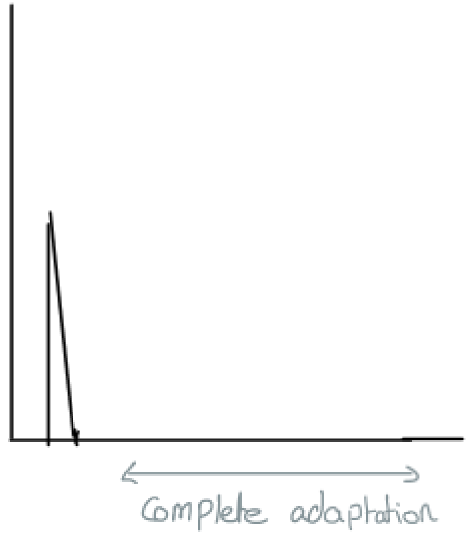
- However, there are many theories, some say that some receptors are not adaptive, in this lec we will consider that all receptors are adaptive, but some need a long time.

- So, sensory receptors differ in the **rate of adaption** [fast or slow], and in the **extent** [sudden or gradual decreasing].

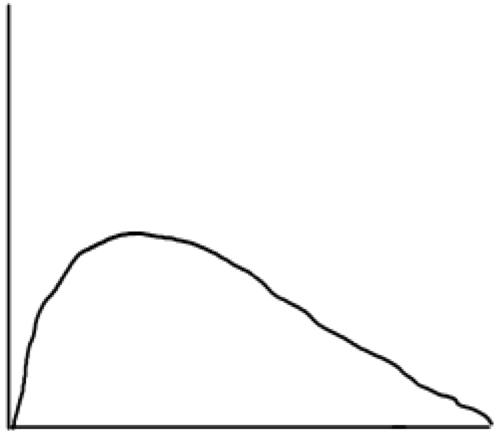
- Why do they differ in the rate and extent?

Because they have different functions.
Pain receptors must be slow - is the slowest -, to give a sign about tissue destruction, until we treat it.
Pain receptors extent decreases gradually, like by compressing the injury, then when the tissue destruction gets treated the pain disappears.

Rapidly adapting



Slowly adapting



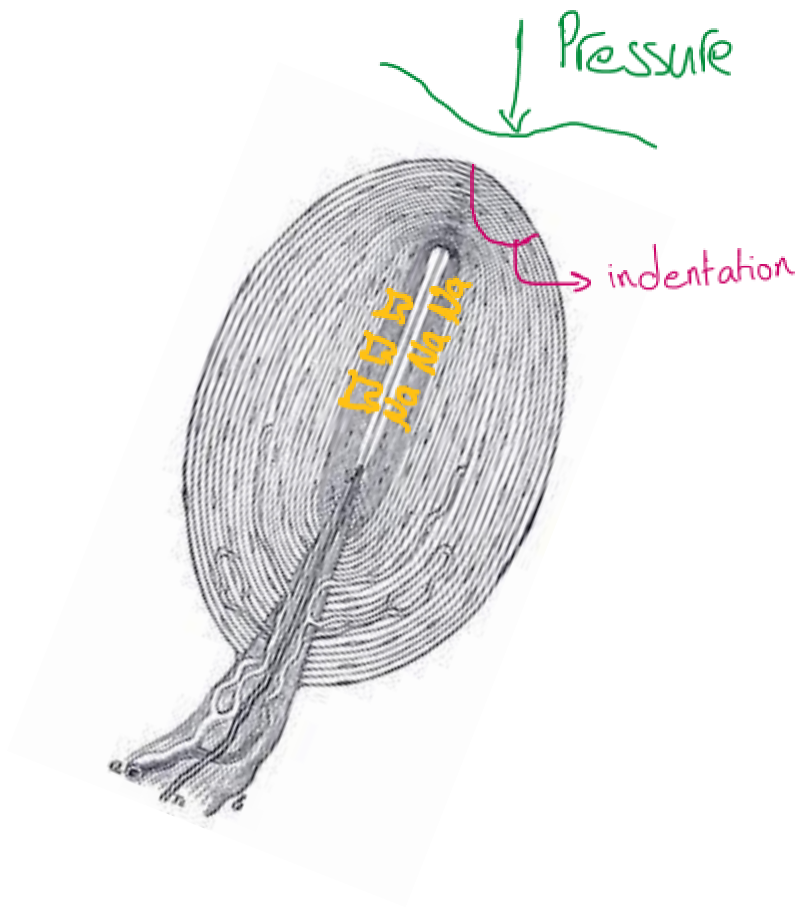
The fastest adaptive receptor is Pacinian corpuscles [encapsulated nerve ending], which responds to pressure and vibration, takes seconds or less.

The mechanical stimulus will deform the Pacinian corpuscles shell by indenting it due to its viscoelastic properties.

This will activate Na channels to do receptor potential and then an action potential.

This viscoelastic properties will help it to return quickly even though the stimulus is still there. Also, the Na channels return to the resting state quickly.

-If the stimulus is constant, the structures return normally, waiting for another stimulus.
-If the stimulus changes, it can be transmitted quickly.



The rapidly adapting receptors also called phasic or rate adapting, because firstly it fires, then completely adapts and no longer gives any signals.
However, if another trigger occurs, it fires again.
So, it responds to different phases or changes, like olfactory receptors.

The slowly adapting receptors also called tonic receptors, remain firing, but the frequency gradually decreases until it ends, like pain & proprioceptors [it is always important to know our position, to maintain balance].

We can arrange all the receptors between the Pacinian corpuscles, which are the fastest, and the pain receptor, which is the slowest.
All receptors will be positioned between them.

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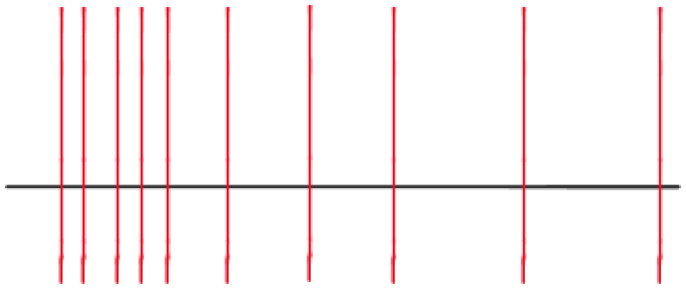
Rapidly adapting

Slowly adapting



Adaptation in sensory receptors

- A characteristic of most sensory receptors is **adaptation**, in which the receptor potential decreases in amplitude and frequency during a maintained, constant stimulus.(no action potential reaches CNS)

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

- Receptors vary in **how they adapt and how quickly they adapt** (tonic vs phasic).

Tactile senses

Recall Tactile senses, 5 subtypes:

- **Touch:** generally results from stimulation of tactile receptors in the skin or in tissues immediately beneath the skin.
- **Pressure**: A sustained sensation that is felt over a larger area than touch, and generally results from deformation of deeper tissues.
- **Vibration**: results from rapidly repetitive sensory signals.

4- Itching 5- Tickle
They need certain movement on the surface of the skin, the receptors are under the skin (very superficial).

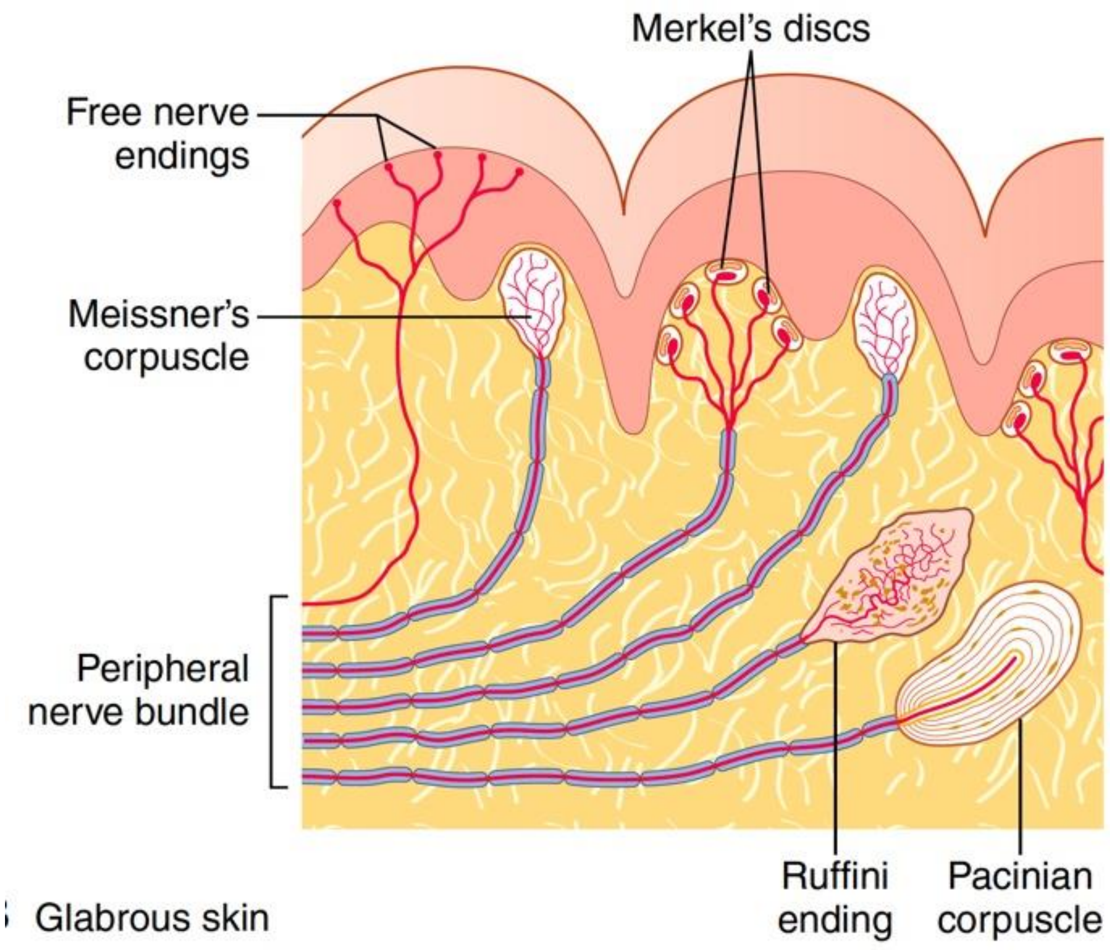
Tactile receptors

- This is a histology topic so we will not dive deep in it , you just need to know some physiological points:

- This figure shows Sensory receptors of the tactile sensations.

- You have to know that there are different types of them such as encapsulated, specialized and free nerve endings.

- From the shape & location of the receptor you can guess the function of it, e.g. Meissner's corpuscle is more superficial than Pacinian corpuscle, so by logic Miessner will detect touch while Pacinian will detect pressure.

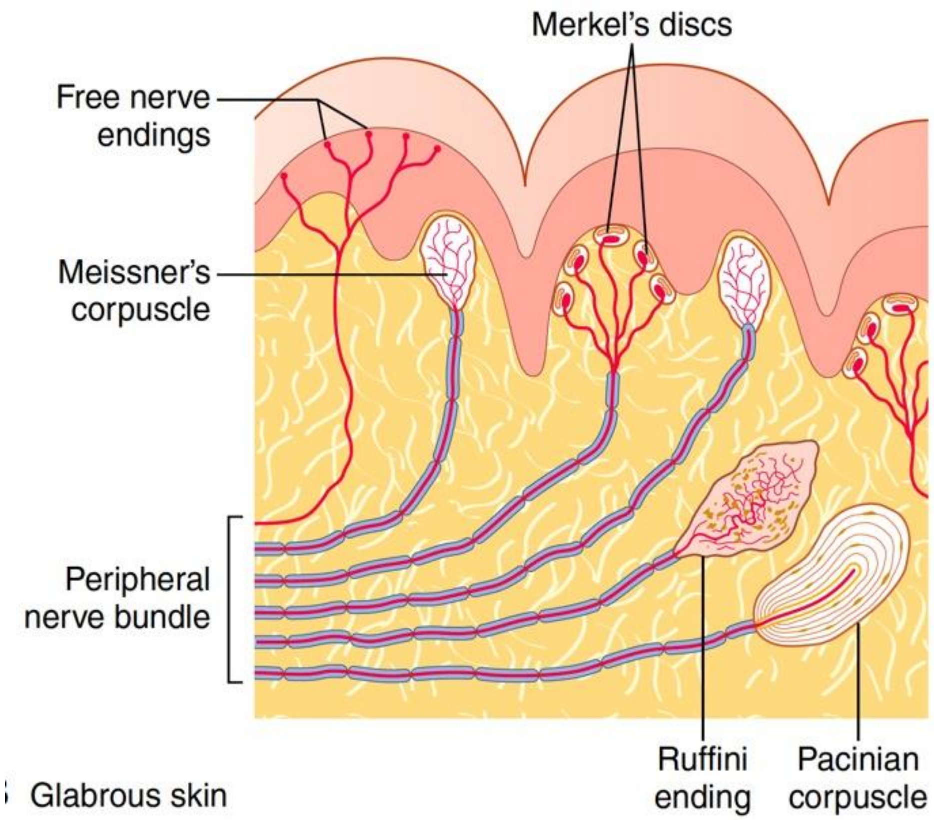


Tactile receptors

- For example, we have hairy skin and non-hairy skin and each one of them has different receptors. So, what we get from this is the second characteristic of receptors which is the rapid adapting (like pacinian corpuscles).

- So how do pacinian corpuscles serve another function in tactile sensation which is **vibration** (based on the feature of rapid adapting).

- As we said in the previous lecture about the first characteristic, we don't say that the receptor has specificity, but we say it has differential sensitivity (although we are in the same modality "tactile", we have different sub modalities).

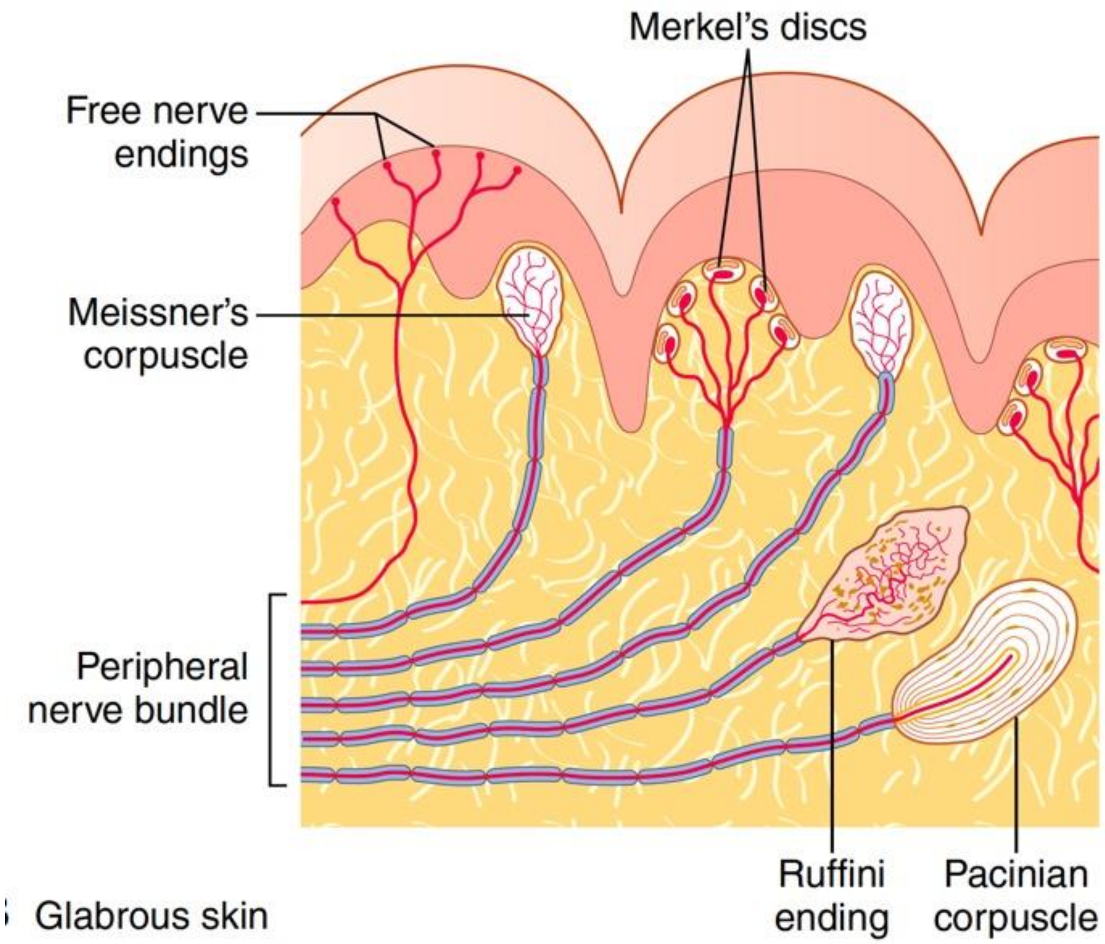


Tactile receptors

- As we said previously about Pacinian corpuscles, it can detect both pressure and vibration. Although there are other structures that can detect vibration but pacinian corpuscles with their rapid adaptation can detect the vibrations with high frequency.

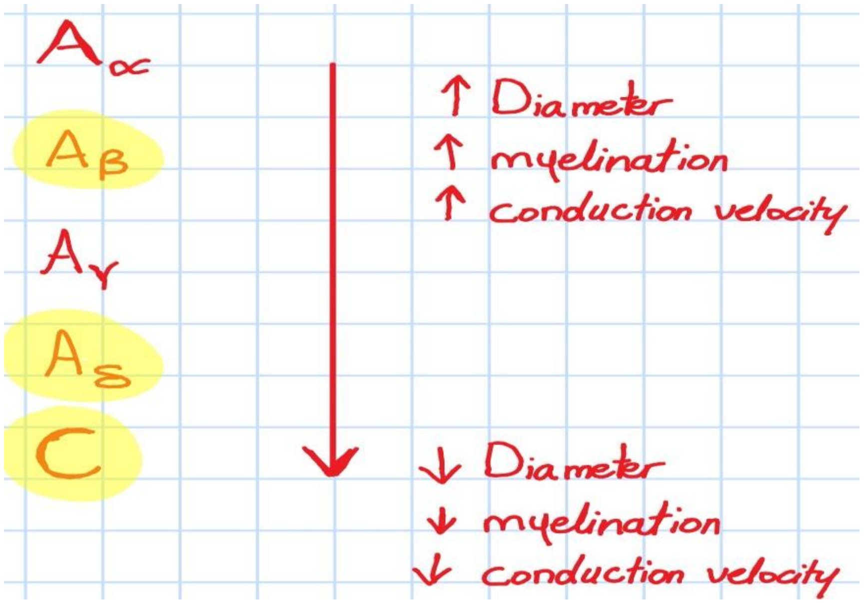
- Let's say we have a vibration (200 or 500 cycle/sec) and another vibration (50 cycle/sec) each one will be detected by different type of receptors (according to the note above, Pacinian corpuscles will detect the first vibration of 200 cycle).

- So there is some sort of overlapping between tactile sensations.



Tactile receptors

- Another amazing feature is that these sensation are transmitted through different nerve fibers, We have C and Aα, Aβ, Aγ and Aδ nerve fiber types.
- the most important types for us are (the highlighted in yellow) and they are the most abundant types.
- The differences between A and C are in the table in blue.
- So sensory signals that comes from Aβ have high conducting velocity while C have small one since it is small & unmyelinated.
- Examples of sensations that pass through C fibers are Itch & tickle.



	A	C
diameter	Large	Small
myelination	Myelinated	Unmyelinated
conduction velocity	High	Slow

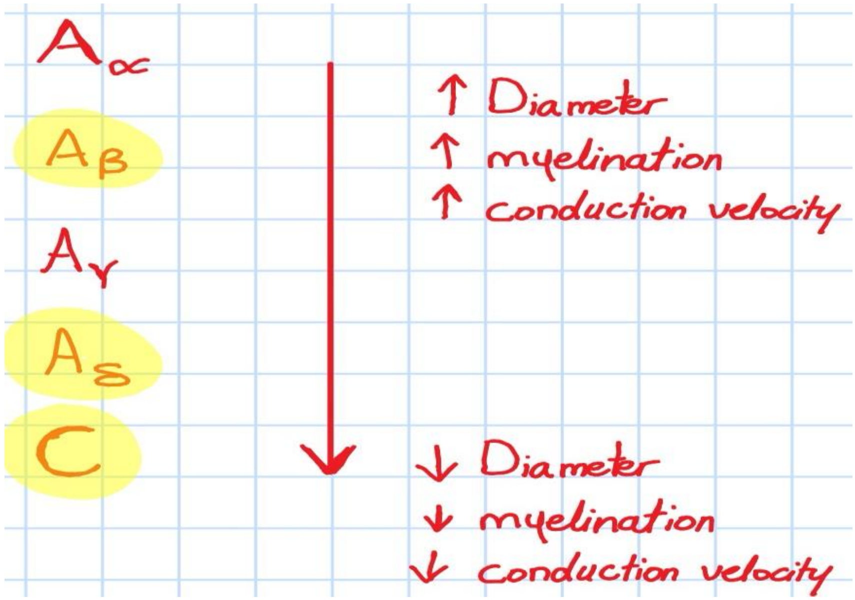
Tactile receptors

- While pressure and touch must be transmitted through Aβ like when you about to put your feet on the ground you need to know the pressure on the ground to balance your body and this info should be transmitted rapidly since cerebellum works fastly to tell the response and make sure your body is balanced.

- Another example, when you about to hold the pencil to write, you will not be able to write correctly if your brain (cortex) didn't get the info rapidly.

- Also in muscle spindles we have Aα and Aβ.

- Some sensations will pass through both A& C like pain (fast pain via Aδ and slow pain via C), pressure and touch (we have fine pressure and touch which is localized and precise , while on the other hand we have crude touch and pressure which is generalized and transmitted via C).



	A	C
diameter	Large	Small
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conduction velocity	High	Slow

Transmission of tactile signals in peripheral nerve fibers

- Almost all specialized sensory receptors, such as Meissner's corpuscles, transmit their signals in type **Aβ** nerve fibers.

- Free nerve ending tactile receptors transmit signals mainly via the small type **Aδ** myelinated fibers.

- Some tactile free nerve endings transmit via type **C** unmyelinated fibers such as in itch and tickle senses.

Tickle and Itch senses

- Itch and tickle receptors are free nerve endings found almost exclusively in superficial layers of the skin, which is also the only tissue from which the tickle and itch sensations usually can be elicited.

Tactile senses

- **Tickle**: Typically arises only when someone else touches you, not when you touch yourself.

Why? ⬇

- The reason could be due to the impulses to and from the cerebellum when you are moving your fingers and touching yourself (which inhibit the ticklish sensation) that don’t occur when someone else is tickling you.

Itch

- The purpose of the itch sensation is presumably to call attention to mild surface stimuli such as a flea crawling on the skin.
- The signals elicited then activate the scratch reflex or other maneuvers that rid the host of the irritant.
- Itch can be relieved by **scratching** if this action removes the irritant or if the scratch is strong enough to elicit pain.
- The pain signals are believed to suppress the itch signals in the cord by lateral inhibition. Also tapping will lead to pressure pain which suppress the itchy feeling (lateral inhibition)

Now let's come back to the topic of the previous lecture , is itching a mechanical or chemical stimulus?

Kidney dialyses patients feel itching although there is no mechanical stimuli on the skin, but what happens here is the chemicals will cause activation of itch receptors.

!! Remember, itch and tickle are related to free nerve endings which are slower than the specialized and encapsulated nerve endings in tactile sensations.

So you will not see Aβ in free nerve endings of somatic sensation. So
Free nerve endings are only type C and slow in conduction and can be stimulated via chemical and mechanical.

To sum up, itching can be mechanical or chemical

Position senses (Proprioceptive senses)

- It is important to know your body parts orientation within the space and relation to each other.

- Let's say here in the class, your setting way is different, e.g. doctor here puts his left leg on top of his right leg (with regard to angels of the joints, let's say we have dorsiflexion in left foot while there is no flexion in the right foot) so once this specific info reach the CNS it will directly understand your position exactly although you are static and not moving.

- These receptors also tell us about touch, pressure and joint angulation. So we have receptors on the joint capsule like ruffini corpuscle. Also, we have the receptors located within the muscle and tendons they help us to know the extent of tension in quadriceps, or how much load is on the tendon now. All of this while you are static and while you are moving.

- That's why we call position senses static position and dynamic position (Kinesthetic proprioception).

- The sensory receptors for this type of sensation is not only in the muscles and tendons receptors (muscle spindles and Golgi tendons), we have also joint capsule receptors and tactile receptors (ruffini and pacinian corpuscles since it is rapidly adapting in anything related to movement).

- Position is important not only to maintain balance but also for daily activitys. Without this kind of sense you will not be able to have the sense of the weight of objects.

- For example, how could I know if this thing is heavy for me? By sensing via muscle spindles and Golgi tendons and other receptors , then I could determine how much strength I need for contraction. Next time I see this object I don't need to do the same things I did in the first time because my body have stored info about it and I already know how much tension is needed and how much contraction of the muscle should be presented.

- Keep in mind, proprioceptive sensation depends on the receptor (to tell if it is rapid or slow adapting) since we have plenty of receptors, for example, muscle spindle should be slowly adapting since we need to know how much contractility in this muscle ALL the time, also Golgi tendon if there is a load on the tendon While pacinian corpuscle it should be rapid.

everything was mentioned earlier in another formula

Position receptors (proprioceptors)

- allow us to know where our body parts are located and how they are moving even if we are not looking at them, so that we can walk, type, or dress without using our eyes.
- Proprioceptors also allow weight discrimination, the ability to assess the weight of an object. This type of information helps to determine the muscular effort necessary to perform a task.

everything was mentioned earlier in another formula

Position receptors (proprioceptors)

- Knowledge of position, both static and dynamic, depends on knowing the degrees of angulation of all joints in all planes and their rates of change.
- Therefore, multiple different types of receptors help to determine joint angulation and are used together for position sense. Both skin tactile receptors and deep receptors near the joints are used.

Position senses

- They are divided into two subtypes:

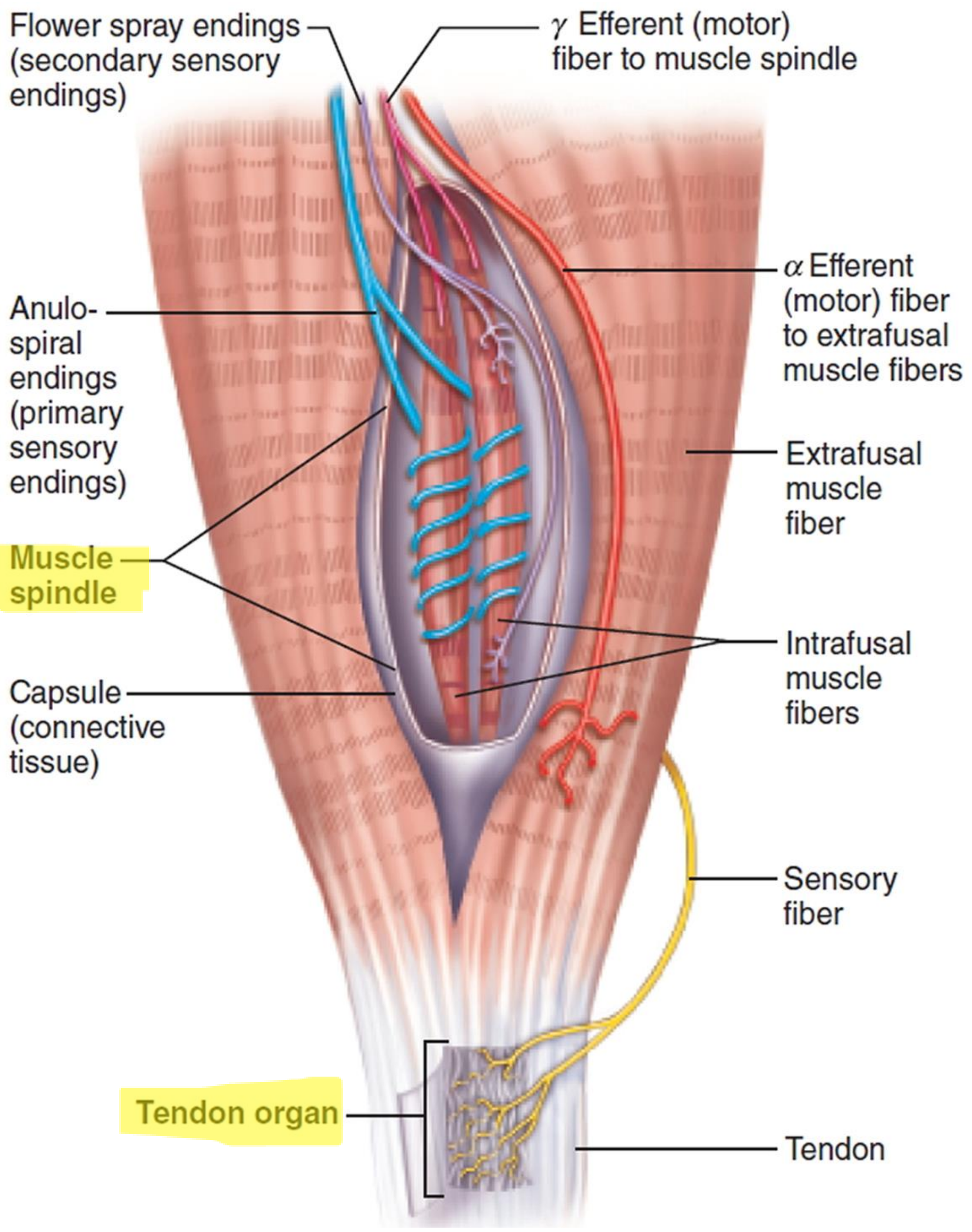
- (1) static position sense, which means conscious perception of the orientation of the different parts of the body with respect to one another.

- (2) rate of movement sense, also called kinesthesia or dynamic proprioception.

Position sensory receptors

- The Pacinian corpuscles and muscle spindles are especially adapted for detecting rapid rates of change.

- It is likely that these are the receptors most responsible for detecting rate of movement.



https://healthjade.com/proprioception/

Thermal sensations

- There are 4 receptors for this type of sensation :
  1. Cold receptors (most of them are Aδ rather than C).
  2. Warmth receptors (most of them are C rather than Aδ).
  3. Pain receptors:
     * pain cold receptors
     * pain heat receptors
- All these receptors of thermal sensation are free ending nerves which means slow conduction velocity.
- Although all of them have free nerve endings but each one of them will respond to different range of temperature.
- All of them are located superficially and their distribution is uneven in the skin.
- We have more cold receptors than warm receptors in our body.

everything was mentioned earlier in another formula

Thermoreceptors

- Cold receptors
- Warmth receptors
- Pain receptors (stimulated only by extreme degrees of heat or cold).

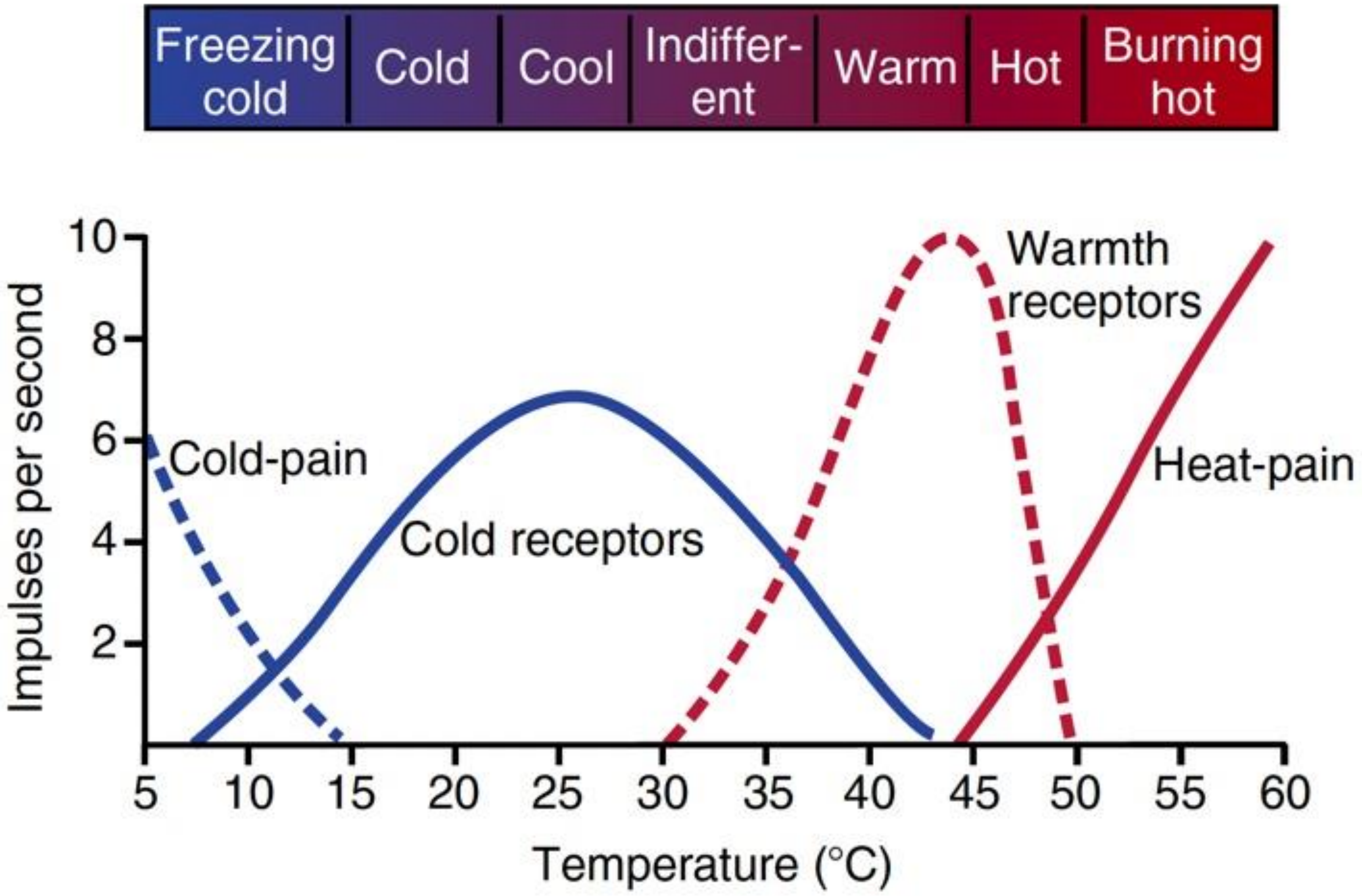
- They are located immediately under the skin at discrete separated spots.
- Most areas of the body have more cold receptors than warmth.
- The number of receptors in different areas of the body varies.

everything was mentioned earlier in another formula

Thermoreceptors

- Free nerve endings.
- Warmth signals are transmitted mainly over type C nerve fibers.
- Cold signals are transmitted mainly via type Aδ nerve fibers.
- In general, thermal signals are transmitted in pathways parallel to those for pain signals.

Thermal sensations



- Let's say I'm at temperature **25**; cold receptors will get activated.

- While when I'm at temperature **37**; a combination of both cold and warm receptors will work with the same degree and that's why you feel temperature indifferent.

- Keep in mind that even within the indifferent region (purple box in previous figure) there are sub degrees which means warm may be more than cold receptors or the opposite as at 35 degree (no. of impulses).

- Above 45 degree, pain receptors will get activated (as we said in the previous lecture, pain receptors get activated on the extreme of the stimuli).

- For example, the freezing weather nowadays may cause pain in the tips of the fingers.

- Also, once you set way too near to the fireplace and temperature exceeded 45 you will feel the pain (usually below 10 degrees cold pain happen).

- If you have a baby in your family, you will see the mother once she wants to shower her baby test the temperature of the water by her fingers, but doctors advise to test it by elbow, why??
- Since thermal receptors receive more change in temperature when the surface area is large, so the larger the surface area is, the more change in temperature will be received and sensed.

- For example, if you but your feet in the pool water you will feel it cold, while if you jumped with your whole body at the beginning, you would feel it super freezing (so it is phasic), but after spending some time in the pool, you will feel better, and this is a kind of adaptation since neither your temp. Nor the pool water temp. had changed so this adaptation is not a complete (less than in pacinian corpuscles).

- So, the thermal receptors respond more to changes in temperature than the absolute temp.

- So, at the beginning you will feel it cold due to the change in temp. But if it stayed steady this sensation will decrease.

- So, the larger the surface area is, the more informative is in thermal sensation and the more accurate the feeling of temperature changes is.

Thermal sensations

- The different gradations of thermal sensations can be determined by the relative degrees of stimulation of the different types of thermoreceptors and nociceptors.

- It is difficult to judge gradations of temperature when small skin areas are stimulated.

- However, when a large skin area is stimulated all at once, the thermal signals from the entire area are cumulative.

Adaptation in thermal receptors

- Thermal senses respond markedly to changes in temperature than to steady states of temperature.

- This means that when the temperature of the skin is actively falling, a person feels much colder than when the temperature remains cold at the same level.

Thermal receptors

- Is thermal sensation considered only a physical stimuli (change in temp. Is the reason of the response and receptor activation and cells change metabolic activity?) or are there other mechanisms?

- Some people don't feel the hot pepper while others feel it, this is due to different threshold among people. So, what happen chili pepper you feel it hot and drink water to decrease this hotness, so you feel this high temperature, But there is no actual change in the temperature! So, what happens here is that there are channels on these sensory receptors we call them (transient receptor potential).

Thermoreceptors

- Spatial Summation of Thermal Sensations:

- Because the number of cold or warmth endings in any one surface area of the body is slight, it is difficult to judge gradations of temperature when small skin areas are stimulated.

- However, when a large skin area is stimulated all at once, the thermal signals from the entire area are cumulative.

Thermoreceptors

- It is believed that thermal detection probably results not from direct physical effects of heat or cold on the nerve endings but from chemical stimulation of the endings as modified by temperature (change in metabolic rates, which alters the rate of intracellular chemical reactions).

Thermal receptors

- Transduction of warm temperatures involves transient receptor potential (TRP) channels in the family of vanilloid receptors (TRPV).

- These channels are activated by compounds in the vanilloid class, which includes capsaicin, an ingredient in spicy foods. (This phenomenon explains why people describe the taste of chili peppers as "hot.")

Thermal receptors

- Transduction of cold temperatures involves a different TRP channel, TRPM8, which is also opened by compounds like menthol (which gives a cold sensation).

اصطَنِعنا يا الله على عَينِكَ
واستَخدِمنِا على الوَجهِ الذي يُرضِيك
واجعَل عِلمنا وعَمَلنا خالِصًا لِوجهِكَ الكَريم

VERSIONS	SLIDE #	BEFORE CORRECTION	AFTER CORRECTION
V1→ V2			
V2→V3			

امسح الرمز و شاركنا بأفكارك لتحسين أدائنا !!