physiology

Faculty Of Medicine - JU 2015

Lecture:23

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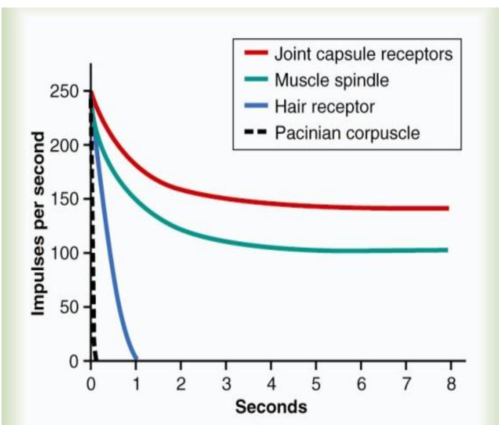
Adaptation

Last time we were talking about receptor adaptaion and we talked that receptors in term of adaptaion there are two kinds. Some of the receptors are fast adapting receptors we call them "phasic receptors" and others are slowly adapting receptors we call them "tonic receptors".

So as you see here the broken line (Pacinian corpuscle) are fast adapting receptors. Because there is a stimulus, so the stimulus increases the rate of



discharge. After very short time

they come to zero action potential which means complete adaptation. Hair receptors adapt within a second or so, and some joint capsule and muscle spindle receptors adapt slowly.

So rate of adaptation varies with type of receptor.Therefore, receptors respond when a change is taking place.

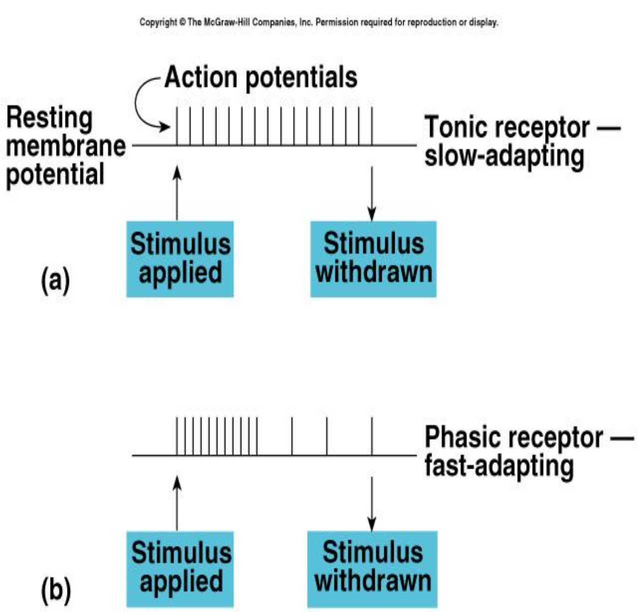
Receptors responding to pressure, touch, and smell adapt quickly, whereas receptors responding slowly include Merkel's discs, Ruffini's corpuscles, and interoceptors that respond to chemical levels in the blood. Pain receptors and proprioceptors do not exhibit adaptation.

Medical Study:

In diabetics something called neuropathy happens, and it means that neurons won't be able to transfer the feeling of pain, so when the person gets cut for example, he won't be able to feel pain, and this cut will cause tissue damage, eventually the damaged organ (finger let's say) will have to be cut (amputated) [Gangrene]

Slowly Adapting (Tonic) Receptors

Slowly adapting receptors continue to transmit impulses to the brain as long as the stimulus is present and they keep the brain apprised of the status of the body with respect to its surroundings. They will adapt to extinction as long as the stimulus is present, however, this may take hours or days. If the stimulus stays the same strength for long time, they might adapt but take long time, that why they are slowly adapting. These receptors include: *muscle spindle*, *Golgi tendon apparatus, Ruffini's endings, Merkels discs, Macula, chemo- and baroreceptors.*



So as you see here. There are two kinds of adaptation. In (a) there is a stimulus supplied and ,as you see, when the stimulus applied there is action potential out through, which means that these are non adapting ,because the action potential still there. In (b) there is a stimulus supplied. It started with very high rate of impulses, then it started to decreases although the stimulus still there which means that they are fast adapting.

*** So what adaptation means?*

Adaptation means that the stimulus is there, when there is no action potential.

So we can conclude that Tonic receptors produce constant rate of firing as long as the stimulus is applied, whereas Phasic receptors produce burst of activity but quickly reduce firing rate if stimulus maintained.

Rapidly Adapting (Phasic) Receptors

Note: 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. Therefore, these receptors are called rate receptors, movement receptors, or phasic receptors.

What is the advantage of rapidly adapting receptors?

They tell you about the strength (intensity) and rate of the stimulus.

For instance, if you are moving in a certain rate, the system calculates the distance and know after how many milliseconds where is your position will be and as a result you know when to stop.

But if the brain doesn't know the speed; as a result of destroying these receptors (it was experienced on monkeys where their receptors were destroyed and the monkeys kept walking until they bumped into something, because they won't have a predictive function). So the phasic receptors are important for predicting the future position or condition of the body and they are very important for balance and movement.

The types of rapidly adapting receptors include: Pacinian corpuscle, semicircular canals in the inner ear.

Signal intensity

The different gradations of intensity can be transmitted either by using increasing numbers of parallel fibers (spatial summation) or by sending more action potentials along a single fiber (temporal summation).

Coding in the sensory system

1) How we code for intensity?

We code for intensity by (a) The rate of discharge =(frequency of action potential=the number of impulses=discharge rate=frequency of impulses=number of action potential), and the higher the rate , the stronger the stimulus is , because at that time we are able to stimulate the neuron during the relative refractory period until we reach absolute refractory period. This mean called (temporal summation). (b) The number of neurons stimulated (spatial summation). If the stimulus is weak, it will be able to stimulate few neurons. If the stimulus is strong, it will be able to stimulate more neurons.

2) How we code for location?

By the labeled line principle.

Each part of your body is represented in special area in the cerebral cortex, but the representation is **contralateral** (which means that the representation of the left side is on the right side of the cortex and vice versa) and the representation is **upside down.** Some areas of the body are represented by large areas in the cerebral cortex—the lips the greatest of all, followed by the face and thumb—whereas the lower part of the body are represented by relatively small areas. The sizes of these areas are directly proportional to the number of specialized sensory receptors in each respective peripheral area of the body. For instance, a great number of specialized nerve endings are found in the lips and thumb, whereas only a few are present in the skin of the lower part of the body.

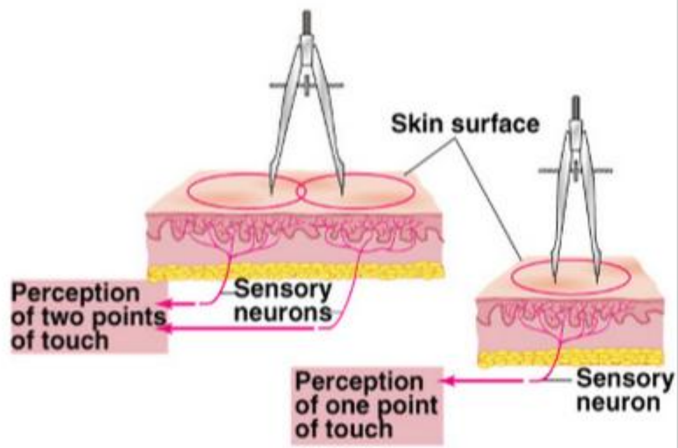
Receptive Fields: what does receptive field mean?

It is the area that the receptor collects the information from.

If there are more receptors, in order to ous to know if the stimulus is coming from one area or from two areas it has to stimulate one or two receptors. If it stimulate one receptor-even if they are two hits-I will perceive them as one point. But to know them as two points they have to hit two receptors. To know them as two points they have to hit two receptors, because each receptor has what we call it receptive field. The smaller the receptive field, the sharper the information (the better the localization), and the larger the receptive field, the less (or the worse) the localization.

Two points discrimination:

It is the minimum distance at which 2 points of touch can be perceived as separate.It depends on the density of the receptor; the more the density of the receptor, the better is the discrimination and the less the number of receptors(density) , the poorer is the discrimination.



The two-point touch threshold test.

If each point touches the receptive fields of different sensory neurons, two separate points of touch will be felt. If both caliper points touch the receptive field of one sensory neuron, only one point of touch will be felt.

On the finger tips, the minimum distance at which two points of touch can be perceived as separate (measure of distance between receptive fields) is 2 mm. whereas on the back, this distance is equal to 5 cm

3) How we code for type of stimulus?

By 1) the type of receptor stimulated (adequate stimulus)   2) The specific pathway over which this information is transmitted to a particular area of the cerebral cortex
Note: Adequate doesn't refer to quantity. It refers to quality.

Neuronal Processing

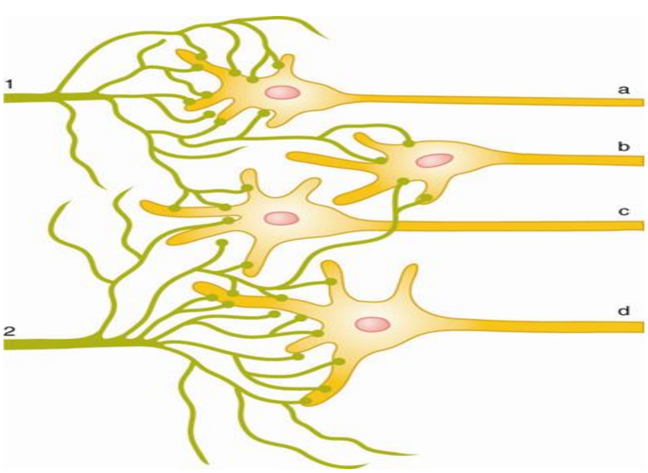
Q: How are these sensations processed?

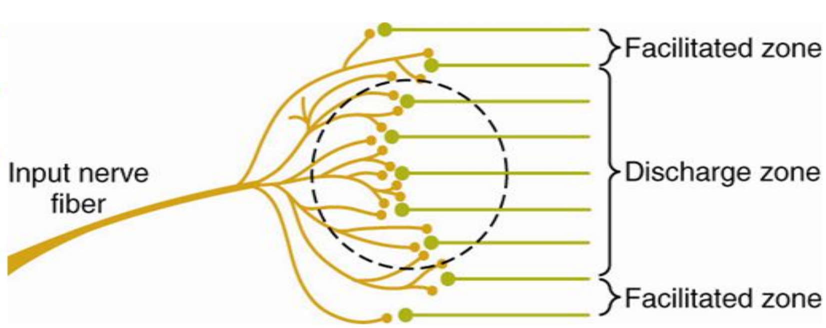
A: The area in the middle of the receptive field is the most stimulated area, a weak stimulus will only stimulate the area in the middle (which is called Discharge zone) and the stronger the stimulus gets, the more the area on the periphery (which is called Facilitated zone) is stimulated. There is receptor potential in the periphery but this potential hasn't reached the threshold. this zone is called facilitated zone (close to the threshold).

- Discharge zone: has action potential.

- Facilitated zone: close to the threshold but hasn't reached it.

As you see in the figure below; neuron1 and neuron2 have divergences on the central neurons (b and c).So if the stimulus is weak, it is going to stimulate (1-a) and (2-b), but (b & c) are not going to be stimulated .But if the stimulus is too strong in a and too strong in b, it is going to stimulate the periphery and we can get stimulation of all the neurons (a & b & c & d)





**The strength of the stimulus in the middle of the receptive field is highest and the threshold is lowest, but the threshold in the periphery is highest.

Neuronal Pools

Groups of neurons with special characteristics of organization.

Note: the entire cerebral cortex could be considered to be a single large neuronal pool. Also, the entire dorsal gray matter of the spinal cord could be considered one long pool of neurons.

Types of neuronal circuits:

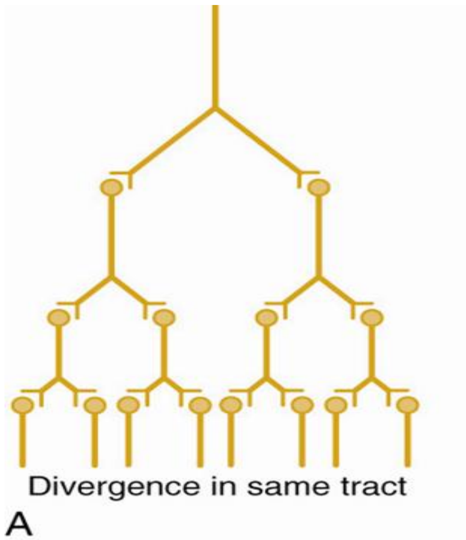
1. Divergence: the neuron divides at the axon. Here we lose the localization because the stimulus spreads to a large area and the signal is amplified along the path. (Output from one neuron onto many)→This type is bad for localization.

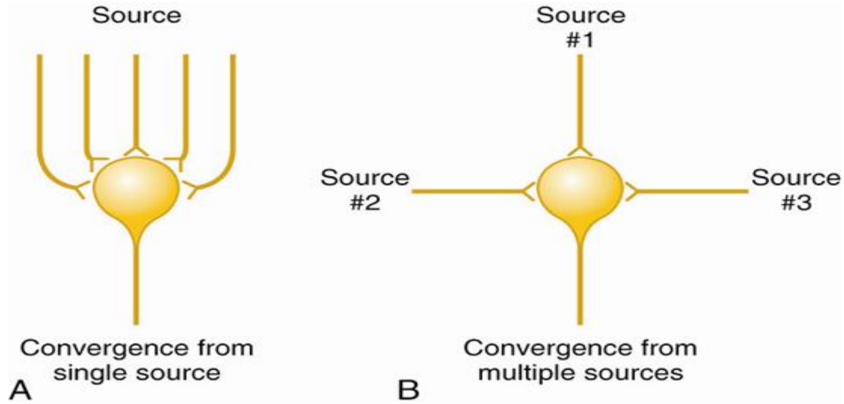
2. Convergence: signals from multiple inputs uniting to excite a single neuron, these signals summate and we may reach the threshold from weak stimulus (advantage).we also have lose of localization here (disadvantage) (output from many neurons onto one),but if it is convergence from single source the localization is okay.

There are two types of convergence:

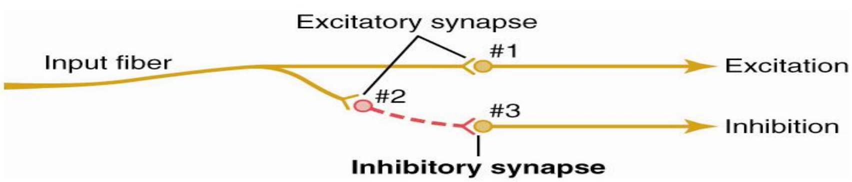
1. Convergence from a single source. (temporal summation)

2. Convergence from multiple sources. (spatial summation)



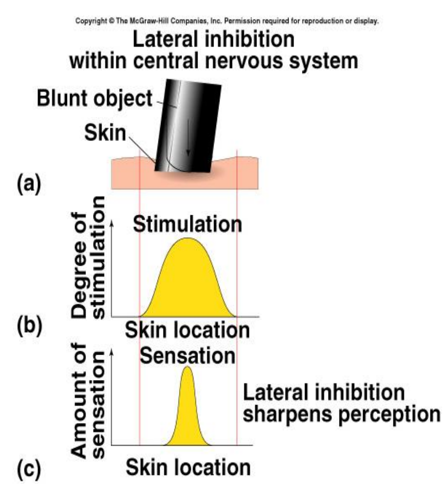


Lateral inhibition :



-Some times we need these signals to be sharp (contrast, EX: difference between black and white), our system do this by stimulating central neurons, and inhibiting peripheral neurons, by a mechanism called lateral inhibition (peripheral neurons will synapse with inhibitory interneurons). <remember> divergence used to generalize impulse , lateral inhibition used to localize (sharpening) the stimulus .

Example for sharpening of sensation by lateral inhibition:



When a blunt object touches the skin, a number of receptive fields are stimulated—some more than others. The receptive fields in the center areas where the touch is strongest will be stimulated more than those in the neighboring fields where the touch is lighter. Stimulation will gradually diminish from the point of greatest contact, without a clear, sharp boundary. What we perceive, however, is not the fuzzy sensation that might be predicted. Instead, only a single touch with well-defined borders is felt. This sharpening of sensation is due to a process called lateral inhibition.

→Lateral inhibition and the resultant sharpening of sensation occur within the central nervous system.

<u>**Mechanisms for prolongation of Time of the signals**</u> :

1-Synaptic after discharge

2-Reverberating Circuits

3-Parallel circuits

- 1-**Synaptic after discharge** :

Remember that EPSP is a local , summated , graded depolarization , it takes time more than action potential , but it decay faster .

since the time of EPSP (15-20 msec) is longer than the time of Action Potential (0.1 – 10 msec) then more Number of Action Potential per one EPSP(if the EPSP was above the threshold for 10 msec it will generate action potential for 10 msec) EX : when you close your eyes after looking to the sun for a long time , you are going to see a light (shadow of the sun) even your eyes are closed ! , why ??

The sun has stimulated your electromagnetic receptors , made a synapse and many discharges , this discharges won't stop until depletion of synaptic vesicles that house neurotransmitters in the synapse .

- 2-**Reverberating Circuits** :

in reverberating circuits an incoming signal travels along a chain made up of neurons, each neuron along the path is linked with the previous cell by collateral synapses. These are involved in the control of activities like breathing. (we have one input , giving to many outputs , some of these outputs are linked to the previous cell , theoretically nerve impulses will not stop at all !)

- 3- **Parallel circuits** :

-here we have too many outputs , with different number of synapse in each output , but it will not prolongate as long as Reverberating Circuits . (each action potential <output> will reach the cell body at different time , depending on number of neurons <synapse> on its way , so we will have at first output 1 , then output 2 … and so on , this will Prolong the time of action potential)

Stabilization of neuronal discharge

We have seen previously that Reverberating Circuits will never stop theoretically, actually , our systems will Stabilize neuronal discharge by many ways :

Synaptic fatigue : It is caused by a temporary depletion of synaptic vesicles that house neurotransmitters in the synapse, generally produced by persistent high frequency neuronal stimulation.

<u>Example</u>: in Epilepsy (الصرع) we have too many uncontrolled discharges to our muscles and CNS .but these muscles will relax suddenly due to Synaptic fatigue.

Neuronal inhibitory circuits:

Gross inhibition –Basal ganglia inhibits muscle tone

Feed back inhibition-Cortico-fugal fibers from cerebral cortex descending fibers to control the intensity and sharpness

Downregulation and upregulation- Long term stabilization through modification of the receptor availability (internalization or externalization)

(we mean here neurotransmitters receptors which are membrane receptors , not sensory receptors)