Physiology

Sheet No.

12

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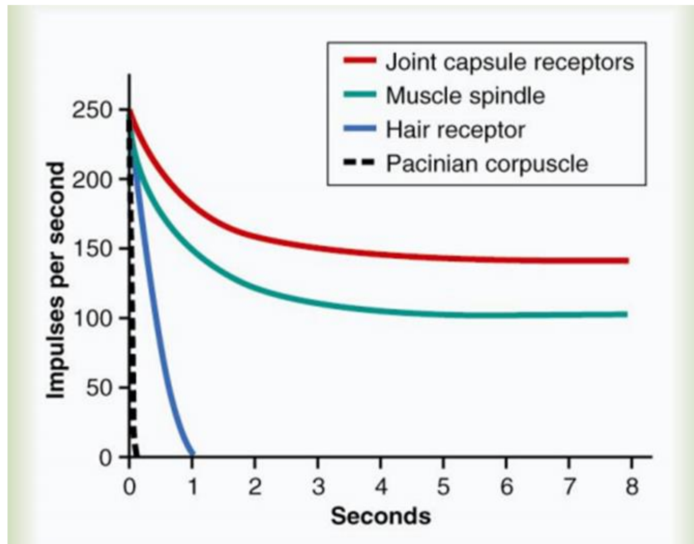
Adaptation of receptors: -

➢ when we influence a receptor by a continuous stimulus with the same frequency, we expect to see action potential as long as that stimulus is present, but actually this doesn't happen in our bodies, the frequency of action potential decreases until it reaches zero…..this is known as adaption of receptors.

Adaptation of different types of receptors showing a rapid adaptation of some receptors and slow adaptation of others. Note that Pacinian corpuscle adapts very rapidly, hair receptors adapt within a second or so, and some joint capsule and muscle spindle receptors adapt slowly.



➢When you wear a shirt, at first you will feel the shirt touching your skin, but after a few moments your receptors adapt to that sensation and no action potential is generated so you will not be able to feel it (this is an example of rapid adaption).

➢ So now we know that the rate of adaption varies with type of receptor, some sensory receptors adapt within a few hundredths of a second known as "rapidly adapting receptors" (i.e… touch, pressure, smell). while some of them will take hours or even days to do so, for this reason they are called "slowly adapting receptors" (i.e…. proprioceptors).

NOTE: PAIN receptors are almost non-adapting receptor, because pain is due to tissue damage and it must always be felt to avoid

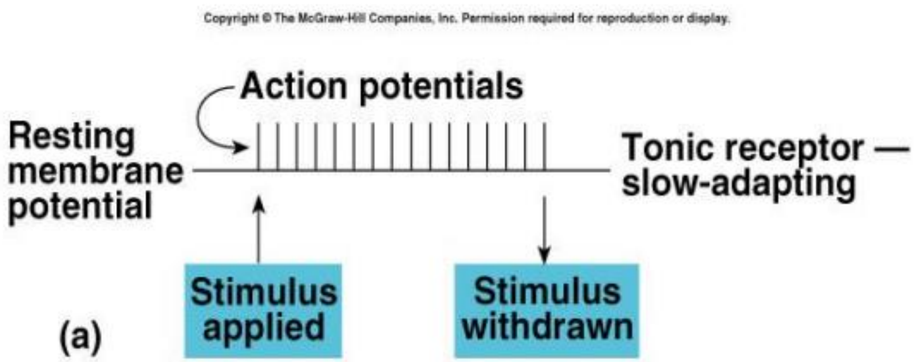
Slowly adapting (Tonic) Receptors

Slowly adapting receptors continue to transmit impulses to the brain for long periods of time as long as the stimulus is present. Therefore, they keep brain constantly apprised of the status and position of the body and its relation to its surroundings. However, they might adapt to **EXTINCTION** (complete adaptaion) if the stimulus is present for some hours or days which is a hard thing to do.

➢ Examples: muscle spindle, Golgi tendon apparatus, Ruffini's endings, Merkle's discs, Macula, chemo- and baroreceptors.

Tonic receptors:

-produce ***constant rate*** of firing as long as stimulus is applied.



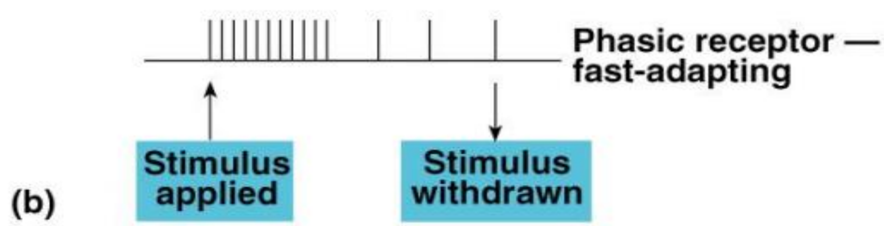
Rapidly adapting (phasic , Rate) Receptors

➢ Rapidly adapting receptors cannot be used to transmit a **continuous signal** because they are stimulated **ONLY** when the stimulus strength **changes.**

➢ Rate and Strength of the response is related to the Rate and Intensity of the stimulus. (Remember that increasing stimulus **strength** increases the **amplitude** of the receptor potential. In turn, increasing the **frequency** of action potentials transmitted from sensory receptors.)

Phasic receptors:

Burst of activity but quickly reduce firing rate (adapt) if stimulus maintained.



*Rapidly Adapting Receptors are Important for Balance and Movement, they are also called **rate receptors** because they know the rate (velocity) at which some changes in bodily status is taking place. As a result, the state of the body a few seconds or even a few minutes later can be predicted!

So how this happens?

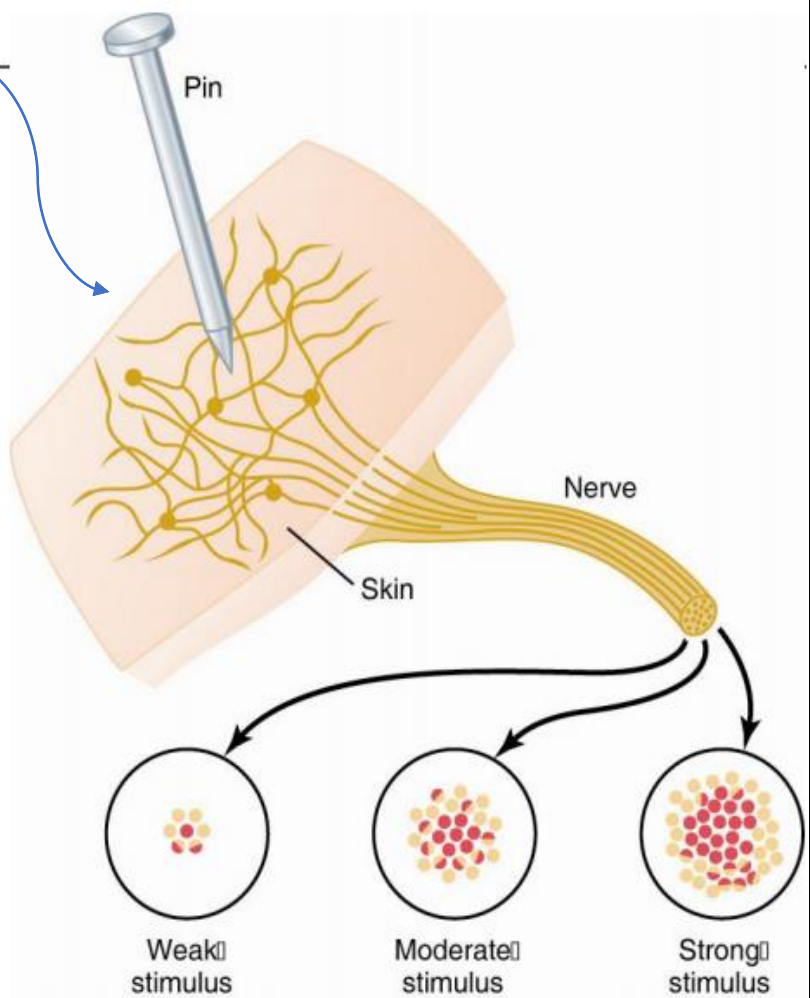
For instance, receptors located in or near the joints help detect the rates (velocities) of movement of the different parts of the body, so running information from the joint rate receptors allows the nervous system to predict where your feet will be during ANY PRECISE FRACTION OF THE NEXT SECOND. So, this tells you when to stop running to avoid hitting objects around. (Time*velocity=distance)

Importance of Signal Intensity

How can the brain determine the intensities of stimuli?

-simply by two mechanisms:

1- spatial summation: It depends on the ***number of fibers*** stimulated, so increasing the number of fibers that are stimulated increases the intensity of the action potential.



2-Temporal summation: Increasing the ***rate of firing*** in a limited number of fibers (sending more action potential along a single fiber=increasing the frequency of nerve impulses)

STIMULUS PROPERTY	MECHANISM OF CODING
TYPE OF STIMULUS (MODALITY)	Distinguished by: 1- Type and SPECIFICITY of the receptor (Adequate Stimulus). 2- The SPECIFIC PATHWAY over which this information is transmitted to a particular area of the cerebral cortex (Labeled Line).
LOCATION OF STIMULUS	Distinguished by: 1- The LOCATION of the activated RECEPTIVE field. 2- The SPECIFIC PATHWAY that is subsequently activated to transmit this information to the area of the SOMATOSENSORY cortex representing the particular location (Labeled Line).
INTENSITY OF STIMULUS (STRENGTH)	Distinguished by: 1- The FREQUENCY of action potentials initiated in an activated AFFERENT neuron (temporal summation). 2-Number of receptors (and AFFERANT neurons) activated (spatial summation).

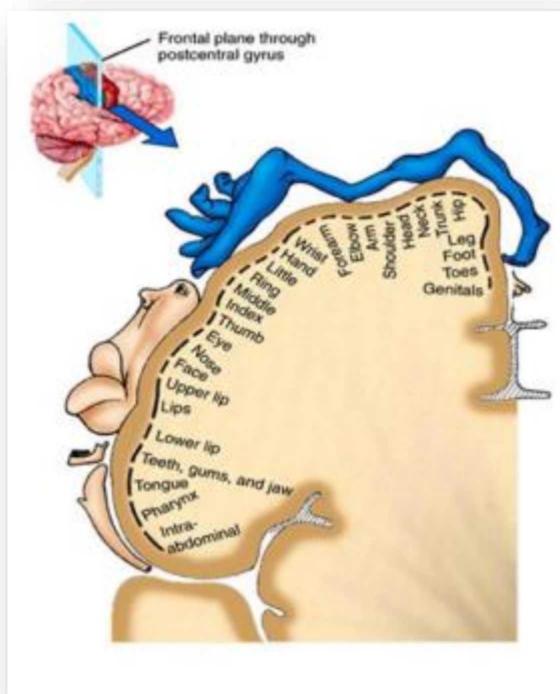
Mapping of the Primary Somatosensory Area

The somatosensory cortex is a part of the cerebral cortex, It receives all sensory inputs from the body; each neuron takes its information to a specific (cortical) region there.

➢ Size of the cortical region representing a body part depends on density (number) of receptors on that part and the sensory impulses received from that part. The resulting image is that of a distorted human body, with disproportionately huge hands, lips, and face. Note that this cortical representation is like an upside-down sensory map of the contralateral side of the body.

Upside down = Lower limb is on the upper side of cerebral cortex and vise versa.

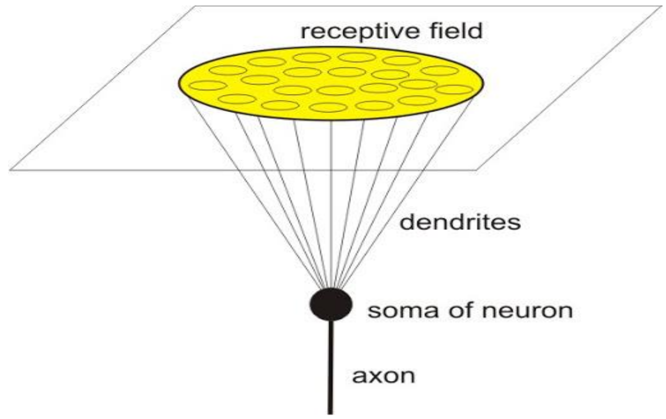
Contralateral = Right side of the body is represented on the left side of cerebral cortex and vice versa.



-more receptors you have in a region → larger size in cortical region → the better you can feel at this point (more precise feeling).

Receptive Fields

It is an area of skin whose stimulation results in changes in the firing rate of the neuron.



➢ Relation between receptive field and density of neurons :-

To make it easier, Density=number of receptors / receptive area

Large receptive area → less density → less precise perception

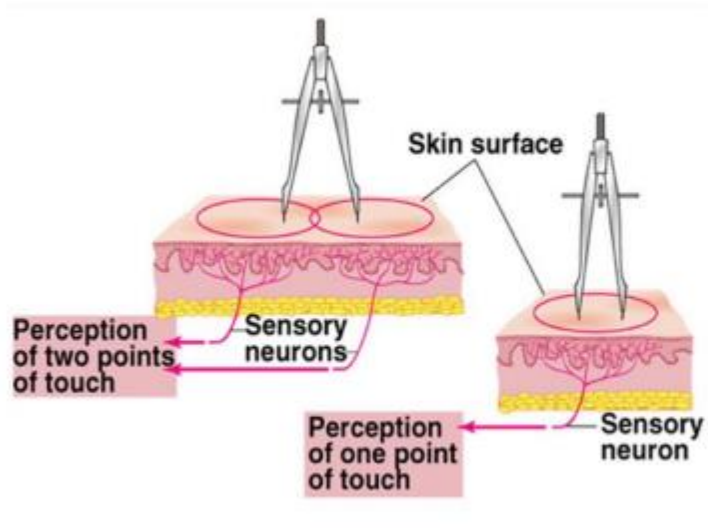
The back and legs have a **few receptors** with **large receptive fields**. However, the fingers, which require the ability to detect fine detail, have many, **densely packed** mechanoreceptors with **small** receptive fields.

Back and Legs	Fingertips
LARGE area	Small area
Few sensory receptors	LARGE number of receptors
Less precision (less details).	More details (finer).

Two-Point Touch Threshold

It is the minimum distance at which two points of touch can be perceived as separate (resolved as two distinct points, not one).

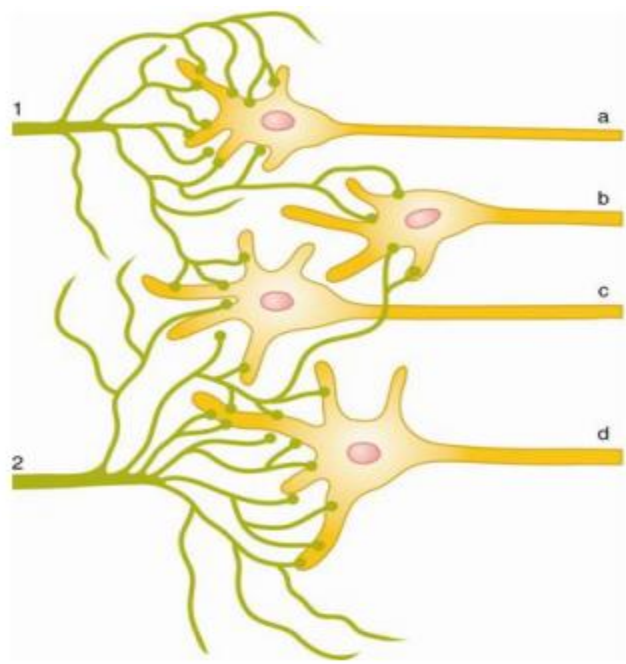
➢ Increasing number of receptors in an area increases the probability to hit two different receptors thus distinguishing two points of touch, If distance between 2 points is less than minimum distance, only 1 point will be felt.



Relaying Signals through Neuronal Pools

Neuronal pools are groups of neurons with special characteristics of organization. Each neuronal pool has its own special organization that causes it to process signals in its own unique way.

➢ Remember that a single excitatory presynaptic terminal almost never causes an action potential in a postsynaptic neuron (only sub-threshold) .Instead, large number of input terminals must discharge on the same neuron either simultaneously (spatial summation) or in rapid succession (temporal summation) to cause excitation.

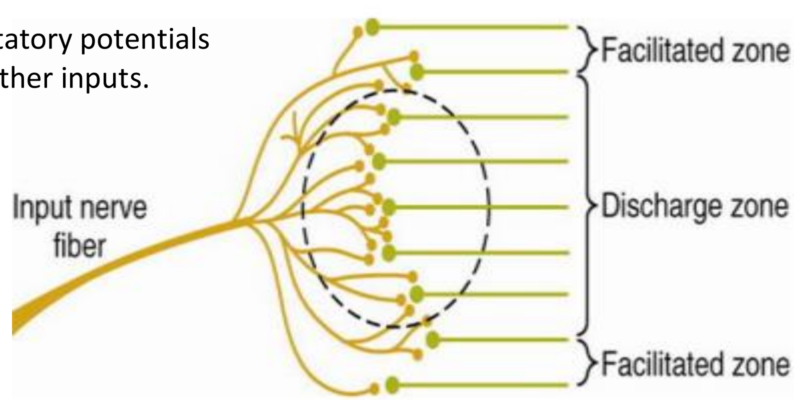


⇨ This figure shows a neuronal pool in which each "input 1 & 2” (presynaptic) fiber divides many times.

➢ There are two type of zones in these pools:-

1-***Discharge zone***: here the number of excitatory potentials are enough to reach threshold without another inputs.

2-***Facilitated zone***: here the number of excitatory potentials are not enough so it needs contributions from another inputs.



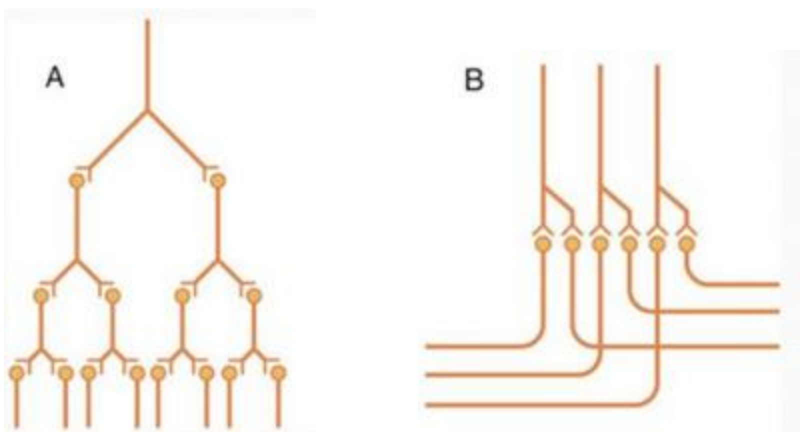
Neuronal pools circuits

Neuronal pools comprise many different types of neuronal circuits. Neuronal circuits could be divided into diverging circuits, converging circuits, and reverberating circuits.

1) Divergence (less inputs, more outputs)

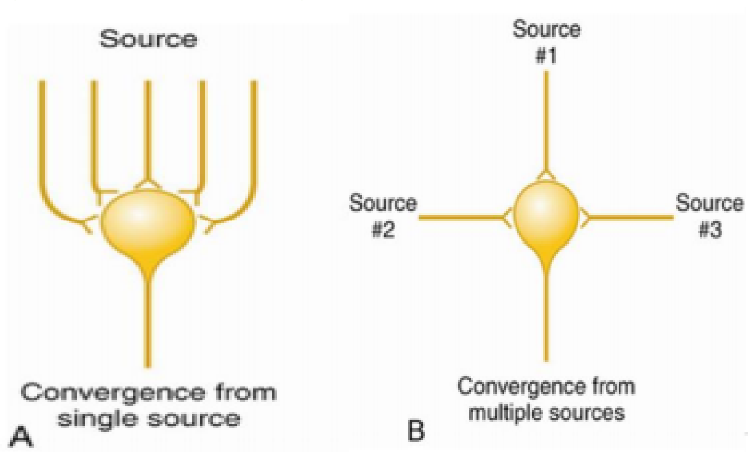
One input spreads into more than one neuron, so **weak signals** that enters a neuronal pool excite **far greater** numbers of nerve fibers leaving the pool, So…. What we did is amplifying the signal (make it larger), because of that we call it "amplifying type" and notice that the signal is transmitted in one tract so we call it "divergence into one tract". *See Figure A*!

➢ The other is "divergence into multiple tracts"; In this case the signal is transmitted in **two directions** from the pool. *See Figure B*!



2) Convergence: (more inputs, less outputs)

It means that signals from **MULTIPLE** inputs uniting to excite a **single neuron** , multiple terminals could be from a ***single source*** or ***multiple sources*** that terminate on the **same neuron**.



Prolongation of a Signal by a Neuronal Pool - “After-discharge”

➢ Prolongation means to make the stimulus last longer ….In many cases, a signal entering a pool causes a prolonged output discharge called “**after-discharge**”, lasting a few milliseconds to as long as many minutes after the incoming signal is over. There are many mechanisms by which after-discharge occurs, lets discuss some of them.

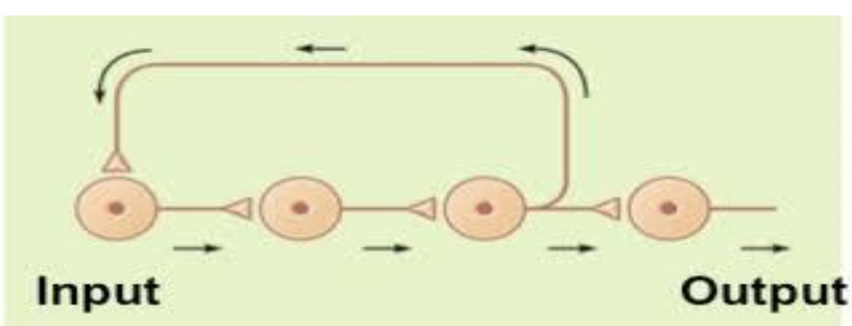
1) Synaptic after Discharge:

We know from previous lectures that the time of EPSP (15-20 msec) is longer than the time of action potentials (0.1 – 10 msec) then a greater number of action potentials per one EPSP. (graded potentials last more than action potential)

➢ When excitatory synapses discharge on the surfaces of dendrites or soma of a neuron, a post synaptic electrical potential develops in the neuron and lasts for many milliseconds, especially when some of the long-acting neurotransmitters are involved. As long as this potential lasts, it can continue to excite the neuron causing it to transmit a continuous train of output impulses.

2) Reverberating Circuits:

Reverberating circuits are caused by positive (+) feedback within the neuronal circuit that feeds back to re-excite the input of the same circuit. Consequently, once stimulated, the circuit may discharge repetitively for a long time.



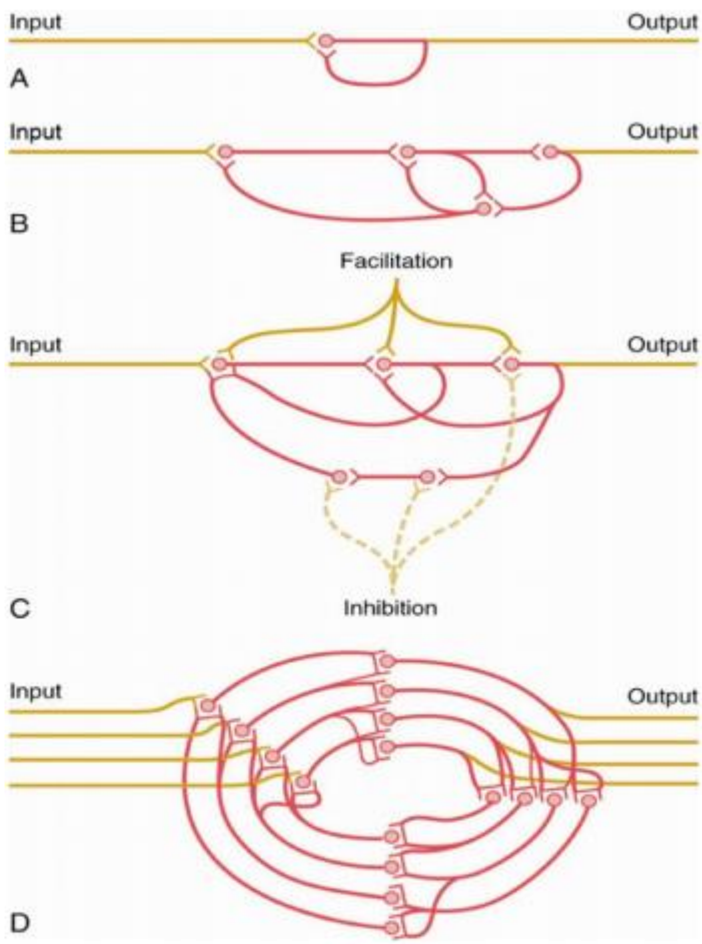
Type of reverberating circuits

A) The simplest reverberating circuit, the output neuron sends a collateral nerve fiber back to its own dendrites or soma to re-stimulate itself.

B) Additional neurons in the feedback circuit, which causes a longer delay between initial discharge and the feedback.

C) A more complex system in which both facilitatory and inhibitory fibers affect the reverberating circuit.

D) Most reverberating pathways are constituted of many **PARALLEL** fibers. In such a system, the total reverberating signal can be either weak or strong, depending on how many parallel nerve fibers are involved in the reverberation.

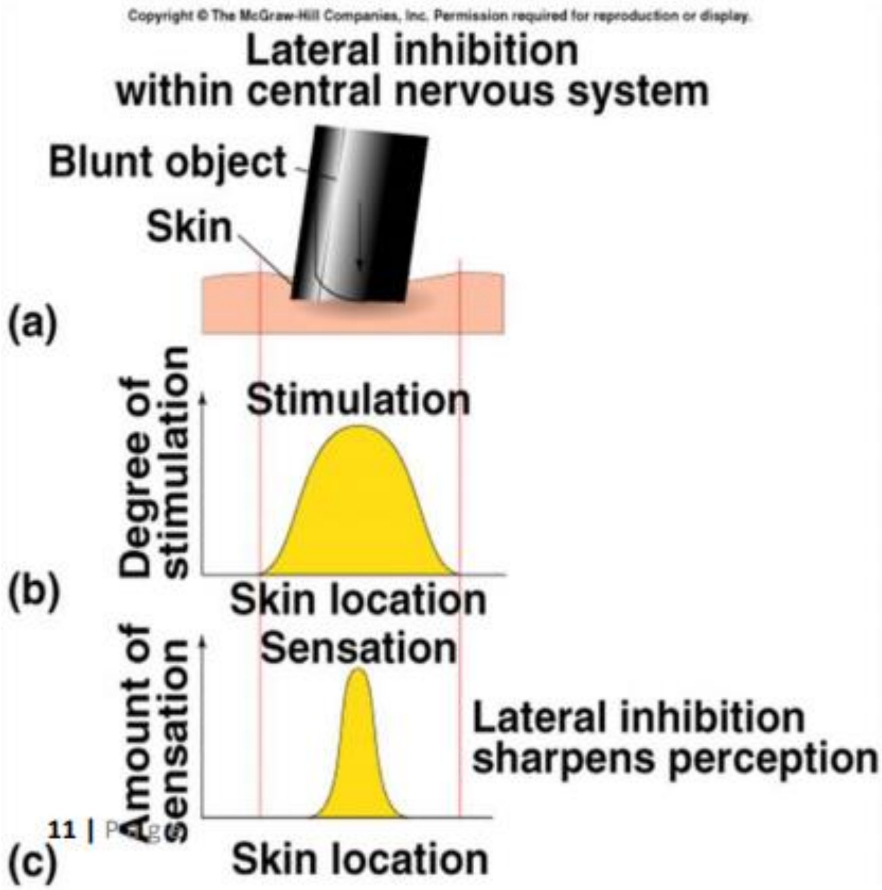


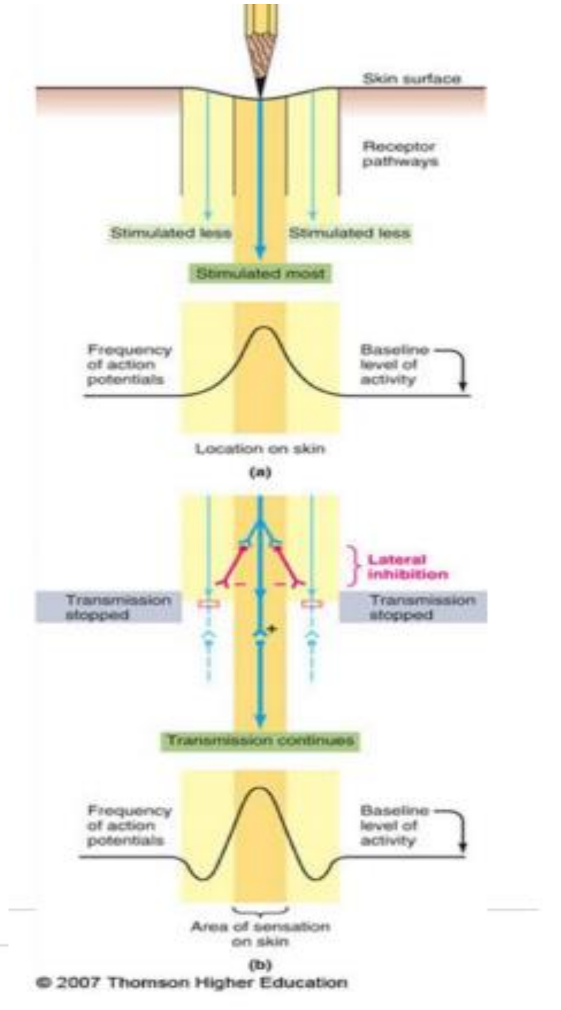
➢ The most important mechanisms by which after-discharge occurs are synaptic after discharge, reverberatory circuits, and increasing the number of parallel fibers.

Sharpening of sensation by lateral inhibition

When a blunt object touches the skin, sensory neurons in the center areas are stimulated more than neighboring fields and stimulation will gradually diminish from the point of greatest contact without a clear, sharp boundary. But thanks to lateral inhibition mechanism, the signal will be perceived as a single touch with well-defined borders.

It occurs within CNC.





➢In the pencile Example, we want to have more precise sensation and feel the touch from the exact location of contact with the skin, without sensing the adjacent areas that is also stimulated by the pencile ……so we use lateral inhibition to get more clear sensation by **SHARPENING** it.

Stability of Neuronal Circuits:

Almost every part of the brain connects either directly or indirectly with every other part, which creates a serious challenge. If the first part excites the second, the second excites the third, the third excites the fourth, and so on until finally the signal re-excites the first part. There are three basic mechanisms that prevent this effect from happening all the time either in the brain or other organs, which are:

1) Inhibitory circuits:

A. **Inhibitory feedback circuits** that return from the termini of pathways back to the initial excitatory neurons of the same pathways. For instance, Cortico-fugal fibers from cerebral cortex descending fibers to control the intensity and sharpness

B. Some neuronal pools that exert GROSS inhibitory control over widespread areas of the brain. For instance, many of the basal ganglia exert inhibitory influences throughout the muscle control system.

2) Synaptic fatigue:

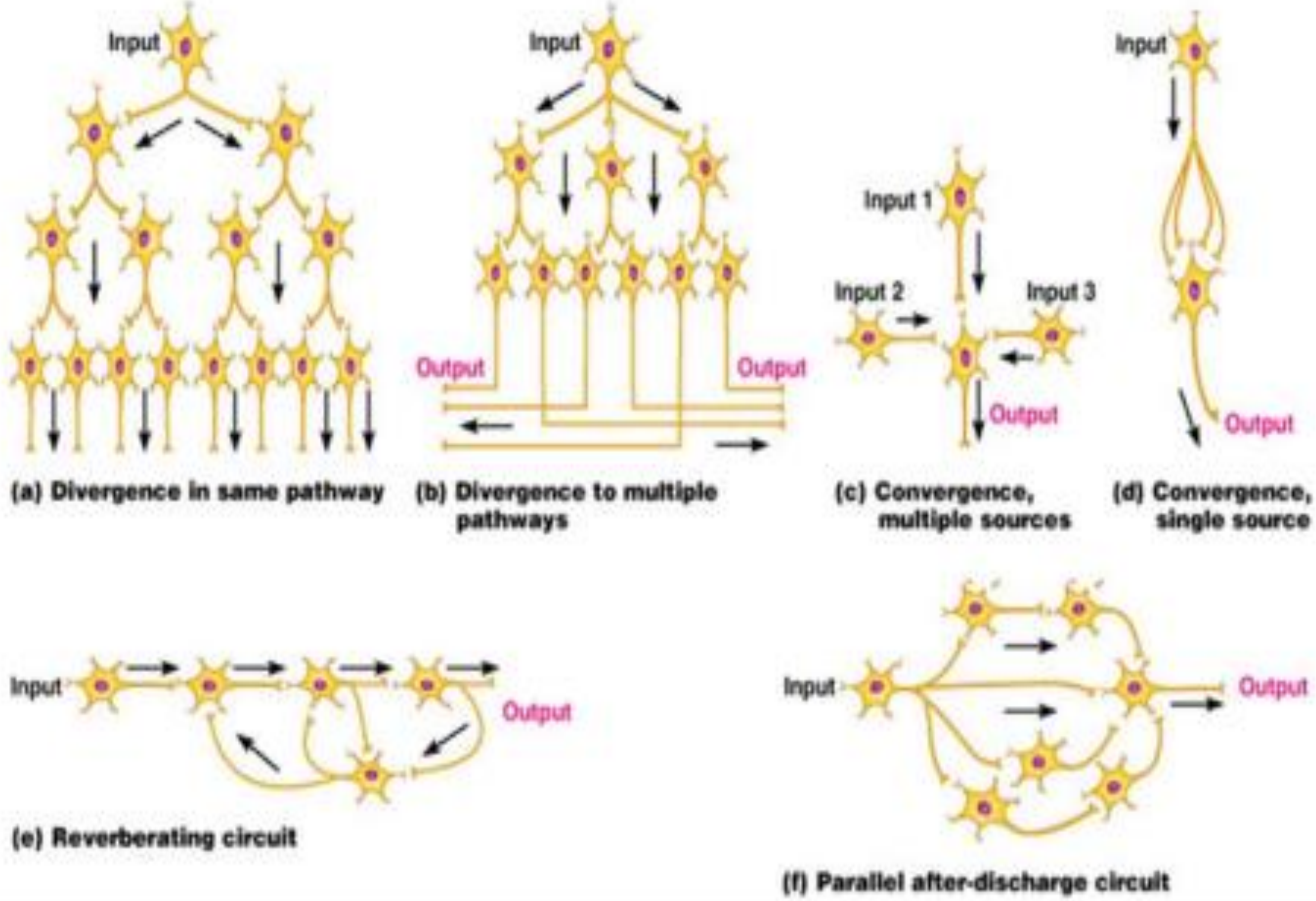
Synaptic transmission becomes progressively weaker the more prolonged and more intense the period of excitation (Depletion of neurotransmitters).

3) Upregulation and downregulation

The long-term sensitivities of synapses can be changed by upregulating (externalization) ➡ Increasing the number of receptors at the synaptic sites.

When there is underactivity and downregulating(internalization) ➡ decreasing the number of receptors when there is over-activity.

BEST OF LUCK ~~



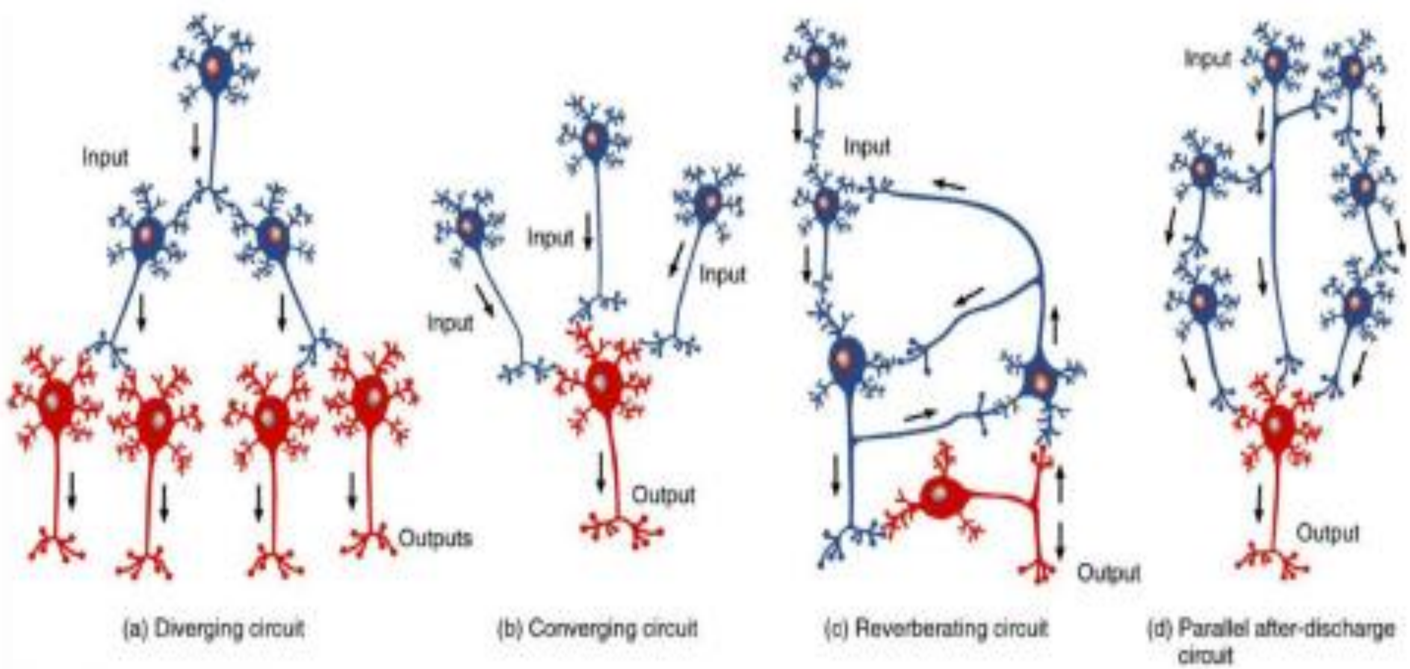


Figure 12.28 Tortora - PAP 12/e