physiology

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◉ Sheet ○ Slides

Number

15

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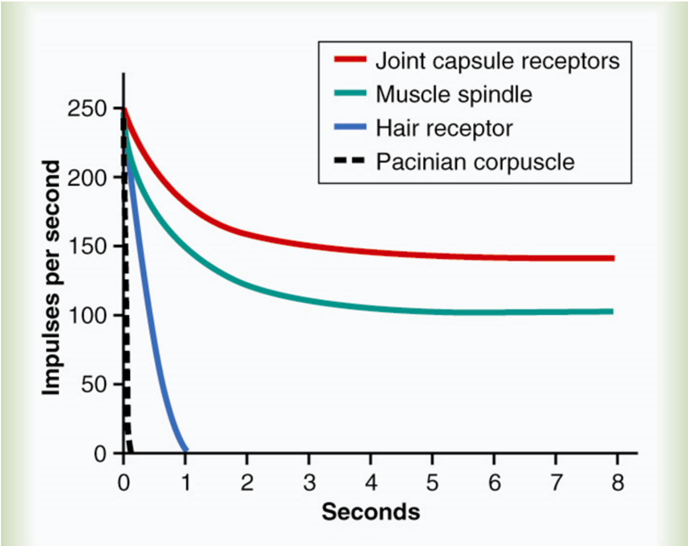
Adaptation of Receptors

Sensory receptors adapt either partially or completely to any constant stimulus after a period of time. That is, when a continuous stimulus is applied, receptors respond rapidly at first, but response declines until all receptors stop firing.

FIGURE 1: ➔

Adaptation of different types of receptors showing 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**.

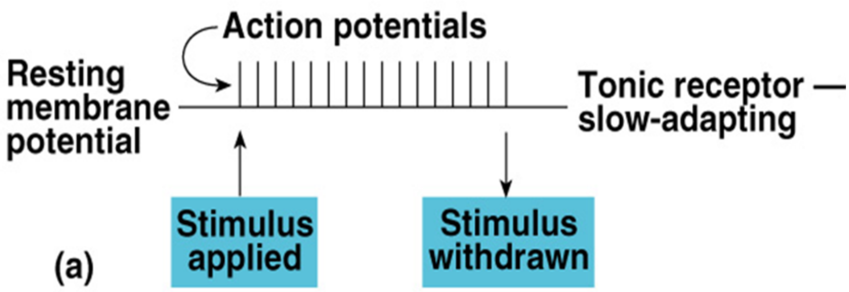


Rate of adaptation varies with type of receptor; some sensory receptors adapt to a far greater extent than do others. For example, the Pacinian corpuscle adapts to **EXTINCTION** within a few hundredths of a second. While other receptors require hours or days to do so, for which reason they are called “non-adapting” receptors.

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 of the body and its relation to its surroundings. However, they might adapt to EXTINCTION if the stimulus is present for some hours or days.

FIGURE 2: ➔
Tonic receptors produce constant rate of firing as long as stimulus is applied.

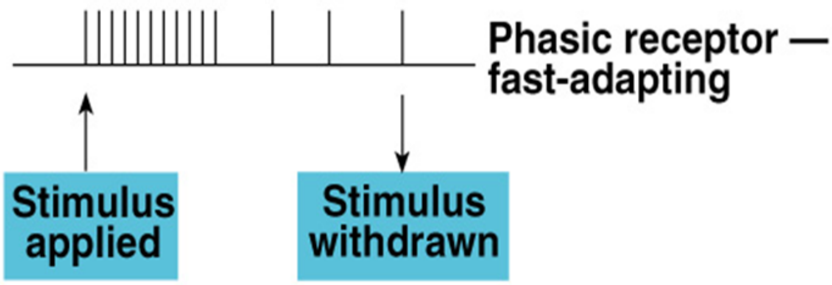


Rapidly Adapting (Phasic, Rate, Movement, ON-OFF) Receptors

Rapidly adapting receptors cannot be used to transmit a **continuous signal** because they are stimulated **ONLY** when the stimulus strength ***changes*** ***(detect onset and offset of the stimulus)***.

Recall that rate and strength of the response is related to the rate and intensity of the stimulus; increasing "stimulus strength" increases "amplitude" of the receptor potential. In turn, the "frequency" of action potentials transmitted from sensory receptors increases.

FIGURE 3: →



Burst of activity but quick reduction of firing rate if stimulus is maintained. Recall that intense stimulation of the receptor causes progressively LESS and LESS additional increase in number of action potentials (adapt).

Rapidly Adapting Receptors are Important for Balance and Movement

Rapidly adapting receptors are also called **rate receptors** because they know the rate (velocity) at which some change 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!**

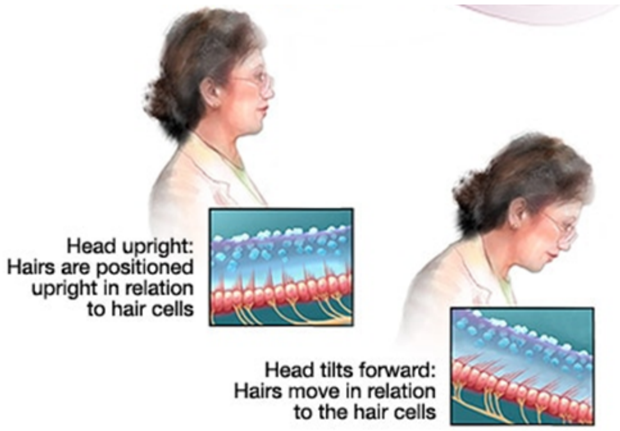
(Time*velocity=distance).

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!

This tells you when to stop running to avoid hitting objects around.

Likewise, receptors located in the **semicircular canals** in the vestibular apparatus of the ear detect the rate (velocity) at which the head begins to turn when you run around a curve, allowing the nervous system to predict how much you will turn within the next 2 seconds and can adjust the motion of your legs earlier than required to **keep you from losing balance.**

PLEASE, don't memorize the examples above; you only need to understand the whole idea. Pictures and details are ONLY for clarification.



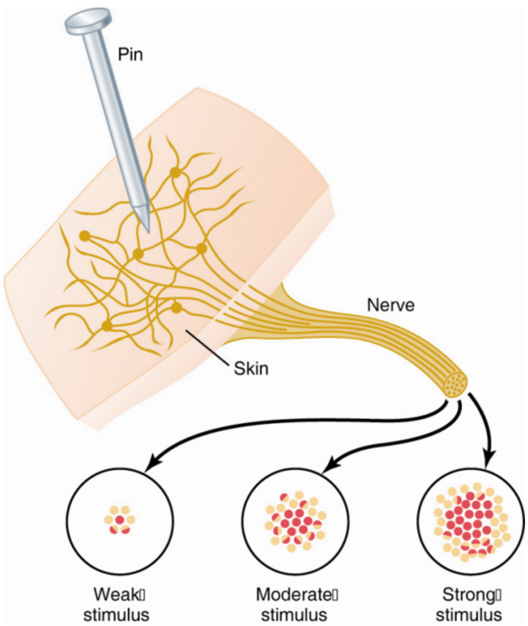
Phasic receptors	Tonic receptors
Pacinian corpuscle	Merkel's discs
Meissner's corpuscle	Ruffini's endings
Semicircular canals in the inner ear	Pain and proprioceptors
Receptors responding to pressure	Muscle spindle and Golgi tendon apparatus
Receptors responding to touch	Macula
Receptors responding to smell	Interoceptors that respond to chemical levels in the blood like chemo- and baroreceptors

*Pain receptors and proprioceptors do not exhibit adaptation.

Importance of Signal Intensity

Signal intensity is critical for interpretation of the signal by the brain-for instance, the intensity of pain. The different **gradations** of intensity can be achieved by two mechanisms:

1- **Spatial summation**: increasing the number of fibers stimulated, see **FIGURE4**. ➔



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

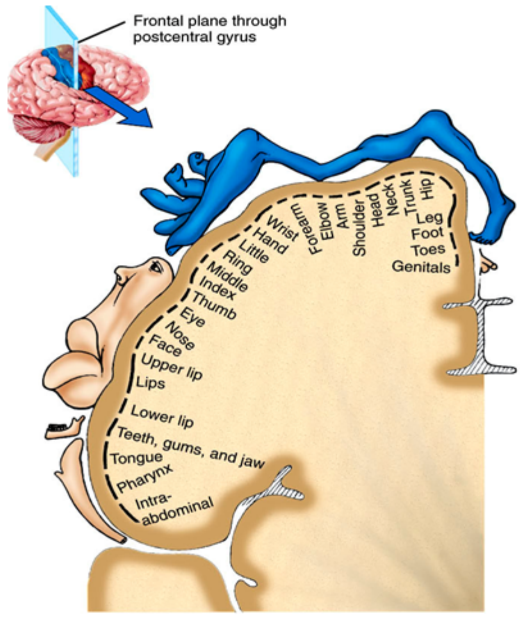
Coding Sensory Information

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 and is located in the **postcentral gyrus** in the middle of the brain. 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. **FIGURE 5:** Note that this cortical representation is like an **upside-down** sensory map of the **contralateral** side of the body.



Upside down = E.g: Lower limb is on the upper side of cerebral cortex.
Contralateral = Right side of the body is represented on the left side of cerebral cortex and vice versa.

Receptive Fields

Receptive field is an area of the body, when stimulated, changes the firing rate of a sensory neuron. It is the region in which a stimulus will modify the firing of that neuron.

Area of each receptor field varies inversely with the density (number) of receptors in the region. **Large** receptive fields allow the cell to detect changes **over a wider area** but lead to a **less precise** perception. For instance, 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.

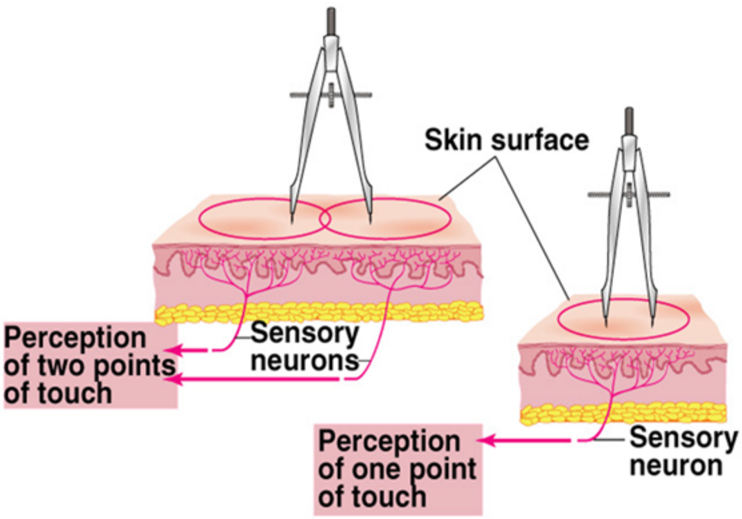
Back and Legs	Fingertips
LARGE area	Small area
Few sensory receptors	LARGE number of receptors
Less precision (less details).	More details (finer).

Two-Point Touch Threshold

Two-Point Touch Threshold is the minimum distance at which two points of touch can be perceived as **separate** (**resolved** as two **distinct** points, not one).

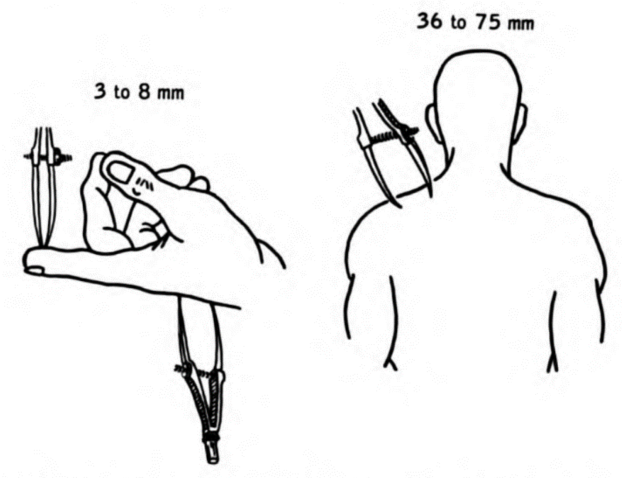
It is a measurement for the **distance between receptive fields** in an area and an indication of **tactile acuity (sharpness of the sense of touch)**.

FIGURE 6: ➔
Increasing number of receptors in an area increases the probability to hit two different receptors thus distinguishing **two** points of touch.



*The TEST (**UNDERSTAND ONLY**):*

It's called two-point discrimination test, it relies on the ability of the patient to report what they are feeling and should be **completed with the patient's eyes closed**.



The therapist alternates randomly between touching the patient with one point or with two points on the area being tested (e.g. finger, arm, leg, and toe).

The patient is asked to report whether one or two points was felt. The smallest distance between two points that still results in the perception of two distinct stimuli is recorded as the patient's two-point threshold.

Neuronal Pools

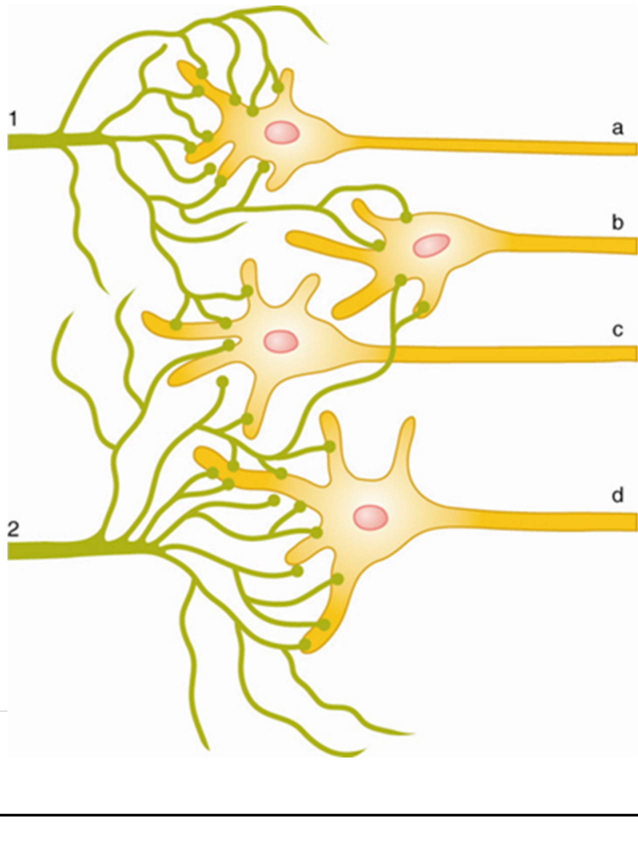
Neuronal pools are groups of neurons with special characteristics of organization. Each neuronal pool has its own special organization that causes it to process signals in its own unique way.

Recall that discharge of a single excitatory presynaptic terminal almost never causes an action potential in a postsynaptic neuron. 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.

FIGURE 7: ➔

shows a neuronal pool in which each "input" (presynaptic) fiber divides many times.

*Note that Dr. Faisal put this figure in his slides but didn't explain it or mention any of the details below.



For UNDERSTANDING ONLY:

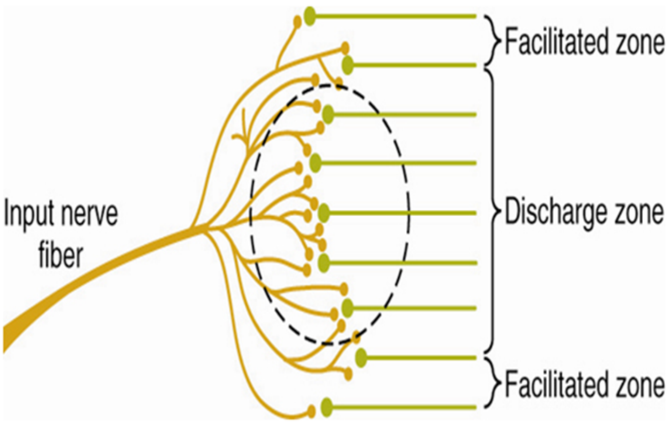
Assume that **six** pre-synaptic terminals must discharge almost simultaneously to excite (by reaching the threshold) any **one** of the post-synaptic neurons.

Note that input fiber (1) has more than enough (six) terminals to cause neuron (a) to discharge. The stimulus from input fiber (1) to this neuron is said to be an **excitatory stimulus**; it is also called a **SUPRA-threshold** stimulus because it is ABOVE the threshold required for excitation.
Input fiber (1) also **contributes** terminals to neurons (b) and (c), but not enough to cause excitation (<6 terminals).

Nevertheless, discharge of these terminals makes both of these neurons (b and c) **more likely** to be excited by signals arriving through other incoming nerve fibers. Therefore, the stimuli to these neurons are said to be **SUB-threshold**, and the neurons are said to be **FACILITATED**.

Similarly, for input fiber (2), the stimulus to neuron (d) is a **SUPRA-threshold** stimulus, and the stimuli to neuron (b) and (c) are **SUB-threshold** but **FACILITATING** stimuli.

FIGURE 8: In the central portion of the field in this figure, designated by the circled area, all neurons are stimulated by the incoming fiber. Therefore, this is said to be the "discharge zone" of the incoming fiber, also called the **"excited zone"**, "firing zone", or "spike generator". To each side, the neuron is facilitated but NOT excited, and these areas are called the **"facilitated zone"**.



Neuronal Pools: Localization of Sensory Information Modification

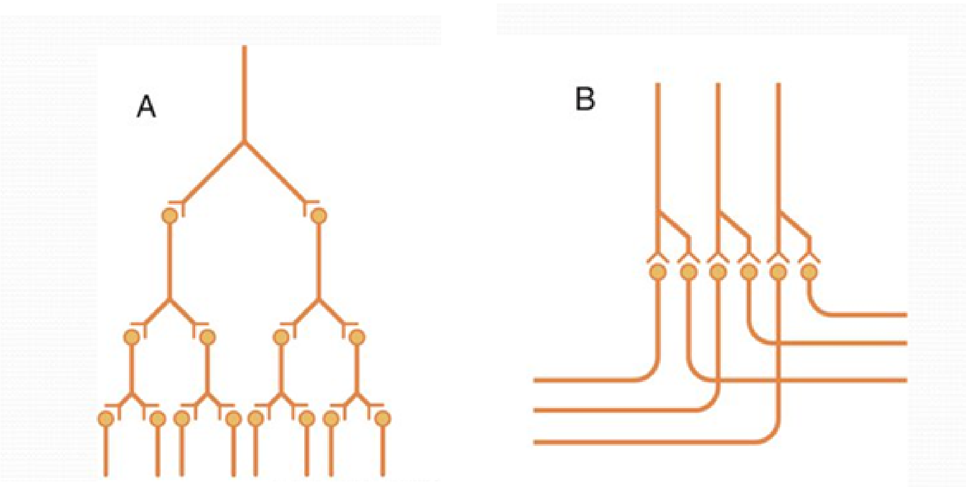
Neuronal pools comprise many different types of neuronal circuits. Neuronal circuits could be divided into diverging circuits, covering circuits, and reverberating circuits.

1) Divergence: It occurs when **weak signals** entering a neuronal pool excite **far greater** numbers of nerve fibers leaving the pool.

Two major types of divergence occur and have entirely different purposes.

The first is an **"Amplifying type" or "divergence into one tract";** when **an input signal** spreads to an **increasing number** of neurons as it passes through successive orders of neurons in its path. **SEE FIGURE8_A.**

The other is **"divergence into multiple tracts"**; In this case the signal is transmitted in **two** directions from the pool. See **FIGURE8_B.**



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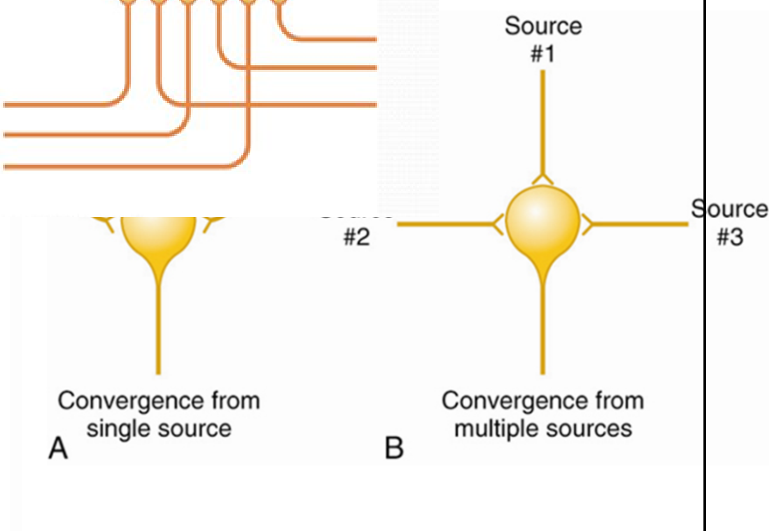
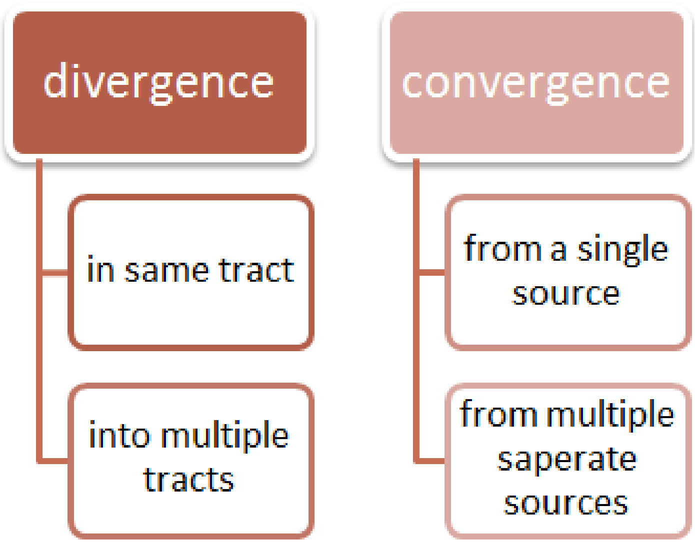
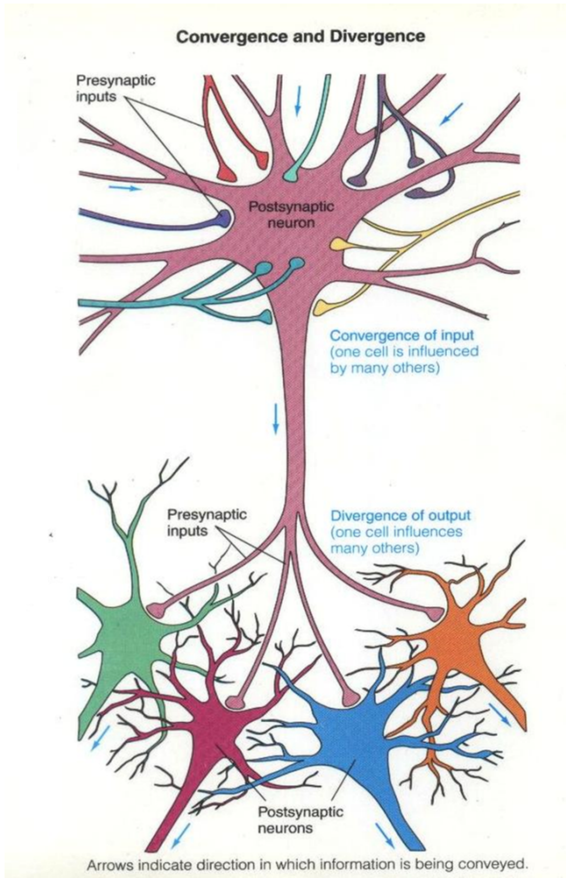


Converge

nce: It means signals from **MULTIPLE** inputs uniting to excite **a single source** – That is, multiple terminals **(from a single source or multiple sources)** terminate on the same neuron. See **FIGURE9** below.

To sum up:





Prolongation of a Signal by a Neuronal Pool - "After-discharge"

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:

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.

**Recall 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.*

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.

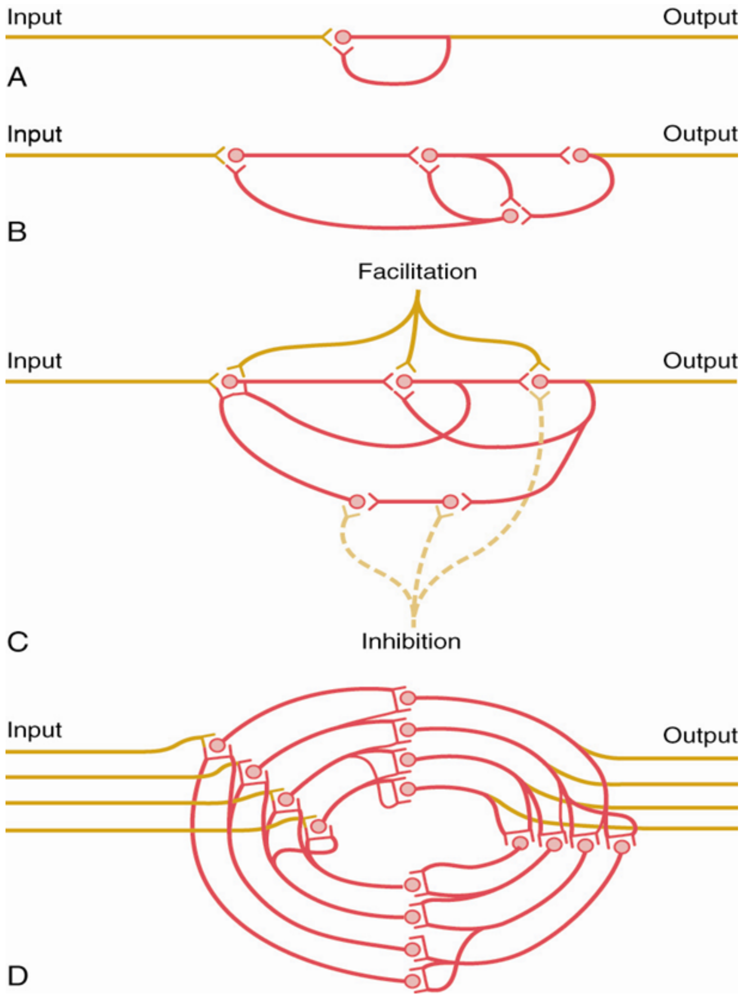
FIGURE 9: ➔

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.



To sum up:

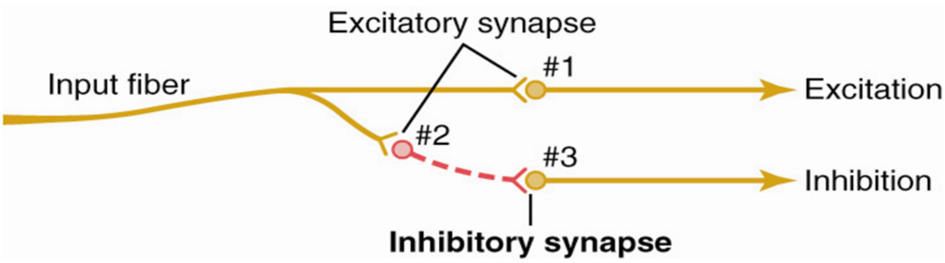
The most important mechanisms by which after-discharge occurs are synaptic after-discharge, reverberatory circuits, and increasing the number of parallel fibers.

Neuronal Circuits with Both Excitatory and Inhibitory Output Signals

Sometimes an incoming signal to a neuronal pool causes an output excitatory signal going in one direction and at the same time an inhibitory signal going elsewhere. This is also called “lateral inhibition”.

FIGURE 10:

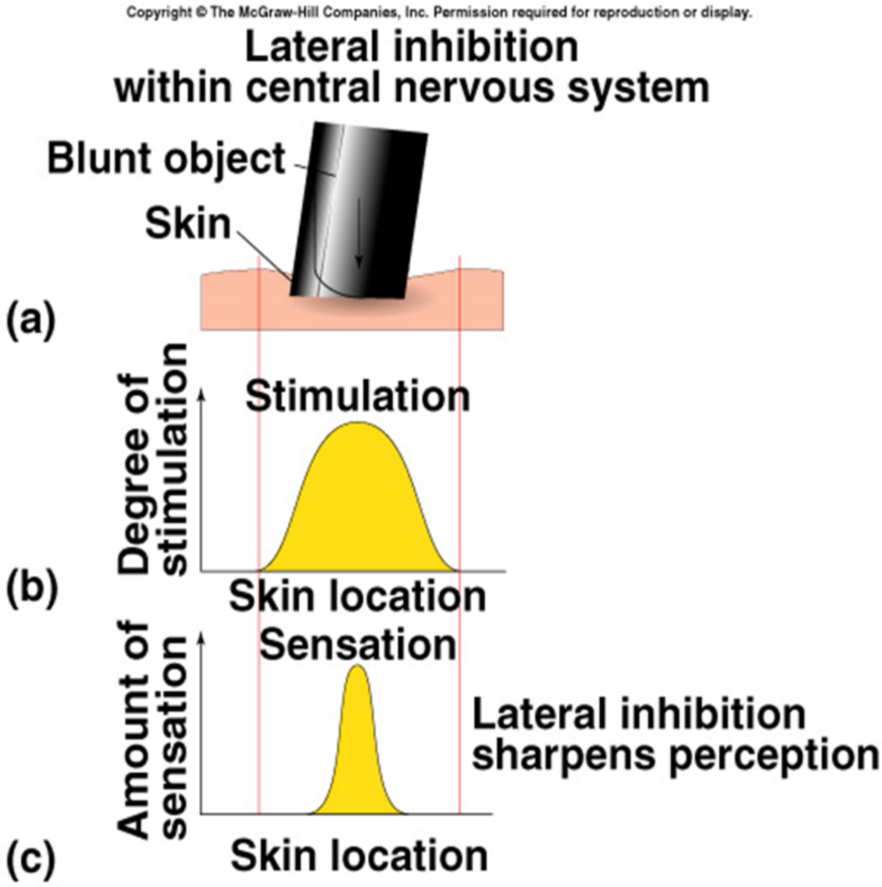
➔ The input fiber **DIRECTLY** excites the excitatory output pathway, but it stimulates an **intermediate inhibitory neuron (2),** which secretes a different type of transmitter substance to inhibit the second output pathway from the pool. This type of circuit is very important in preventing **over-activity** in many parts of the brain.

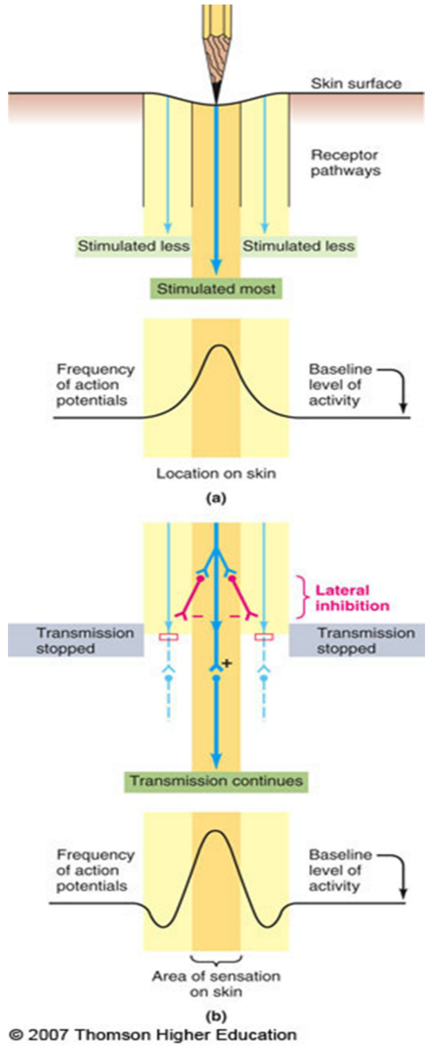


Sharpening of sensation by lateral inhibition

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.

Recall that this occurs within CNS (brain).





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:

Two types of inhibitory circuits in widespread areas of the brain help prevent excessive spread of signals:

A. <u>Inhibitory feedback</u> 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 **<u>GROSS inhibitory</u>** 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).

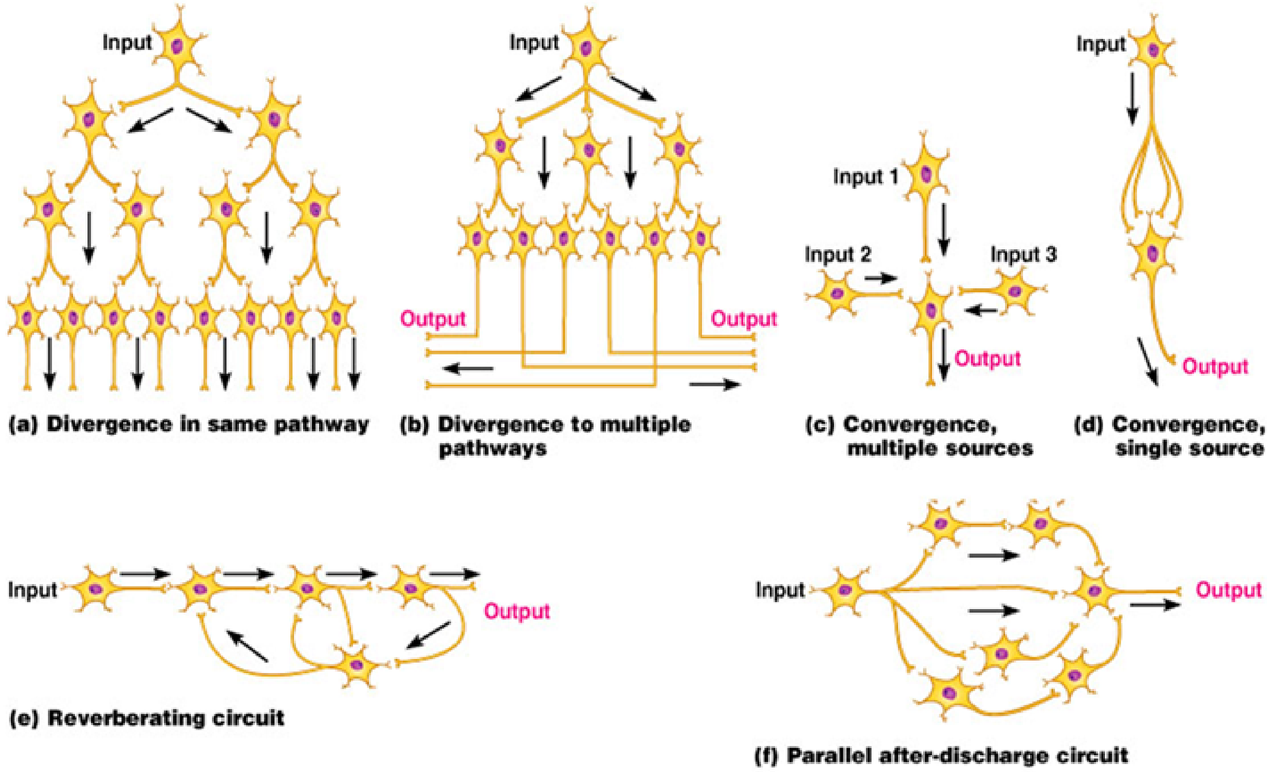
3) <u>Long-term</u> changes in synaptic sensitivity caused by automatic **<u>down-regulation</u>** or **<u>up-regulation</u>** of synaptic receptors: The long-term sensitivities of synapses can be changed by **up-regulating (externalization)-Increasing** the number of receptors at the synaptic sites when there is **under-activity** and **down-regulating (internalization)-decreasing** the number of receptors when there is **over-activity**.

See the figures in the next page to confirm your understanding.

Please remember that you don’t need to memorize examples and mechanisms, understand each and every point but DO NOT memorize any.

If you have any question don’t hesitate to ask, and ادعوا لنا .

GOOD LUCK



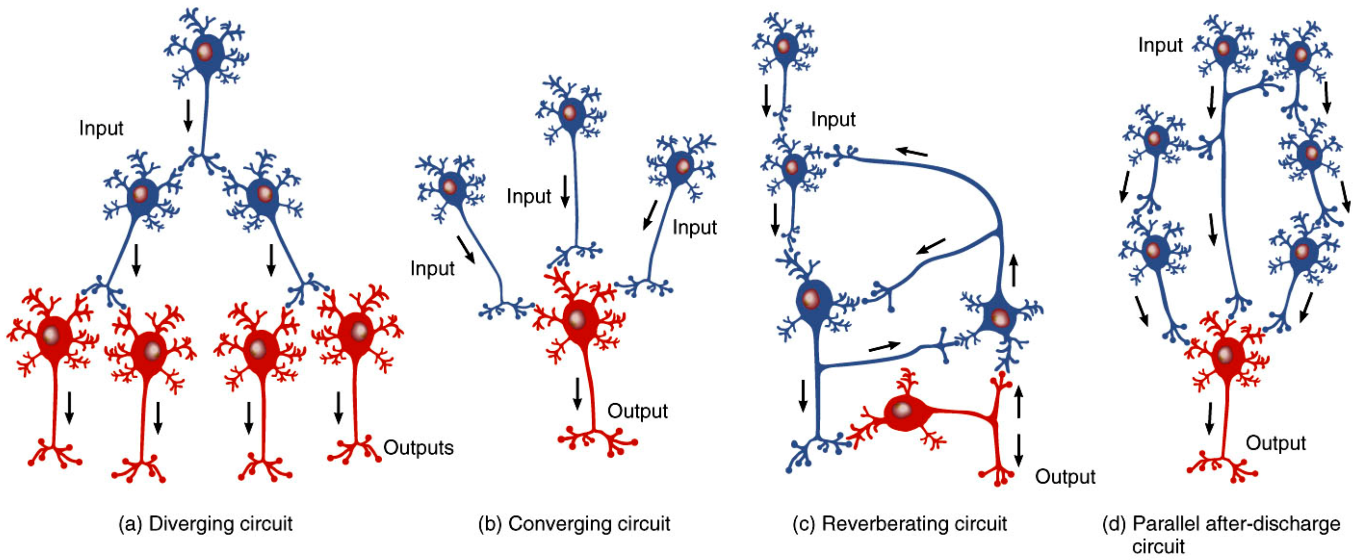


Figure 12.28 Tortora - PAP 12/e