CHAPTER 1

THE SENSORY RECEPTORS

The sensory receptors are specialized structures located at the peripheral ends of sensory (= afferent) neurons, and they may be a part of the neuron or a separate organ. They are excitable structures, since they respond to various forms of energy (i.e. various stimuli) by generating action potentials.

FUNCTIONS OF THE SENSORY RECEPTORS

(1) They act as detectors and transducers : They detect energy changes in both the external and internal environments and transform such changes into action potentials (i.e. nerve impulses).

(2) They inform the CNS about changes occurring inside and outside the body : The nerve impulses generated at the receptors are transmitted to the CNS via ***afferent neurons*** where they give rise to various sensations and initiate appropriate reflex actions that ***maintain homeostasis***. Accordingly, ***the CNS becomes almost useless without receptors***..

PROPERTIES OF THE SENSORY RECEPTORS

(1) SPECIFICITY (differential sensitivity)

Each type of receptors responds to a specific form of energy called its **adequate stimulus** and produces a particular sensation. Some receptors can respond to other stimuli called ***inadequate stimuli*** e.g. the adequate stimulus of the retinal receptors is light, but they can also be stimulated by mechanical pressure. However, to produce a response, the threshold of such inadequate stimuli must be high, and they *produce the same sensation for which the receptor is specialized* (i.e. light in case of retinal receptors).

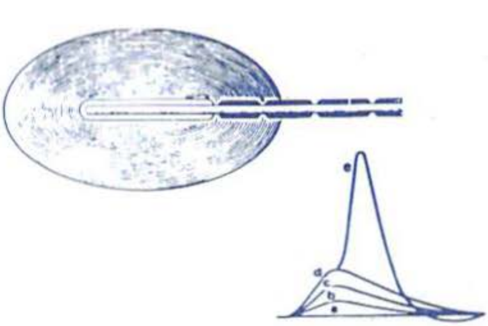

Figure 1 : the Pacinian corpuscle. (a, b, c and d) are generator potentials in response to gradually-increasing pressures, while (e) is an action potential.

(2) EXCITABILITY (THE RECEPTOR POTENTIAL)

This is the property of responding to stimuli by generating action potentials. It has been studied in certain mechanoreceptors called ***Pacinian corpuscles***. Each corpuscle consists of a sensory nerve ending surrounded by multiple concentric lamellae of connective tissue, and the *terminal part of the nerve ending is unmyelinated* while its remaining part is myelinated, and *the first node of Ranvier is present inside the corpuscle* (figure 1).

When the corpuscle is not stimulated, the sensory nerve ending is in the polarized state (with a resting membrane potential about -70 mV). However, if it is stimulated (by applying pressure), the *unmyelinated part* is partially depolarized due **to *increased Na^+ influx secondary to Na^+ channel activation***. This state of partial depolarization of the sensory nerve ending is called the **receptor or generator potential**, and its magnitude is ***proportionate to the intensity of the stimulus*** (a, b, c and d in figure 1).

The receptor potential is ***passively conducted to the first node of Ranvier*** (by local circuits of current flow) causing its depolarization, and if this reaches the firing level, it initiates an action potential (e in figure 1) that is propagated along the afferent nerve to the nervous system.

The ***threshold receptor potential that discharges an action potential is about 10 mV***, and if its magnitude rises above that level (depending on the intensity of the stimulus), the frequency of discharge increases proportionately (figure 2).

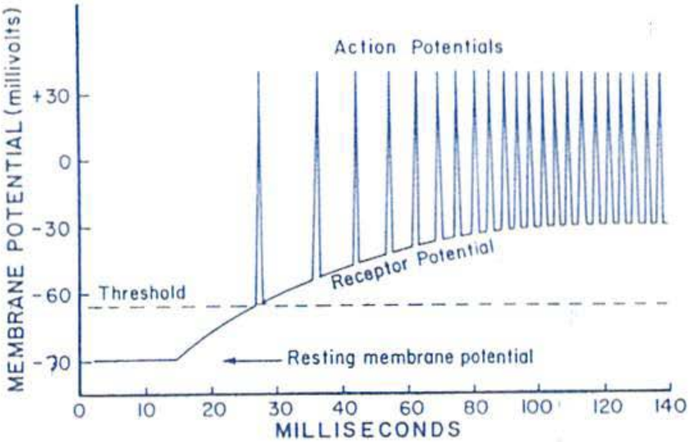

Figure 2 : Relation between the receptor potential (RP) & action potentials (APs). As the (RP) rises above threshold, the frequency of (APs) increases.

Properties (characteristics) of the receptor potential

(1) It *does not obey the all or none law*, so it *can be graded.*
(2) It is *not followed by an absolute refractory period,* and its *duration is long* (about 5 milli-seconds), so it *can be summated*
(3) It *is not blocked by local anesthetic drugs* .
(4) It leads to *a propagated action potential on reaching the threshold level.*

(3) DISCHARGE OF IMPULSES

The frequency of discharge of impulses from receptors depends on the intensity of stimulation, and it determines the magnitude of the perceived sensation. It occurs according to the ***Weber-Fechner law*** which states that " ***the frequency of discharge from receptors is directly proportional to the logarithm of intensity of the applied stimuli*** ". However, this law was found to *apply only to high intensities of stimulation*, and the following power function (known as the ***power law***) expresses the mathematical relation between the intensity of stimulation and the frequency of discharge more accurately **:**

$$R = KS^{A}$$

Where **R** is the sensation felt, **S** is the intensity of the stimulus, **K and** A are constants (which vary with each type of sensation).

(4) ADAPTATION

This is a decline in the frequency of discharge of action potentials from receptors that occurs on ***maintained stimulation by stimuli that have a constant strength***. **Adaptation is different from fatigue and the following table shows the differences between both :**

	ADAPTATION	FATIGUE
Cause	Maintained stimulation	Previous activity
Mechanism	Accommodation in nerve terminals or other factors	Lactic acid accumulation
Oxygen lack	No effect	Accelerates fatigue
Onset and Recovery	Rapid	Slow
Site of occurrence	Many tissues including the sensory receptors	Some tissues but not the sensory receptors

Mechanism of adaptation

The following are probable mechanisms for adaptation of receptors :

(1) Accommodation to the stimulus in the terminal nerve fibre that occurs secondary to progressive inactivation (closure) of the Na^+ channels in the nerve fibre membrane (which decreases the magnitude of the receptor potential and consequently the frequency of discharge).

(2) Readjustment in the structure of the receptor itself after its initial distortion by the stimulus (so that the receptor potential is no longer elicited even though the stimulus is maintained).

CODING OF SENSORY INFORMATION

This is the ability of the nervous system to discriminate (or identity) the ***modality*** (= ***type***), ***locality and intensity of various sensations,*** *although all sensations are transmitted from the receptors to the higher centres in the same form* (*i.e. as action potentials*).

(1) MODALITY DISCRIMINATION

The various sensory pathways are discrete (i.e. separate from each other), and the modality of a certain sensation is ***discriminated at the specific brain area where its pathway terminates***. This agrees with Muller's law.

Muller's law of specific nerve energies

This law states that *stimulation of a certain sensory pathway* ***no matter how or where*** *produces the sensation to which its receptors are specialized*. Such effect is also called the ***labeled line principle*** i.e. each sensory pathway (*from the receptors till the termination at the higher centres*) is labeled for a specific sensation (so stimulation of the retinal receptors whether by light or mechanically by pressure always produces a light sensation, page 1).

(2) LOCALITY DISCRIMINATION

The discrimination of the locality of a certain sensation also depends on the specific pathway of that sensation. When this pathway is stimulated anywhere along its course, the evoked sensation is projected to (i.e. referred to) the location of its receptors. This effect is called " **law of projection** ", and it is evident in patients whose limbs are amputated, who *may feel severe pain in the phantom limb* (*i.e. the non-existing limb*) *due to irritation of the sensory nerves at the site of amputation.*

(3) INTENSITY DISCRIMINATION

The discrimination of the intensity of a certain sensation depends on the number of ***activated receptors and their frequency of discharge*** as well as on the ***state of nerve centres*** (if they are depressed e.g. due to O_2 lack or hypoglycemia, the sensations become dull and their intensity is decreased).

(A) Ruffini's endings.
(B) Merkel's disks.
(C) Meissner's corp.
(D) Pacinian corp.
(E) Krause's end bulbs.
(F) Free nerve endings.

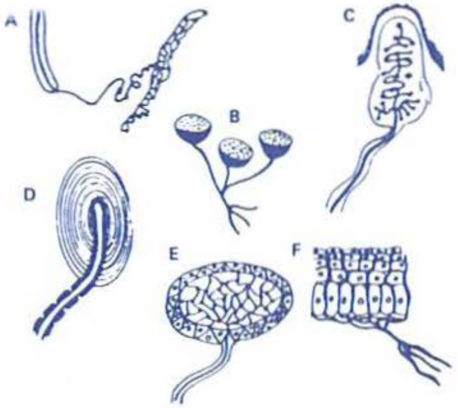

Figure 3 : The various cutaneous sensory receptors.

TYPES & CLASSIFICATION OF SENSORY RECEPTORS

The sensory receptors can be classified **according to their specificity, situation and adaptation**.

(A) ACCORDING TO SPECIFICITY OF THE RECEPTORS

(1) Mechanoreceptors **:** These are stimulated by ***mechanical forms of energy***, and they include the following **:**

(a) ***Touch (or tactile) receptors*** : These are present in the skin (figure 3) and include free nerve endings, Merkel's disks, Meissner's corpuscles, Pacinian corpuscles and hair end organs (= basket endings around hair follicles).

(b) ***The baroreceptors*** elsewhere (refer to the cardiovascular system).

(c) ***The proprioceptors*** in the muscles, tendons, ligaments and joints (e.g. the muscle spindles and Golgi tendon organs).

(d) ***The sound and vestibular (equilibrium) receptors*** in the internal ear.

(e) ***Pressure receptors in the skin and deep tissues*** (Pacinian corpuscles).

(f) ***Stretch receptors*** e.g. those present in the walls of the right atrium, the urinary bladder and the lung alveoli.