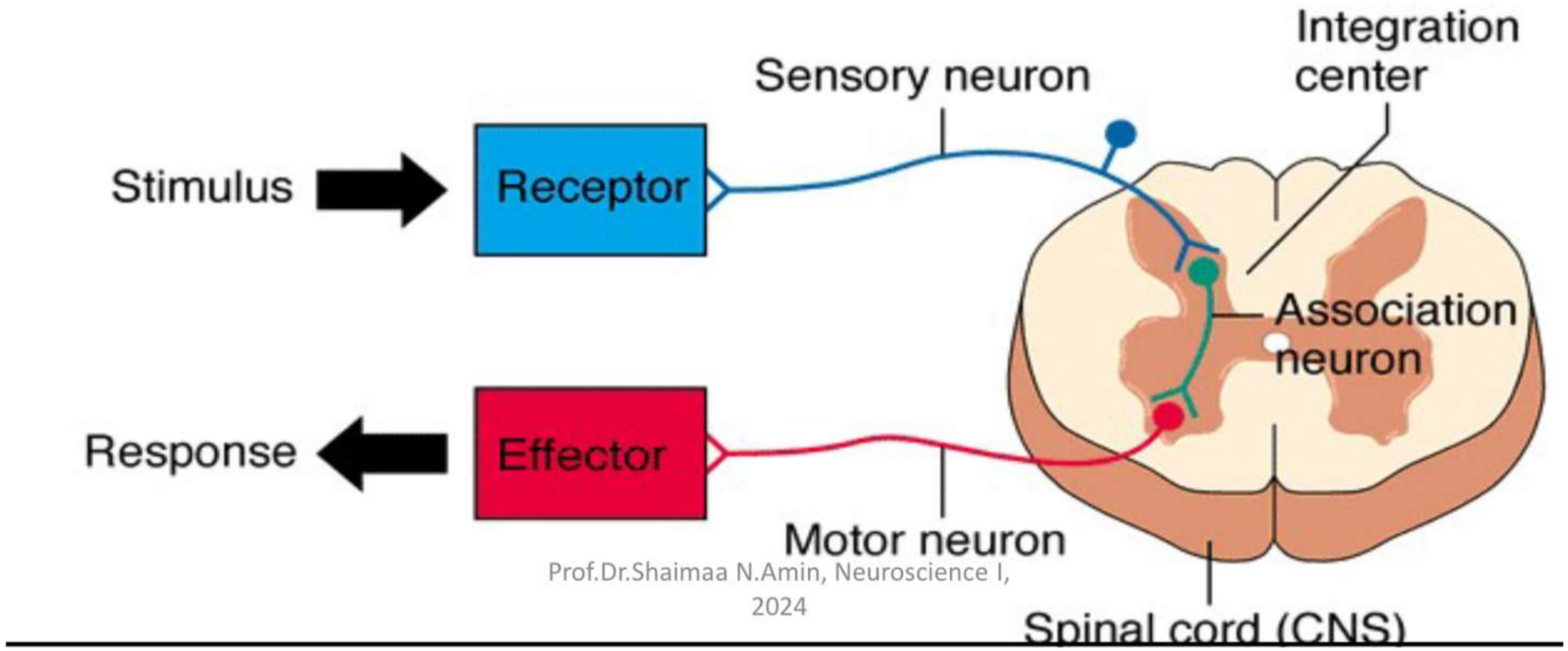
بسم الله الرحمن الرحيم

Spinal Cord & Somatic Sensations

Lecture 1

Sensations & perceptions

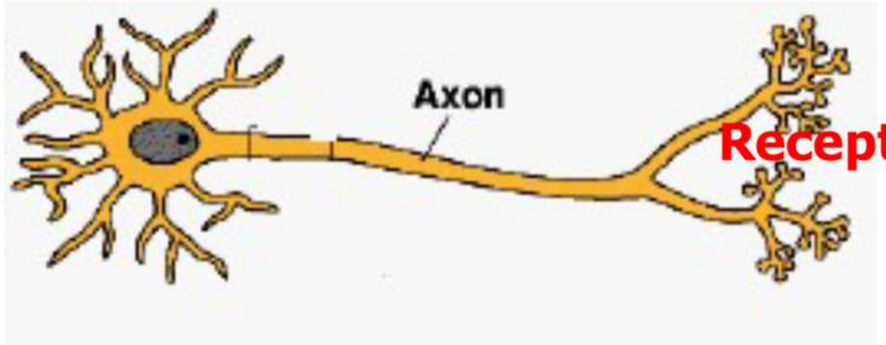
Sensations : is an awareness of sensory stimuli in brain

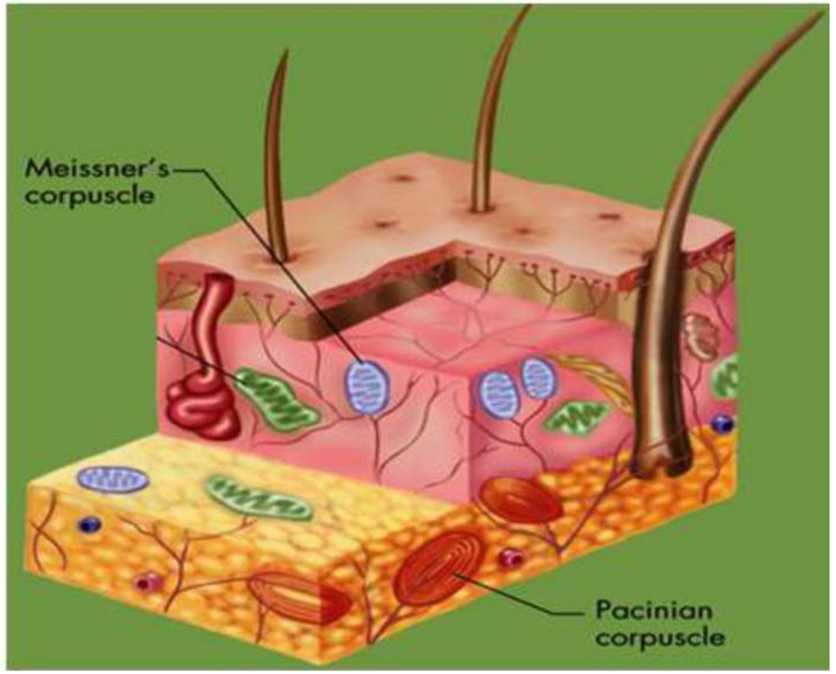


THE SENSORY RECEPTORS

1- specialized stuctures or

2- modified n. ending at the peripheral termination of afferent fibers.





THE SENSORY RECEPTORS

The sensory receptors are : specialized structures located at the peripheral ends of sensory afferents (neurons 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

(I) 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).

FUNCTIONS OF THE SENSORY RECEPTORS

(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. They give rise to various sensations and initiate appropriate reflex actions that maintain homeostasis. Accordingly, the CNS becomes almost useless without receptors.

TYPES & CLASSIFICATION OF SENSORY RECEPTORS ACCORDING TO THE SPECIFICITY OF THE RECEPTORS

Classification (by stimulus type)

1. Mechanoreceptors
2. Thermoreceptors
3. Pain receptors
4. Electromagnetic receptors
5. Chemoreceptors

TYPES & CLASSIFICATION OF SENSORY RECEPTORS

(I) Mechanoreceptors

These are stimulated by mechanical forms of energy. Moreover, they include the following:

(a)Touch (or tactile) receptors: These are present in the skin 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).

TYPES & CLASSIFICATION OF SENSORY RECEPTORS

(II) Thermoreceptors

These are stimulated by thermal forms of energy, and those present in the skin are specialized free nerve endings.

(III) Chemoreceptors

These are stimulated by chemical forms of energy, and they include the taste receptors, the smell receptors (in the olfactory mucous membrane), and nociceptors (These are free naked nerve endings that perceive pain sensation).

PROPERTIES OF THE SENSORY RECEPTORS

(1) SPECIFICITY (differential sensitivity)

(2) EXCITABILITY (THE RECEPTOR POTENTIAL)

(3) DISCHARGE OF IMPULSES

(4) ADAPTATION

PROPERTIES OF THE SENSORY RECEPTORS

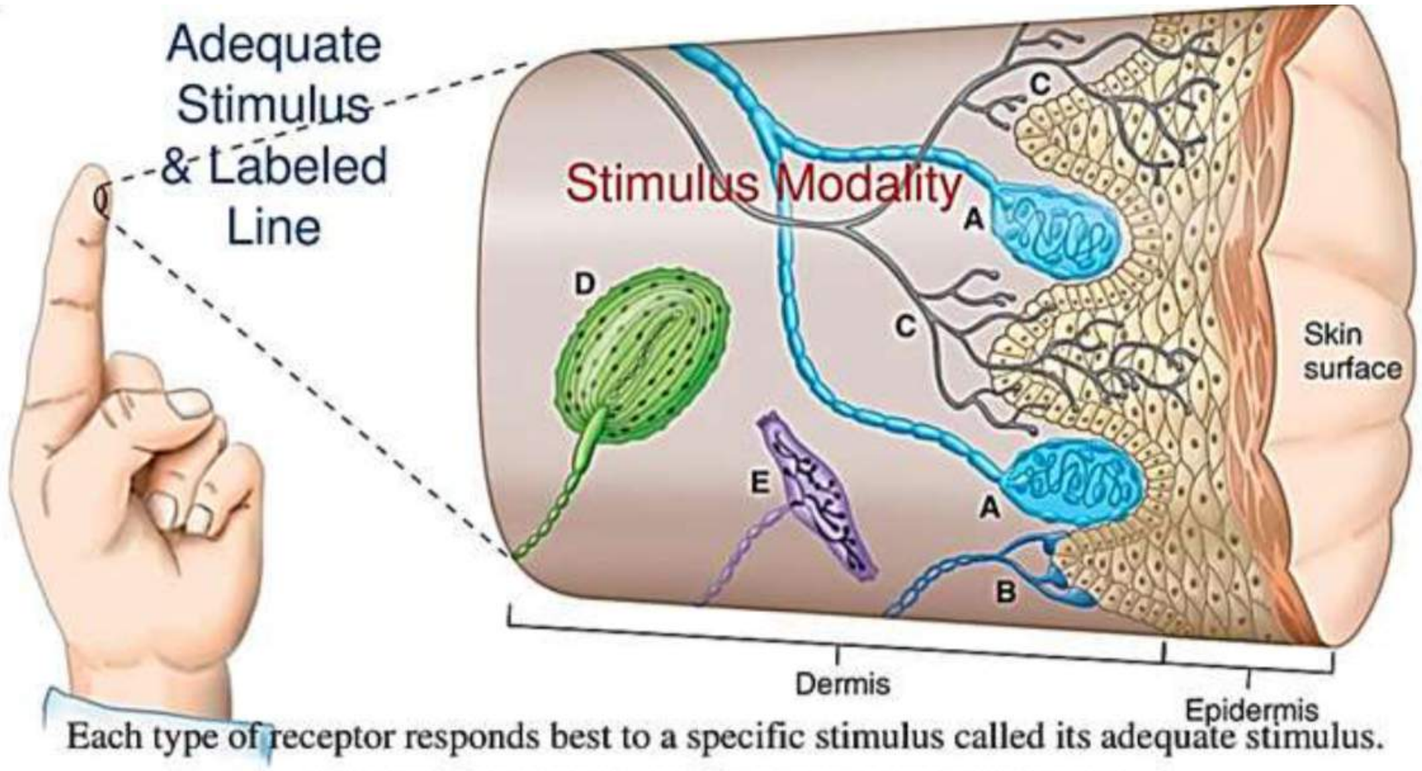
(1) SPECIFICITY (differential sensitivity)

-Each type of receptor 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 retinal receptors' adequate stimulus 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 the case of retinal receptors).

PROPERTIES OF THE SENSORY RECEPTORS



Each type of receptor responds best to a specific stimulus called its adequate stimulus.

A. Meissner's corpuscle—rapidly adapting mechanoreceptor, touch and pressure
B. Merkle's corpuscle—slowly adapting mechanoreceptor, touch and pressure
C. Free nerve ending—slowly adapting, some are nociceptors, some are thermoreceptors, and some are mechanoreceptors
D. Pacinian corpuscles—rapidly adapting mechanoreceptor, vibration and deep pressure
E. Ruffini corpuscle—slowly adapting mechanoreceptor, skin stretch

PROPERTIES OF THE SENSORY RECEPTORS

(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.

-In contrast, its remaining part is myelinated, and the first node of Ranvier is present inside the corpuscle. When the corpuscle is not stimulated, the sensory nerve ending is in the polarized state (with a resting membrane potential of about -70 mV).

PROPERTIES OF THE SENSORY RECEPTORS

(2) EXCITABILITY (THE RECEPTOR POTENTIAL)

-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.

PROPERTIES OF THE SENSORY RECEPTORS

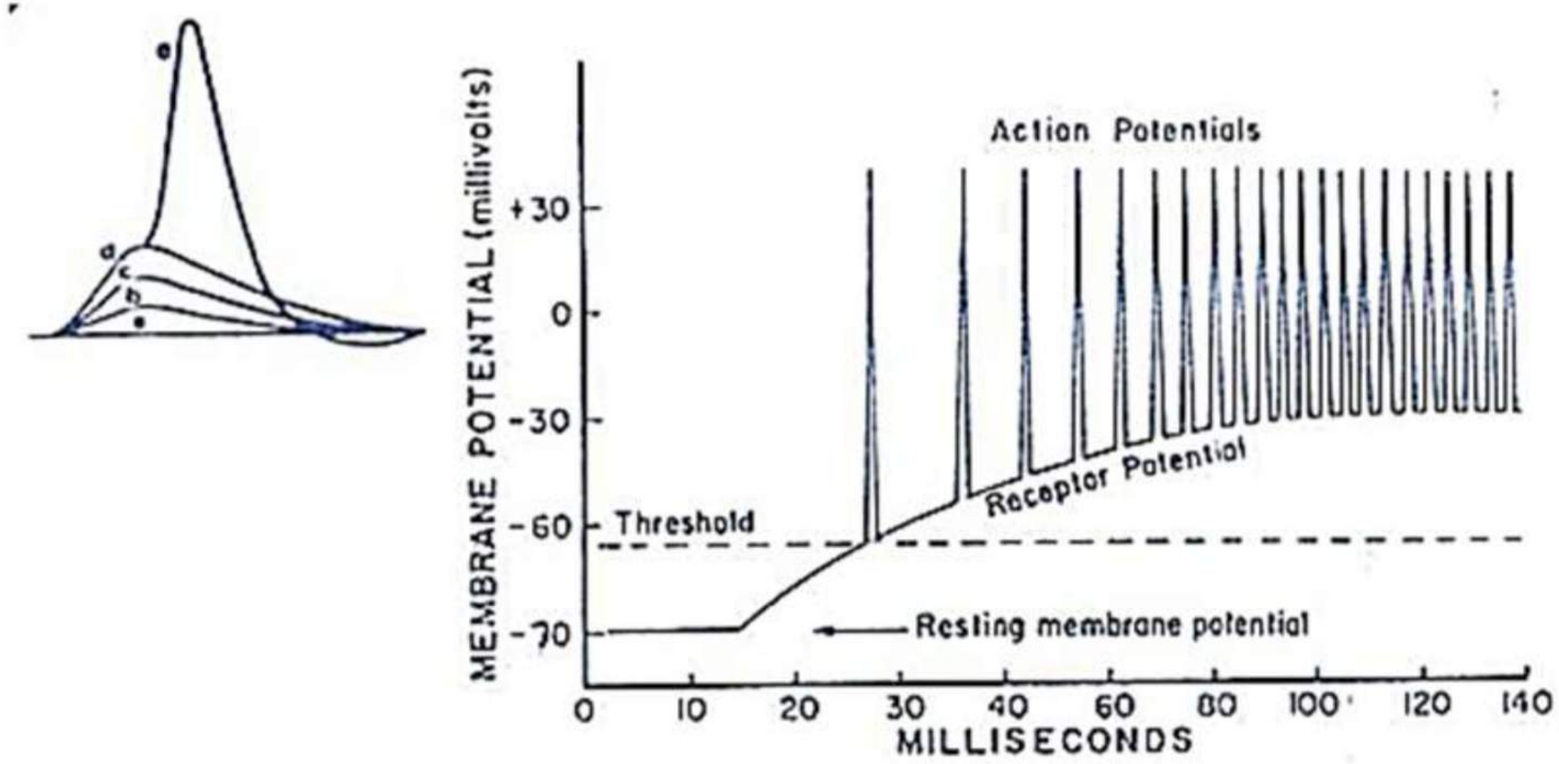
(2) EXCITABILITY (THE RECEPTOR POTENTIAL)

-The receptor potential is passively conducted to the first node of Ranvier (by local circuits of current flow), causing its depolarization.

-If this reaches the firing level, it initiates an action potential that is propagated along the afferent nerve to the nervous system, and if its magnitude rises above that level (depending on the intensity of the stimulus). the frequency of discharge increases proportionately.

PROPERTIES OF THE SENSORY RECEPTORS

(2) EXCITABILITY (THE RECEPTOR POTENTIAL)



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

a-It does not obey all or none law so that it can be graded.

b- It leads to a propagated action potential reaching the threshold level.

PROPERTIES OF THE SENSORY RECEPTORS

(3) DISCHARGE OF IMPULSES

-The frequency of discharge of impulses from receptors depends on the intensity of stimulation, which determines the magnitude of the perceived sensation.

- According to the Weber-Fechner law, it states that " the frequency of discharge from receptors is directly proportional to the logarithm of the intensity of the applied stimuli.

PROPERTIES OF THE SENSORY RECEPTORS

(3) DISCHARGE OF IMPULSES

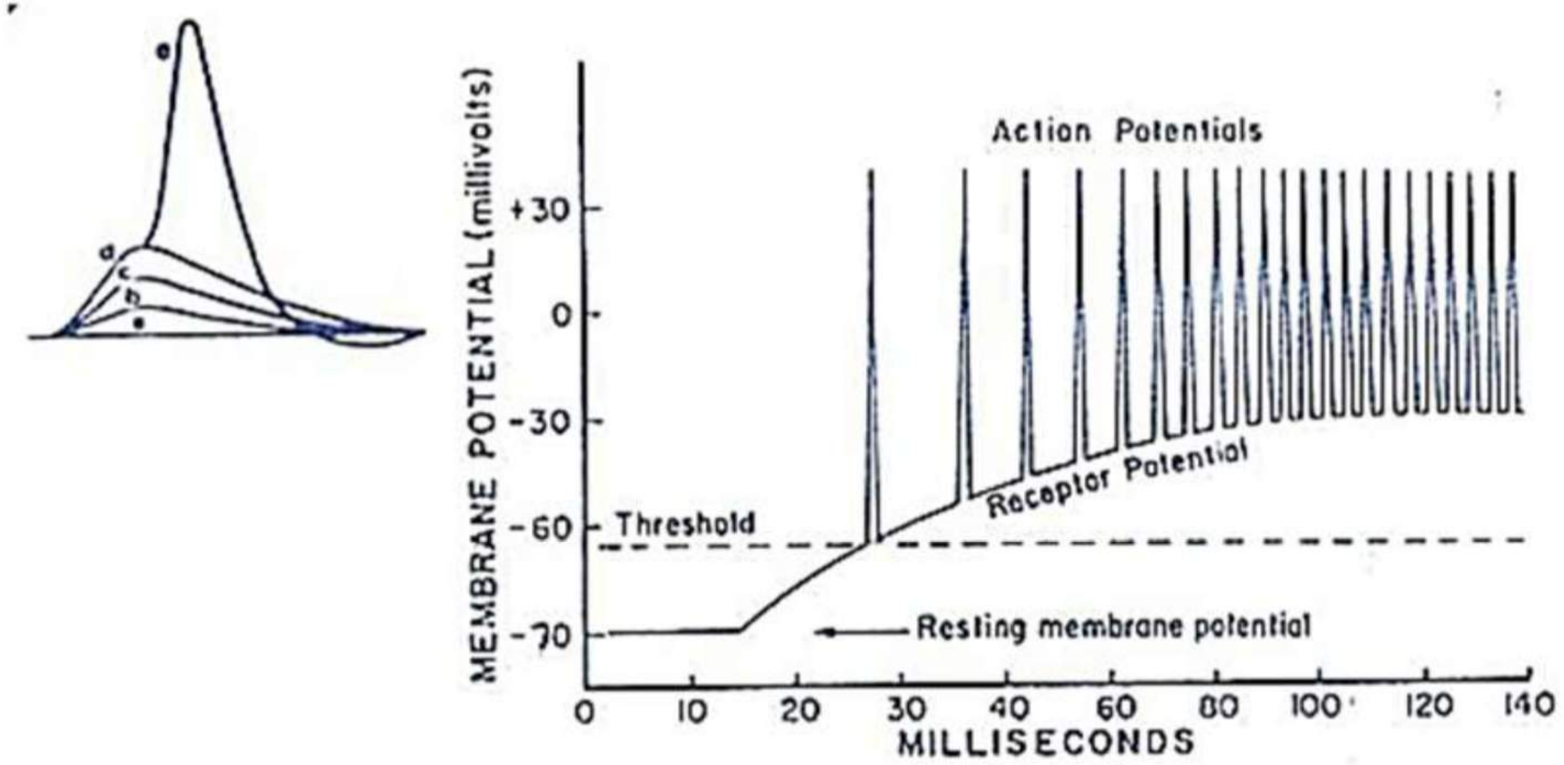
-However, this law was found to apply only to high intensities of stimulation, and the following power function (known as the power law) expresses the mathematical relation between the intensity of stimulation and the frequency of discharge more accurately:

$$R = \log S \times K$$

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).

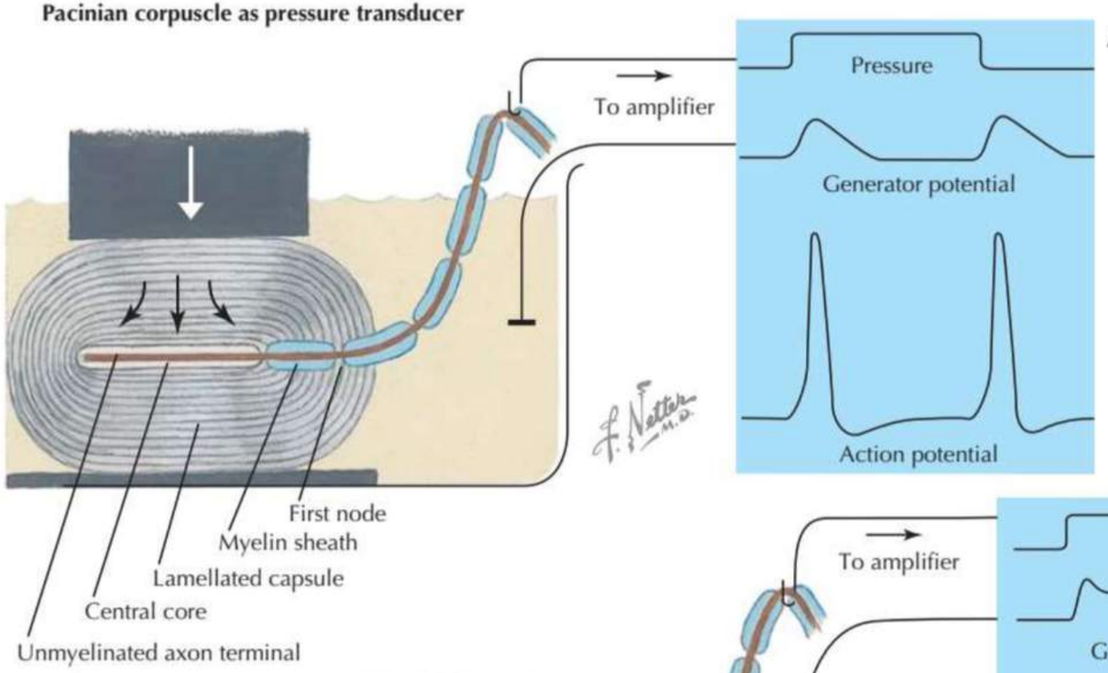
PROPERTIES OF THE SENSORY RECEPTORS

(3) DISCHARGE OF IMPULSES

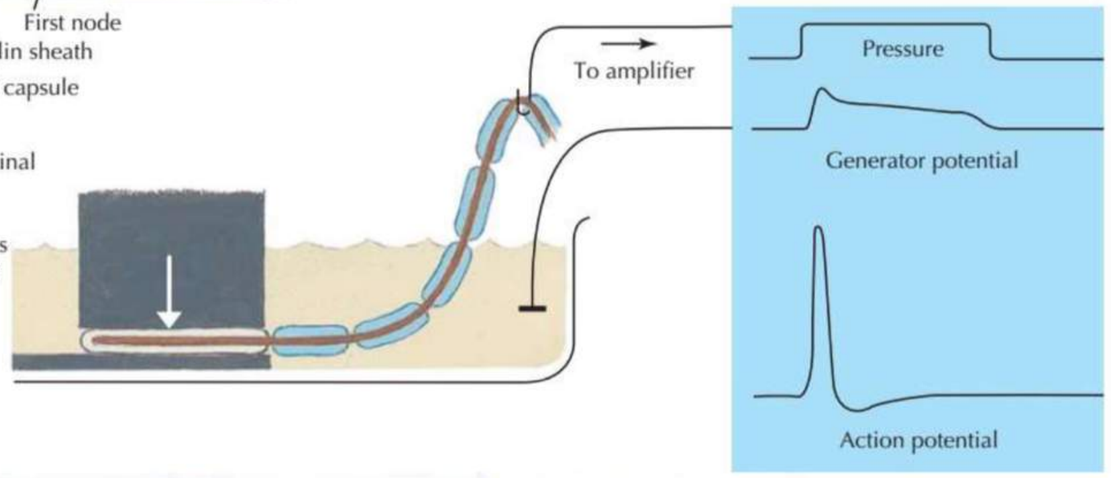


Relation between the receptor potential (RP) & action potentials (APs). As the (RP) rises above threshold, the frequency of (APs) increases.

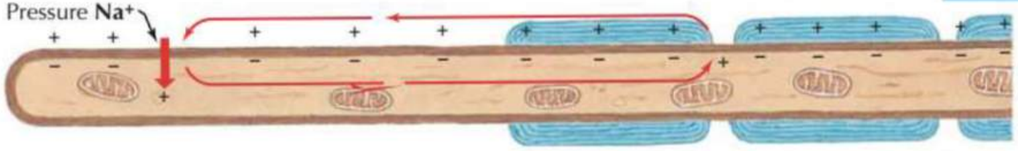
Pacinian corpuscle as pressure transducer



A. Sharp "on and off" changes in pressure at start and end of pulse applied to lamellated capsule are transmitted to central axon and provoke generator potentials, which in turn may trigger action potentials; there is no response to a slow change in pressure gradient. Pressure at central core and, accordingly, generator potentials are rapidly dissipated by viscoelastic properties of capsule. (Action potentials may be blocked by pressure at a node or by drugs.)



B. In absence of capsule, axon responds to slow as well as to rapid changes in pressure. Generator potential dissipates slowly, and there is no "off" response.



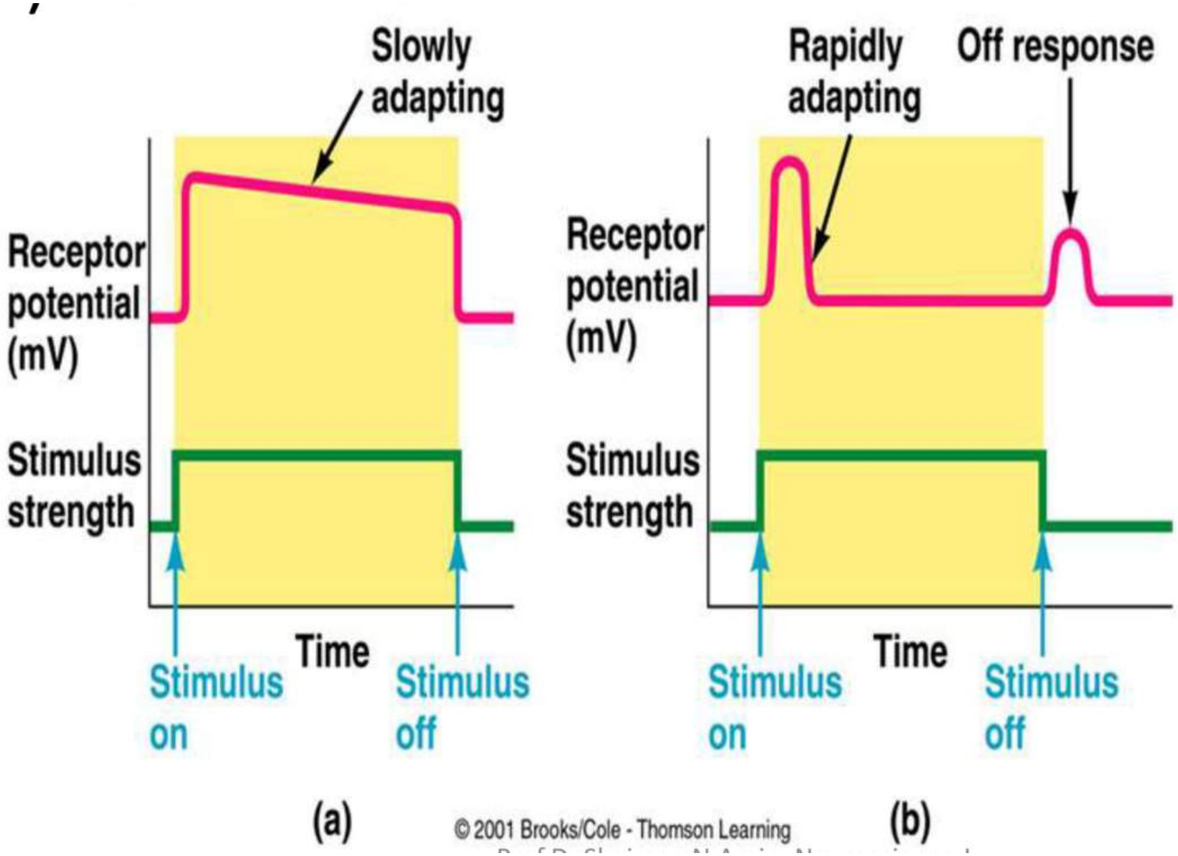
Pressure applied to axon terminal directly or via capsule causes increased permeability of membrane to Na^+, thus setting up ionic generator current through first node.

If resultant depolarization at first node is great enough to reach threshold, an action potential appears and is propagated along nerve fiber.

PROPERTIES OF THE SENSORY RECEPTORS

(4) ADAPTATION

This is a decline in the frequency of discharge of action potentials from receptors on maintained stimulation by stimuli with a constant strength.



According To Adaptation, Receptors Can Be Classified Into:

(1) Rapidly adapting receptors

(2) Slowly adapting receptors

(3) Moderately adapting receptors

According To Adaptation, Receptors Can Be Classified Into:

(1) Rapidly adapting receptors

-These are called the phasic (or rate) receptors because their discharge of impulses declines rapidly despite maintained stimulation.

-They include mainly the touch receptors (especially the Meissner's and Pacinian corpuscles), the rapid adaptation of which is important to avoid unnecessary or excessive sensations that might be irritating (e.g., there is no need for continuous information about the presence of clothes).

According To Adaptation, Receptors Can Be Classified Into:

(2) Slowly adapting receptors

-These are called the tonic receptors because they continue discharging as long as they are stimulated.

-They include the pain receptors, muscle spindles, and baroreceptors, and slow adaptation is important because the continuous discharge of the pain receptors elicits protective reflexes that prevent tissue damage by noxious agents.

- In contrast, the muscle spindles continuously inform the CNS about the body posture and position of the limbs, and the baroreceptors are essential to maintaining a normal level of arterial blood pressure.

According To Adaptation, Receptors Can Be Classified Into:

(3) Moderately adapting receptors

-These include the smell and taste receptors and the thermoreceptors (the warmth receptors adapt more rapidly than the cold receptors).

CODING OF SENSORY INFORMATION

-This is the ability of the nervous system to identify the modality (= type), locality, and intensity of various sensations.

-However, all sensations are transmitted from the receptors to the higher centers as action potentials.

CODING OF SENSORY INFORMATION

1-Modality (Muller's Law, Labeled line Principle)

2-Locality (Law of Projection)

3-Intensity (Recruitment of receptors,

frequency on impulses).

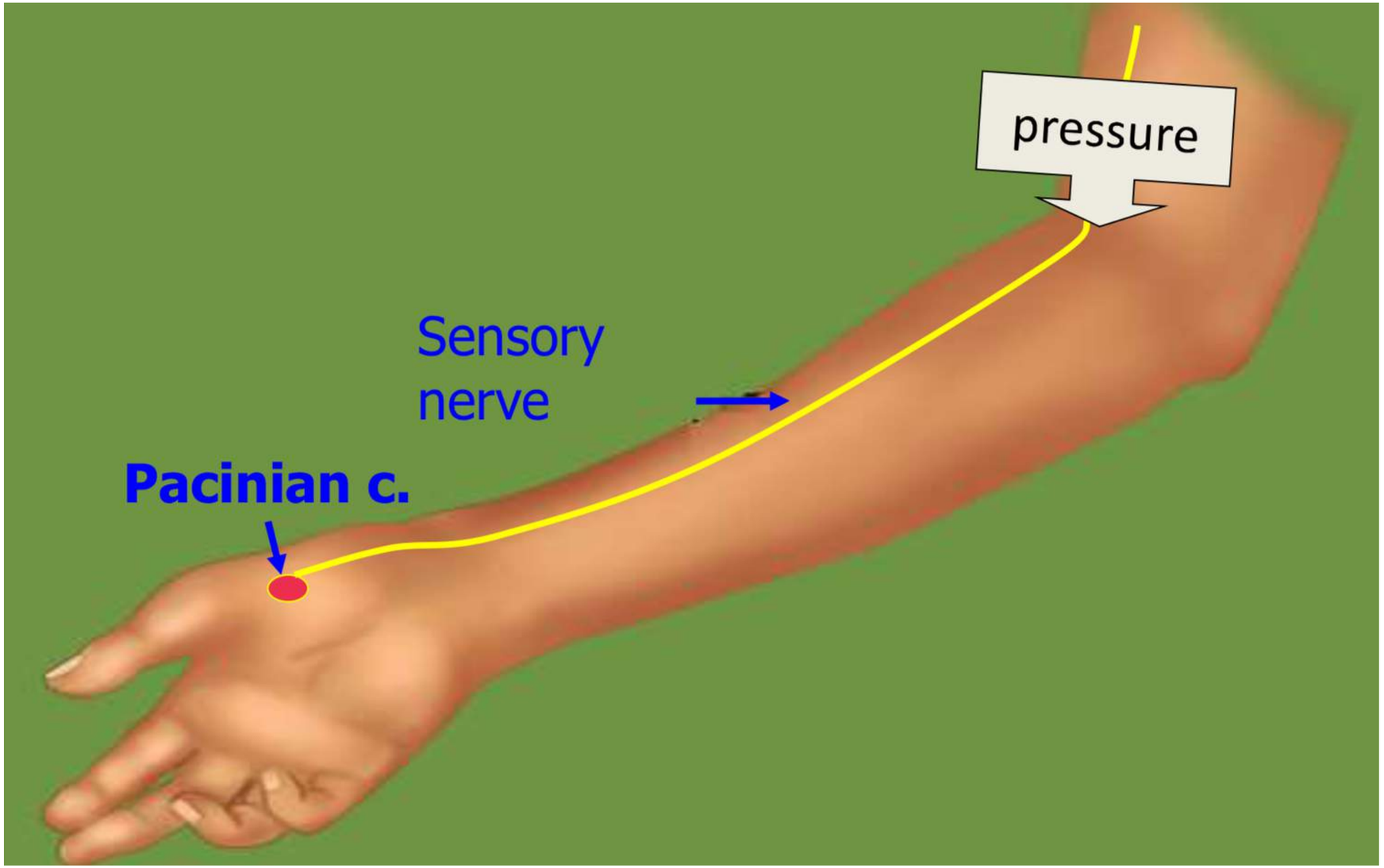
CODING OF SENSORY INFORMATION

(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 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).


pressure
Sensory
nerve
Pacinian c.

CODING OF SENSORY INFORMATION

(2) LOCALITY DISCRIMINATION:

—The discrimination of the locality of a certain sensation also depends on the specific pathway of that sensation.

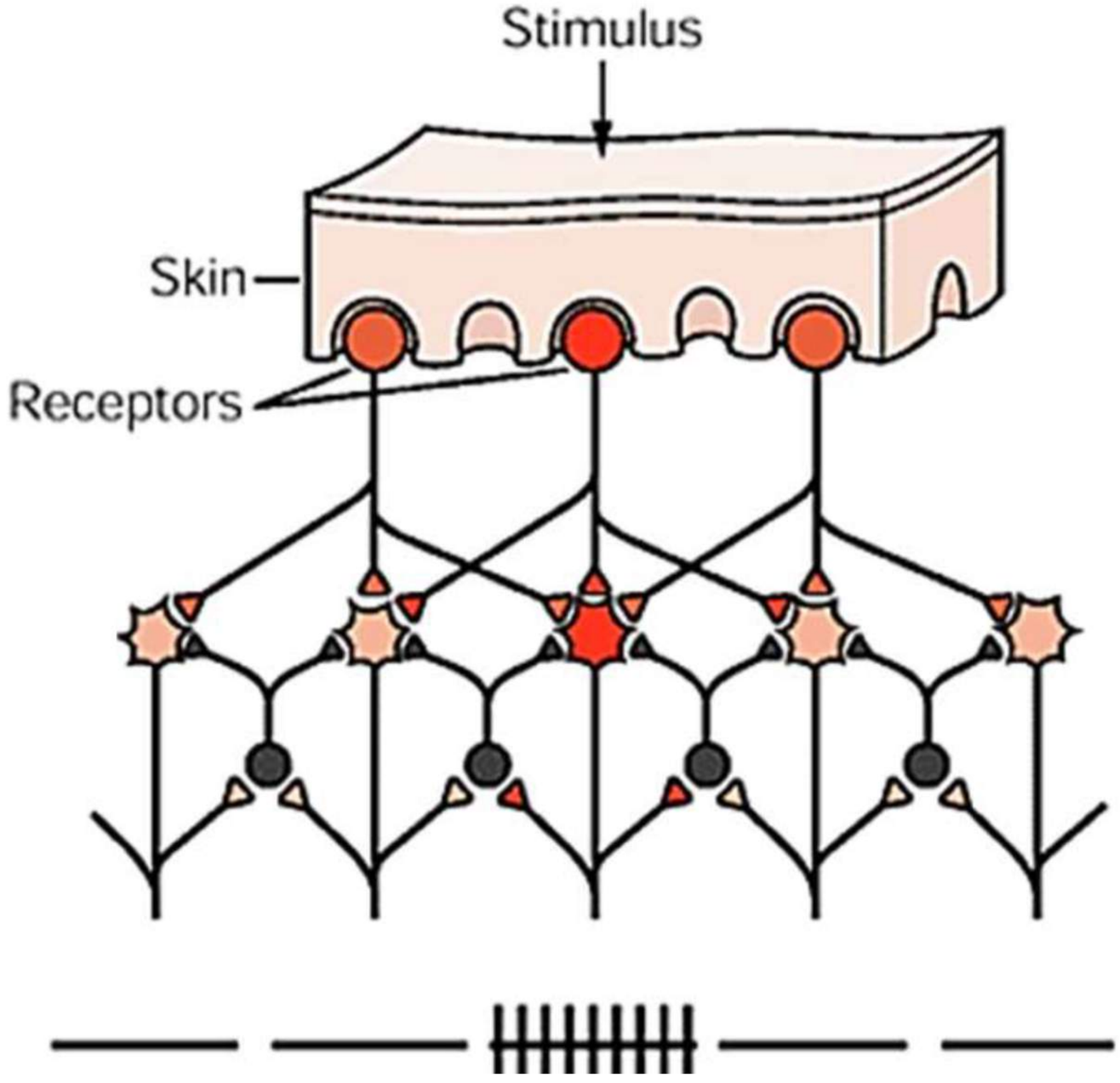
-When this pathway is stimulated anywhere along its course, the evoked sensation is projected to (i.e., referred to) the location of its receptors.

-This effect is called the 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.

CODING OF SENSORY INFORMATION

(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 centers (if they are depressed, e.g., due to O2 lack or hypoglycemia, the sensations become dull and their intensity is decreased).


Stimulus
Skin
Receptors

Weber-Fechner principle

This is a logarithmic function which states that: the perceived sensation is proportional to log intensity of the stimulus.

$$R = \log S \times K$$

R: perceived sensation.

S: stimulus intensity.

K: constant.

This means that 100-fold increase in stimulus intensity, will increase the perceived sensation by 2 times, 1000 fold increase will increase the sensation by 3 times and so forth.

LAWS IN SENSORY PHYSIOLOGY

1. **Muller's Doctrine of specific nerve energies:** No matter where along the nerve pathway one stimulates, the type of sensation will depend on which part of the brain is finally going to be stimulated.
2. **Law of Projection:** No matter where along the nerve pathway one stimulates, the sensation will be felt at the site of the receptor Phantom limb sensation is best described by this law.
3. **Bell-Megendie Law:** This law states that the dorsal root is sensory and ventral root is motor.
4. **Labelled-line theory:** All the sensations from the different parts of the body travel along specified paths. For example, in the posterior column, fibers from the lower parts of the body are placed medially.
5. **Weber-Fechner's law:** In 1834, Weber demonstrated that the *sensitivity of a sensory system* to differences in intensity depends on the absolute *strength of the stimuli*. We easily perceive that 1 kg is different from 2 kg, but it is difficult to distinguish 50 kg from 51 kg. Yet both sets differ by 1 kg. This relationship is expressed in the equation now known as:
   - **Weber's law: $\Delta S = K. S$** 舰舰…[where ΔS is the minimal difference in strength between a reference stimulus S and a second stimulus that can be discriminated, and K is a constant.]
   - **Fechner** extended Weber's law to describe the relationship between the stimulus strength (S) and the intensity of the sensation (I) experienced by a subject: **$I = K \log (S/S_0)$**…… [where S_0 is the threshold amplitude of the stimulus and K is a constant.]
   - **Stevens' law** states that: **$I = K (S - S_0)^n$**