Introduction to Sensory System
&
Physiology of Receptors

General Principles :-

Sensory system makes us aware of our External & Internal Environments

The process of this awareness is initiated by the application of a stimulus

Stimulus- Any change in the parameters of External or Internal Environment

Receptor :- The Afferent Nerve endings that sense the Stimulus & then convert it into Action Potential (Impulse) by means of transduction

This Impulse is carried to the Spinal Cord through Sensory Nerves

From Spinal Cord to the Brain by means of Ascending Neurons

In CNS, the Sensory information is processed in various centers & finally brings a change in behavior via efferent pathways

The Sensory System consists of :-

i) **Receptors**– that receive & transduce the stimulus into Action potential in Sensory Neurons

ii) **Afferent Pathways** (Sensory Neurons)---that transmit the Stimulus in the form of Action Potential to the CNS

iii) **Neurons in the CNS-**---that modulate Sensory information

iv) **Areas in the Brain-**---that recognize the Stimulus

Sensation :-

The Basic Recognition of a Stimulus

Clinically, it is called “Esthesia”, a greek word,which means feeling

Absence of Sensation =Anesthesia

Abnormal Sensation= Parasthesia

Sensation of Movement = Kinesthesia

Types of Sensations :-

a) Somatic Sensation/Somesthesia :-

Arise from Receptors present on the Body surface,in the body wall, Muscles,Tendons,Bones,Joints & Connective tissues.

Includes Sensation of :-

- ❑ Touch
- ❑ Pain
- ❑ Temperature
- ❑ Vibration
- ❑ Joint movement (Proprioception)

b) Visceral Sensations :-

- Originate from Stimulation of Receptors in the Viscera
- Usually, Receptors are located in the wall of Viscera or in the Connective tissue of the Viscera
- The Visceral organs are present in the Skull,Thorax,Abdomen & Pelvis

c) Special Sensations :-

- Originate in Special sense Organs
- Include—Vision,Audition,Olfaction,Gustation & Vestibular Sense
- Sensed by Special Sensory Receptors present in Eye,Ear,Nose & Tongue

Perception :-

- Appreciation & Interpretation of Sensation
- Involves first Recognition & then Comparison,Discrimination, Integration & Localization of the Sensations

Sensory Modulation :-

- Sensation elicited by a Stimulus differs in quality & intensity depending on the Afferent pathways carrying it,CNS areas activated by it & the nature of processing of information in the CNS areas.
- It may result in Accentuation/Inhibition of the Sensations
- This type of Modification/Control of Sensation is referred to as “Sensory Modulation”

Dimensions of Sensation :-

Diferent aspects of a Sensation like-

- ❑ Modality
- ❑ Intensity
- ❑ Affect
- ❑ Acuity

i) Modality :-

Quality or Type of Sensation

Ex:- Modality of Tactile Sensation=Touch

ii) Intensity :-

- Degree of Perception of a Stimulus

- Rapidly Adapting Sensation= That Spontaneously decreases in Intensity quickly when the Stimulus is applied for a Longer Duration
  Ex:-Touch

- Slowly Adapting Sensation= That Spontaneously decreases in Intensity slowly when the Stimulus is applied for a Longer Duration

- Non-Adapting Sensation = Sensation that doesnot change in its Intensity when the Stimulus is applied for a Longer Duration
  Ex-Pain

iii) Affect :-

- ❑ Emotional Component of a Sensation
- ❑ Sensations that donot have an Emotional Component = Neutral
- ❑ Sensations evoking a Pleasant Emotional Response= Positive
- ❑ Sensations evoking an Unpleasant Emotional Response=Negative

  For ex-Pain has Negative Affect

iv) Acuity :-

Precision of Stimulus Localization

Varies with the

- Concentration of Receptors (Innervation Density)
- Receptive Field Size of the area where the Stimulus is applied
- Size of Cortical area representing that Somatic Body part

Physiology of Receptors

- Receptors are Transducers that convert various forms of Energy in the Environment into Action Potentials in Sensory Neurons

- Receptors are Endings of Afferent Nerve fibers.It may be a part of Neuron or a Specialized cell

- It is generally associated with Non-Neural cells that surround it

- The Receptor + Non-Neural Structures = Sense Organ

- They are specific for a particular stimulus/form of energy.The form of energy to which the Receptor is most sensitive =Its Adequate Stimulus.
  Ex:- Adequate Stimulus for Rods & Cones=Light

Classification of Receptors

A) Based on Function

i) Exteroceptors :-

- Present in Skin & Subcutaneous tissue
- Concerned with a change in the External Environment close to the body
- Ex-Mechanoreceptors that sense Touch,Pressure & Vibration

ii) Interoceptors :-

- Present inside the Body
- Detect change in the Internal Environment of the Body
- Ex-Baroreceptors detect change in blood Pressure
  Osmoreceptors detect change in Osmolality of Body fluids

iii) Proprioceptors

- Provide Information about the position (Both Dynamic Movements & Static Position) of the body in space at any given time
- Present in Muscles,Tendon & Joints
- Ex- Muscle Spindle

iv) Teleceptors

- Receptors that receive stimuli or the sensation that are present far away from the body
- Ex-Auditory Receptors,Olfactory Receptors,Photoreceptors

B) Based on Adequate Stimulus :-

Depending upon different types of Adequate Stimuli (Forms of Energy Sensed),there are different Receptors

Different Types of Energy are :-

- ❑ Touch-Pressure (Mechanical Energy) ---Mechanoreceptors
- ❑ Cold-Warmth (Thermal Energy) ---Thermoreceptors
- ❑ Pain (Noxious Energy) ---Nociceptors
- ❑ Chemicals (Chemical Energy) ---Chemoreceptors
- ❑ Photons (Light Energy) ---Photoreceptors

A) Mechanoreceptors :-

- Respond to Application of a Mechanical Stimulus,ex-touching/stroking the Skin

- Broadly divided into 3 categories :-

- **Expanded Endings**-Merkel's Disks & Ruffini's endings
- **Encapsulated Endings-**
  Pacinian Corpuscles,Meissner's Corpuscles & Krause's end bulbs
- **Naked Nerve Endings-**
  All the 4 Cutaneous Sensory Modalities (Touch,Pressure,Pain & Temp.) can be elicited from the areas that contain only Naked Nerve Endings

B) Thermoreceptors :-

- Sensitive to changes in Temperature of the Skin
- 2 types :-
  - Warmth Receptor
  - Cold Receptor

C) Nociceptors :-

- Respond to Painful Stimuli,the stimuli that are harmful to the body i.e damages the tissue or threaten to produce damage to the Organism
- 2 types :-
  - Aδ-Mechanical Nociceptors
  - C-polymodal Nociceptors

Aδ-Mechanical Nociceptors-

- ❖ Respond to Fast pain.Ex-Sharp pain due to Pricking
- ❖ They donot respond to Pain activated by Thermal or Chemical Stimuli

C-polymodal Nociceptors—

- ❖ Respond to Several types of Noxious stimuli including Thermal & Chemical Stimuli

D) Chemoreceptors---

- ❑ Respond to Chemical Stimuli
- ❑ Ex- Taste Receptors,Olfactory Receptors

E) Photoreceptors :-

- ❑ Respond to Photons (Light).Ex-Rods & Cones of Retina

C) Based on Location :-

- **Superficial Receptors** – Located on Skin. Ex-Touch & Pressure Receptors
- **Deep Receptors**-Located in Muscles,Bone,Tendons. Ex-Muscle Spindle
- **Visceral Receptors-** Located in Viscera .Ex-Visceral Pain Receptors

Important Mechanoreceptors

1.Pacinian Corpuscles

- Located in the Skin & Subcutaneous tissues

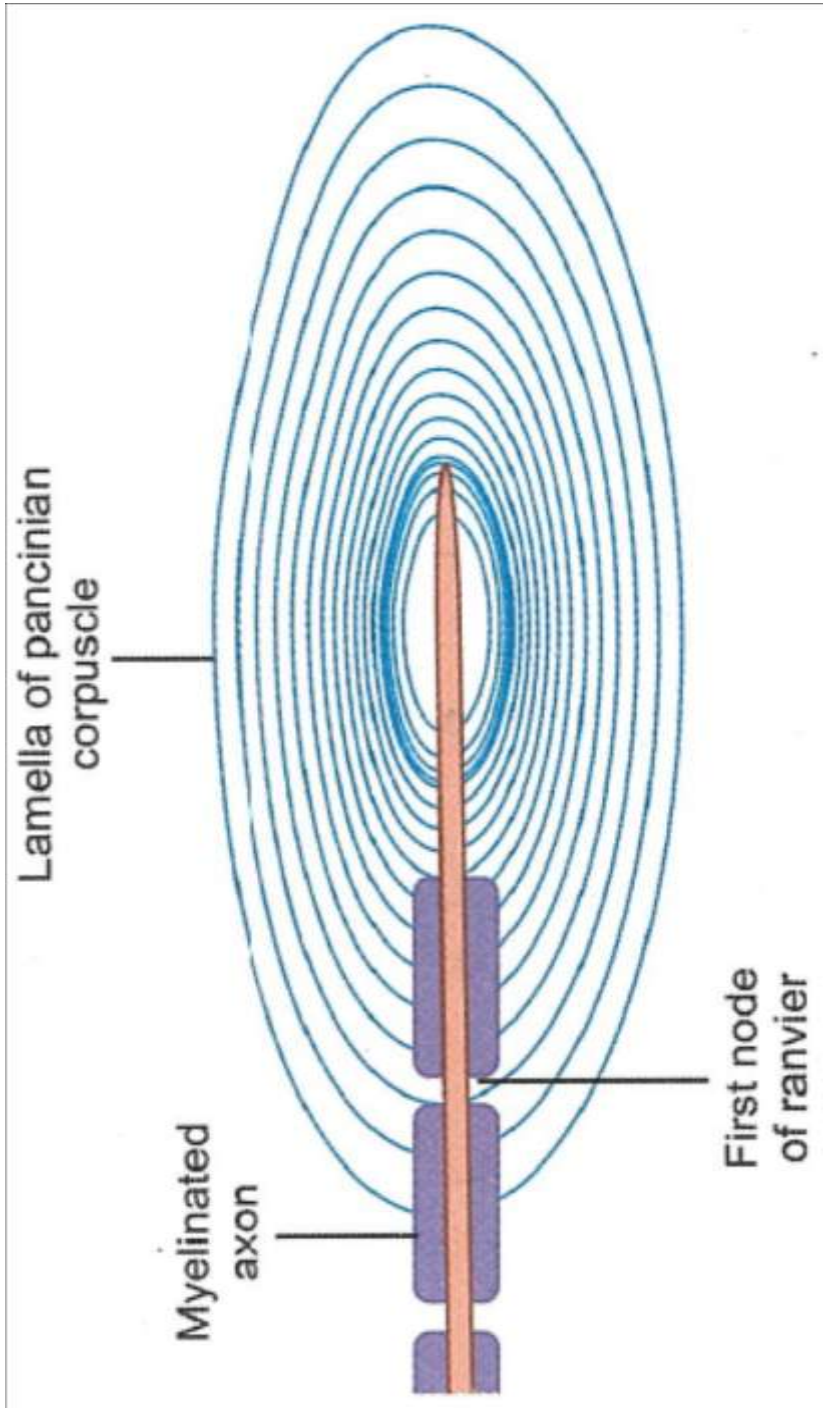
- Mediate the Sensation of Touch,Vibration & Pressure

- **Structure :-**

Consists of a Body composed of many Concentric layers (Lamellae)

- **Dimensions :-**

0.5-2 mm Long & 0.7 mm in Diameter (Largest Mechanoreceptor)



- The Distal end of a Primary Afferent fiber penetrates into the Concentric lamellae of Pacinian Corpuscle

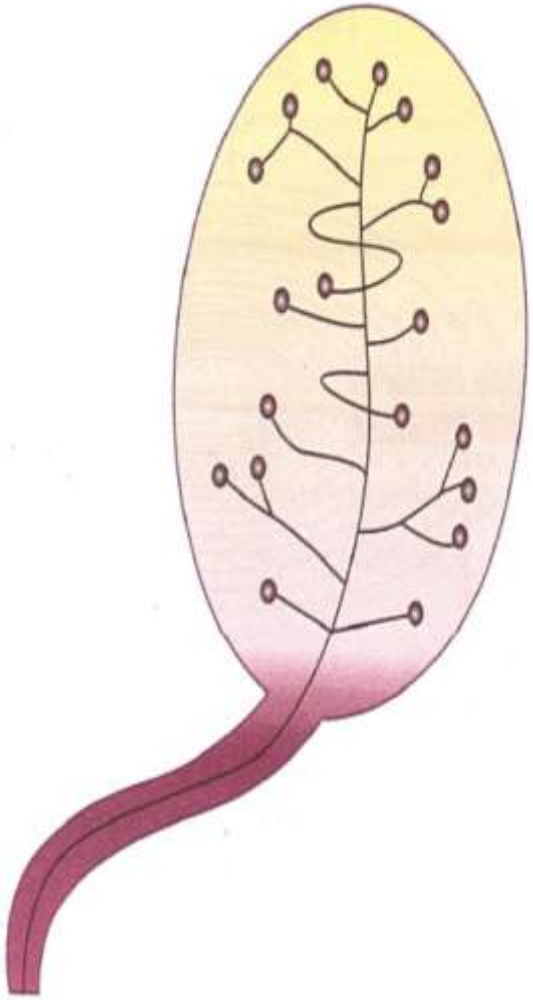
- The Cell body of this Aβ fiber lies in the Dorsal root ganglion
  Its Axon enters the Spinal Cord through Dorsal root

- The fiber is myelinated but the ending which lies in the Concentric lamellae of the Pacinian Corpuscle is unmyelinated

- **Function :-**

Rapidly Adapting Mechanoreceptor that Senses Vibration,fine touch & Pressure Sensation

2.Meissner's Corpuscle :-



- Relatively Large receptor located in the Dermal ridge of the Glabrous (Hairless) Skin

- Structure—
  - Length=150 µm
  - Diameter=50 µm

- This is an encapsulated ending having a Single layered capsule into which the ending of the Afferent Nerve penetrates.

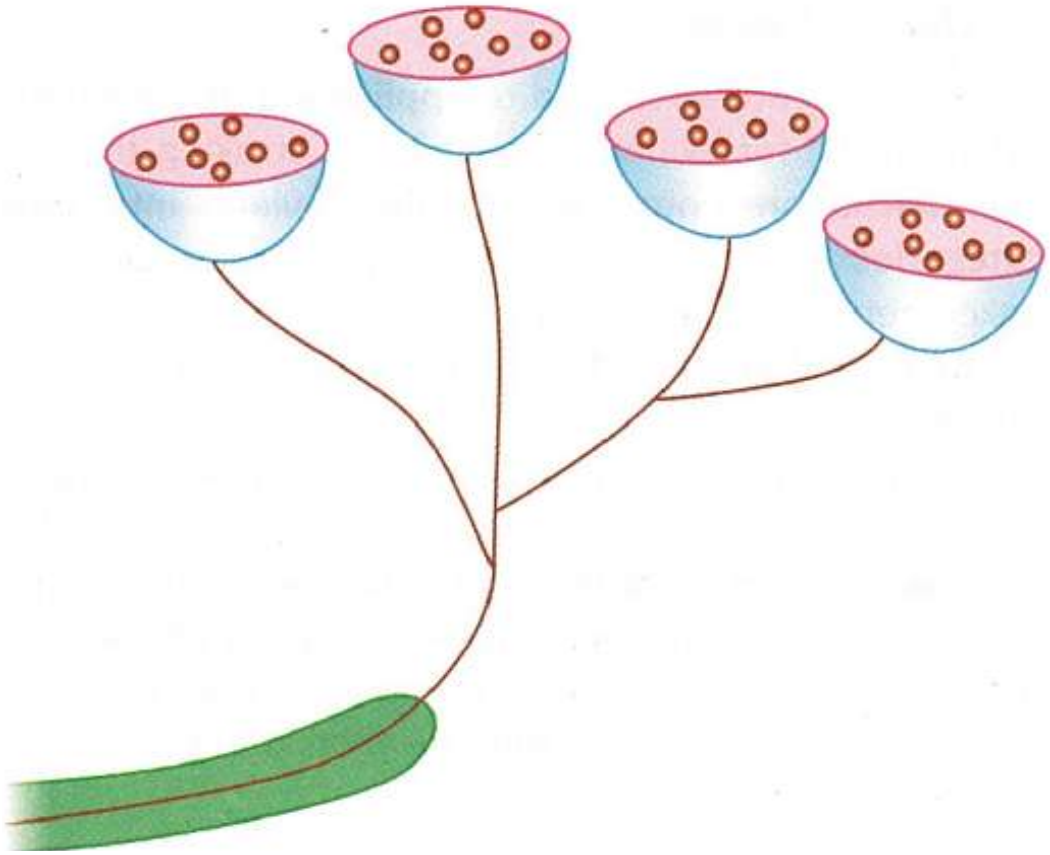
- The Afferent fiber is myelinated but ending is unmyelinated

- Ending is branched to form a Complex structure inside the Corpuscle

- **Function :-**

  It’s a rapidly adapting receptor that senses Vibration & Touch

3.Merkel's Disks :-



- Most superficial Mechanoreceptor present in the Epidermis of Glabrous & Hairy Skin

- Structure :-
  - Formed by flattened terminations of primary afferent endings

  - The fibers are myelinated but lose their Myelin Sheath before entering Epidermis

- The Afferent ending branches to form cup like flattened structures called “Merkel’s Disks”

- Merkel’s Disks synapses with the special modified cells ,”Merkel’s Cells”

- Merkel’s Cells along with Merkel’s Disk are combinedly called as “Merkel’s Apparatus” or “Iggo-dome Receptor”(as they elevate the Skin epithelium)

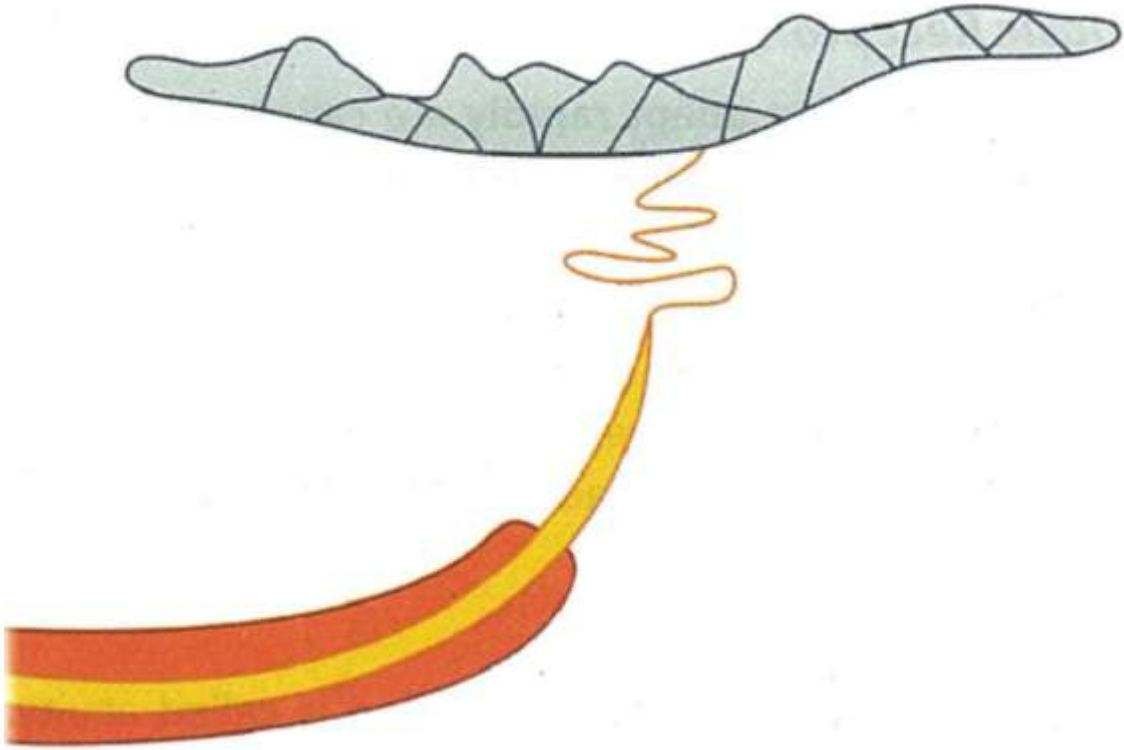
- **Function :-**
  Are Slowly Adapting Mechanoreceptor that senses Touch-Pressure

4.Ruffini's Endings :

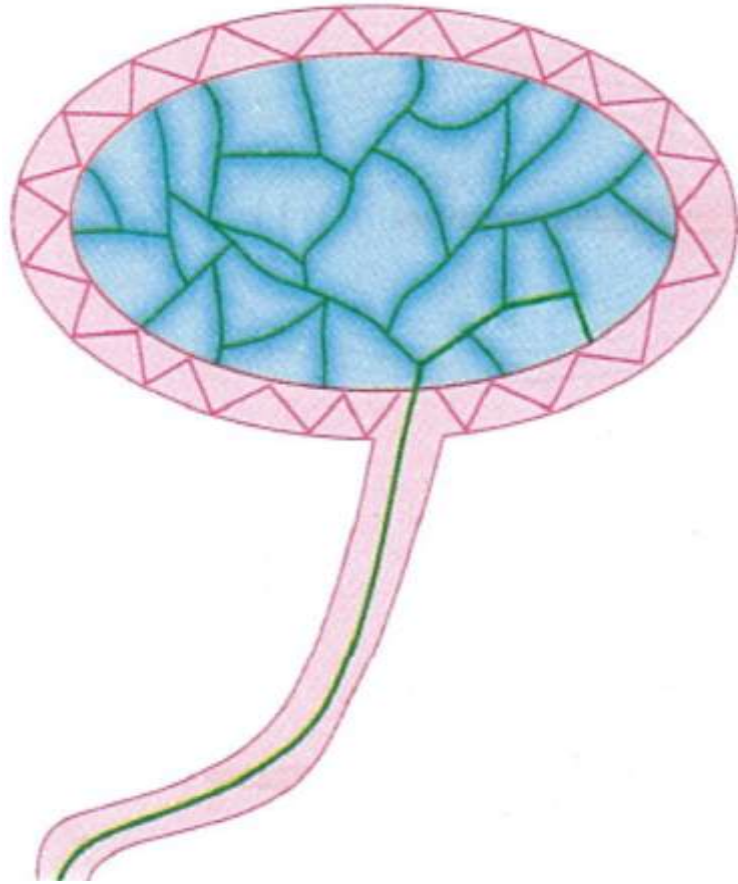
- Smallest Mechanoreceptors present in both Glabrous & Hairy Skin

- Structure :-
  Expanded endings of Afferent Aβ fiber.The Unmyelinated Nerve endings branch out to form a Complex expanded Structure

- Function :-Slowly adapting Receptors that sense Crude Touch



5.Krause's End Bulb



- Are Rapidly Adapting Mechanoreceptors present in Dermis

- Structure :-
  - Encapsulated Receptors into which Primary Afferent Nerve penetrates
  - The Capsule is made up of modified cells that encircle the branched unmyelinated endings of Aβ myelinated fiber

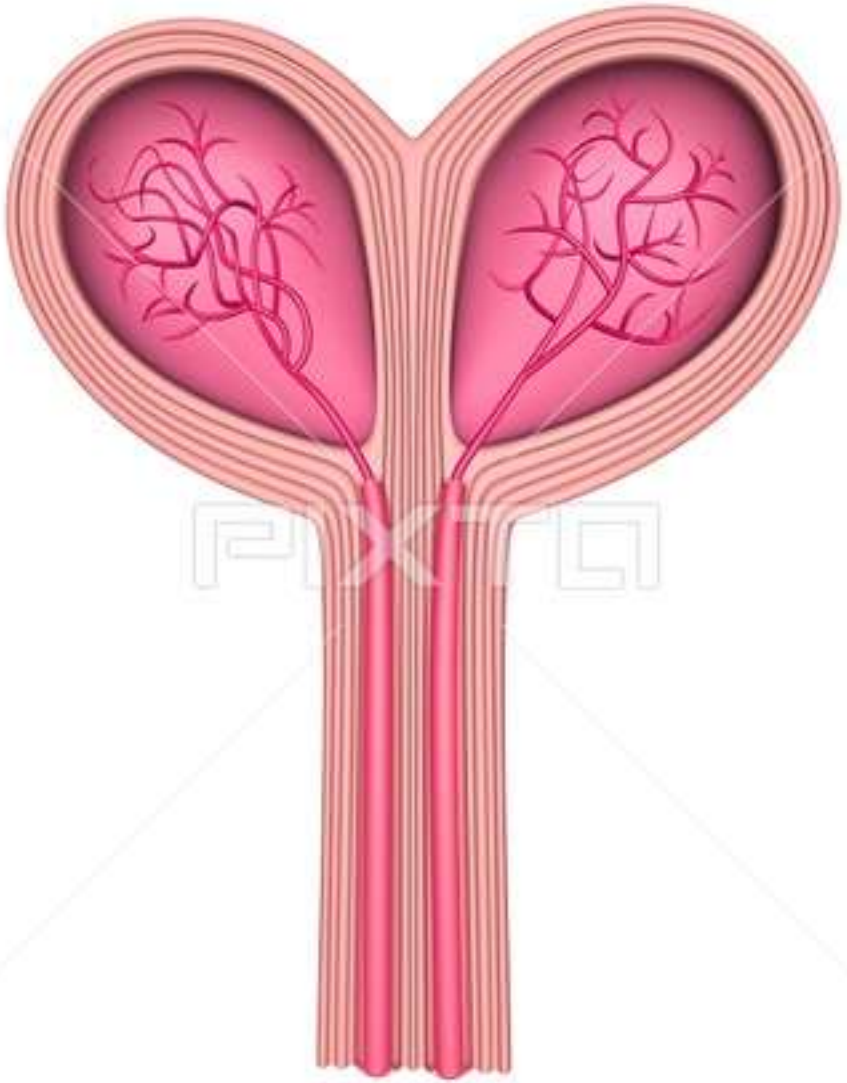
- Function :- Rapidly adapting Mechanoreceptors that sense touch & pressure

6. Golgi-Mazzoni Corpuscle

- Present in Tendons,Muscles & Skin

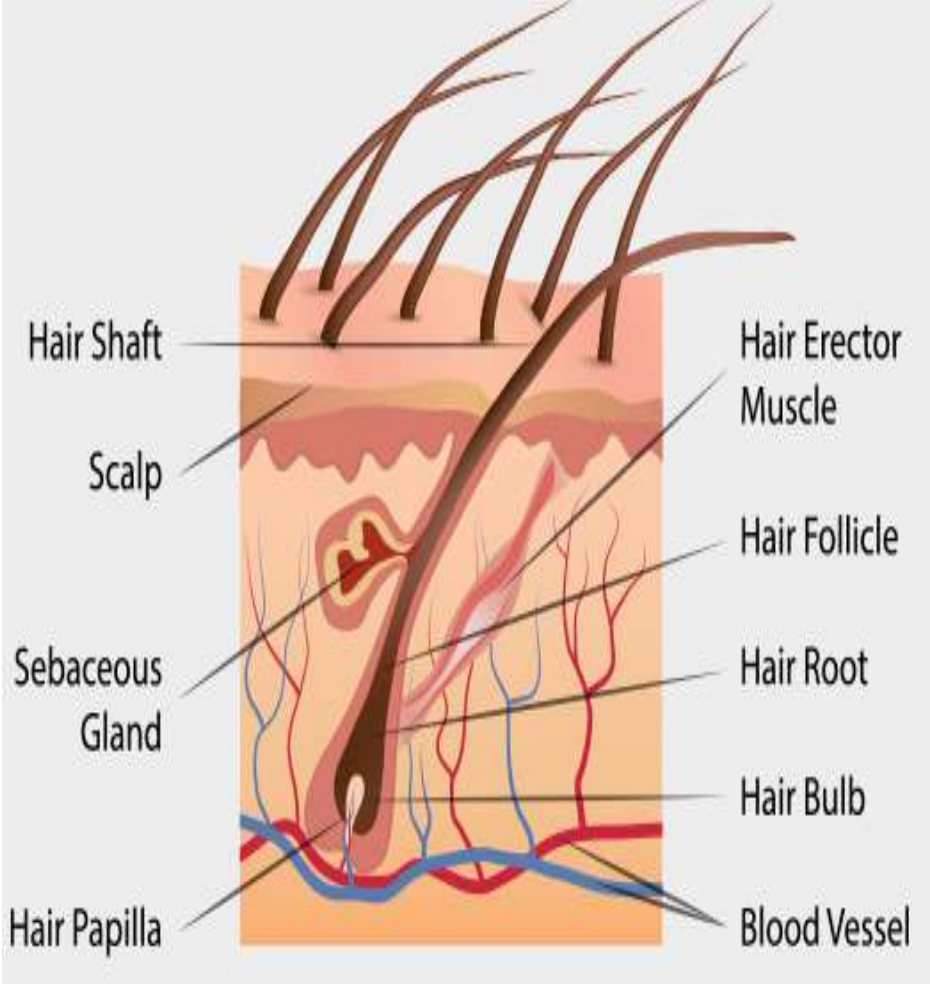
- Structure :-
  - Encapsulated Receptors consisting of 10-15 lamellae
  - 150-250µm in Diameter

- Function :-
  These are Rapidly adapting Mechanoreceptors sensing Touch & Pressure



7.Hair Follicle Endings

- Endings of Afferent fibers present adjacent to Hair follicles.
- Pressure on the Hair distorts & stimulates the associated afferent endings in the Hair follicle
- 3 types of Hair follicles innervated by 3 morphologically distinct afferent endings---
  - Simple Hair Follicle
  - Non-Sinus Facial Hair Follicle
  - Sinus Hair Follicle



i) Simple Hair Follicle :-

- Are Hair follicles without Erectile tissue
- Innervated by Unmyelinated nerve terminals of many Myelinated Axons
- Are Rapidly adapting Mechanoreceptors

ii) Non-Sinus Facial Hair Follicle

- Associated with Spray like terminals resembling Ruffini's Endings
- Present mainly in the Skin of Face
- Behave like Slowly Adapting Mechanoreceptors

iii) Sinus Hair Follicle :-

- Are associated with Hairs having Large Diameter & Erectile tissue at the Base surrounding the Follicle
- These Follicles are rich in Nerve Supply
- Both Slowly & Rapidly adapting endings are present in these follicles
- The Hairs with these follicles are called “Vibrissae” or “Tactile Hairs”

Receptor Potential

- Receptors convert Environmental Energy into Action Potential in the Sensory Nerves.

- On application of Stimulus,a potential change is observed in the Receptor,which is a Non propagating Depolarizing Potential that resembles an EPSP. It is referred to as “Receptor Potential/Generator Potential”

- When the Stimulus Intensity is Increased,the magnitude of Receptor Potential is also proportionately increased.

- When it reaches about 10-15 mV, the Action Potential is generated in the Sensory Nerve.

- Pacinian Corpuscles,due to their Large Size,are the best studied Receptors for studying the Genesis of Receptor potential

- It has been Experimentally observed that for the generation of Receptor Potential,the Lamellae of the Pacinian Corpuscles are not required.

- It is the Unmyelinated Nerve Terminal that generates the Receptor Potential

- The Receptor Potential forms Action Potential in the Sensory Nerve at the First Node of Ranvier,which is located in the Lamellae of Pacinian Corpuscle

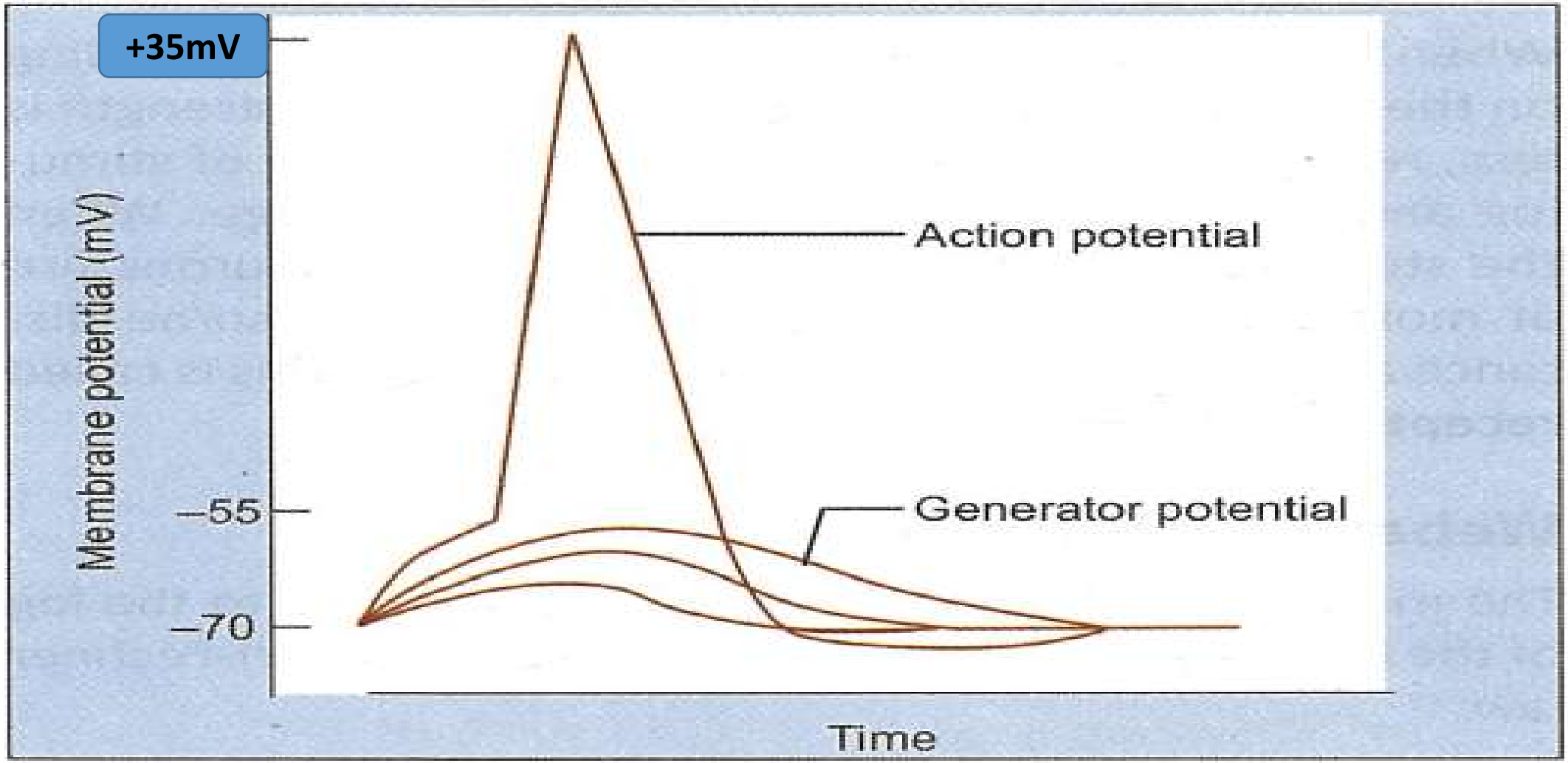
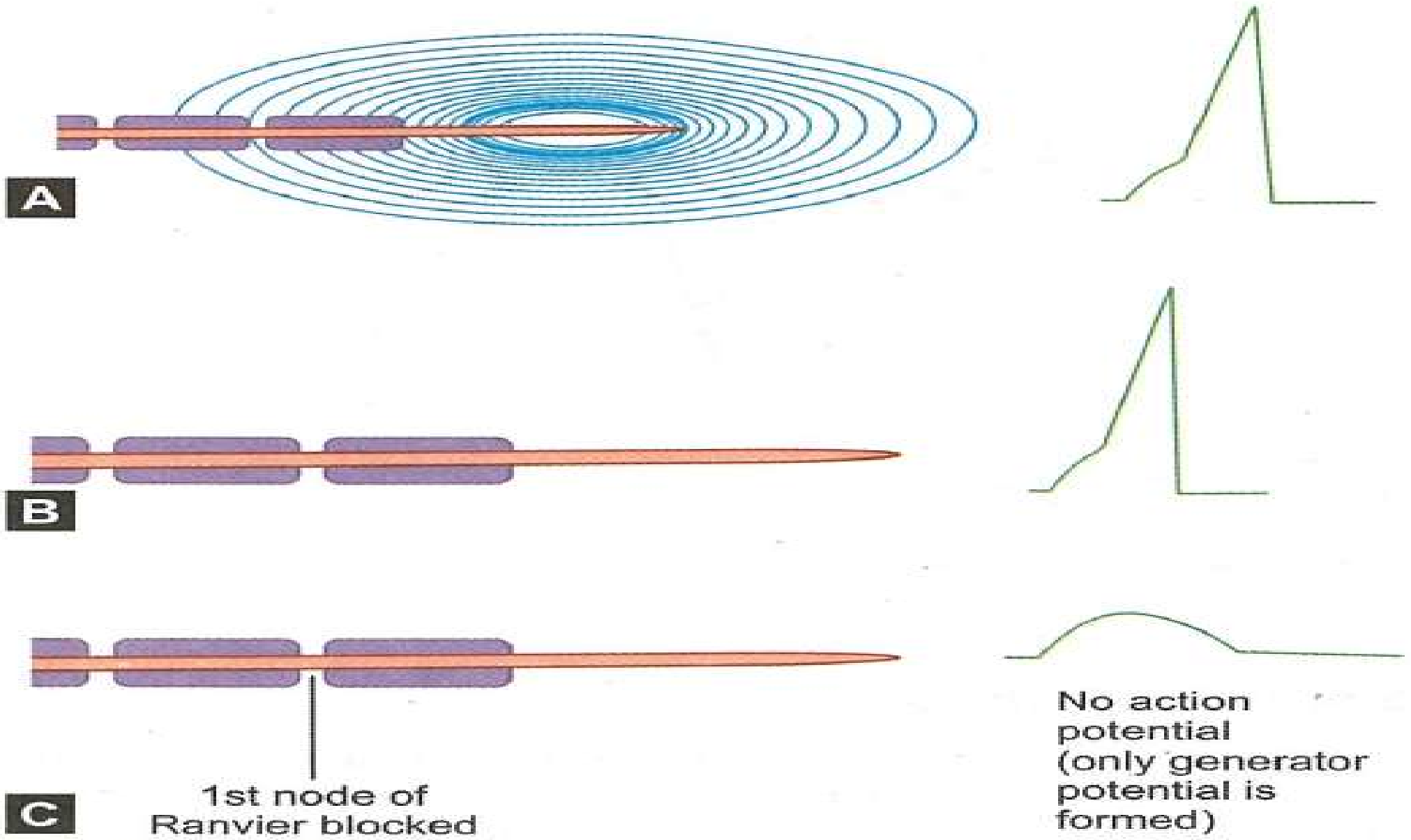


Fig. 117.6: Receptor (generator) potential and action potential, formed in receptors.



Figs. 117.7A to C: Demonstration of site of action potential genesis in Pacinian corpuscle. Note, action potential is formed following removal of lamella of Pacinian corpuscle (B); but, action potential is not formed following blockade of first node of Ranvier (C).

Mechanism of Genesis of Receptor Potential :-

Pressure on the Pacinian Corpuscle

↓

Causes Mechanical Distortion of the Lamellas

↓

Opening of Stretch Sensitive Sodium Channels in the Nerve Terminal

↓

Increased Influx of Sodium Ions

↓

Production of Receptor Potential

↓

The Magnitude & Frequency of Action Potential is proportionate to the Intensity of Stimulus

Properties of Receptors

1.Specificity :-

Receptors are specific to a particular type of Stimulus.

For ex :- Touch Receptors are stimulated by tactile stimulation

2.Adequate Stimulus :-

The Particular form of energy to which the Receptor is most Sensitive is called “Adequate Stimulus”

Ex:-Adequate Stimulus for Rods & Cones = Light

3.Adaptation :-

When a Stimulus of Constant strength is applied continuously to a Receptor,frequency of Action Potential in the Sensory Nerve decreases,which is referred to as “Adaptation/Desensitization”

Based on this property, Receptors are classified into 2 types :-

i) **Phasic Receptors-** adapt rapidly
Ex:- Touch & Pressure Receptors

ii) Tonic Receptors-adapt slowly or do not adapt at all
Ex:- Baroreceptors present in Carotid Sinus & Aortic Arch
Pain Receptors

4.Acuity :-

The Precision of Stimulus Localization is called “Acuity”

It depends on the Number of Receptors present in the Area where the Stimulus is applied

5.Intensity :-

- When a Stimulus is applied,Receptors discharge depending on the Strength of Stimulus
- When Stimulus Strength is Less,Receptors that are present close to the Site of Stimulus & Receptors with Low threshold,discharge
- When Stimulus strength is more,the Activated Neurons fire at more rate & the Receptors at some Distance away also discharge
- This phenomenon is called “Receptor Recruitment”

6.Weber-Fechner Law :-

The Magnitude of Sensation felt is proportionate to the Log of Intensity of the Stimulus.This is called “Weber-Fechner Law”

In Other Words the Law states that the change in a Stimulus that will be just noticeable is a Constant ratio of the Original Stimulus

For Ex :-
If you can only just distinguish the weight of 105g from that of 100g, then Just Noticeable Difference=5g.Now,according to the law,for some one to be able to reliably detect the increase,the stimulus must increase by a Constant ratio of 5/100 or 5%.So, if the Weight is doubled=200g then 210 g (5% of 200) will be just distinguishable by a Subject

7.Law of Projection :-

No matter where a Specific Sensory Pathway is stimulated along its course to the Cortex,the Sensation formed is referred to the Location of Receptors.This is called “Law of Projection”

It means,Irrespective of the Site of Application of the Stimulus in the Sensory Pathway,the Sensation evoked is felt at the Nerve Endings (Receptors)

Phantom Limb The phenomenon where a Limb has been amputated but still the Patient complains of Pain or Itch in the Limb because of the fact that no matter where in the Sensory Pathway of Pain or Itch the stimulus gets applied the patient’s Brain will always assume it to be coming from the Amputated Limb where the Receptors used to be located

8. Doctrine of Specific Nerve Energy :-

The Sensation evoked by a Stimulus that generates Impulse in the Specific Sensory Pathway depends on the Precise Area of the Brain that is eventually activated by the Stimulus

It was first described by Muller,hence called as “Muller’s Doctrine of Specific Nerve Energy”

For Ex:- If Sensory Fiber for Touch is stimulated anywhere along its course from Receptor to the Cortex,the Sensation evoked=Touch because of the fact that these pathways are activating the Touch perceiving Areas of the Cortex

This Doctrine can be stated in other words that When a Nerve Pathway from a Particular Sense Organ is stimulated,the Sensation evoked is always that for which the Receptor is specialized,no matter how or where along the pathway the activity is initiated.

For ex :-

- Touch pathway originating from the Mechanoreceptors present in the skin upon stimulation anywhere and anyhow will always lead to Perception of Touch as the Mechanoreceptors present over the skin are specialized for Touch-Pressure sensation

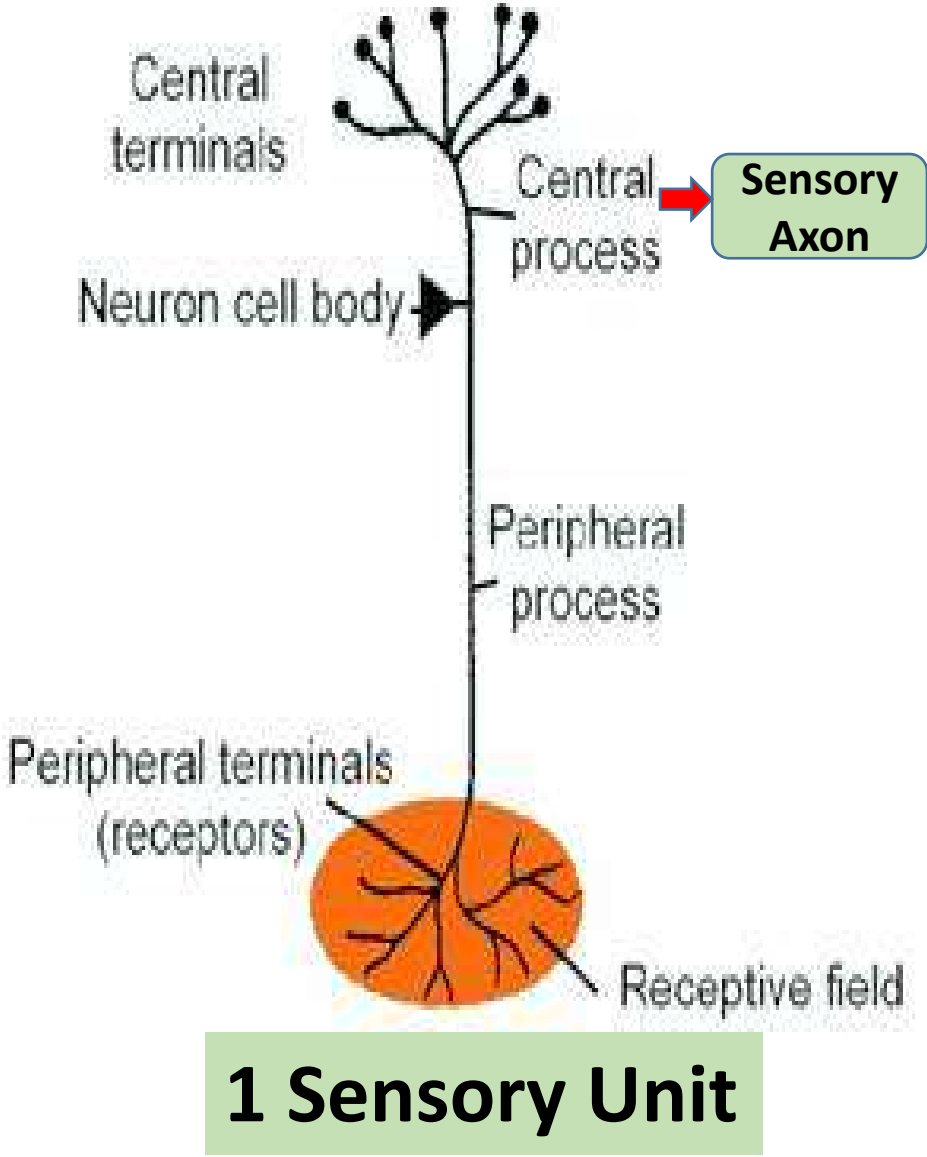
9.Sensory Unit :- Single Sensory Axon + All its Peripheral Branches

Receptive field of a Sensory Unit :-

- Area from which a Stimulus produces a response in that Unit
- Usually there is some degree of overlap of Sensory units of the Nearby regions

Recruitment of Sensory Unit :-

- Receptors spread over a Large area are activated when the Strength of Stimulus is Increased as nearby Sensory Units are also get involved.



1 Sensory Unit

CHAPTER SUMMARY

Important to Know (Must Read)

1. 'Classify receptors and give the structure and functions of each, and describe the mechanism of genesis of receptor potential' or 'Describe the properties of receptors' may come as a **Long Question**.
2. Receptor potential, Pacinian corpuscle, Properties of receptors may come as **Short Questions** in exam.
3. In **Viva**, examiner may ask... Define a receptor, What are the types of sensations, What are the dimensions of sensation, Classify receptors, What are the structure and functions of each receptor, What is a receptor potential, How is receptor potential generated in Pacinian corpuscle, What are the properties of receptors, About each property.