SENSORY RECEPTORS

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- Sensory receptors are transducers that convert various forms of energy in the environment into action potentials in sensory neurons
- Ending of afferent nerve fibre
- Generates action potentials in neurons on adequate specific stimulus
- Relay information about the internal & external environment to the CNS

Sense organs

- The receptor is often associated with nonneural cells that surround it, forming a sense organ

Classification of receptors

➢ Based on location

- Exteroceptors
- Interoceptors
- Teleceptors

Exteroceptors

- Detect the change in the external environment
- Cutaneous receptors- Meissner's corpuscle, Pacinian corpuscle, Merkel's disks, Ruffini endings, Krause's end bulb, free nerve endings

Interoceptors

- Detect change in the internal environment

✓ Baroreceptors

✓ Chemoreceptors

✓ Osmoreceptors

✓ Proprioceptors (position of body in space)

✓ Volume receptors

Teleceptors

- Receive stimuli or sensation that are present far away from the body

✓ Vision-Rods and Cones

✓ Olfaction-Olfactory receptors

✓ Audition-Auditory receptors Hair cells

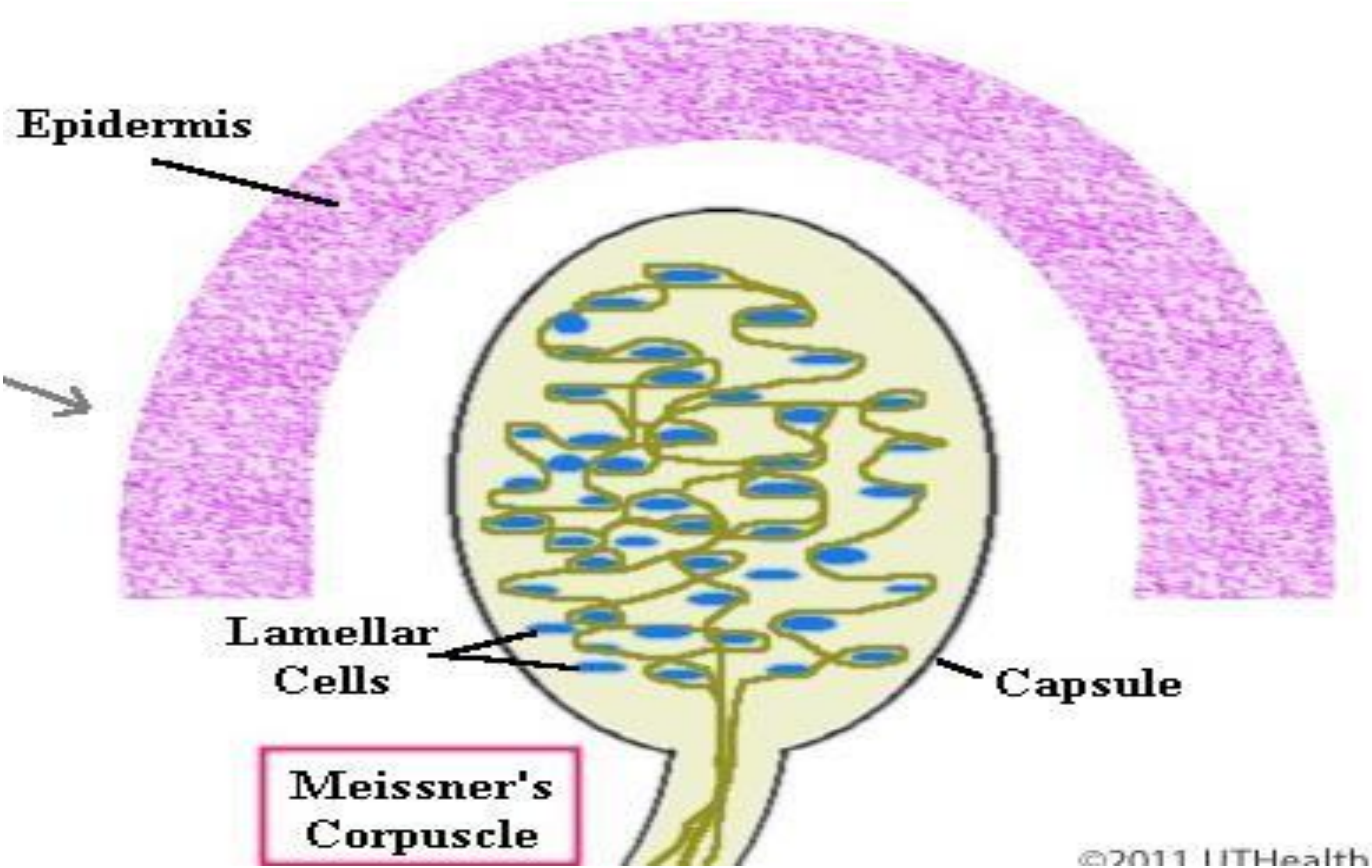
Based on the nature of stimulus

1) Mechanoreceptors
2) Thermoreceptors
3) Nociceptors
4) Photoreceptors
5) Chemoreceptors

1) Mechanoreceptors

- Detect mechanical compression or stretching of the receptor or of tissues adjacent to the receptor
- Meissner’s corpuscle, Pacinian corpuscle, Merkel’s disks, Ruffini endings, Krause’s end bulb, free nerve endings

Meissner’s corpuscle

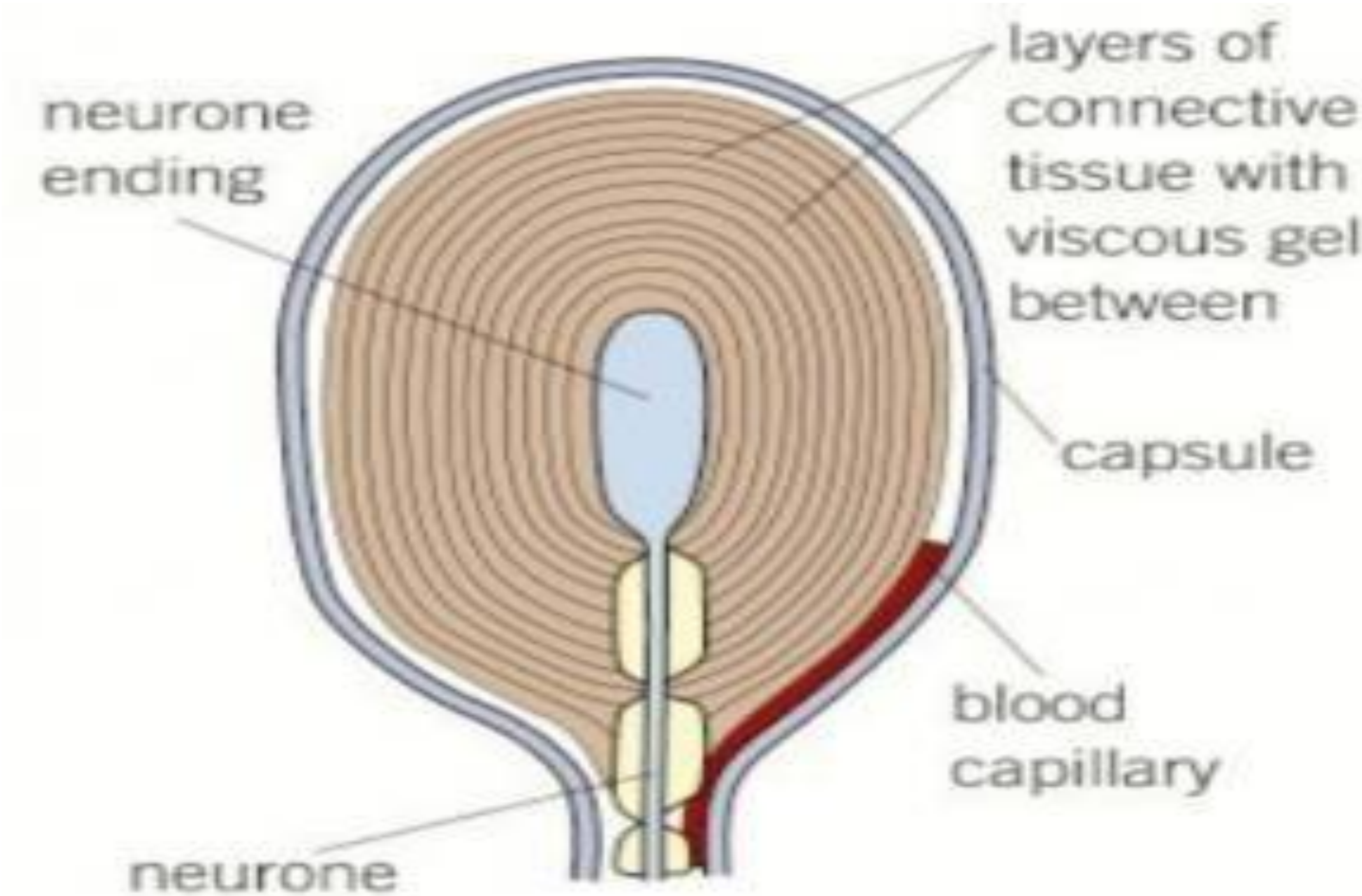


Meissner's corpuscle

- Encapsulated
- Endings of Aβ sensory nerve fibers
- Rapidly adapting
- Location
  - Non-hairy parts of skin
  - Abundant in fingertips, lips, nipple
- Stimulus
  - Movement of objects over skin
  - Slow vibration

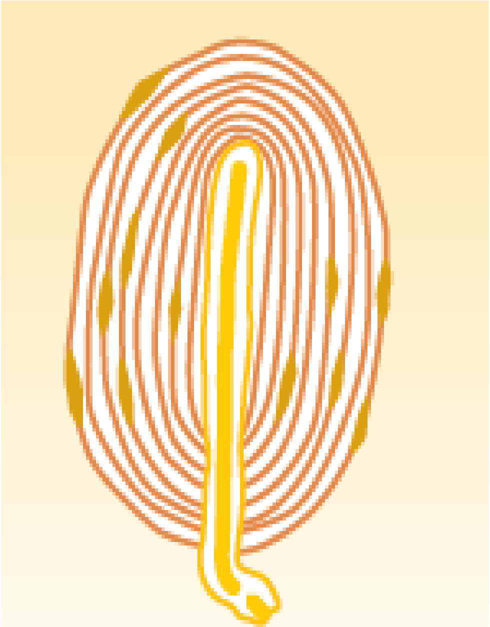
Meissner's corpuscle

Pacinian corpuscle



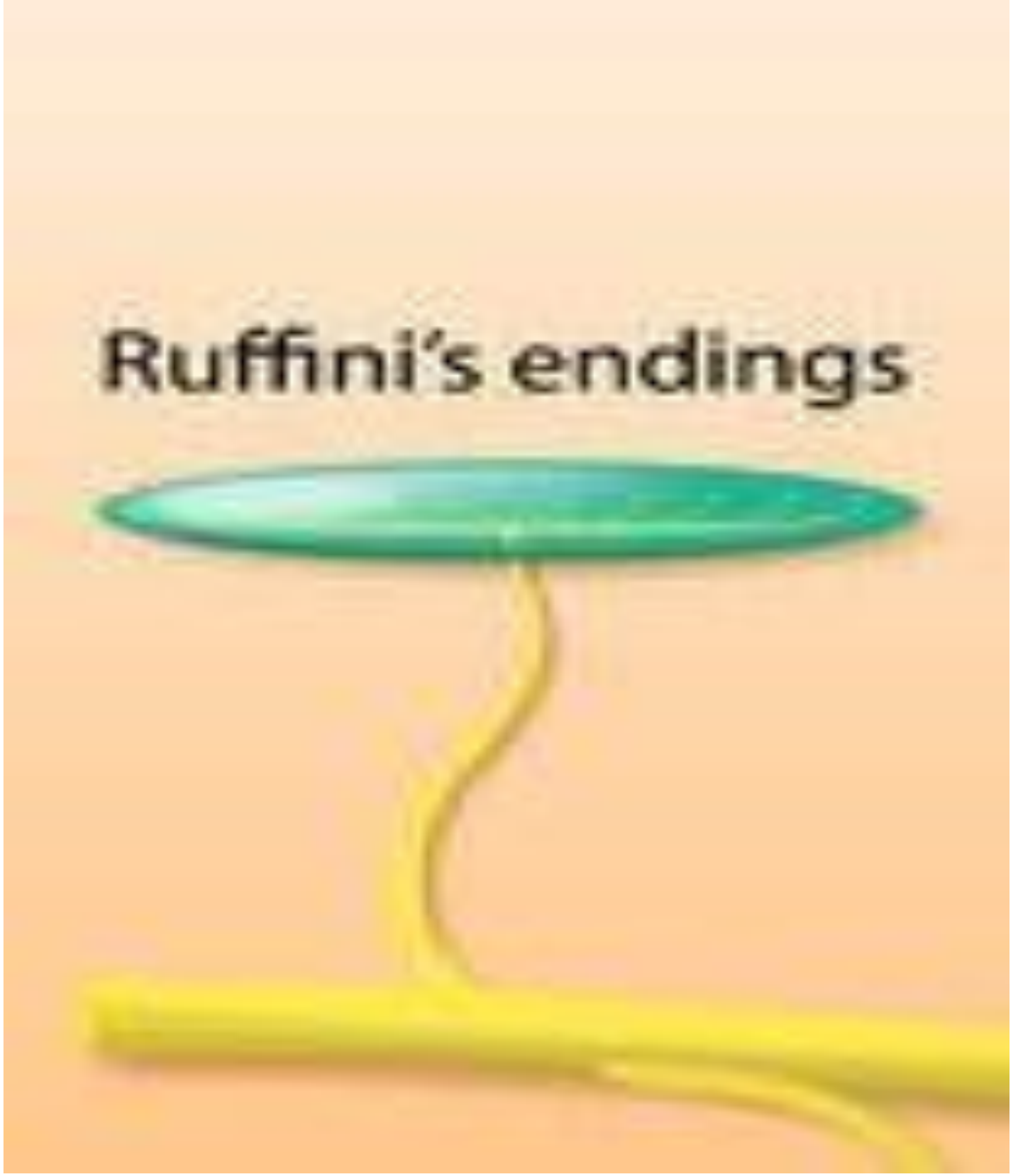
Pacinian corpuscle

- Encapsulated
- Unmyelinated dendritic ending of sensory nerve fiber (Aβ) -2µm in diameter
- Capsule: Surrounded by concentric lamellae of connective tissue - appearance of onion
- These receptors respond to deep pressure & fast vibration
- Location : Skin, subcutaneous tissue, mesentery, periosteum



Pacinian corpuscle

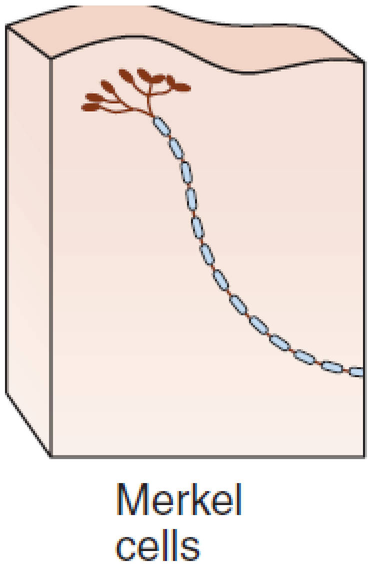
- Rapidly adapting
- Myelin sheath
  - Begins inside the corpuscle
  - 1st node of Ranvier - inside capsule
  - 2nd - near the point at which the nerve fiber leaves the corpuscle

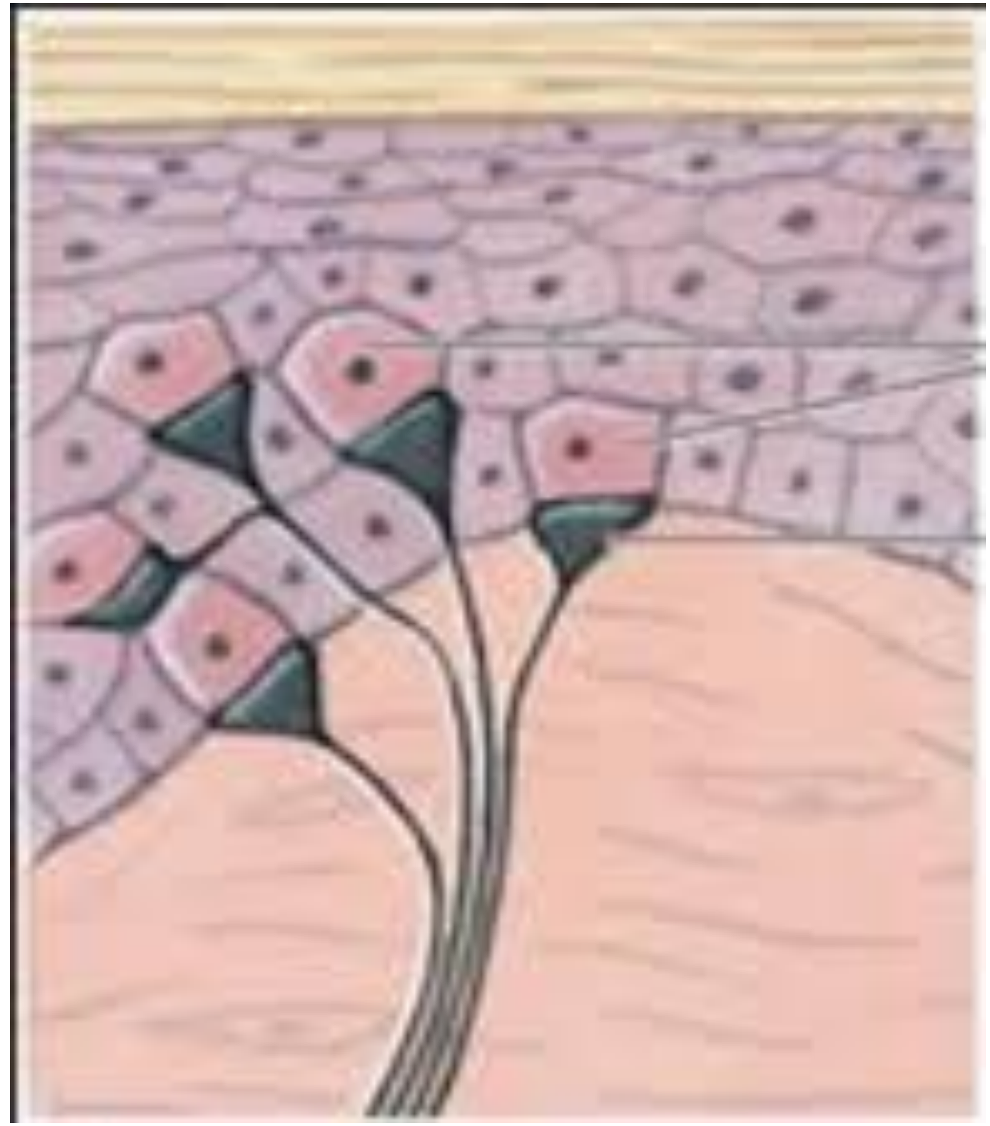

Ruffini's endings

Ruffini's endings

- Multibranched, enlarged, dendritic ending of Aβ fibers
- Elongated capsule
- Location
  - Deeper layers of skin & internal tissues
  - Joint capsule
- Stimulus
  - Sustained touch & pressure
  - Signals degree of joint rotation
- Slowly adapting

Merkel's disc/cells



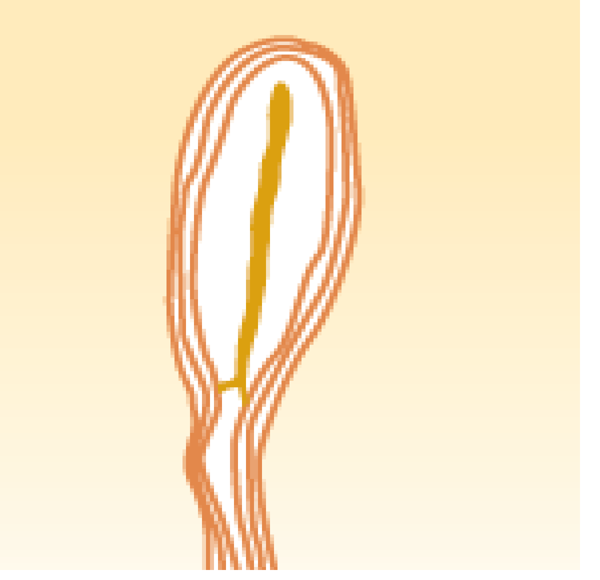


Merkel's disc/cells

- Expanded dendritic ending (Iggo-dome organs)
- Innervated by Aβ fibers
- Location
  – Large numbers seen in areas where Meissner's corpuscles are present
  – Moderate numbers in hairy parts of the skin
- Slowly adapting
- Stimulus
  – Sustained pressure & touch

Krause's corpuscles/end bulbs

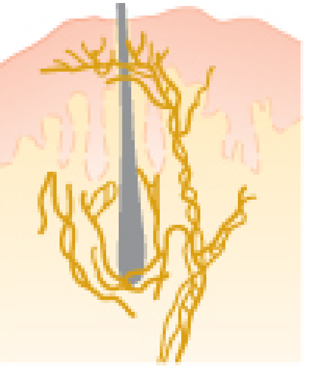
- Spherical mechanoreceptors
- Encapsulated
- Afferent fibers –Aδ group
- Respond to touch & pressure
- Location
  - Conjunctiva
  - Papillae of lips & tongue
  - Skin of genitalia
  - Sheath of nerves



Krause's corpuscle

Hair end organ

- Constituted by each hair & its basal nerve fiber - Aβ
- Rapidly adapting
- Detects
  - Initial contact of objects with body
  - Movement of objects on surface of the body
- The pressure on the skin distort the hair and get stimulated



- Three types
- **Simple Hair follicle-**
  - Rapidly adapting mechanoreceptors
- **Nonsinus facial hair follicle-**
  - Slowly adapting mechanoreceptor
- **Sinus hair follicle-**
  - Both rapidly and slowly adapting mechanoreceptors

Free nerve endings

- Found everywhere in skin & many other tissues
- Terminal branches of thin, unmyelinated Aδ & C fibers
- Detect touch, pain & temperature

Sensation carried -revision

- Touch-Meissner’s corpuscle
- Pressure-Merkel’s disc and Pacinian corpuscle
- Vibration-Pacinian corpuscle
- Pain-Free nerve endings

2. Thermoreceptors

- Detect changes in temperature
- **Cold receptors** or **cool receptors**
  - Mainly Aδ
  - Stimulated by temperature between 10°C and 40°C
  - Maximal discharge at 24°C

Warmth receptors

- Mainly C fibers
  - Stimulated by temperature between 30°C and 45°C
  - Maximal discharge at around 43°C

3) Nociceptors (pain receptors)

- Detect physical or chemical damage occurring in the tissues
- Aδ-mechanical nociceptors
  - Do not respond to thermal or chemical stimuli to pain
- C-Polymodal nociceptors
  - Respond to many type of pain inducing stimuli

Nociceptors- types

- Nociceptors can be separated into several types
- **Mechanical nociceptors** - respond to strong pressure (eg: from a sharp object)
- **Thermal nociceptors** - activated by skin temperatures above 42°C or by severe cold
- **Chemically sensitive nociceptors** - respond to various chemicals such as bradykinin, histamine, high acidity & environmental irritants
- **Polymodal nociceptors** - respond to combinations of these stimuli

4) Photoreceptors and 5)Chemoreceptors

4) Photoreceptors- detect light on the retina of the eye

- rods & cones in retina

5) Chemoreceptors - detect taste in the mouth, smell in the nose, oxygen level in the arterial blood, osmolality of the body fluids, carbon dioxide concentration & other factors that make up the chemistry of the body

Signal transduction in sensory receptors

Short essay

Receptor Potential

- It’s the change in the membrane potential of the receptor when excited by a stimulus

- When the magnitude of the generated potential is 10mV → AP is generated in the sensory nerve

Mechanism

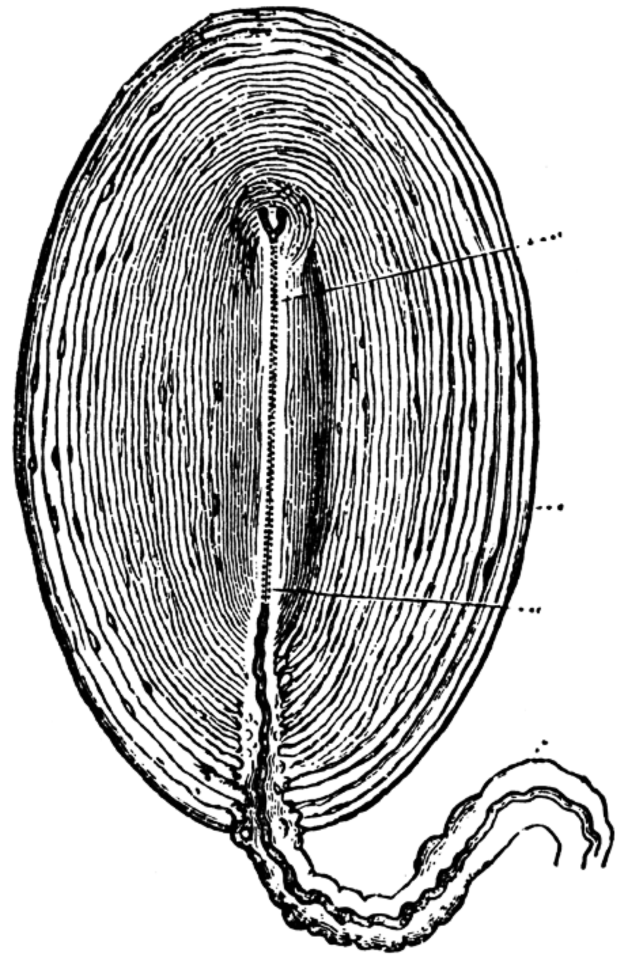
- Different receptors can be excited in one of several ways to cause receptor potentials
- (1) by mechanical deformation of the receptor, which stretches the receptor membrane & opens ion channels
- (2) by application of a chemical to the membrane, which also opens ion channels

- (3) by change of the temperature of the membrane, which alters the permeability of the membrane

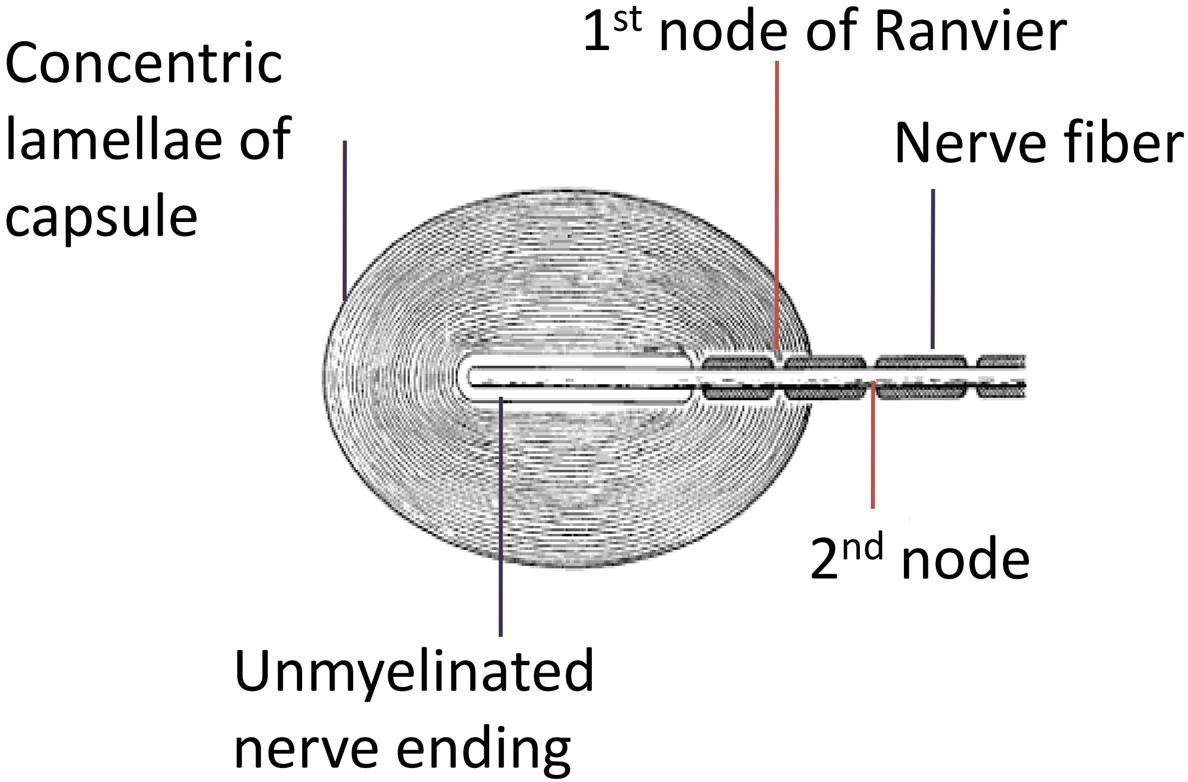
- (4) by the effects of electromagnetic radiation, such as light on a retinal visual receptor, which either directly or indirectly changes the receptor membrane characteristics & allows ions to flow through membrane channels

Recording of receptor potential

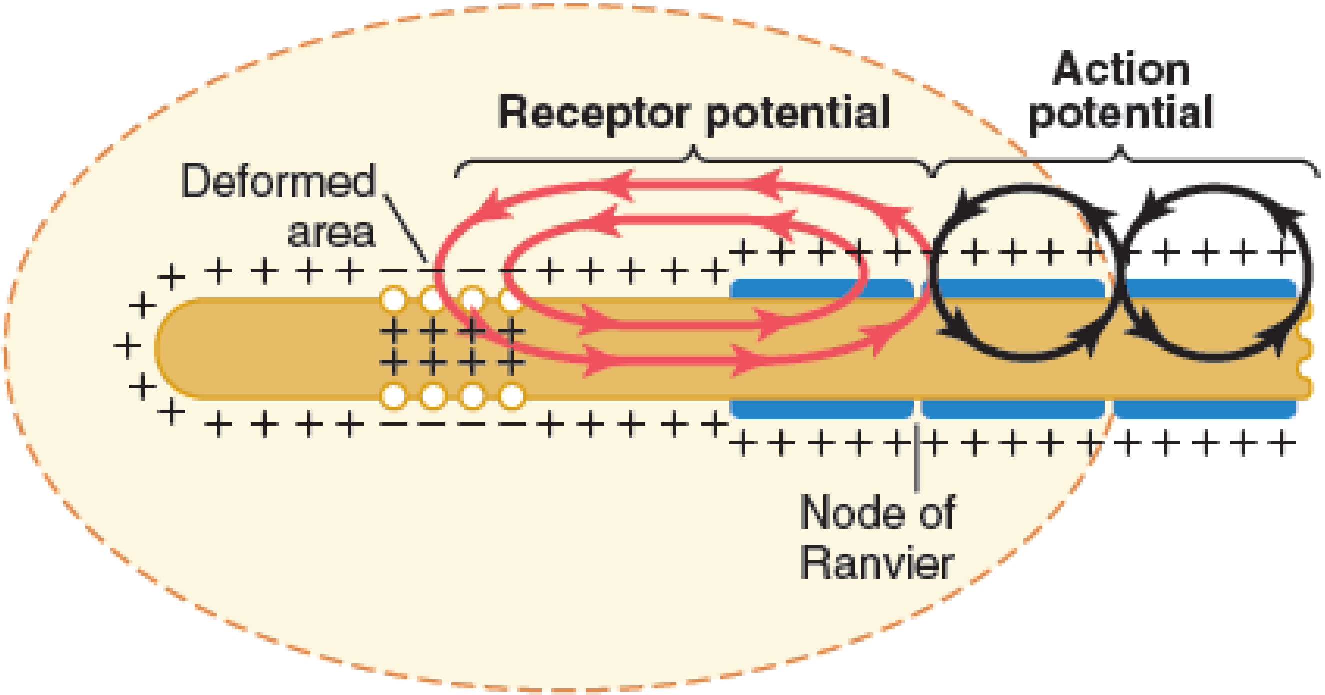
- Pacinian corpuscles
- Large sized
- Easily dissected from mesentery of experimental animals
- Anatomical configuration allows study with micro electrode



Pacinian corpuscle



Generation of receptor and action potential



- Pacinian corpuscle has a central nerve fiber extending through its core

- Surrounding this central nerve fiber are multiple concentric capsule layers

- Thus compression anywhere on the outside of the corpuscle will elongate, indent or otherwise deform the central fiber

Compression

↓

Deformation of corpuscle & small area of nerve terminal

↓

Ion channels in membrane are opened

↓

Na^{2+} diffuses to the interior

↓

Increased positivity inside fiber

↓

Receptor potential

↓

↓

Local circuit of current flow

↓

Spreads along the nerve fiber

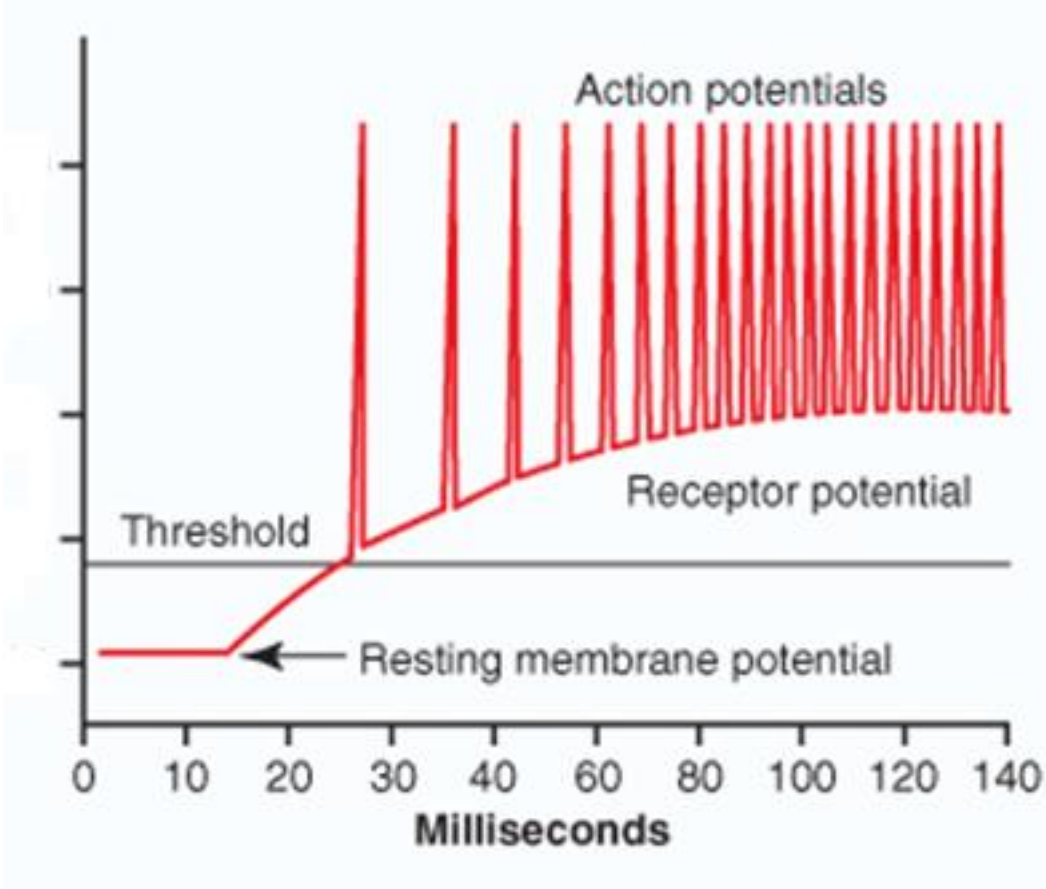
↓

At first node of Ranvier local current flow sets off AP

↓

Transmitted along nerve fiber to CNS

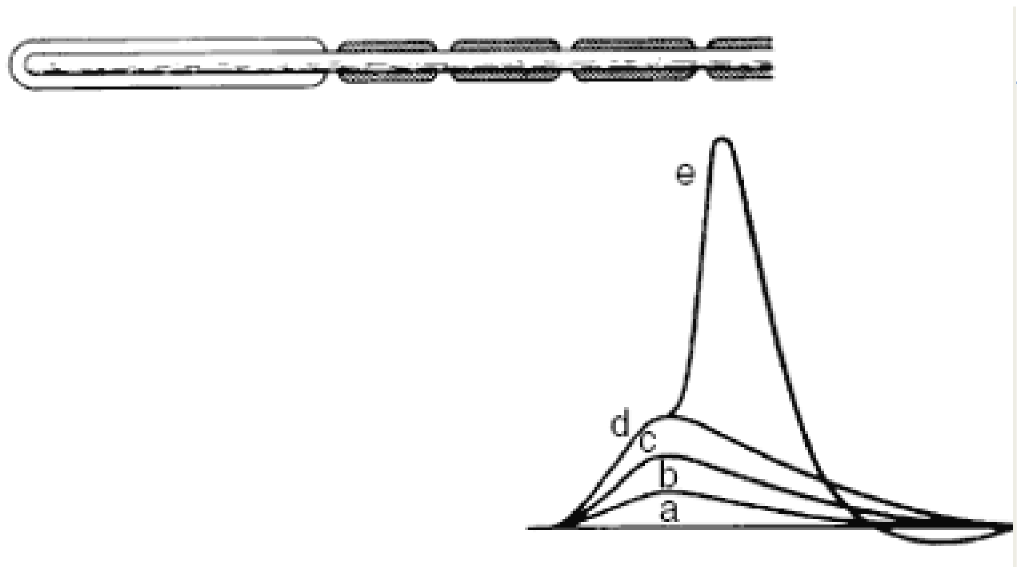
Relation between RP & AP



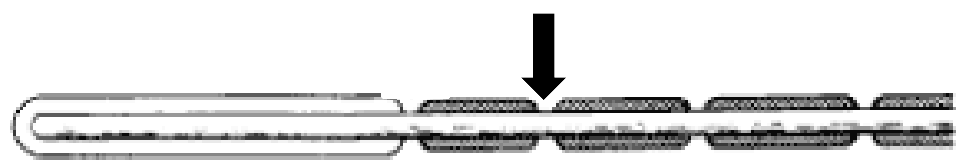
- GP or RP is produced in non-myelinated nerve terminal
- RP in turn depolarises the sensory nerve at 1^{st} node of Ranvier
- When firing level is reached – AP is produced in the 1^{st} node & the membrane then repolarizes
- If the GP is great enough → neuron fires again as soon as it repolarizes
- It continues to fire repetitively as long as the GP is large enough to bring the membrane potential of the node to firing level
- Thus the node converts the graded response to AP, the **frequency of which is proportional to magnitude of stimulus**

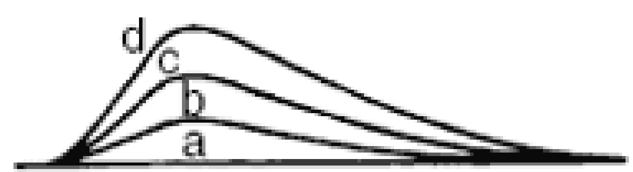
Source of generator potential (GP) or RP

- Removal of connective tissue lamellae from unmyelinated nerve ending in PC does not abolish GP or AP

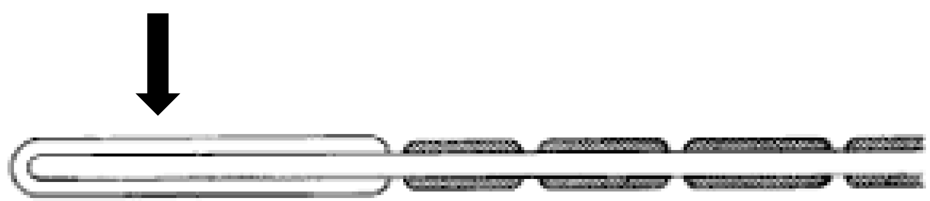


- When 1st node of Ranvier is blocked by pressure or narcotics
  - GP - unaffected
  - Conducted impulses abolished





- When sensory nerve is sectioned & non myelinated terminal is allowed to degenerate
  - No GP is formed



RP or GP

- Does not obey “All or none law”
- Do not exhibit refractory period
- So they can be summated
- Local response

PROPERTIES OF RECEPTORS

Short essay

Properties of receptors

1. Adequate stimulus
2. Adaptation
3. Muller’s Doctrine of specific nerve energies
4. Law of projection
5. Receptive field & recruitment of sensory units
6. Law of intensity discrimination
7. Weber-Fechner law
8. Specificity
9. Acuity

1.Adequate stimulus

- The receptor in each sense organ is adapted to respond to one particular form of energy at a much lower threshold than other receptors respond to it

- The particular form of energy to which a receptor is most sensitive - adequate stimulus

- Receptors do respond to forms of energy other than their adequate stimuli but the threshold for these nonspecific responses is much higher

- Eg: Pressure on the eyeball will stimulate the rods and cones but the threshold of these receptors to pressure is much higher than the threshold of the pressure receptors in the skin

2.Adaptation/desensitization

- If a stimulus of constant strength is maintained on a sensory receptor
- The frequency of the action potentials in its sensory nerve declines over time - Adaptation
- Degree to which adaptation occurs varies from one sense to another

- Based on this, receptors can be divided in to
    - Rapidly adapting (phasic) receptors
    - Slowly adapting (tonic) receptors

Phasic receptors

- Meissner & Pacinian corpuscles are examples
- Receptors that adapt rapidly cannot be used to transmit a continuous signal
- Because they are stimulated only when the stimulus strength changes
- But they react strongly while a change is actually taking place
- Therefore these receptors are called **rate receptors, movement receptors or phasic receptors**

Tonic receptors

- Slowly adapting receptors
- Continue to transmit impulses to the brain as long as the stimulus is present, even if intensity of stimulus remains constant
- They keep the brain constantly aware of the status of the body & its relation to its surroundings
- Eg: Merkel cells, Ruffini endings, Muscle spindle, Golgi tendon organ, receptors of macula in the vestibular apparatus, pain receptors, baroreceptors of the arterial tree & chemoreceptors of the carotid and aortic bodies

Mechanism of adaptation

- Mechanism of receptor adaptation is different for each type of receptor
- In the eye, the rods and cones adapt by changing the concentrations of their light-sensitive chemicals

Pacinian corpuscle adaptation mechanism

a) Pacinian corpuscle is a viscoelastic structure, so that when a distorting force is suddenly applied to one side of the corpuscle

- This force is instantly transmitted by the viscous component of the corpuscle directly to the same side of the central nerve fiber - elicits a receptor potential

- Immediately the fluid within the corpuscle redistributes & the receptor potential is no longer elicited

- b) Accommodation which occurs in the nerve fiber itself
- Results from progressive inactivation of the sodium channels in the nerve fiber membrane

3.Muller’s Doctrine of specific nerve energies

- When the nerve from a particular sensory receptor is stimulated, the sensation evoked is that for which the receptor is specialized no matter how or where along the nerve the activity is initiated

- This principle was first established by Johannes Müller in 1835

- Specific sensory pathways are discrete from sense organ to cortex
- Sensation produced by impulses generated in a receptors depends upon the specific part of the brain to which the nerve fiber from it leads to sensory homunculus
- Specific nerve fibers transmit only one modality of sensation
- This specificity of nerve fibers for transmitting only one modality of sensation is called the labeled line principle

4.Law of projection

- No matter where a particular sensory pathway is stimulated along its course to the cortex, the conscious sensation produced is referred to the location of the receptor
- For eg: if the sensory area in the cortex which receive impulses from left hand is directly stimulated, the patient reports sensation in left hand not in head

Phantom limb

- Seen in amputees
- Ends of nerves cut at time of amputation may discharge spontaneously or generate impulses when irritated
- Impulses are generated in nerve fibers that previously came from receptors in removed limb
- Sensation evoked are projected to the area where receptors used to be located
- Patient complaints of pain &proprioceptive sensation in absent limb

5.Receptive field & recruitment of sensory units

- **Sensory unit** - single sensory axon and all of its peripheral branches
- These branches vary in number but may be numerous especially in the cutaneous senses

- **Receptive field** of a sensory unit is the spatial distribution from which a stimulus produces a response in that unit

- Receptor fields differ in size & response
- The area supplied by one unit nerve may overlap & interdigitate with areas supplied by others
- Weak stimuli activate receptors with lowest thresholds
- As strength of stimulus is increased it tends to spread over a large area & activate not only receptor immediately in contact but also recruits those in surrounding areas
- These are interpreted in brain as an increase in intensity of sensation

6.Law of intensity discrimination

- Intensity of sensation is determined by the amplitude of stimulus applied to a receptor
- There are 2 ways in which information about intensity of stimuli is transmitted to brain
- Greater the intensity of applied stimulus, larger will be the magnitude of RP
- Greater the magnitude of RP, greater will be the frequency of AP in sensory nerves
- Greater the intensity of stimulus, there will be recruitment of more receptors in to the receptive field

7.Weber-Fechner law

- The magnitude of sensation felt is proportionate to the log of intensity of the stimulus
- The relation is more accurately explained by a power function
- $R=KS^A$
- R=Sensation felt
- S=Intensity of stimulus
- K & A are constants for any sensory modality

8. Specificity

- Receptors are specific to a particular type of stimulus

9. Acuity

- Precision of stimulus localization
- Depends on the number of receptors present in the area where stimulus is applied

Sensory coding

- Converting a receptor stimulus to a recognizable sensation is termed sensory coding

- All sensory systems code for four elementary attributes of a stimulus:
  - Modality
  - Location
  - Intensity
  - Duration

- **Modality** - type of energy transmitted by the stimulus
- **Location** - site on the body or space where the stimulus originated
- **Intensity -** is signalled by the response amplitude or frequency of action potential generation
- **Duration -** refers to the time from start to end of a response in the receptor

Sensations

- 3 types
- Superficial
- Cortical
- Synthetic

Superficial sensation

- Four
- Touch, pressure, pain, temperature

Cortical sensations

- Tactile localization
- Two point discrimination
- Stereognosis
- Finer aspects of sensations are integrated in cerebral cortex

Synthetic sensation

- Combination of superficial sensations
- Vibration
- Itching
- Tickling