physiology

faculty of medicine - JU2017

◉ Sheet ○ Slides

Number

18

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Sensory receptors

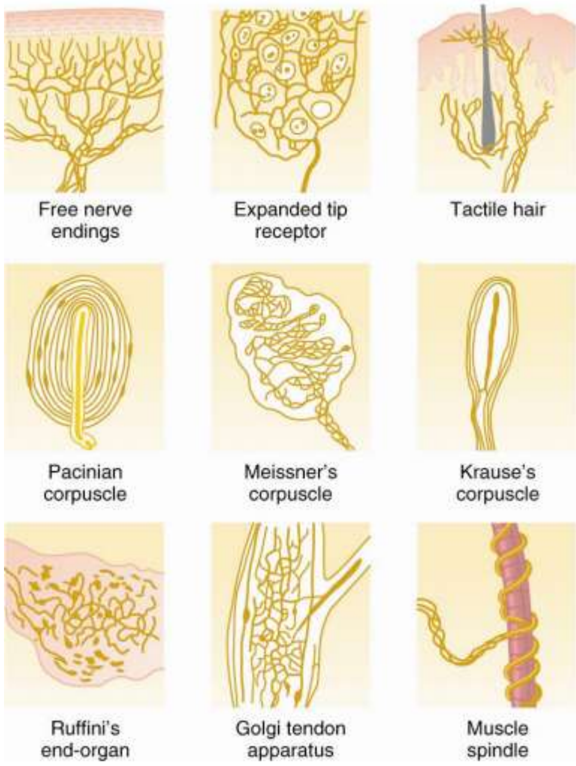
- Sensory receptors are **organs** that sense changes in sensory stimuli ex: touch, pressure, temperature, electrical stimulation, hearing, electromagnetic…
- They convert any type of stimuli into **electrical** because the cerebral cortex understands only action potentials (electrical signals), by these electrical signals the cerebral cortex knows if there is sensation or not, the intensity of the sensation and the type of it (pain, touch….).
- These receptors are different from the membrane protein receptors that we studied in previous lectures (sensory receptors are organs not proteins).
- These receptors are called **transducers** because they convert types of energies into electrical signals (transduction) which changes the behavior downstream.
- Cerebral cortex receives electrical signals, so how does it differentiate between types of stimulation (touch, pressure, temperature…)?
  Answer: the receptors are specific (ex: receptors for touch only receive touch and this is called **modality of sensation**), also they have special pathway that terminates in a specific area in the brain (labeled line principle).
  This specificity allows brain to perceive the stimulus accurately under normal conditions.
  "The answer is that each nerve tract terminates at a specific point in the central nervous system, and the type of sensation felt when a nerve fiber is stimulated is determined by the point in the nervous system to which the fiber leads. For instance, if a pain fiber is stimulated, the person perceives pain regardless of what type of stimulus excites the fiber. The stimulus can be electricity, overheating of the fiber, crushing of the fiber, or stimulation of the pain nerve ending by damage to the tissue cells. In all these instances, the person perceives pain. Likewise, if a touch fiber is stimulated by electrical excitation of a touch receptor or in any other way, the person perceives touch because touch fibers lead to specific touch areas in the brain. Similarly, fibers from the retina of the eye terminate in the vision areas of the brain, fibers from the ear terminate in the auditory areas of the brain, and temperature fibers terminate in the temperature areas."[1]
- How do these receptors respond to stimuli?
  Answer: by changing their membrane potential which is called receptor potential (generator potential).
- More than 90% of the sensations are not felt because the body adapted to them. For example, when sitting on a chair you feel that there is pressure, but after a while you stop feeling it.
- Some receptors adapt very fast ex: smell, but others never adapt ex: pain.
- why is it important to feel pain if there is a stimulus?
  Answer: pain is due to the damage of tissue so if there is damage of a tissue, you feel pain in order to treat it. However, if there is damage in the tissue without feeling it, it will lead to gangrene which is treated with amputation.

1 Guyton 13th Edition- Page 595

- Note: diabetic patients have abnormalities in the sensory (afferent) fibers so they don’t transmit pain, as a result, if a diabetic patient has an injury he won’t feel pain, tissue damage will accumulate leading to gangrene.
- **Classification of receptors according to modality (type of sensation):**
  1. Mechanoreceptors:
     Detect mechanical stimulation ex: pressure, deformation and touch.
  2. Thermoreceptors:
     Detect change in temperature.
  3. Nociceptors:
     Detect tissue damage (pain).
  4. Electromagnetic (Photoreceptors):
     Detect light (rods and cones).
  5. Chemoreceptors:
     Detect changes in chemicals ex: taste, smell(odor), CO_2, O2 ...
- **Classification according to location:**
  1. Exteroceptors:
     - sensitive to stimuli arising from outside the body.
     - Located at or near body surfaces.
     - Include receptors for touch, pressure, pain, and temperature.
  2. Interoceptors (visceroceptors):
     - Receive stimuli from internal viscera.
     - Monitor a variety of stimuli (distension of viscera, osmoreceptors, pain…).
  3. Proprioceptors:
     - Sense change in position, monitor degree of stretch (By detecting the change in joint’s angulation).
     - Located in musculoskeletal organs [muscle (called muscle spindle), tendons (called Golgi tendon organs) and skin around joints].
- **Types of sensory receptors:**
  1. **free nerve endings:**
  - found in the epidermis
  - detect touch and pressure.
  2. **Pacinian corpuscle:**
  - Like onion rings in shape
  - Found deep in the dermis and around the joints
  - Capsulated

**usually receptors with capsules are fast adapting receptors so they sense vibration (on and off stimuli).

- Detect pressure, vibration and other rapid changes in the skin.



3. **Meissner's corpuscles:**
- Capsulated
- Found in the epidermis
- rapidly adapting (within a fraction of a second) and detect movement of light objects over skin
- found on non-hairy skin (glabrous skin), fingertips and lips

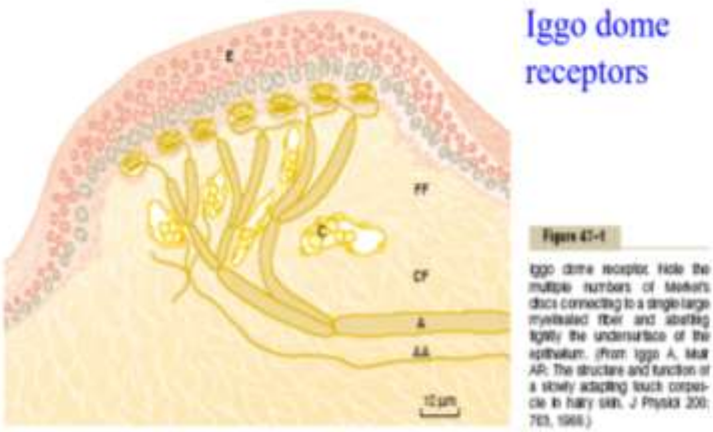
4. **Ruffini's end organ:**
- Found in the dermis
- slowly adapting and respond to continual deformation of the skin and joint rotation

5. **Golgi tendon apparatus:**
- Found in tendons, considered proprioceptor

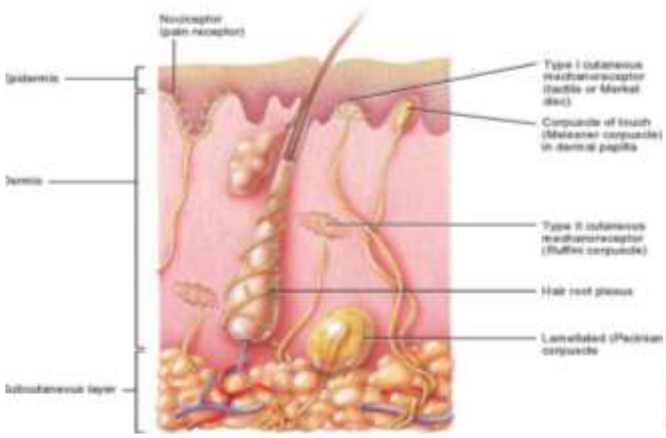
6. **Muscle spindle:**
- Found in muscles, considered proprioceptor

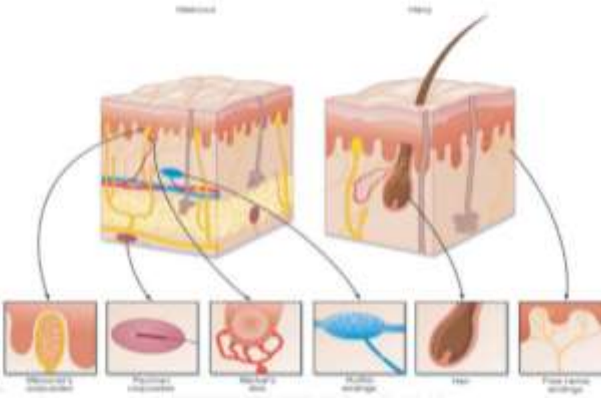
7. **Hair end organ:**
- adapts rapidly and detects movement over the body
- found around hair roots

8. **Merkel's discs:**
- Found in the epidermis, sensing touch.
- respond rapidly at first and then slowly adapt, detect the "steady state".
- found on hairy as well as glabrous (non-hairy) skin
- sometimes they form domes: using electron microscope, we can see that the epidermis has edges and

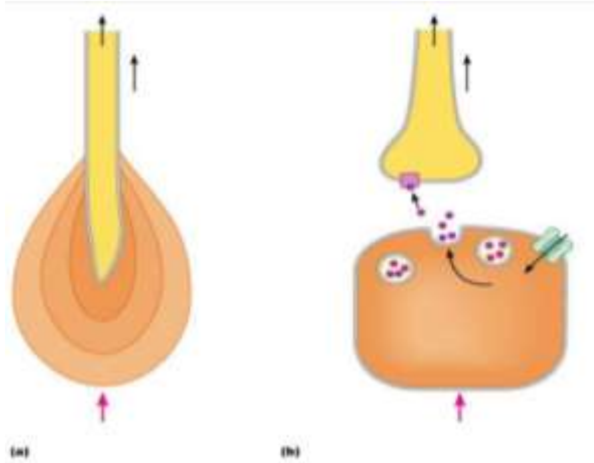


under these domes endings of Merkel's discs sensory fibers are found, these domes are called "Iggo receptors" after the first person who examined them.





- these receptors are connected to different types of afferent neurons:
  - Meissner's corpuscles, hair receptors, Pacinian corpuscles and Ruffini's end organs transmit signals in type Aβ nerve fibers at 30-70 m/sec.
  - Free nerve endings transmit signals in type Aδ nerve fibers at 5-30 m/sec, some by type C unmyelinated fibers at 0.5-2 m/sec.
- If the information is critical and important then it has to be transmitted very fast. So, the more critical the information the faster the rate of transmission.
- Sensory receptors have two general structures:
  1. The receptor is the terminal part of the afferent neuron.
  2. The receptor is in separate area from the afferent neuron it supplies, they are connected through the release of chemical mediators as neurotransmitters.



→in both kinds, the receptor's area is non excitable. Instead, they respond by changing the membrane potential which is called receptor potential (this is **local potential**).

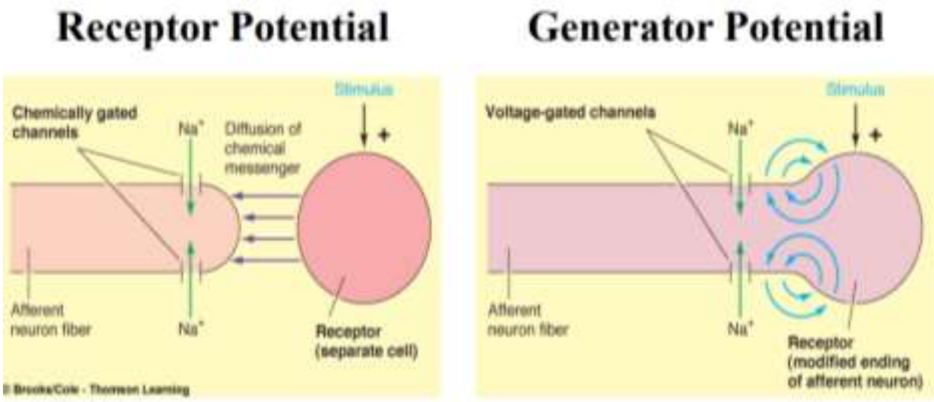
Note: excitable cells are neurons and muscles only. **All cells are polarized but not all cells respond by action potential.**

- The difference between local potential and action potential:
    1- Local potential can be summated (graded), which means the stronger the stimulus the higher the potential difference.
    2- Action potential follows all or none principle, you either have action potential (stimulus >= threshold) or not having any change if (stimulus < threshold), so it can't be summated.
- For example:
  (the numbers in the examples are to understand only)
  - If there is a weak stimulus in the receptor's area (RMP=-70) and it changes the membrane potential from -70 to -60, the amplitude is only 10 which is not enough to stimulate the neuron so, there won't be a feeling of discrimination(change).
  - If the next stimulus is stronger and it changes the membrane potential from -70 to -40, the amplitude is 30, which just equals the threshold, so it is going to stimulate the neuron (if the receptor is the terminal part of the neuron) or release neurotransmitters which are enough to cause an action potential in the neuron (if the receptor is separated from the neuron). If the time for action potential equals 10 milliseconds and the stimulus is always there changing the membrane potential from -70 to -40 so, the rate of action potential reaching the cerebral cortex =100 impulses/second.
  - If the stimulus gets stronger changing the membrane potential form -70 to 0, the amplitude is 70, which is above the threshold so it is going to stimulate the neuron during the relative refractory period, decreasing the duration of action potential reaching for example 5 milliseconds, the rate=200 impulses/second so, the cerebral cortex interprets it as a stronger stimulus.
  - If another stimulus is even stronger changing the membrane potential from -70 to +30, the amplitude is 100, reaching the absolute refractory period but it can't exceed it. If the absolute refractory period ends at 1 millisecond, then the highest rate equals 1000 impulses/second

  ➔ All of these previous examples occur because the receptor's area is not excitable (the stimulus changes the membrane potential becoming higher and higher as the stimulus gets stronger)
- What if the receptor's area is excitable?
  - If the stimulus is small there won't be action potential.
  - If the stimulus is high reaching the threshold there will be action potential.

- If the stimulus is stronger than the previous one, it will lead to action potential also so, the rate of impulses remains the same and the cerebral cortex won't feel the difference in the stimulus intensity.

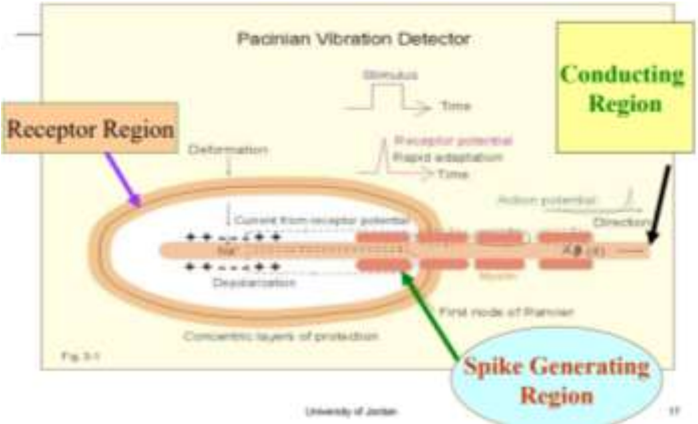
- So**, the importance of having the receptor's area non excitable** is to discriminate different intensities (strength) of stimuli.
- What is the difference between the terms "receptor potential" and "generator potential"?
  Receptor potential is the change in membrane potential of the receptor's area if it is separated from the neuron.
  Generator potential is the change in membrane potential of the receptor's area if it is the terminal part of the neuron.
  (the doctor said that he uses these terms interchangeably so, don't worry about the names just know them).

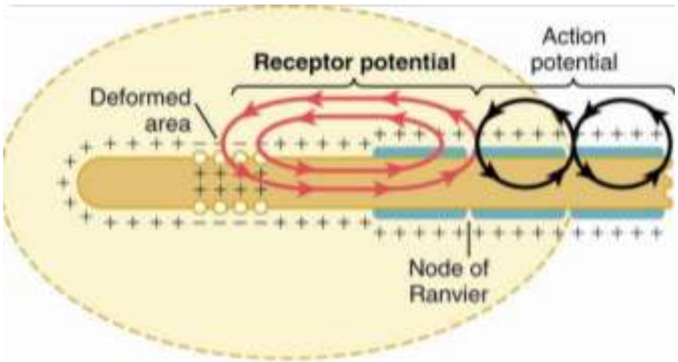


- How is the receptor's potential generated (receptor excitation)?
  1. mechanical deformation stretches the membrane and opens ion channels.
  2. application of chemicals also opens ion channels.
  3. change in temperature alters the permeability of the membrane through changing the metabolic rate.
  4. electromagnetic radiation that changes the membrane characteristics

  →Stimuli open stimulus gated channels (for example sodium channels) causing depolarization, if this depolarization is high enough to reach the threshold it will cause action potential in the neuron, otherwise it won't be felt.
  *receptor potential is analogous to EPSPs.

Note : the action potential starts at the first node of Ranvier of the neuron which is called **spike generating region** .This region is similar to the axon hillock →it has the least threshold since it has the highest amount of voltage gated sodium channels.





- Sensation characteristic of each sensory neuron is produced by its normal or adequate stimulus.
- Adequate stimulus:
  - Requires least amount of energy to activate a receptor regardless how the sensory neuron is stimulated (for each kind of sensation there is a special pathway called labeled line).
  - This term is used for qualitative not quantitative stimuli.
- Sensory receptors can be stimulated by other stimuli (not the adequate) but the threshold for these stimuli is very high.

- The greater the intensity of the stimulus, the greater the amplitude, so greater receptor potential which leads to higher frequency of action potentials.