

Introduction to Physiology for medical and dental students 2022-2023

Sensory Receptors

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The process of sensation

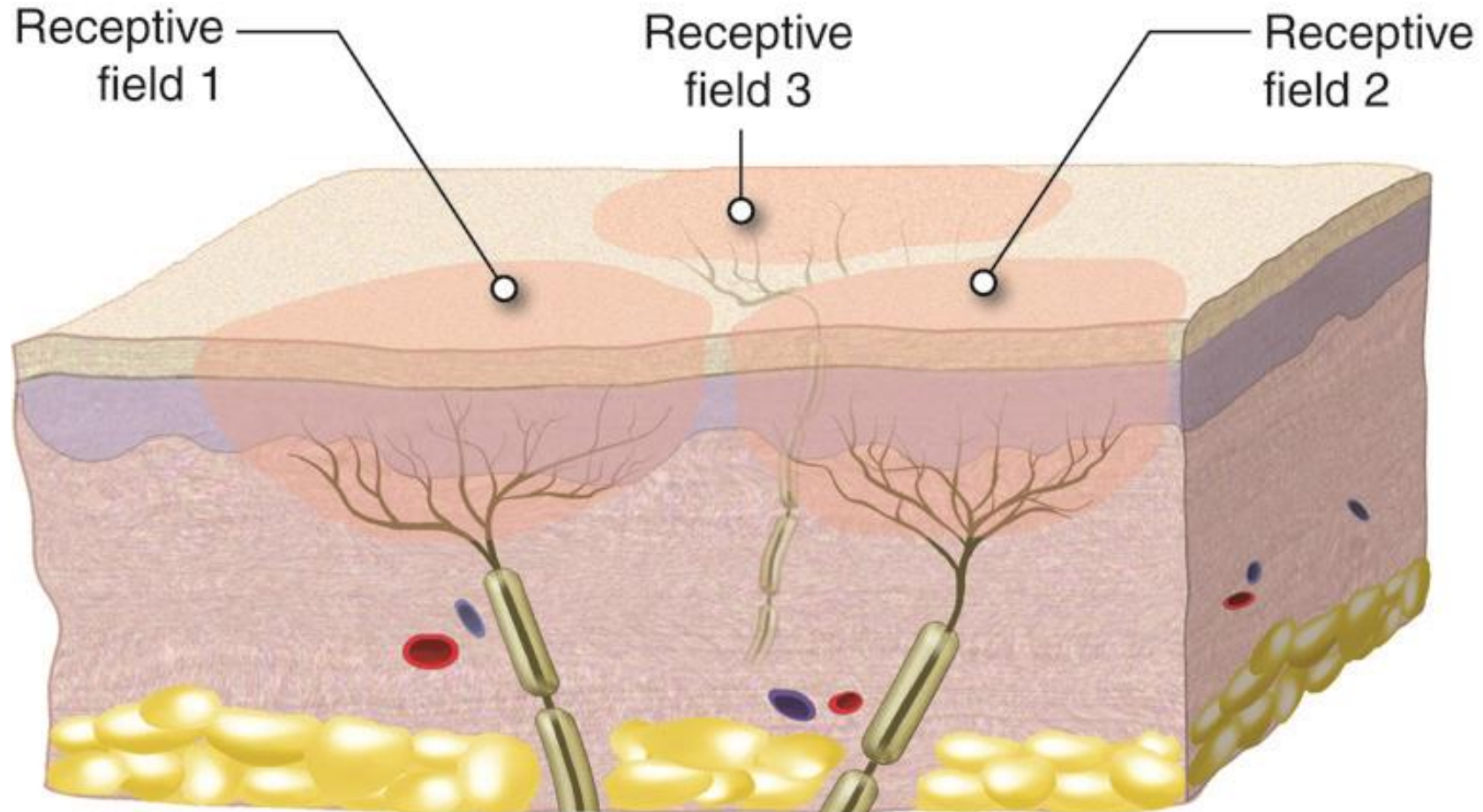
- For a sensation to arise, the following events typically occur:

- **1. Stimulation of the sensory receptor.**

An appropriate stimulus must occur within the sensory **receptor's receptive field**, that is, the body region where stimulation activates the receptor and produces a response.



Receptive field



Receptive field

- Receptive fields vary in size. The smaller the receptive field, the more precisely the sensation can be localized or identified.

Differential sensitivity of sensory receptors

- **Each type of receptor is highly sensitive to one type of stimulus** for which it is designed and yet is almost nonresponsive to other types of sensory stimuli.
- For example, the osmoreceptors of the supraoptic nuclei in the hypothalamus detect minute changes in the osmolality of the body fluids but have never been known to respond to sound.

Sensation

- **2. Transduction:** A sensory receptor transduces (converts) energy in a stimulus into a graded potential.
- Each type of sensory receptor exhibits selectivity: It can transduce only one kind of stimulus.



Receptor potential

All sensory receptors have one feature in common:

Whatever the type of stimulus that excites the receptor, its immediate effect is to change the membrane electrical potential of the receptor. This change in potential is called a receptor potential.



Receptor potential

- In all instances, the basic cause of the change in membrane potential is a change in membrane permeability of the receptor, which allows ions to diffuse more or less readily through the membrane and thereby to change the membrane potential.

Graded potential vs Action potential

Comparison of Graded Potentials and Action Potentials in Neurons

CHARACTERISTIC

GRADED POTENTIALS

ACTION POTENTIALS

Origin

Arise mainly in dendrites and cell body.

Arise at trigger zones and propagate along axon.



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Voltage-gated channels for Na⁺ and K⁺.



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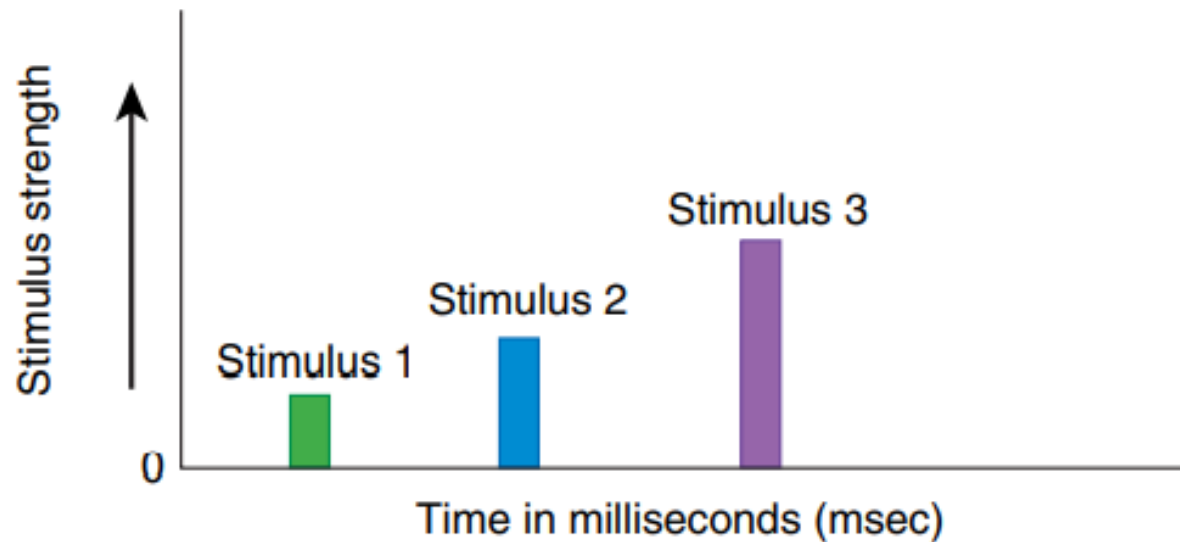
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Refractory period	Not present; summation can occur.	Present; summation cannot occur.



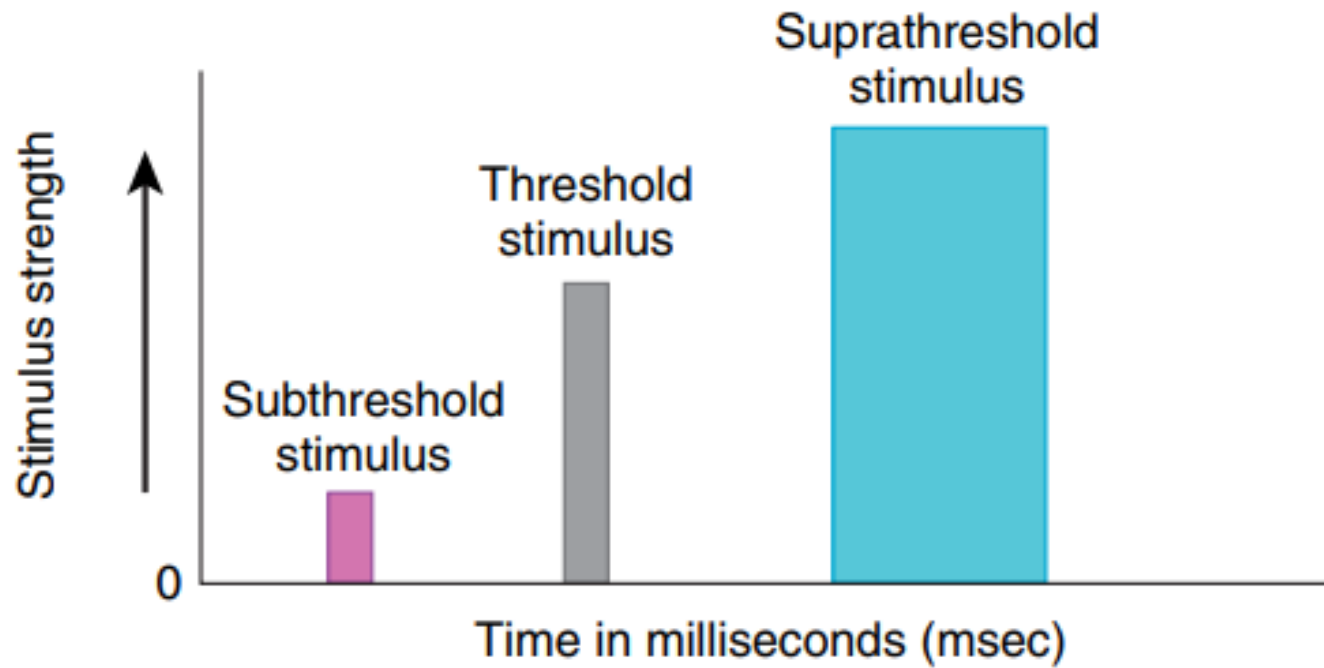
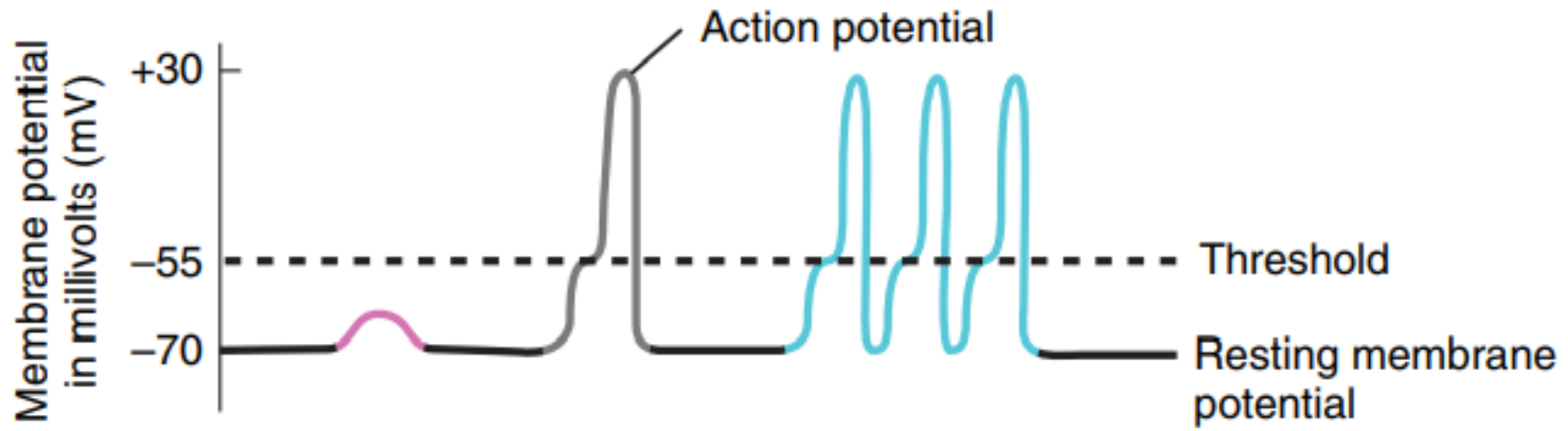
The amplitude of a graded potential depends on the stimulus strength. The greater the stimulus strength, the larger the amplitude of the graded potential.

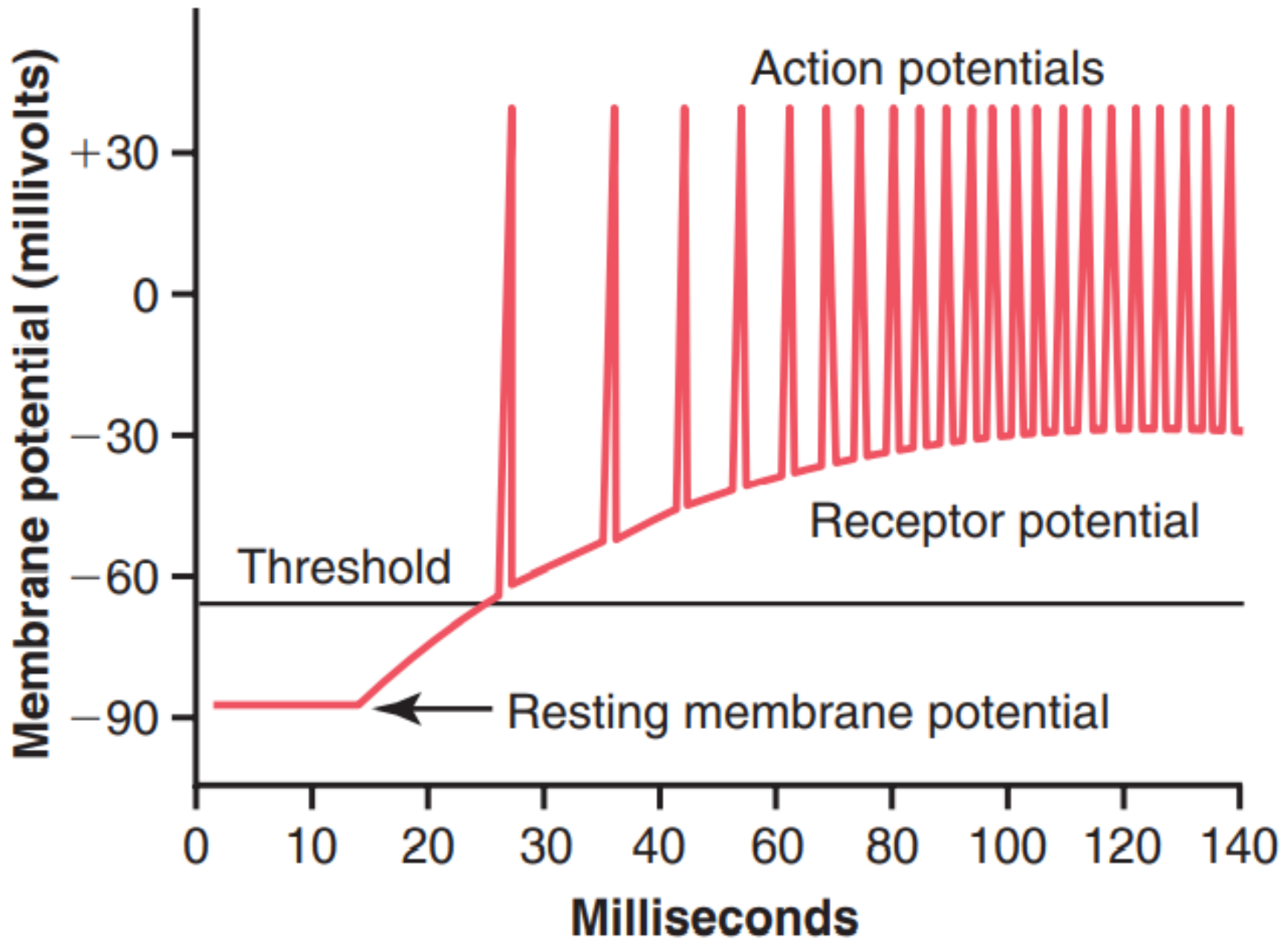


Sensation

- 3. Generation of nerve impulses. When a graded potential in a sensory neuron reaches **threshold**, it triggers one or more nerve impulses, which then propagate toward the CNS.



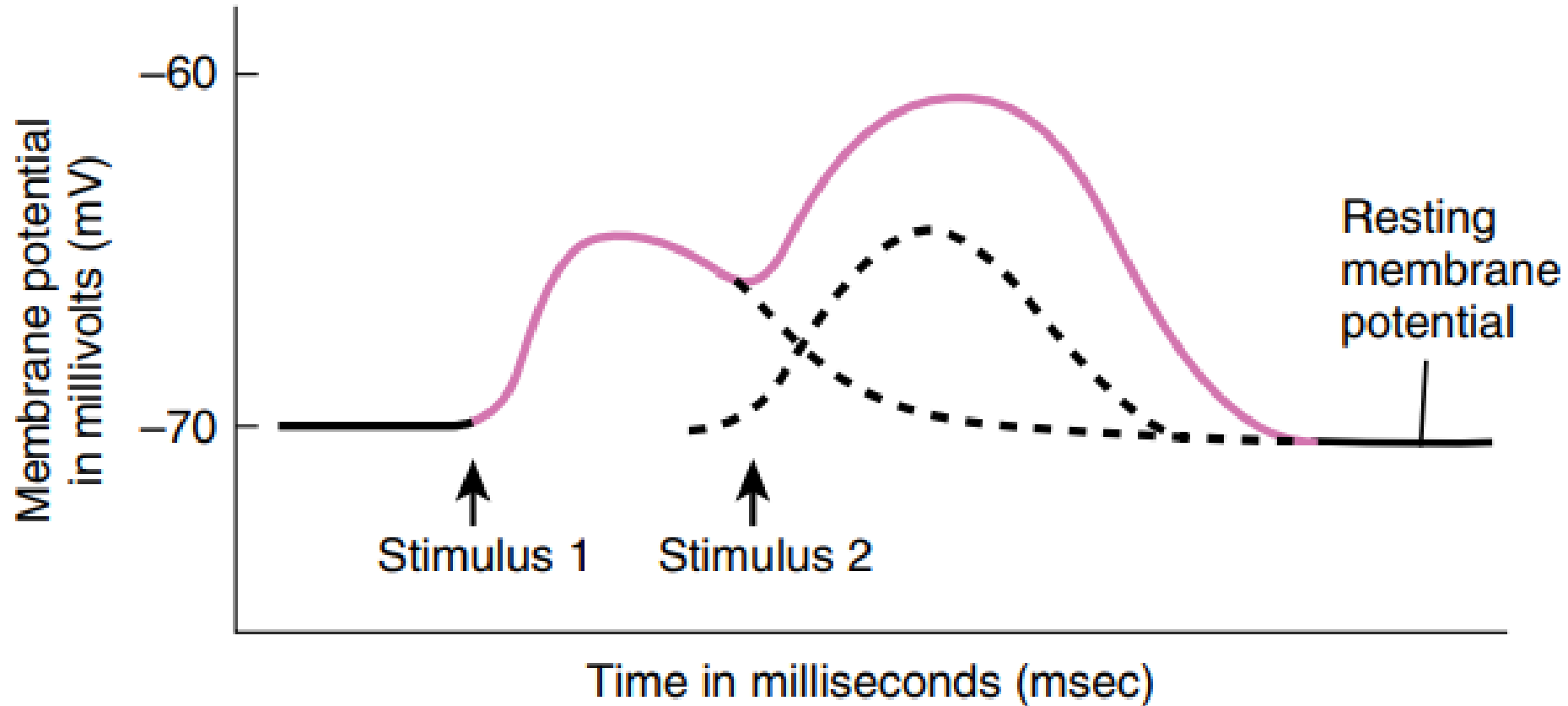




Stimulus intensity and Receptor potential

- The frequency of repetitive action potentials transmitted from sensory receptors increases approximately in proportion to the increase in receptor potential.
- The more the receptor potential rises above the threshold level, the greater becomes the action potential frequency.
- Very intense stimulation of the receptor causes progressively less and less additional increase in numbers of action potentials.

Summation in graded potential



The labeled-line principle

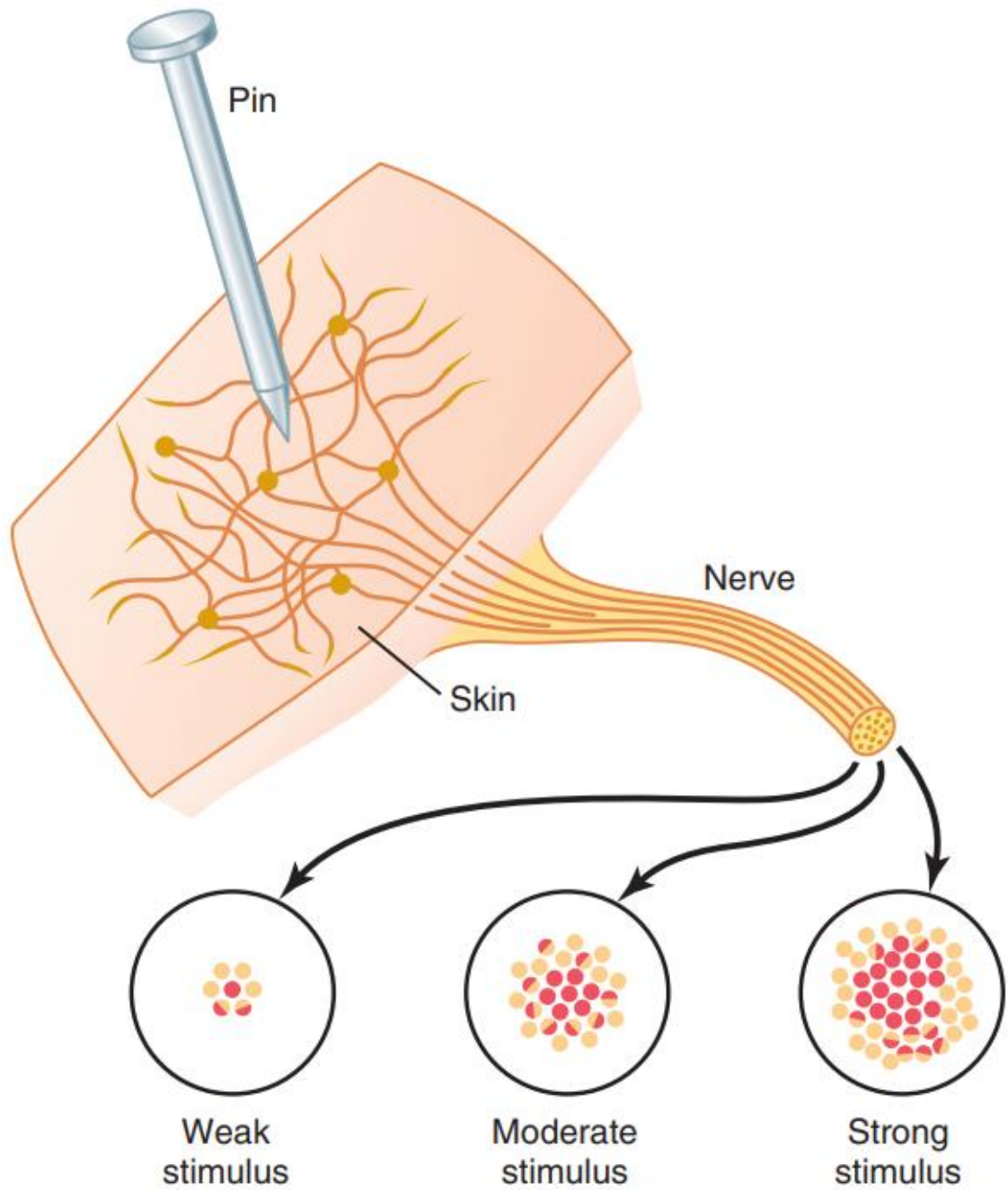
- Despite the fact that we experience different modalities of sensation, nerve fibers transmit only impulses.
- The specificity of nerve fibers for transmitting only one modality of sensation is called the **labeled line principle**.
- Each nerve tract terminates at a specific point in the central nervous 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. 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.

Summation

- One of the characteristics of each signal that always must be conveyed is signal intensity—for instance, the intensity of pain.
- The different gradations of intensity can be transmitted either by using increasing numbers of parallel fibers or by sending more action potentials along a single fiber. These two mechanisms are called, respectively, spatial summation and temporal summation.

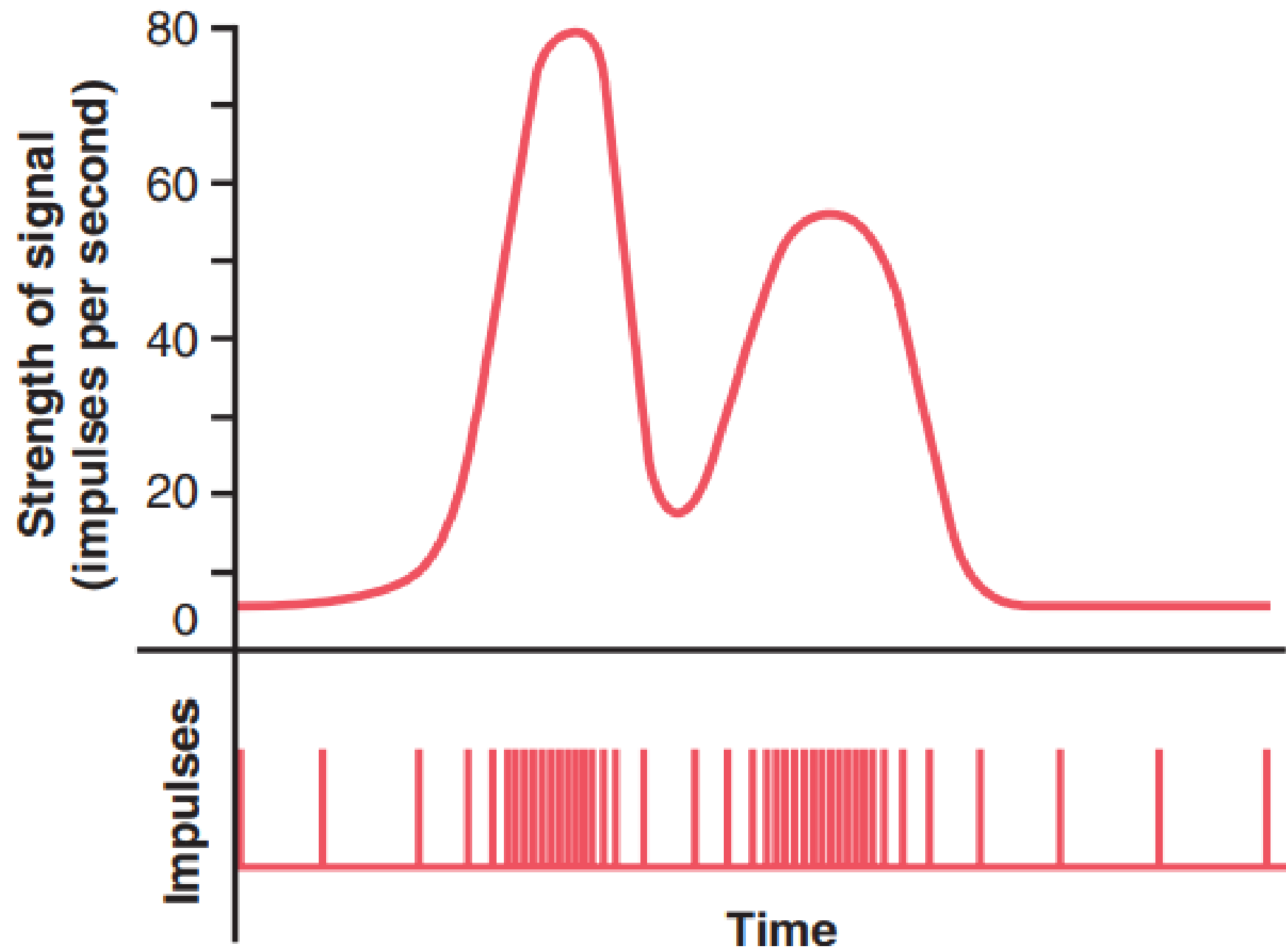
Spatial summation

- Increasing signal strength is transmitted by using progressively greater numbers of fibers.
- When the pinprick is in the center of the receptive field of a particular pain fiber, the degree of stimulation of that fiber is far greater than when it is in the periphery of the field because the number of free nerve endings in the middle of the field is much greater than at the periphery.



Temporal summation

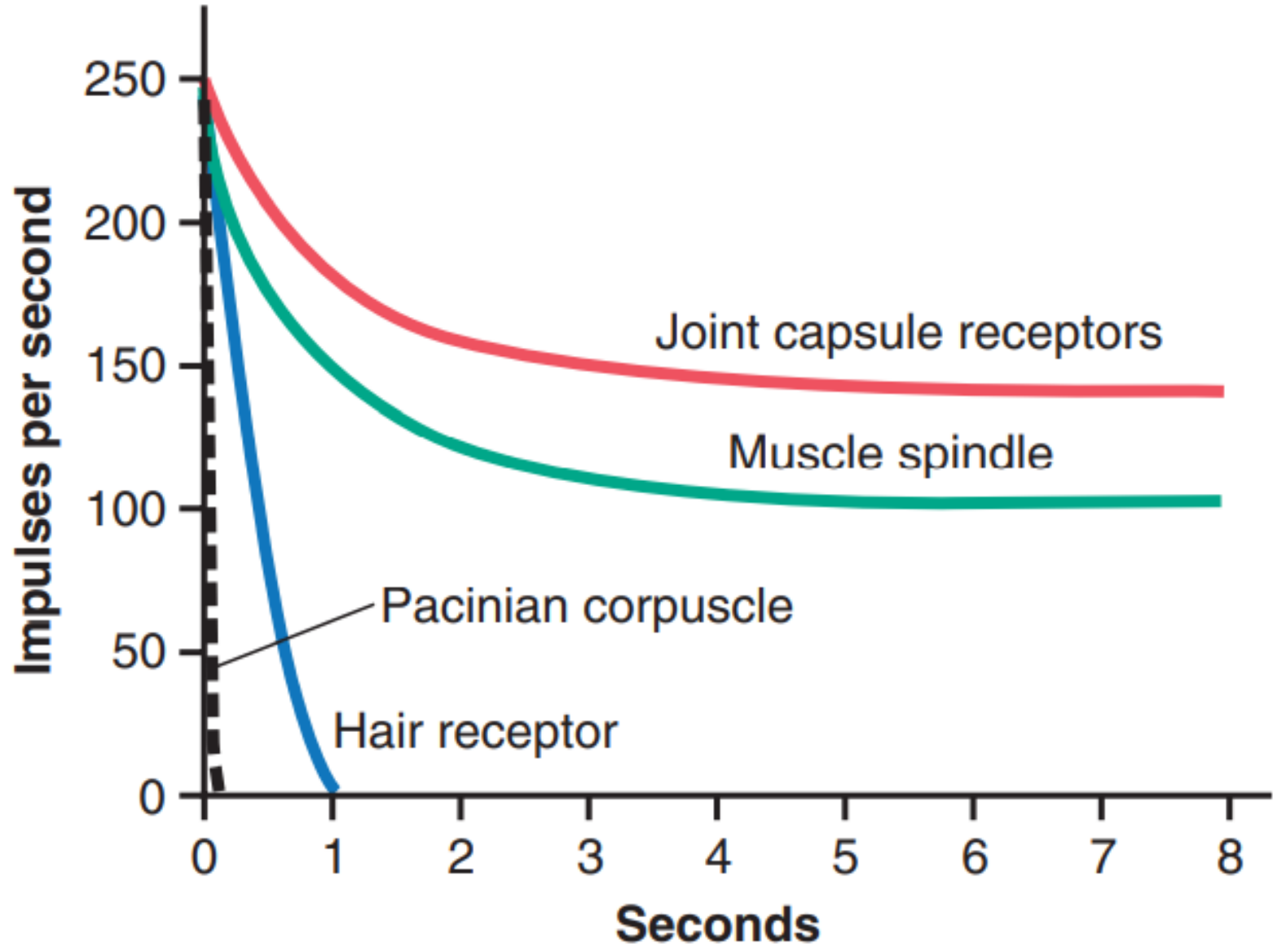
- A second means for transmitting signals of increasing strength is by increasing the frequency of nerve impulses in each fiber, which is called temporal summation.



Adaptation

- A characteristic of most sensory receptors is adaptation, in which the receptor potential decreases in amplitude during a maintained, constant stimulus.
- This causes the frequency of nerve impulses in the first-order neuron to decrease.
- Because of adaptation, the perception of a sensation may fade or disappear even though the stimulus persists.





Adaptation of sensory receptors

- When a continuous sensory stimulus is applied, the receptor responds at a high impulse rate at first and then at a progressively slower rate until finally the rate of action potentials decreases to very few or often to none at all.
- Sensory receptors adapt either partially or completely to any constant stimulus after a period of time.

Adaptation

- Receptors vary in how quickly they adapt, and some sensory receptors adapt to a far greater extent than do others.
- Rapidly adapting receptors adapt very quickly. They are specialized for signaling changes in a stimulus.
- Receptors associated with pressure, touch, and smell are rapidly adapting.

Adaptation

- Receptors vary in how quickly they adapt.
- Slowly adapting receptors adapt slowly and may continue to trigger nerve impulses as long as the stimulus persists.
- Slowly adapting receptors monitor stimuli associated with pain, body position, and chemical composition of the blood.

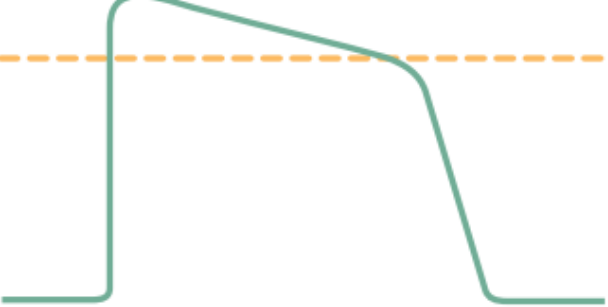
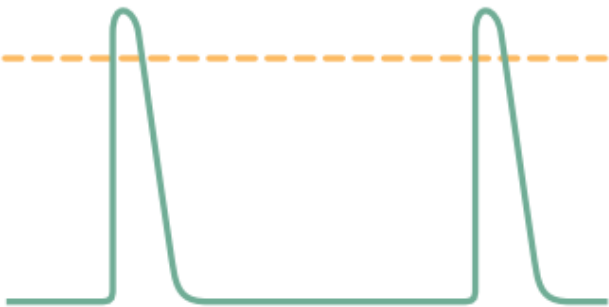
**Phasic receptor
(rapidly adapting)**

**Tonic receptor
(slowly adapting)**

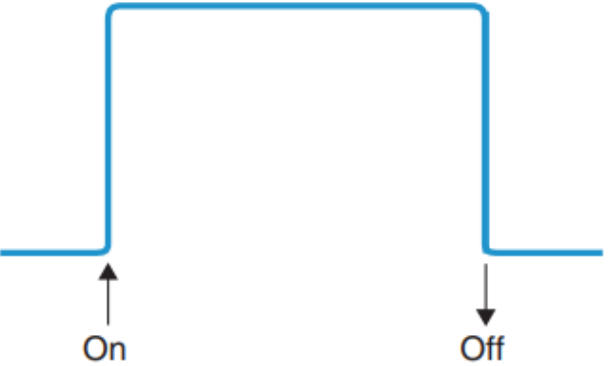
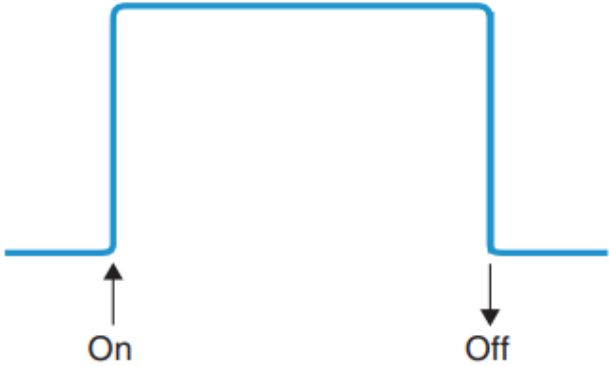
Action potentials



Receptor potentials



Stimulus



Slowly adapting receptors

- Detect Continuous Stimulus Strength: **Tonic Receptors.**
- Slowly adapting receptors continue to transmit impulses to the brain as long as the stimulus is present (or at least for many minutes or hours). Therefore, they keep the brain constantly apprised of the status of the body and its relation to its surroundings.

Slowly adapting receptors

- Impulses from the muscle spindles and Golgi tendon apparatuses allow the nervous system to know the status of muscle contraction and load on the muscle tendon at each instant.
- Some of the receptors (the chemoreceptors and pain receptors) probably never adapt completely.

Slowly adapting receptors

- Slowly adapting receptors include:
- pain receptors.
- baroreceptors of the arterial tree.
- chemoreceptors of the carotid and aortic bodies.
- proprioceptors such as muscle spindle and Golgi tendon organ.



Rapidly adapting receptors

- Detect Change in Stimulus Strength. Also called Rate Receptors, Movement Receptors, or Phasic Receptors.
- Receptors that adapt rapidly cannot be used to transmit a continuous signal because they are stimulated only when the stimulus strength changes. Yet, they react strongly while a change is actually taking place.

Predictive function of the rate receptors

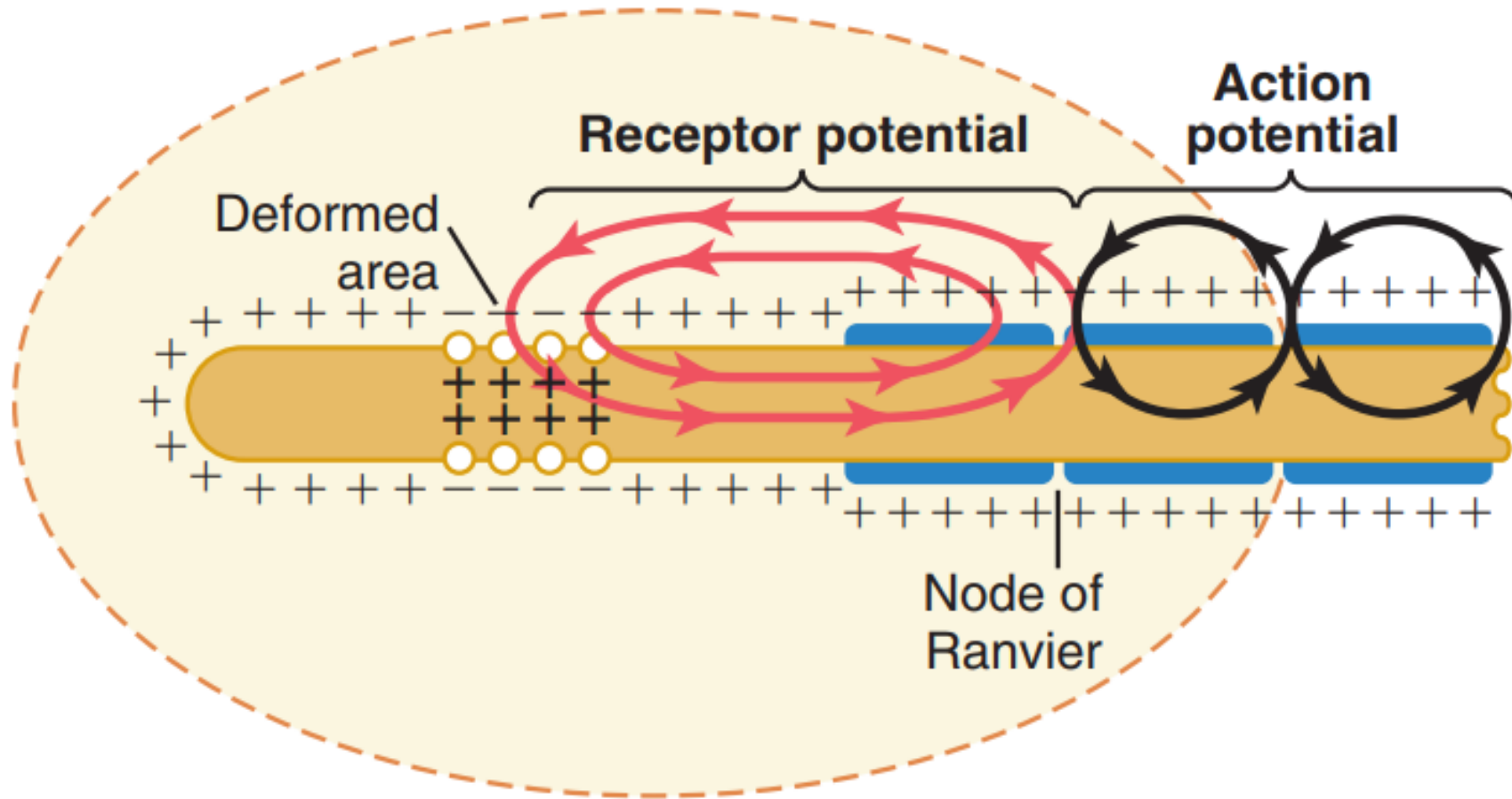
- If one knows the rate at which some change in bodily status is taking place, the state of the body a few seconds or even a few minutes later can be predicted.
- For instance, when one is running, information from the joint rate receptors allows the nervous system to predict where the feet will be during any precise fraction of the next second. Therefore, appropriate motor signals can be transmitted to the muscles of the legs to make any necessary anticipatory corrections in position so that the person will not fall.

Adaptation of sensory receptors

- The **mechanism** of receptor adaptation is different for each type of receptor, in much the same way that development of a receptor potential is an individual property.
- For instance, in the eye, the rods and cones adapt by changing the concentrations of their light-sensitive chemicals.



Pacini corpuscle



Rapidly adapting receptors

- In the case of the Pacinian corpuscle, sudden pressure applied to the tissue excites this receptor for a few milliseconds, and then its excitation is over even though the pressure continues. Later, however, it transmits a signal again when the pressure is released.

Rapidly adapting receptors

- Pacinian corpuscle is exceedingly important in apprising the nervous system of rapid tissue deformations, but it is useless for transmitting information about constant conditions in the body.

Adaptation of Pacinian corpuscles

- Adaptation occurs in this receptor in two ways.
- First, the 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, thus eliciting a receptor potential.

Adaptation of Pacinian corpuscles

- However, within a few hundredths of a second, the fluid within the corpuscle redistributes and the receptor potential is no longer elicited.

Adaptation of Pacinian corpuscles

- The second, much slower mechanism of adaptation, results from a process called accommodation, which occurs in the nerve fiber itself.
- This probably results from progressive “inactivation” of the sodium channels in the nerve fiber membrane, which means that sodium current flow through the channels causes them gradually to close, an effect that seems to occur for all or most cell membrane sodium channels.

Adaptation of Pacinian corpuscles

- These same two general mechanisms of adaptation may apply also to the other types of mechanoreceptors.
- That is, part of the adaptation results from readjustments in the structure of the receptor, and part results from an electrical type of accommodation in the terminal nerve fibril.

Sensory coding

CNS can distinguish 4 stimulus properties:

- 1. sensory modality: labeled line principle
- 2. location: receptive field
- 3. intensity: spatial and temporal summation
- 4. duration: rapidly vs slowly adapting





Questions? Feedback?

Thank you

