Neurophysiology

Somatic sensation

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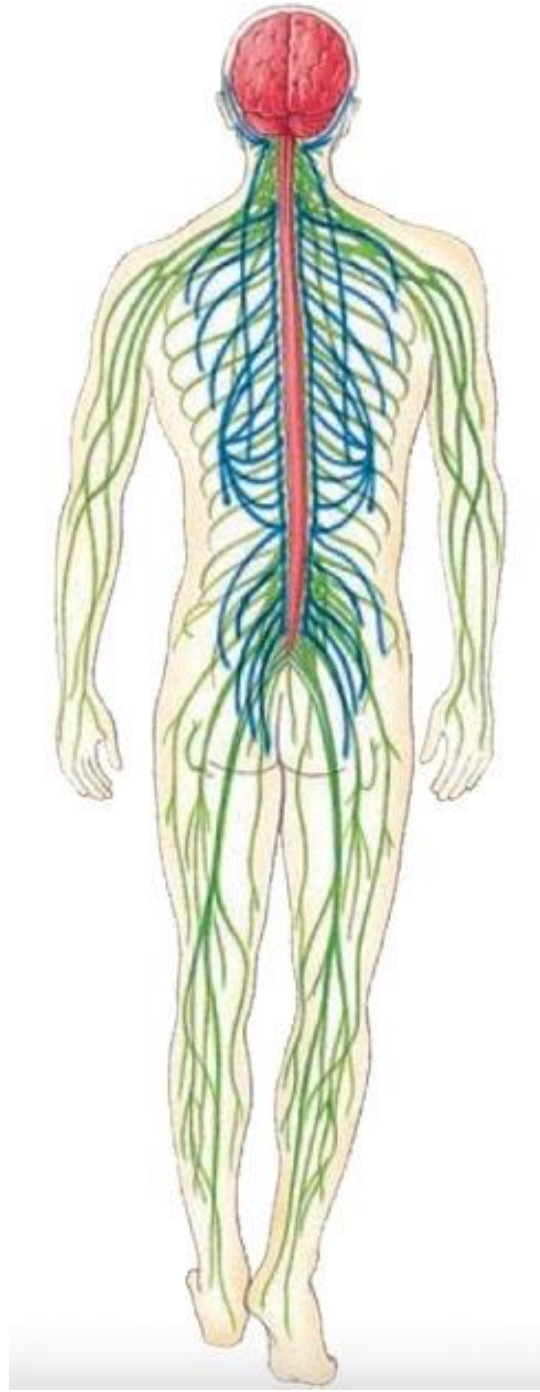


Functions of the nervous system

- **Sensory function**: sensory receptors detect internal or external stimuli. The sensory information is carried to the CNS through cranial and spinal nerves.

- **Integrative function**: processes sensory information by analyzing it and making decision for appropriate responses.

- **Motor function**: changes the activity of the effectors (muscles and glands) through cranial and spinal nerves.

Divisions of nervous system

Central nervous system (CNS)

- Brain
- Spinal cord

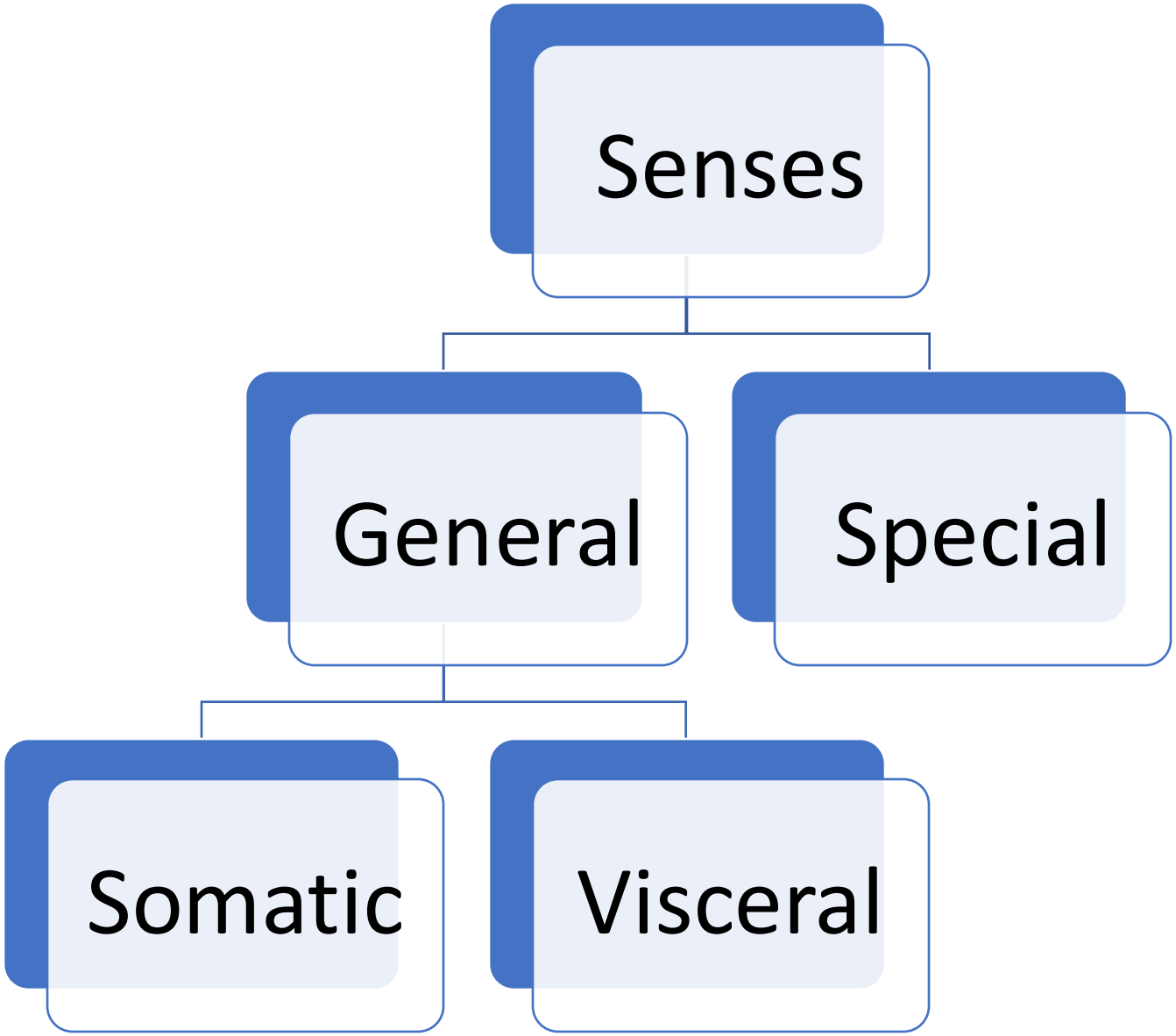
Peripheral nervous system (PNS)

- Somatic system (SNS)
- Autonomic system (ANS)
- Enteric system (ENS)

Sensation

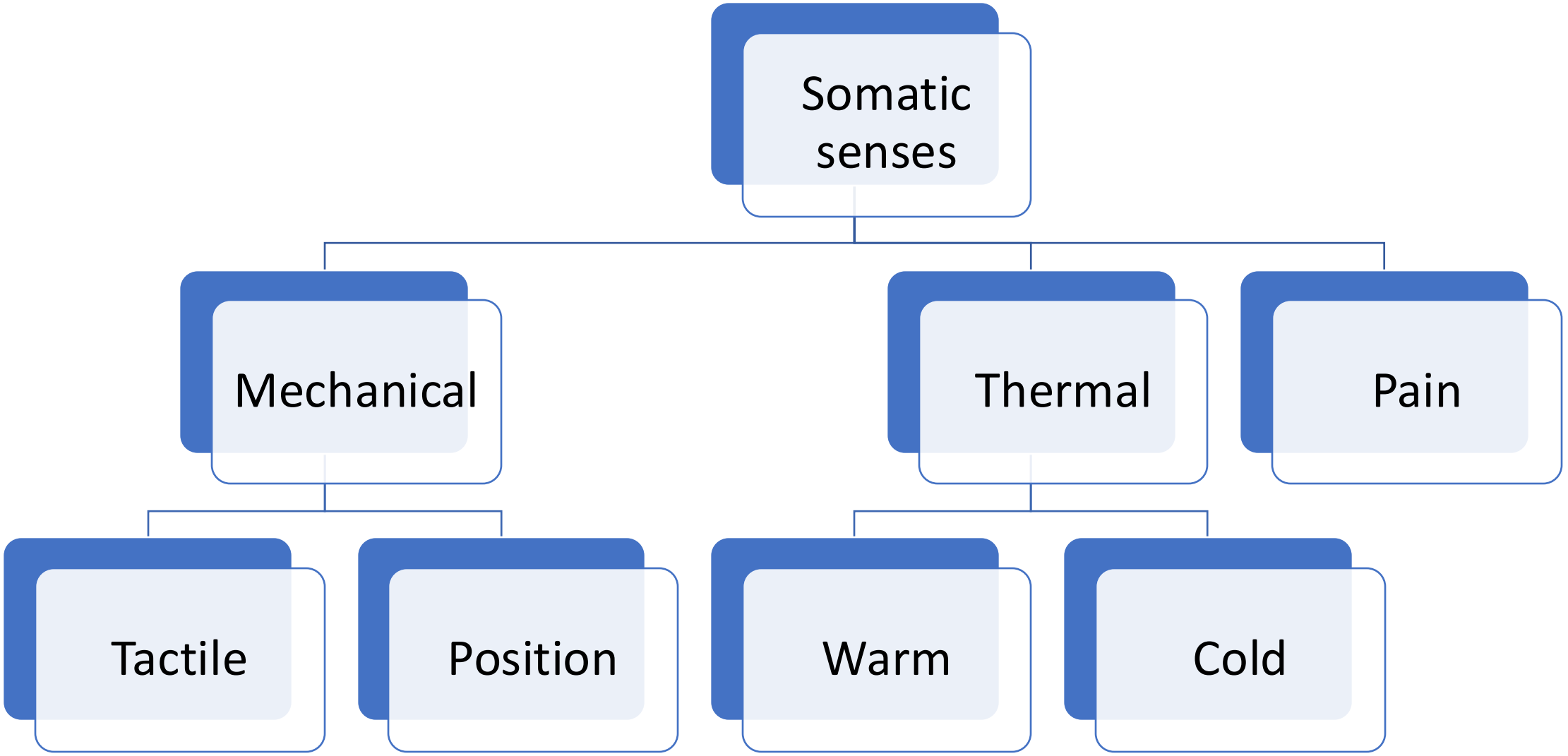
- **Sensation** is the conscious or subconscious awareness of changes in the external or internal environment.

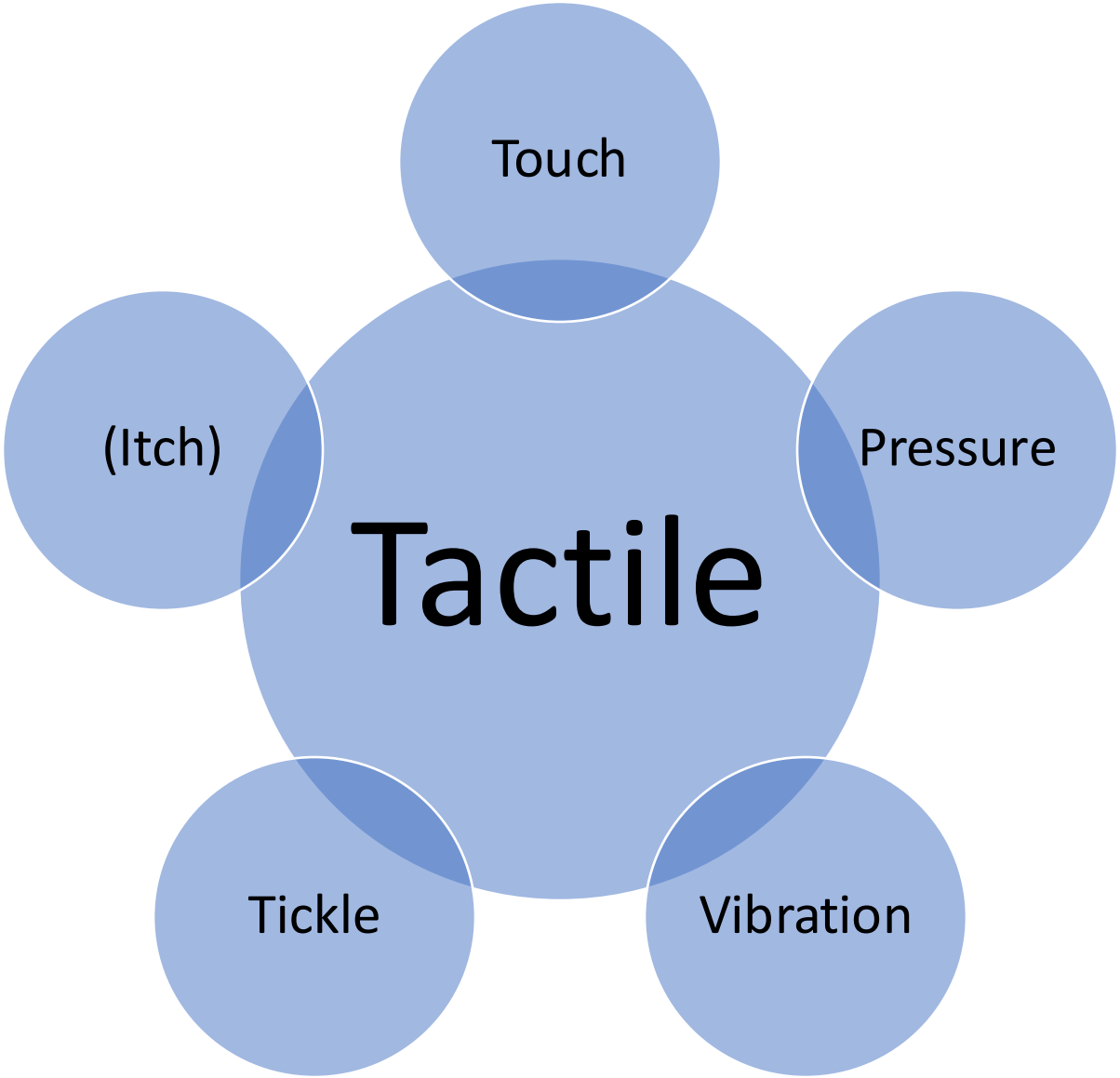
- **Perception** is the conscious interpretation of sensations and is primarily a function of the cerebral cortex.

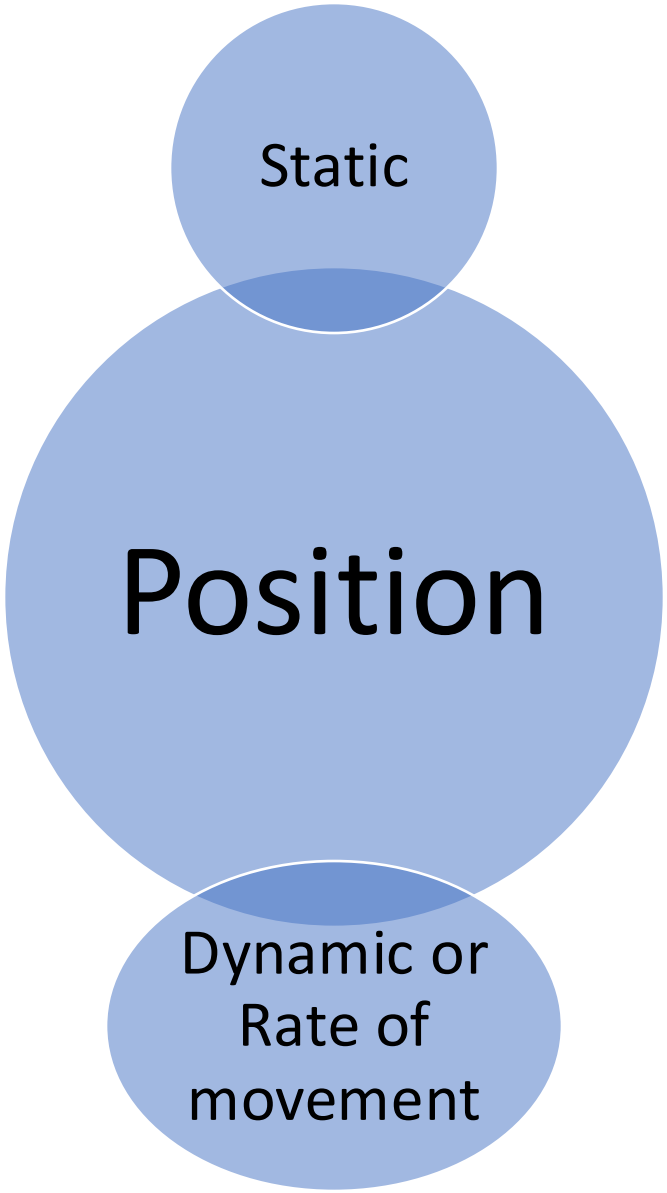

Senses
General
Special
Somatic
Visceral

Somatic sensory receptors

- Somatic sensations arise from stimulation of sensory **receptors embedded in** the:
- Skin
- Subcutaneous layer
- Mucous membranes
- Skeletal muscles
- Tendons
- Joints.


Somatic senses
Mechanical
Thermal
Pain
Tactile
Position
Warm
Cold


Touch
(Itch)
Pressure
Tactile
Tickle
Vibration


Static
Position
Dynamic or
Rate of
movement

The process of sensation

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

A receptor may be either (1) a specialized ending of the afferent neuron or (2) a separate receptor cell closely associated with the peripheral ending of the neuron.

The process of sensation

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

- 2. **Transduction of the stimulus**. A sensory receptor converts the energy in the stimulus into a graded (receptor) potential.

The process of 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.

- 4. **Integration of sensory input**. A particular region of the CNS receives and processes the sensory nerve impulses.

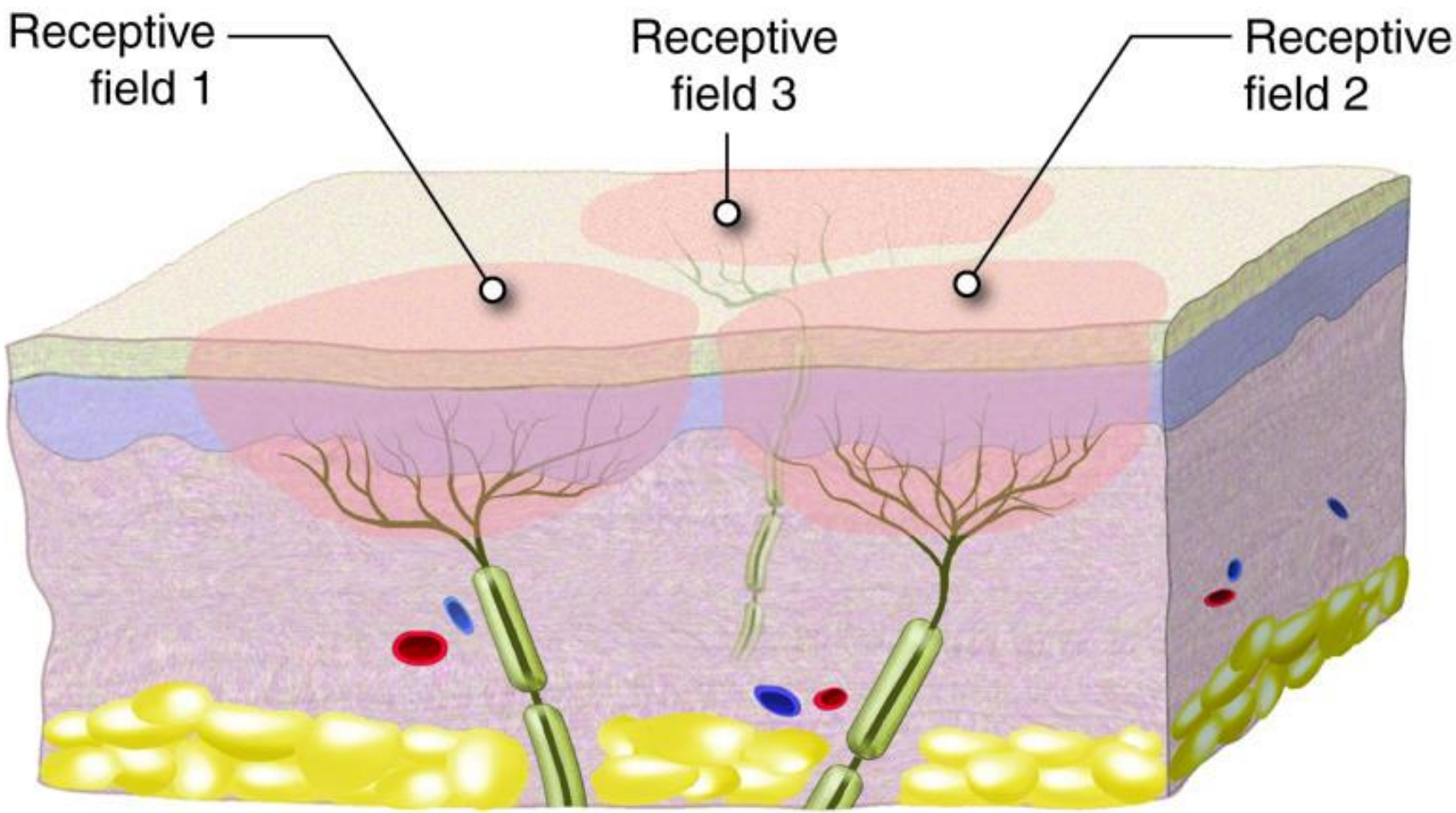
Characteristics of sensory receptors

- **Differential sensitivity**

Each type of receptor is specialized to respond to one type of stimulus**.**

Receptive Field

- Each sensory neuron responds to a stimulus only within a specific region surrounding it, this region is called its **receptive field**.
- The size of a receptive field varies inversely with the density of receptors in the region.
- The smaller the receptive field is in a region, the greater its acuity or discriminative ability: **2 point discrimination**



https://psychology.stackexchange.com/questions/13172/what-is-the-definition-of-a-receptive-field

Somatic sensory receptors distribution

- Receptors are **distributed unevenly**.

- The areas with the highest density of somatic sensory receptors are the tip of the tongue, the lips, and the fingertips.

Lateral Inhibition

- Blockage of further transmission in the weaker inputs increases the contrast between wanted and unwanted information so that the stimulus is precisely localized.

- With lateral inhibition, each activated signal pathway inhibits the pathways next to it by stimulating inhibitory interneurons that pass laterally between ascending fibers serving neighboring receptive fields.

- The extent of lateral inhibitory connections within sensory pathways varies for different modalities. Those with the most lateral inhibition: touch and vision

Labeled Line Principle

- Even though all information is propagated to the CNS via the same type of signal (action potentials), the brain can **decode** the type and location of the stimulus.

- A particular sensory modality detected by a specialized receptor type is sent over a specific afferent and ascending pathway to excite a defined area in the somatosensory cortex.

- Thus, different types of incoming information are kept separated within specific labeled lines between the periphery and the cortex.

Stimulus intensity

- The intensity of the stimulus is reflected by the magnitude of the receptor potential.
- The larger the receptor potential, the greater the frequency of action potentials generated in the afferent neuron.
- A larger receptor potential cannot bring about a larger action potential but it can induce more rapid firing of action potentials.

Stimulus intensity

- Stimulus strength is also reflected by the size of the area stimulated: Stronger stimuli usually affect larger areas, so correspondingly more receptors respond.

- **Temporal and spatial summation**.

True or false

- Stimuli of the same intensity always result in receptor potentials of the same magnitude in the same receptor.

Adaptation in sensory receptors

- A characteristic of most sensory receptors is **adaptation**, in which the receptor potential decreases in amplitude during a maintained, constant stimulus.

- Because of adaptation, the perception of a sensation may fade or disappear even though the stimulus persists.

- Receptors vary in **how they adapt and how quickly they adapt** (tonic vs phasic).

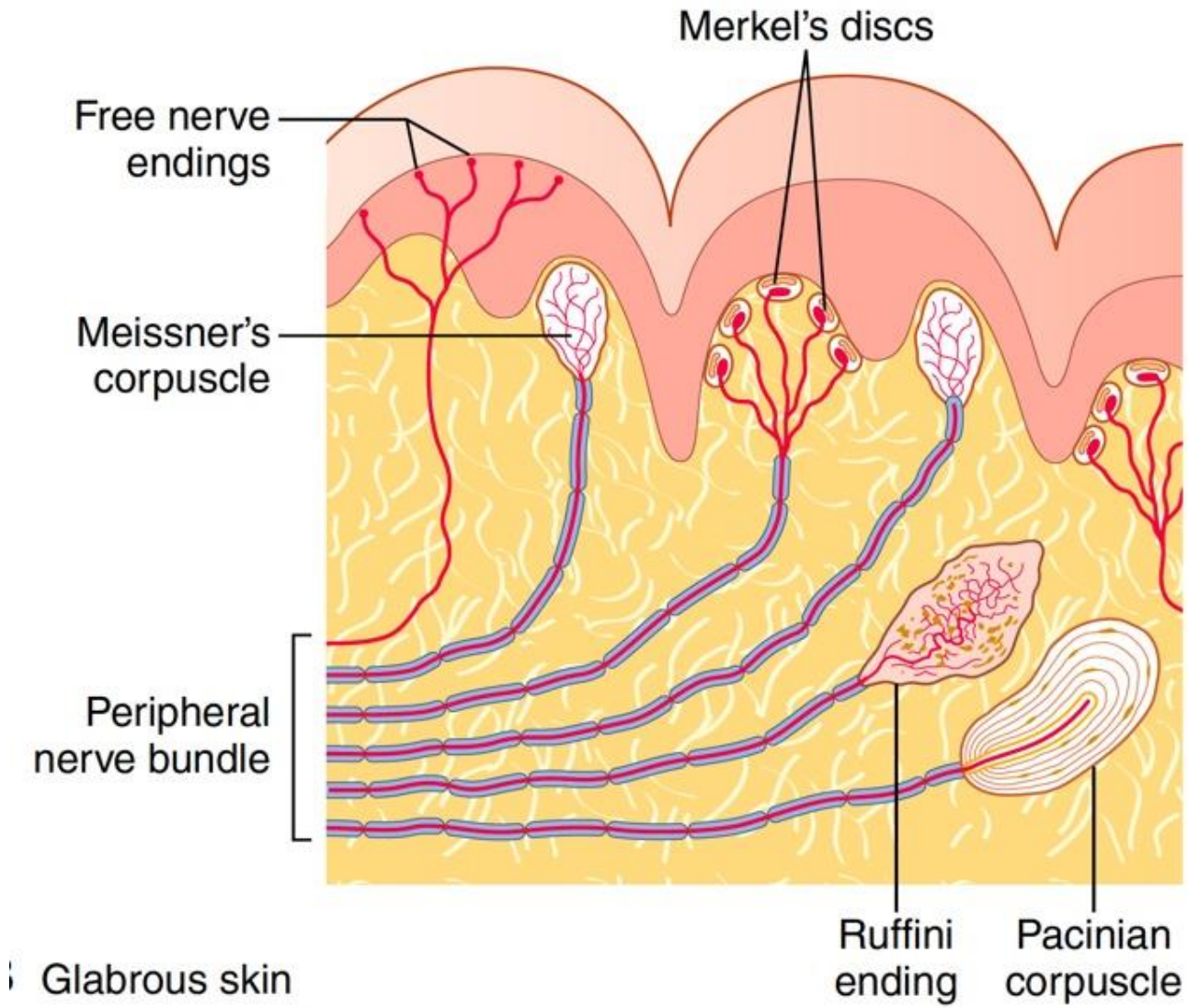
Tactile senses

- **Touch:** generally results from stimulation of tactile receptors in the skin or in tissues immediately beneath the skin.

- **Pressure**: A sustained sensation that is felt over a larger area than touch, and generally results from deformation of deeper tissues.

- **Vibration**: results from rapidly repetitive sensory signals.

Tactile receptors



Transmission of tactile signals in peripheral nerve fibers

- Almost all specialized sensory receptors, such as Meissner's corpuscles, transmit their signals in type **Aβ** nerve fibers.

- Free nerve ending tactile receptors transmit signals mainly via the small type **Aδ** myelinated fibers.

- Some tactile free nerve endings transmit via type **C** unmyelinated fibers such as in itch and tickle senses.

Tickle and Itch senses

- Itch and tickle receptors are free nerve endings found almost exclusively in superficial layers of the skin, which is also the only tissue from which the tickle and itch sensations usually can be elicited.

Tactile senses

- **Tickle**: Typically arises only when someone else touches you, not when you touch yourself.

- The reason could be due to the impulses to and from the cerebellum when you are moving your fingers and touching yourself that don’t occur when someone else is tickling you.

Itch

- The purpose of the itch sensation is presumably to call attention to mild surface stimuli such as a flea crawling on the skin.
- The signals elicited then activate the scratch reflex or other maneuvers that rid the host of the irritant.
- Itch can be relieved by **scratching** if this action removes the irritant or if the scratch is strong enough to elicit pain.
- The pain signals are believed to suppress the itch signals in the cord by lateral inhibition.

Position senses (Proprioceptive senses)

Position receptors (proprioceptors)

- allow us to know where our body parts are located and how they are moving even if we are not looking at them, so that we can walk, type, or dress without using our eyes.

- Proprioceptors also allow weight discrimination, the ability to assess the weight of an object. This type of information helps to determine the muscular effort necessary to perform a task.

Position receptors (proprioceptors)

- Knowledge of position, both static and dynamic, depends on knowing the degrees of angulation of all joints in all planes and their rates of change.

- Therefore, multiple different types of receptors help to determine joint angulation and are used together for position sense. Both skin tactile receptors and deep receptors near the joints are used.

Position senses

- They are divided into two subtypes:

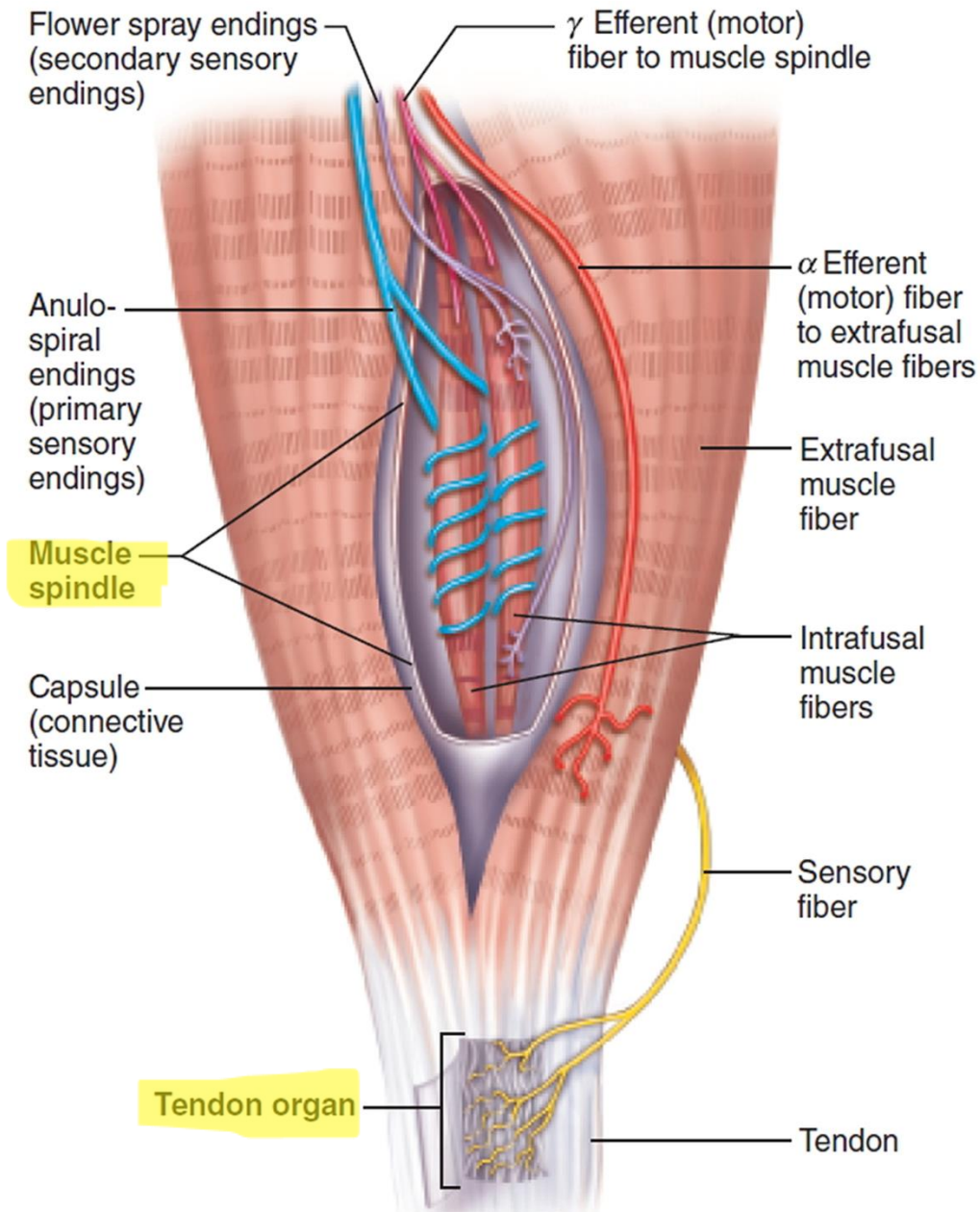
- (1) static position sense, which means conscious perception of the orientation of the different parts of the body with respect to one another.

- (2) rate of movement sense, also called kinesthesia or dynamic proprioception.

Position sensory receptors

- The Pacinian corpuscles and muscle spindles are especially adapted for detecting rapid rates of change.

- It is likely that these are the receptors most responsible for detecting rate of movement.



https://healthjade.com/proprioception/

Thermal sensations

Thermoreceptors

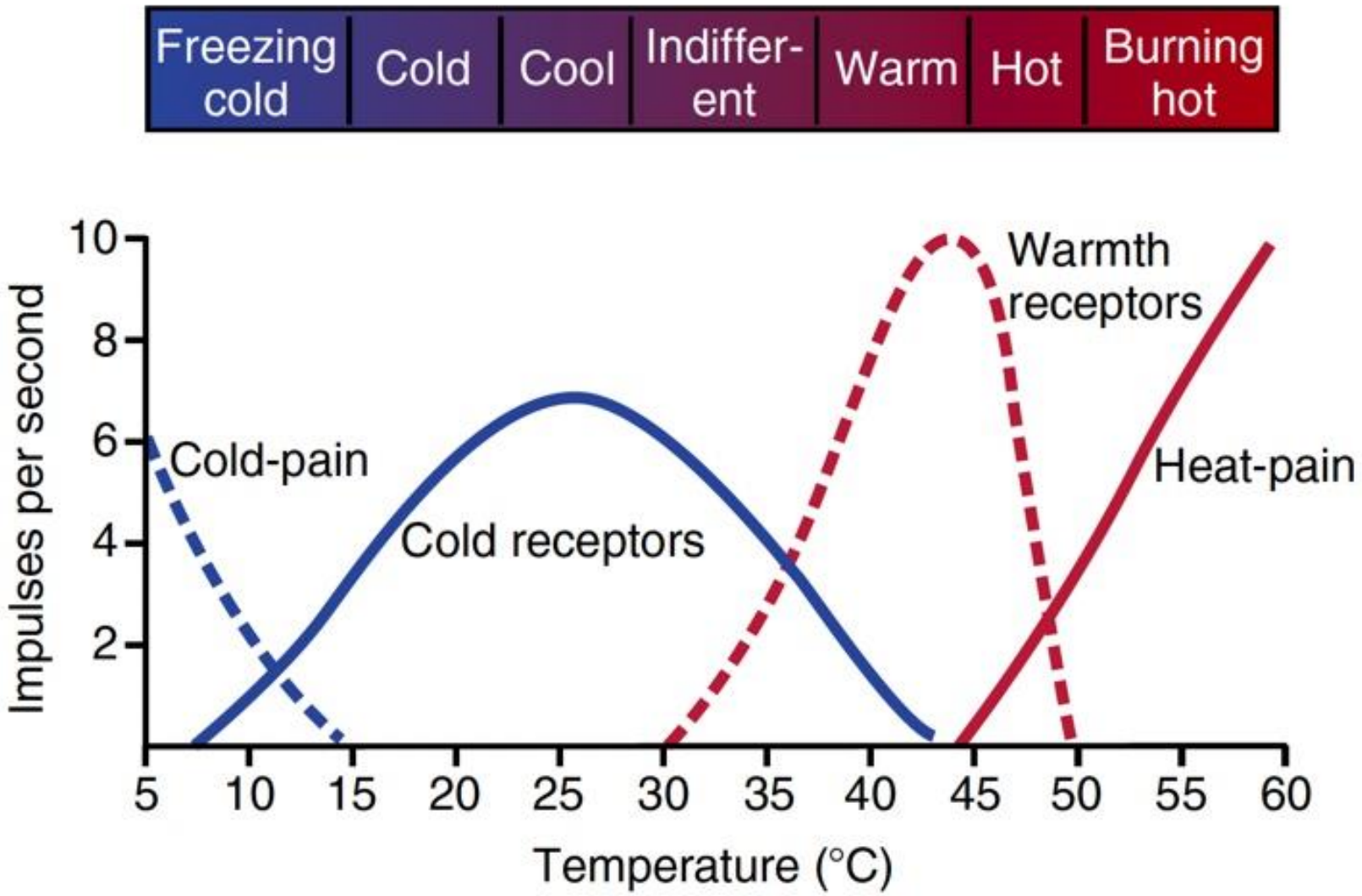
- Cold receptors
- Warmth receptors
- Pain receptors (stimulated only by extreme degrees of heat or cold).

- They are located immediately under the skin at discrete separated spots.
- Most areas of the body have more cold receptors than warmth.
- The number of receptors in different areas of the body varies.

Thermoreceptors

- Free nerve endings.
- Warmth signals are transmitted mainly over type C nerve fibers.
- Cold signals are transmitted mainly via type Aδ nerve fibers.
- In general, thermal signals are transmitted in pathways parallel to those for pain signals.

Thermal sensations



Thermal sensations

- The different gradations of thermal sensations can be determined by the relative degrees of stimulation of the different types of thermoreceptors and nociceptors.

- It is difficult to judge gradations of temperature when small skin areas are stimulated.

- However, when a large skin area is stimulated all at once, the thermal signals from the entire area are cumulative.

Adaptation in thermal receptors

- Thermal senses respond markedly to changes in temperature than to steady states of temperature.

- This means that when the temperature of the skin is actively falling, a person feels much colder than when the temperature remains cold at the same level.

Thermoreceptors

- Spatial Summation of Thermal Sensations:

- Because the number of cold or warmth endings in any one surface area of the body is slight, it is difficult to judge gradations of temperature when small skin areas are stimulated.

- However, when a large skin area is stimulated all at once, the thermal signals from the entire area are cumulative.

Thermoreceptors

- It is believed that thermal detection probably results not from direct physical effects of heat or cold on the nerve endings but from chemical stimulation of the endings as modified by temperature (change in metabolic rates, which alters the rate of intracellular chemical reactions).

Thermal receptors

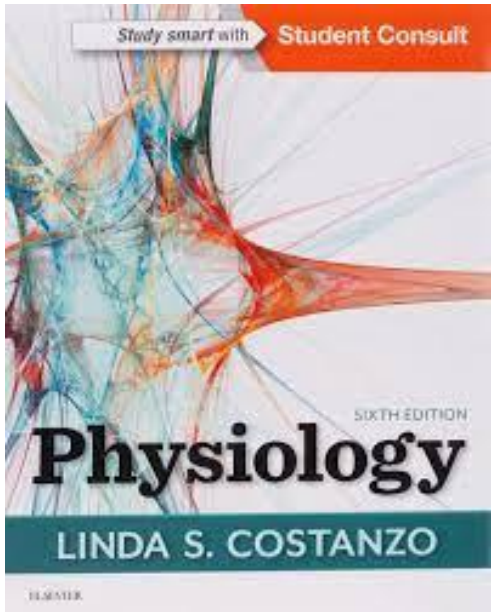
- Transduction of warm temperatures involves transient receptor potential (TRP) channels in the family of vanilloid receptors (TRPV).

- These channels are activated by compounds in the vanilloid class, which includes capsaicin, an ingredient in spicy foods. (This phenomenon explains why people describe the taste of chili peppers as “hot.”)

Thermal receptors

- Transduction of cold temperatures involves a different TRP channel, TRPM8, which is also opened by compounds like menthol (which gives a cold sensation).

References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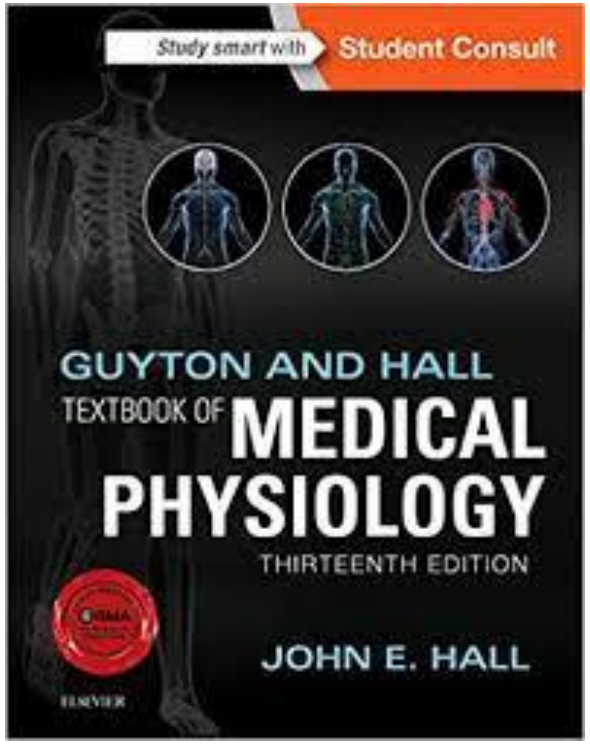
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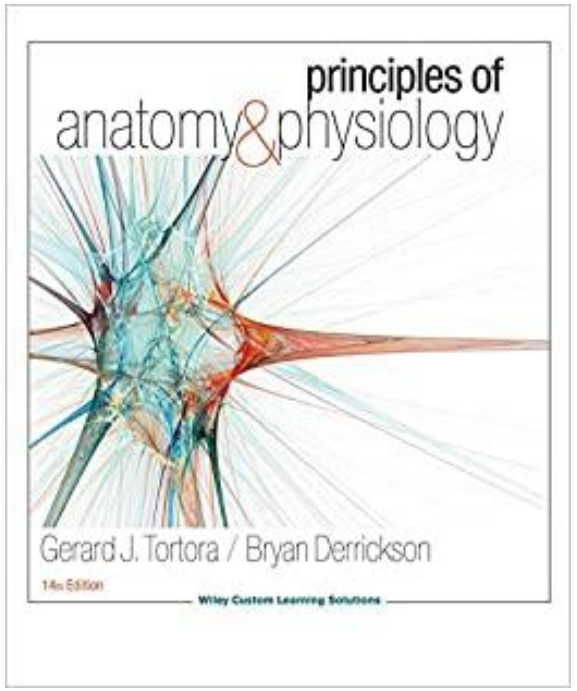
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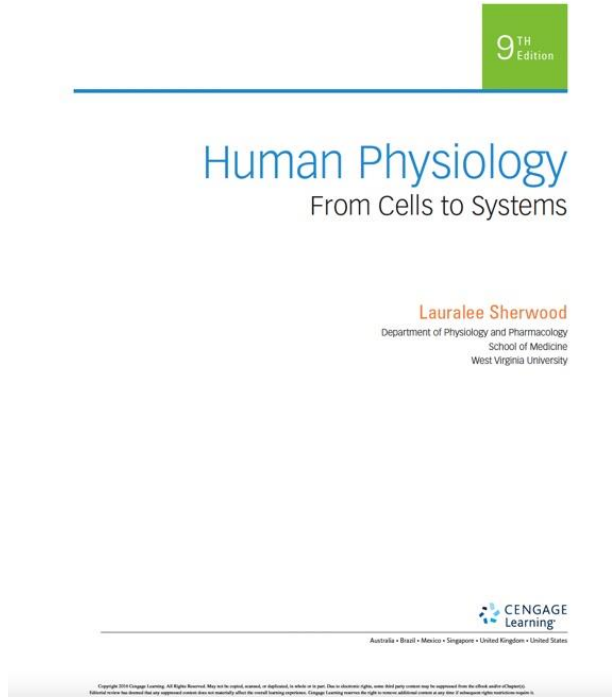
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