Introduction to Physiology for medical and dental students 2022-2023

Introduction to neurophysiology

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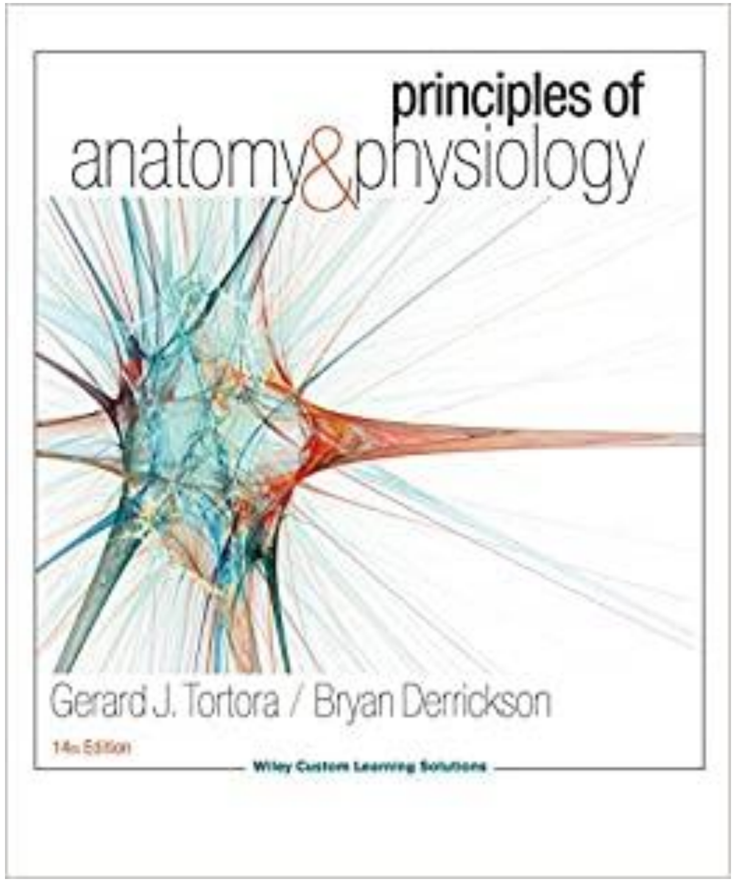
References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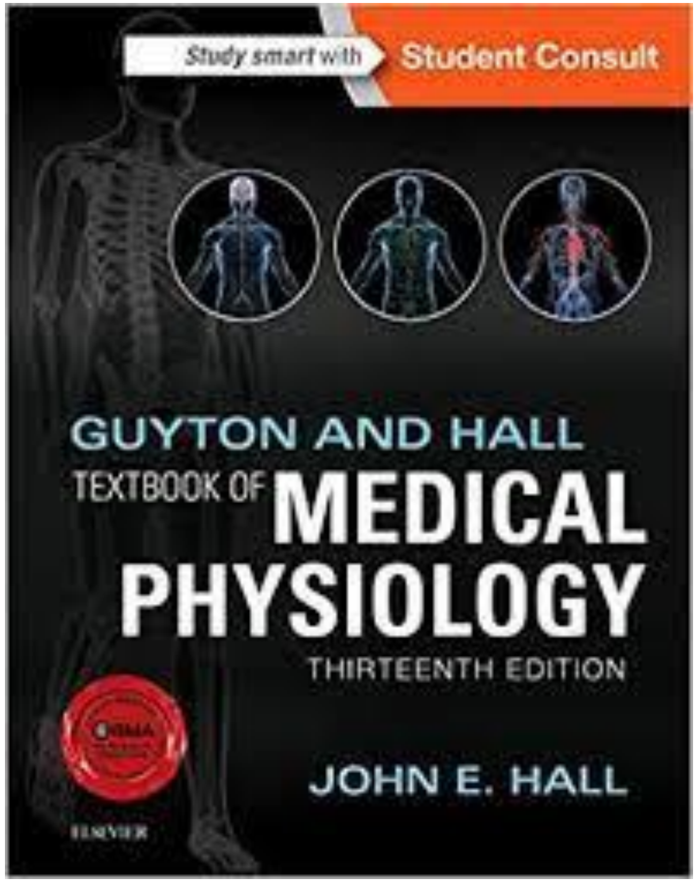
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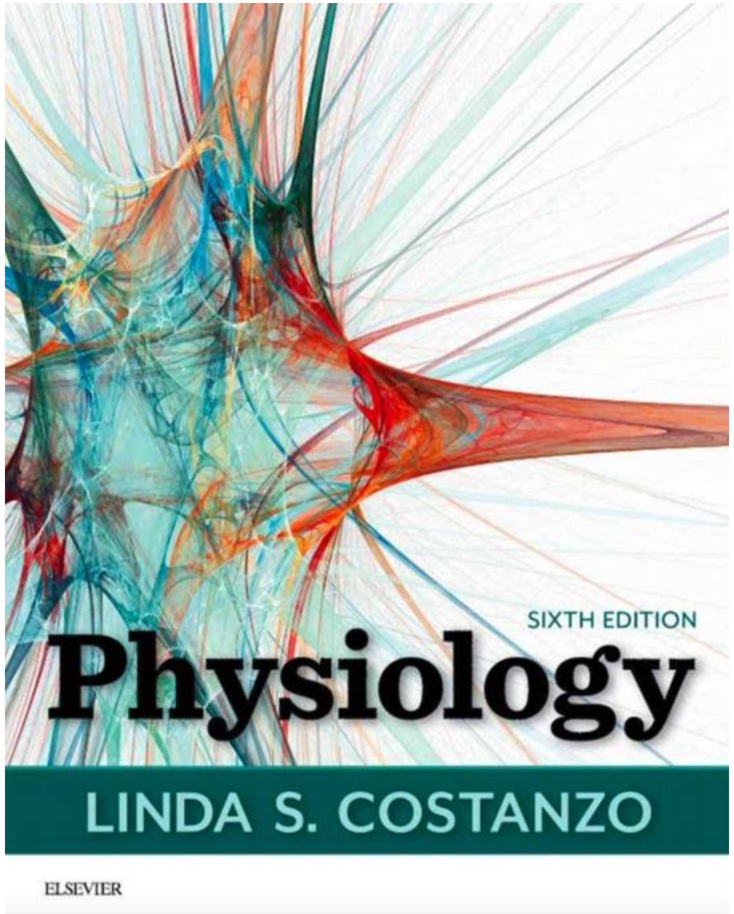
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Overview of this lecture

- Organization of the nervous system (NS).
- Subdivisions of NS.
- Functions of NS.
- Sensations and different sensory modalities.
- Types of sensory receptors.
- Some characteristics of sensory receptors.

Learning objectives

- To recognize different parts of the nervous system and their subdivisions.
- To understand the functions of the nervous system.
- To identify different types of sensory modalities.
- To recognize different types of sensory receptors .

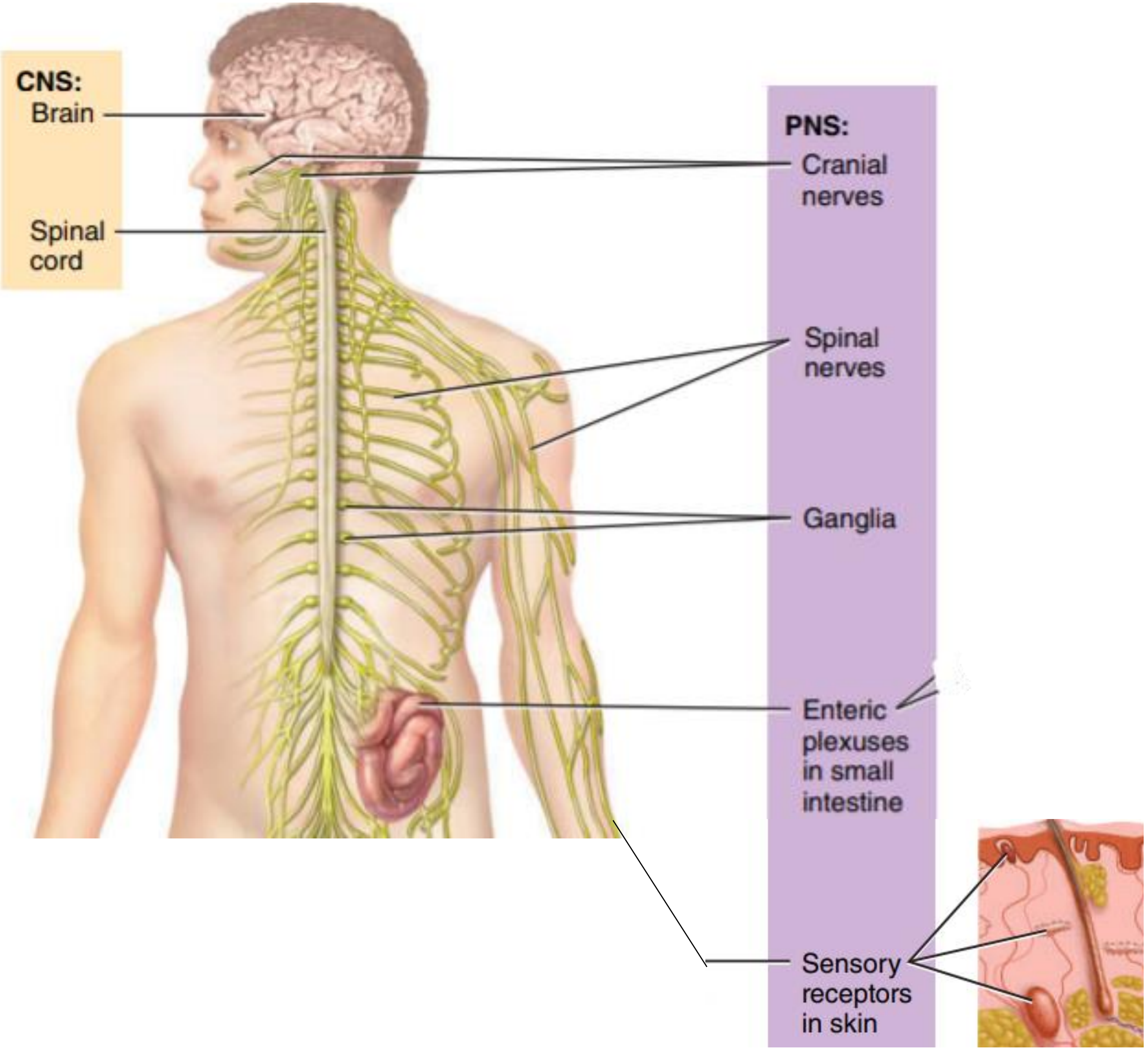
Overview of the nervous system

- The nervous system is composed of two divisions:

- The central nervous system (CNS), which includes the brain and the spinal cord.

- The peripheral nervous system (PNS), which includes sensory receptors, nerves, and ganglia.

Organization of the nervous system



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**: process sensory information by analyzing it and making decision for appropriate responses.

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

Sensory function

- Most activities of the nervous system are initiated by sensory experiences that excite sensory receptors.

- These sensory experiences can either cause immediate reactions from the brain, or memories of the experiences can be stored in the brain for minutes, weeks, or years and determine bodily reactions at some future date.

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Integrative function

- More than 99 percent of the sensory information is discarded by the brain as irrelevant and unimportant.

- However, when important sensory information excites the mind, it is immediately channeled into proper integrative and motor regions of the brain to cause desired responses.

- This channeling and processing of information is called the integrative function of the nervous system.

Storage of information: memory

- Only a small fraction of even the most important sensory information usually causes immediate motor response.

- Much of the information is stored for future control of motor activities and for use in the thinking processes.

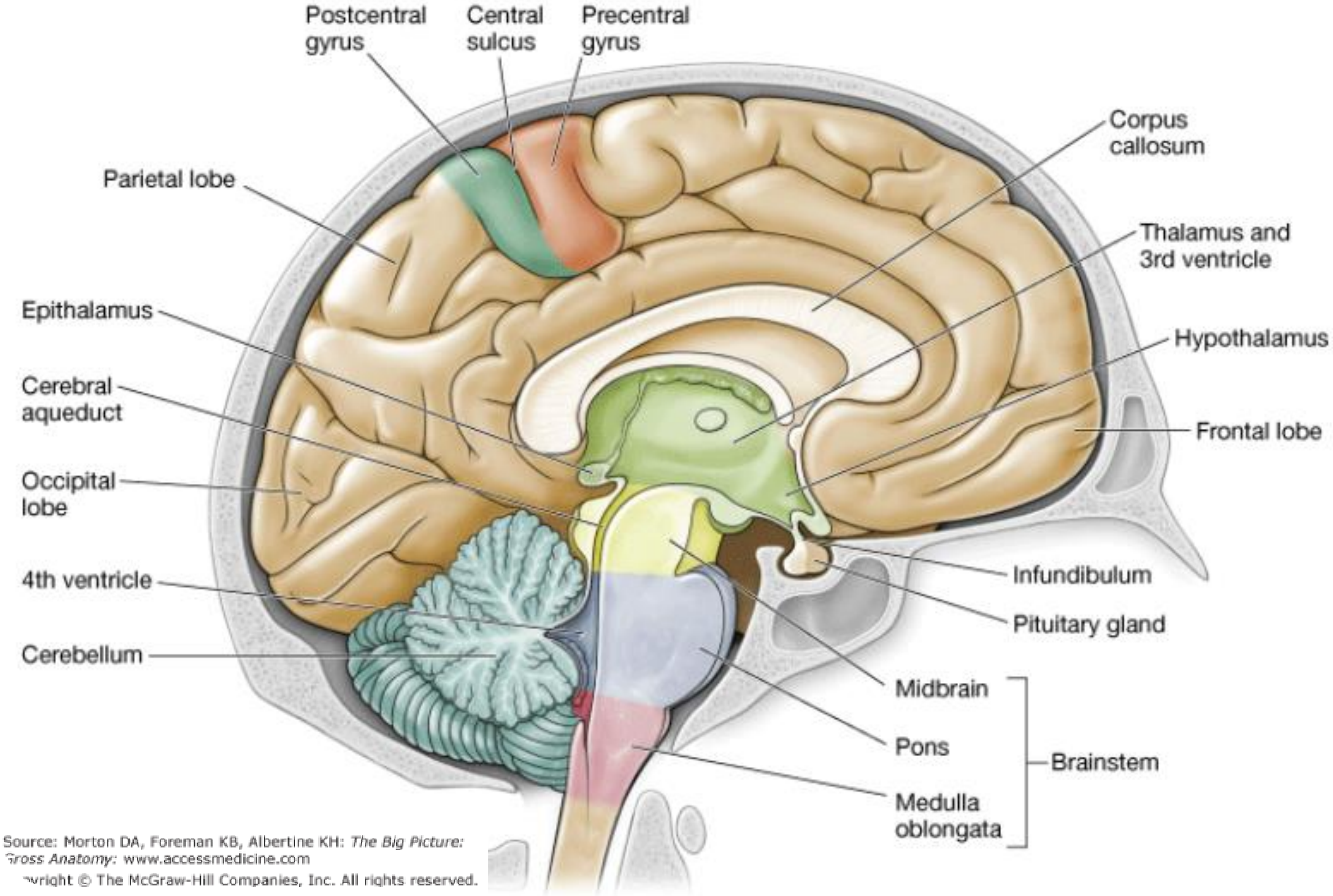
- Most storage occurs in the cerebral cortex, but even the basal regions of the brain and the spinal cord can store small amounts of information.

Storage of information: memory

- Once memories have been stored in the nervous system, they become part of the brain processing mechanism for future “thinking.”

- The thinking processes of the brain compare new sensory experiences with stored memories; the memories then help to select the important new sensory information and to channel this into appropriate memory storage areas for future use or into motor areas to cause immediate bodily responses.

Brain



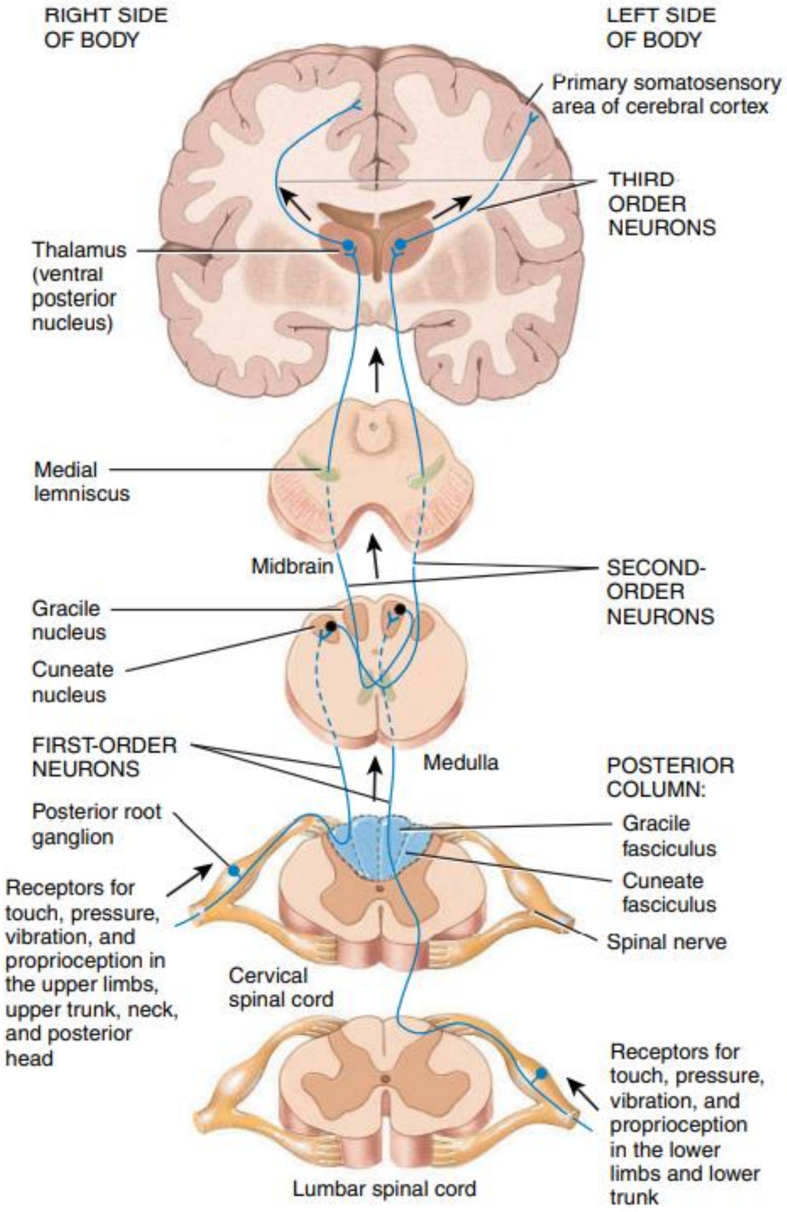
Source: Morton DA, Foreman KB, Albertine KH: *The Big Picture: Gross Anatomy:* www.accessmedicine.com

Spinal cord

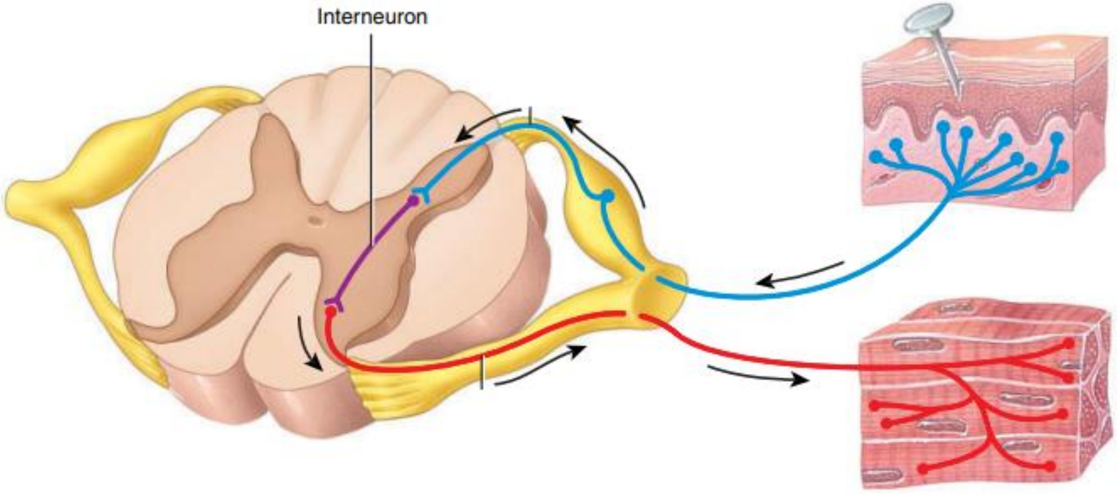
- The spinal cord has two main functions:

- 1- nerve impulse propagation (sensory and motor tracts): transmits signals from the periphery of the body to the brain, or in the opposite direction from the brain back to the body.

- 2- integration of information (such as in spinal reflexes).



Posterior column–medial lemniscus pathway



Lower brain (subcortical regions)

- Many, if not most, of the subconscious activities of the body are controlled in the lower areas of the brain.
- Examples of subcortical structures are brain stem, cerebellum, diencephalon, basal nuclei, hippocampus, and amygdala.

Higher brain (cerebral cortex)

- Cerebral cortex is an extremely large **memory storehouse**.

- Without the cerebral cortex, the functions of the lower brain centers are often imprecise. Cortical information usually converts these functions to determinative and **precise operations**.

- The cerebral cortex is essential for most of our **thought processes**.

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**: process sensory information by analyzing it and making decision for appropriate responses.

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

Motor function

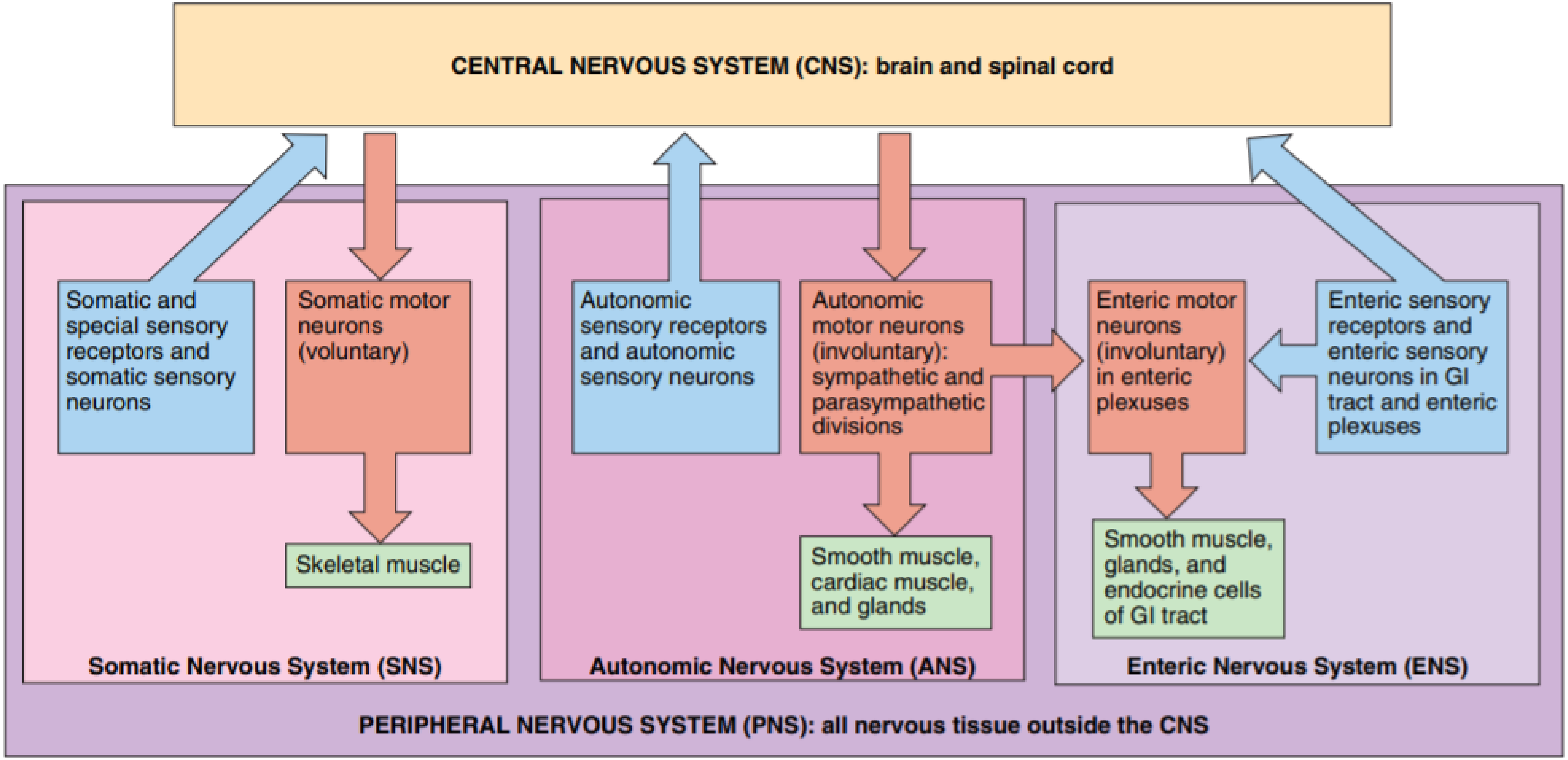
- The most important eventual role of the nervous system is to **control the various bodily activities.**

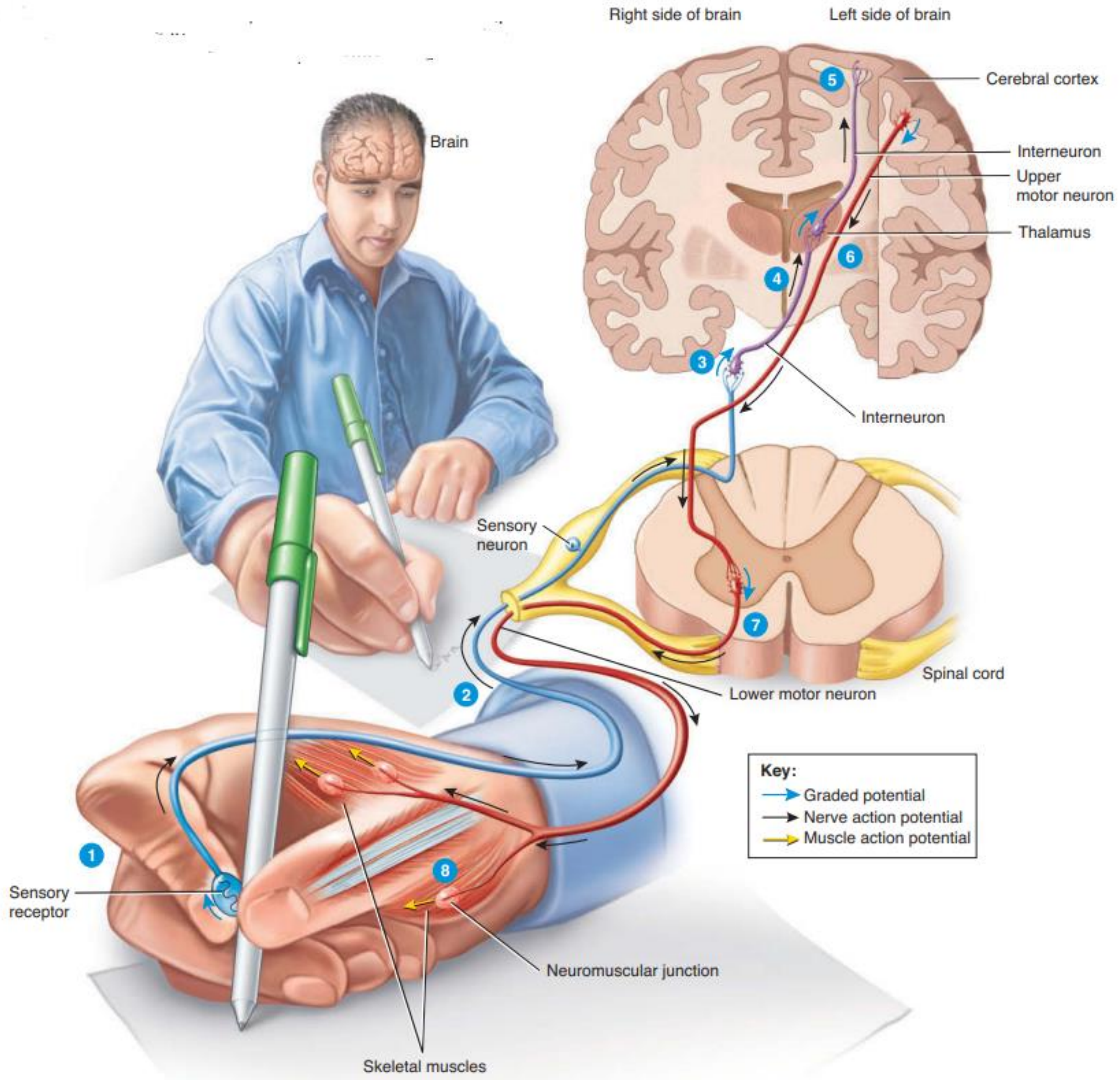
- This task is achieved by controlling:
- (1) contraction of appropriate skeletal muscles throughout the body.
- (2) contraction of smooth muscle in the internal organs.
- (3) secretion of active chemical substances by both exocrine and endocrine glands in many parts of the body.

Motor function

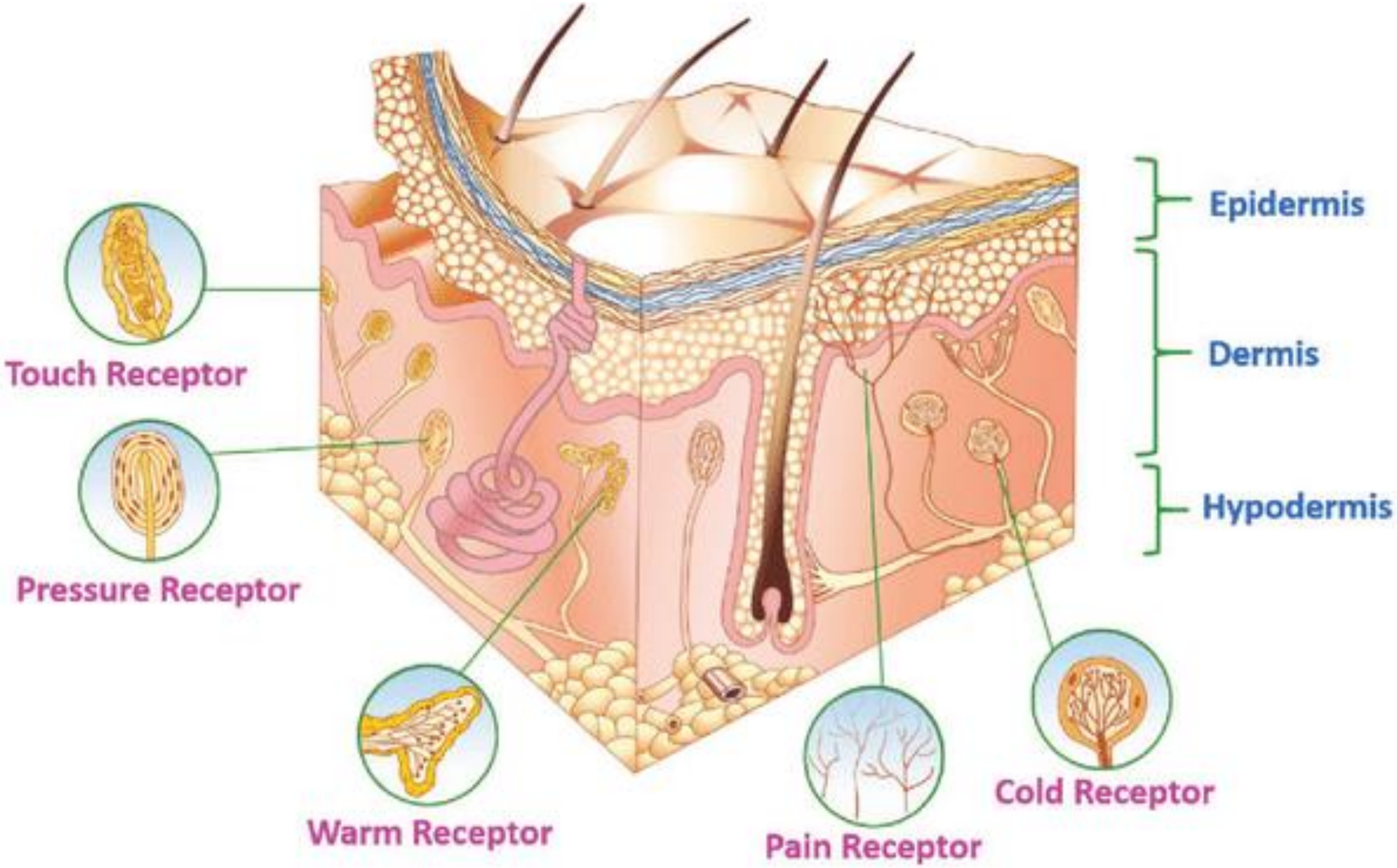
- These activities are collectively called motor functions of the nervous system.

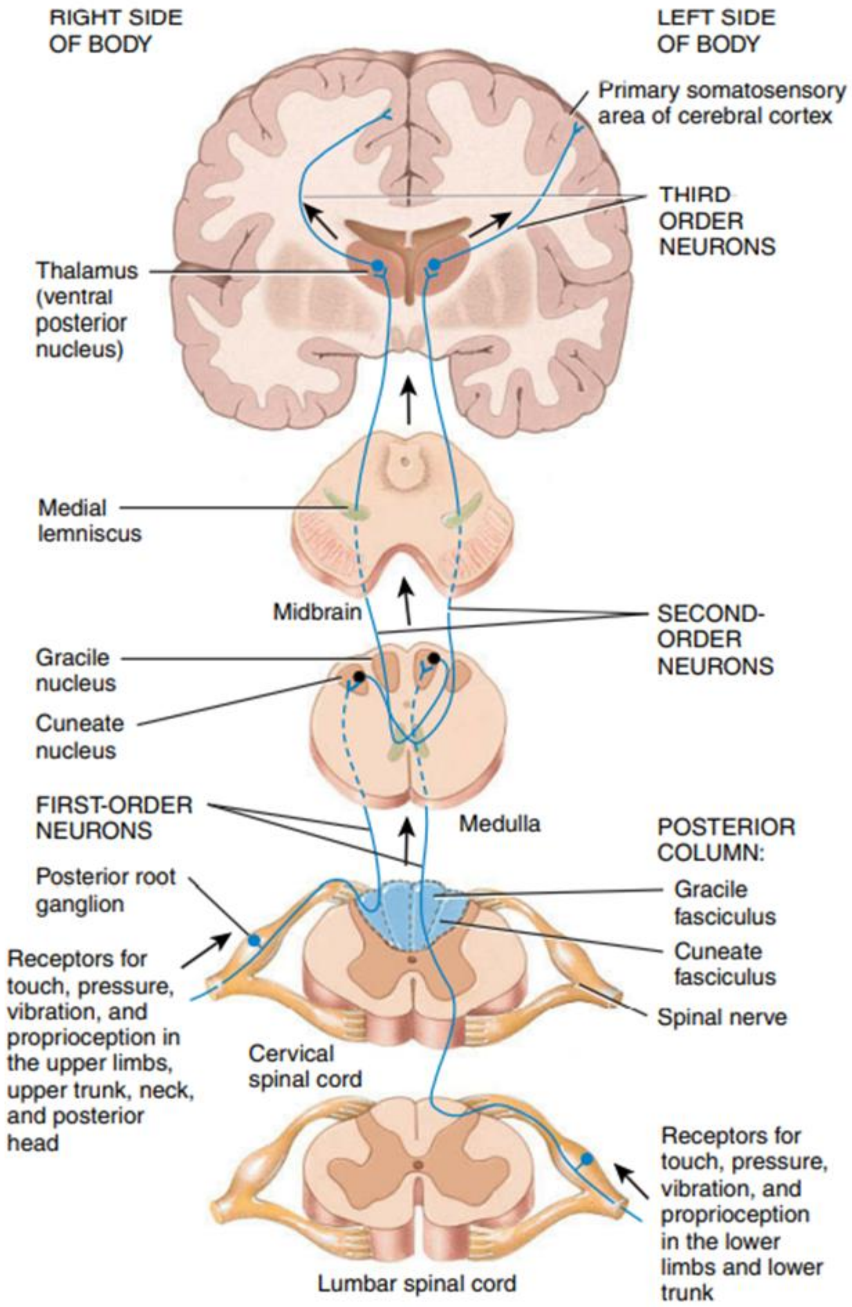
- The muscles and glands are called **effectors** because they are the actual anatomical structures that perform the functions dictated by the nerve signals.


CENTRAL NERVOUS SYSTEM (CNS): brain and spinal cord
Somatic and special sensory receptors and somatic sensory neurons
Somatic motor neurons (voluntary)
Skeletal muscle
Somatic Nervous System (SNS)
Autonomic sensory receptors and autonomic sensory neurons
Autonomic motor neurons (involuntary): sympathetic and parasympathetic divisions
Smooth muscle, cardiac muscle, and glands
Autonomic Nervous System (ANS)
Enteric motor neurons (involuntary) in enteric plexuses
Enteric sensory receptors and enteric sensory neurons in GI tract and enteric plexuses
Smooth muscle, glands, and endocrine cells of GI tract
Enteric Nervous System (ENS)
PERIPHERAL NERVOUS SYSTEM (PNS): all nervous tissue outside the CNS

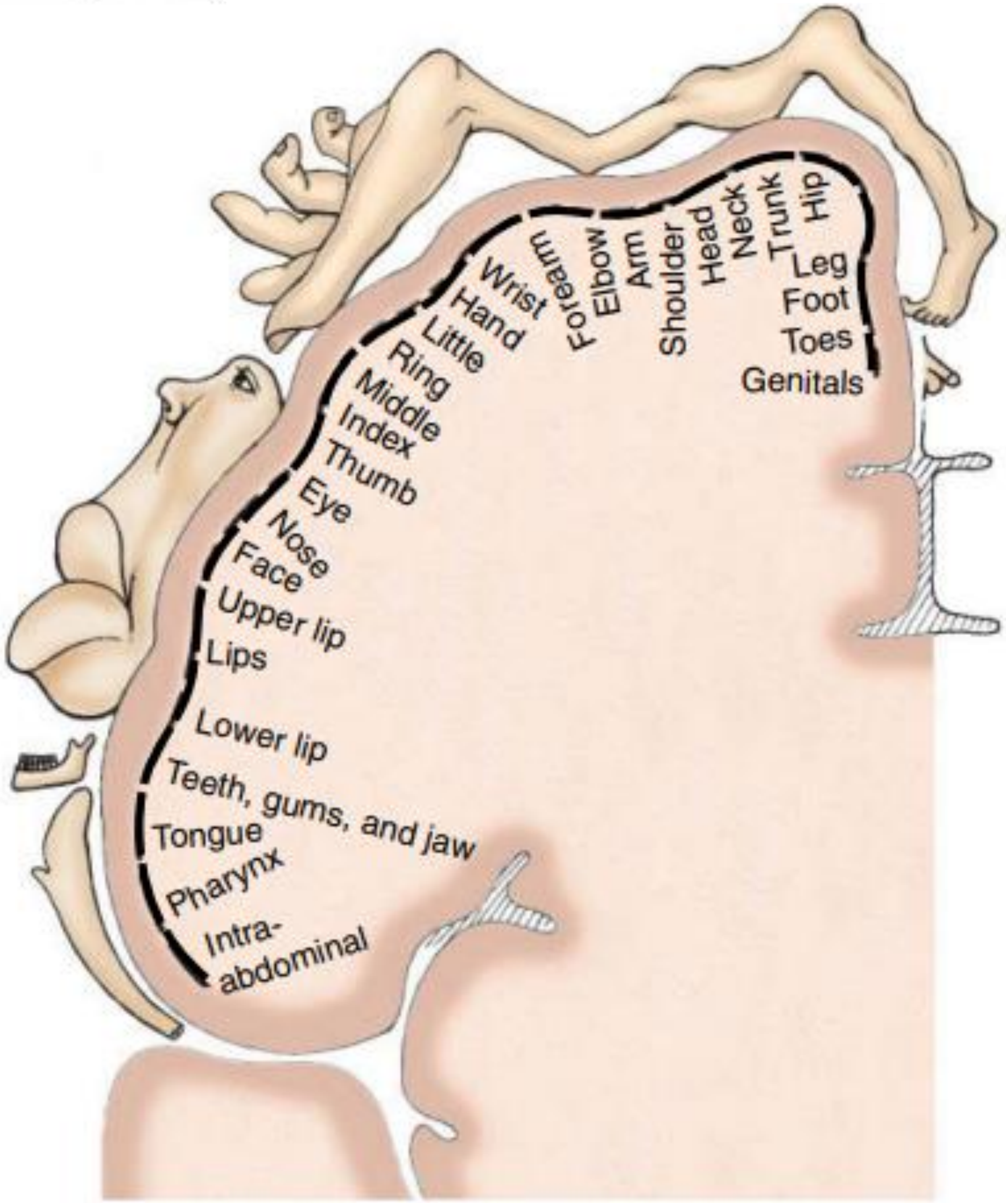


Right side of brain
Left side of brain
Cerebral cortex
Brain
Interneuron
Upper motor neuron
Thalamus
Interneuron
Sensory neuron
Spinal cord
Lower motor neuron
Key:
Graded potential
Nerve action potential
Muscle action potential
Sensory receptor
Neuromuscular junction
Skeletal muscles
1
2
3
4
5
6
7
8

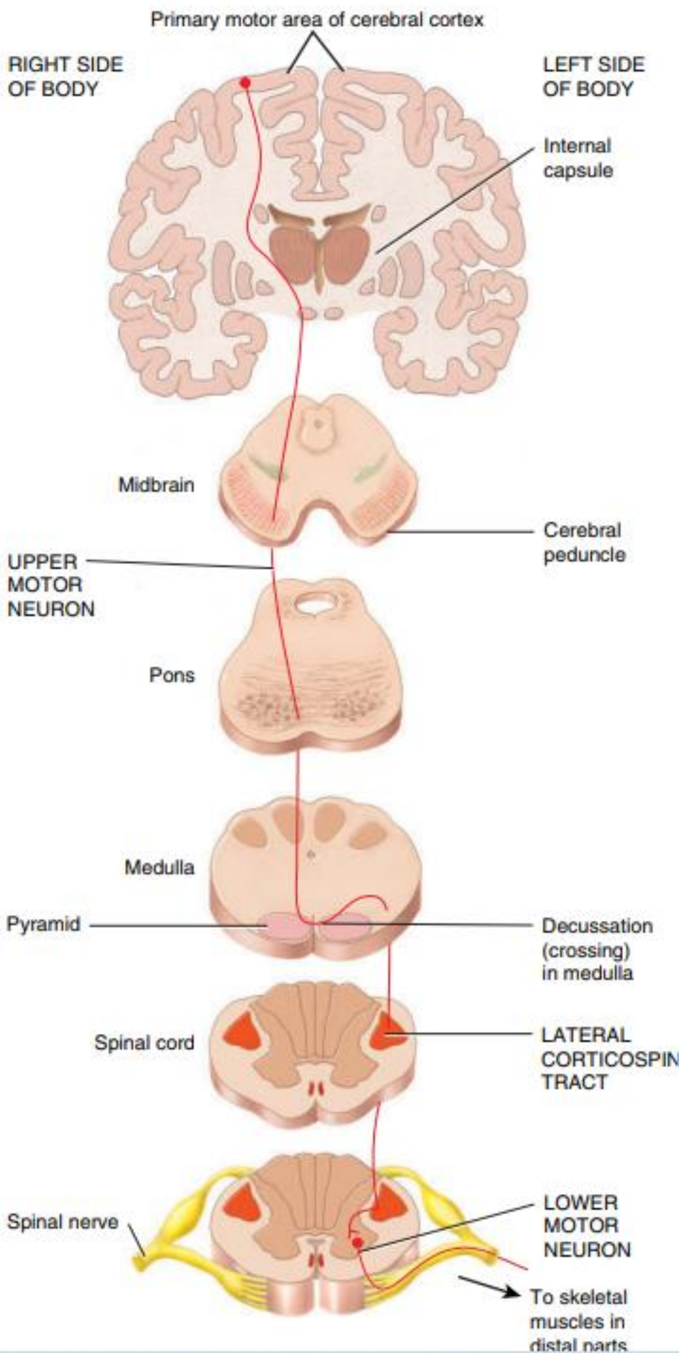

Epidermis
Dermis
Hypodermis
Touch Receptor
Pressure Receptor
Warm Receptor
Pain Receptor
Cold Receptor



Posterior column–medial lemniscus pathway



(a) Frontal section of primary somatosensory area in right cerebral hemisphere


Primary motor area of cerebral cortex
RIGHT SIDE OF BODY
LEFT SIDE OF BODY
Internal capsule
Midbrain
Cerebral peduncle
UPPER MOTOR NEURON
Pons
Medulla
Pyramid
Decussation (crossing) in medulla
Spinal cord
LATERAL CORTICOSPIN
TRACT
Spinal nerve
LOWER MOTOR NEURON
To skeletal muscles in distal parts

Sensation

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

- When sensory impulses reach the cerebral cortex, we become consciously aware of the sensory stimuli and can precisely locate and identify specific sensations such as touch, pain, hearing, or taste.

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

Sensory modalities

- Each type of sensation that we can experience, such as touch, pain, vision, or hearing, is called a **sensory modality**.

- Sensory modalities can be grouped into two classes: general senses and special senses.

- The **special senses** include the sensory modalities of smell, taste, vision, hearing, and balance.

General senses

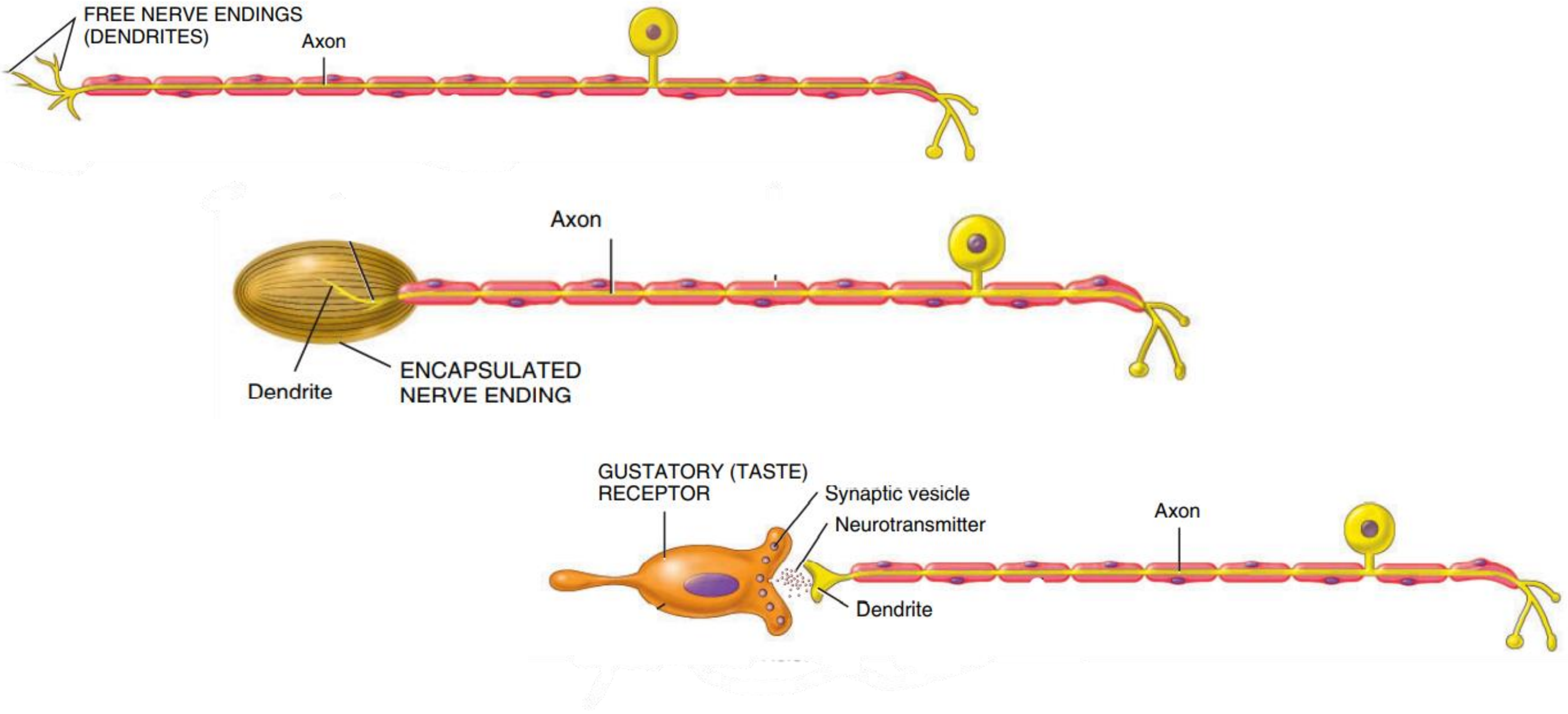
- The general senses are:
- **Somatic senses:** transmit sensory information from the receptors of the entire body surface and from some deep structures.
- They include tactile sensations (touch, pressure, vibration, itch, and tickle), thermal sensations (warm and cold), pain sensations, and proprioceptive sensations (for position and movement).

- **Visceral senses** provide information about conditions within internal organs such as: pressure, stretch, and temperature.

Sensory receptors

- Several structural and functional characteristics of sensory receptors can be used to group them into different classes. These include
- (1) microscopic structure.
- (2) location of the receptors and the origin of stimuli that activate them.
- (3) type of stimulus detected.

Structure of sensory receptors

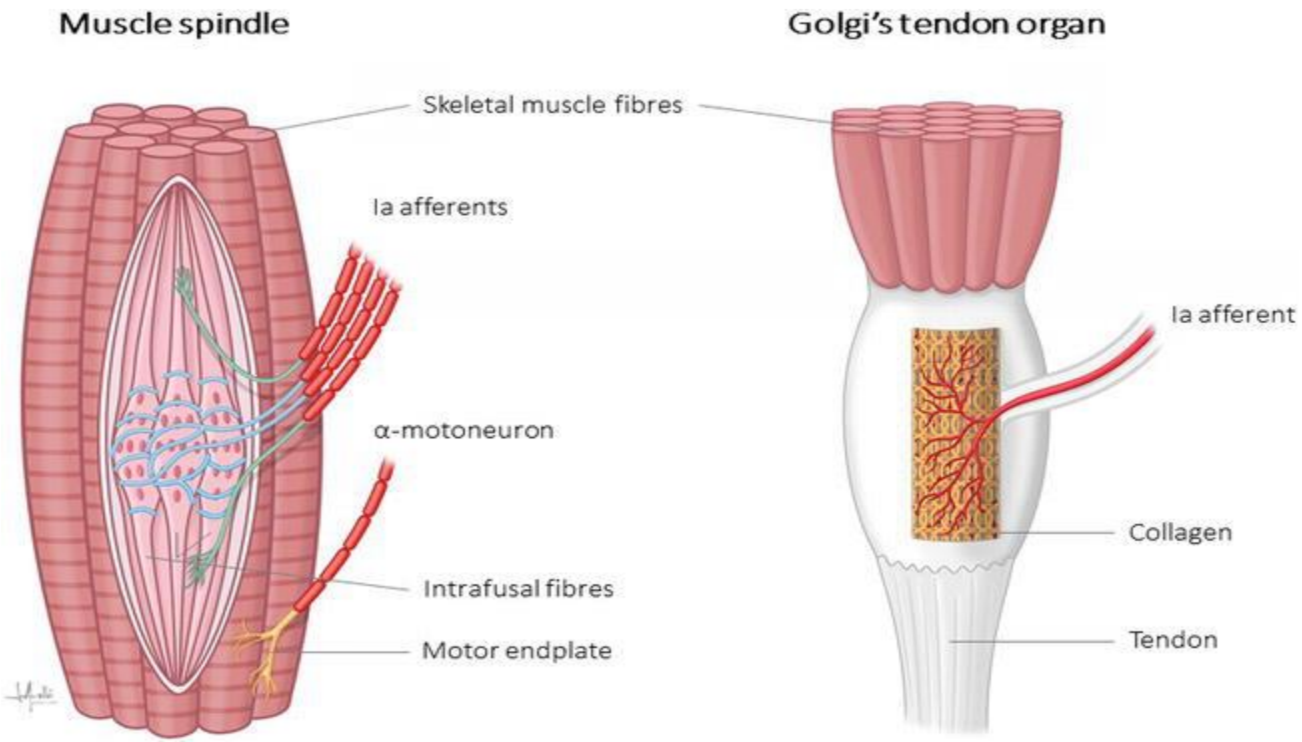


Location of sensory receptors

- 1- **Exteroceptors** are located at or near the external surface of the body; they provide information about the external environment.
- Examples are the sensations of hearing, vision, smell, taste, touch, pressure, vibration, temperature, and pain.

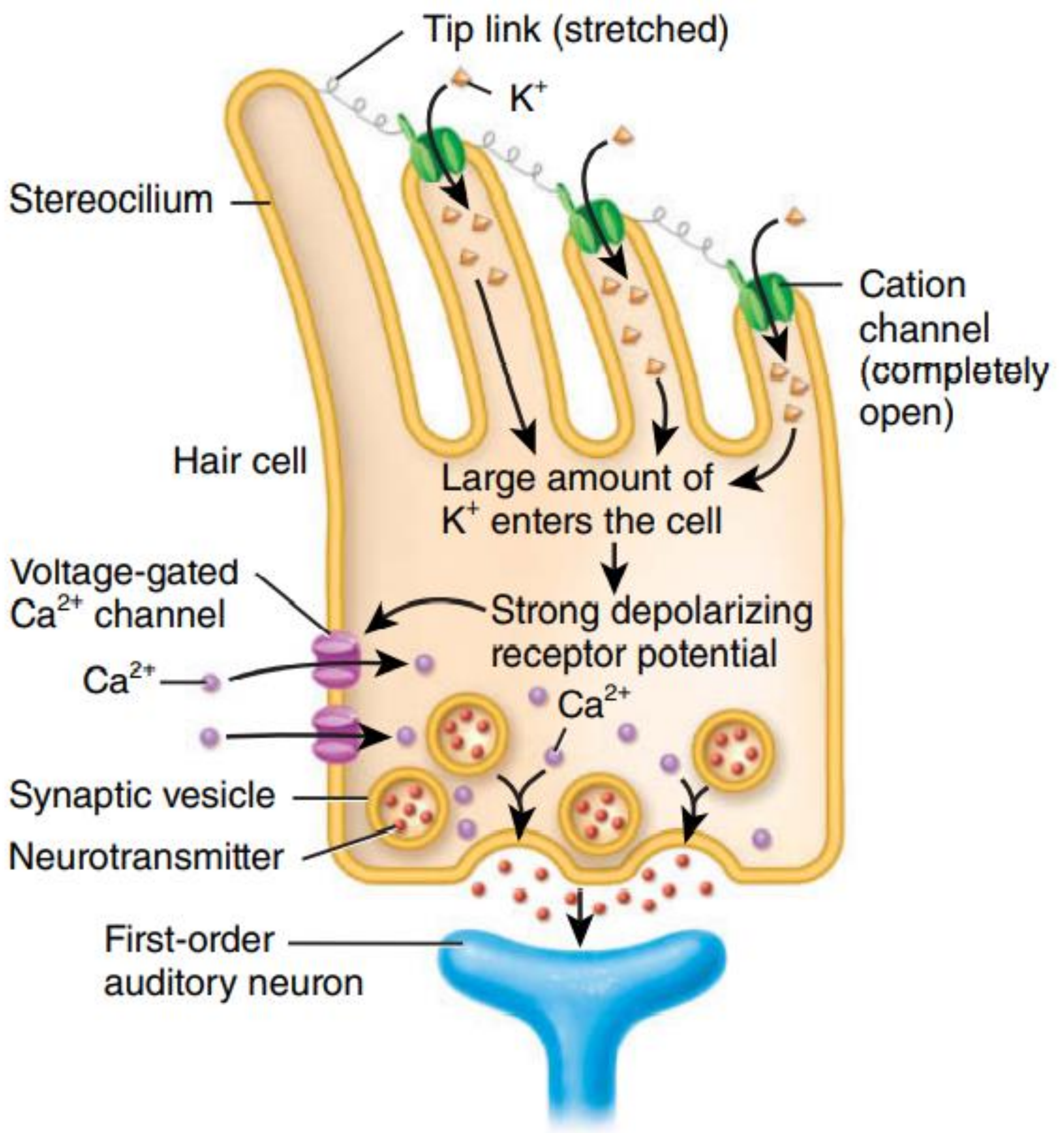
- 2- **Interoceptors** or visceroceptors monitor conditions in the internal environment.

- 3- **Proprioceptors** are located in muscles, tendons, joints, and the inner ear. They provide information about body position, muscle length and tension, and the position and movement of the joints.



Sensory receptors

- The types of sensory receptors according to the type of stimulus:
- (1) **mechanoreceptors**, which detect mechanical compression or stretching of the receptor or of tissues adjacent to the receptor.



(b) Strongly depolarized hair cell

Sensory receptors

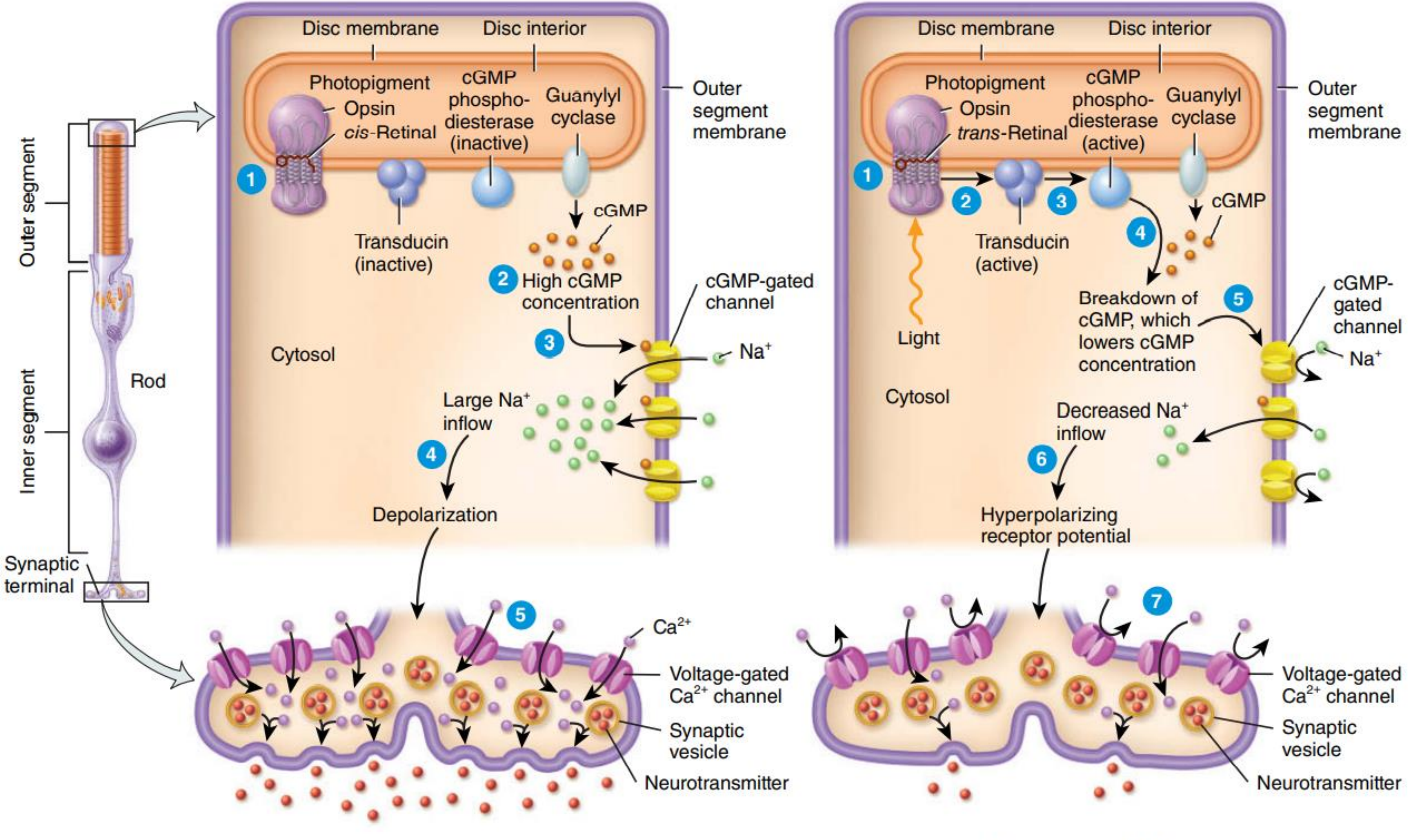
- (2) **thermoreceptors**, which detect changes in temperature, with some receptors detecting cold and others warmth.

Sensory receptors

- (3) **nociceptors** (pain receptors), which detect physical or chemical damage occurring in the tissues.

Sensory receptors

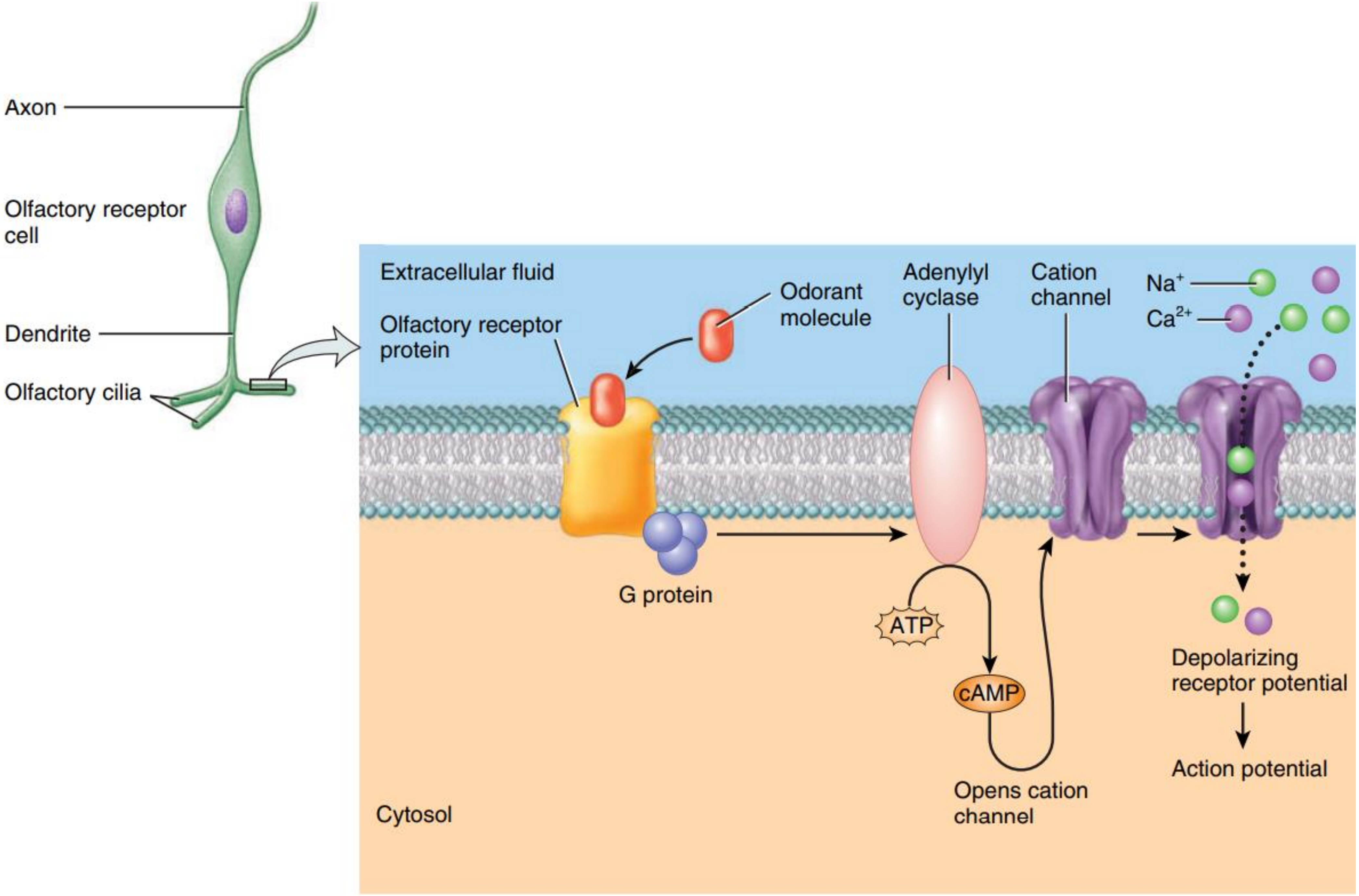
- (4) **electromagnetic receptors**, which detect light on the retina.



Outer segment
Inner segment
Rod
Synaptic terminal
Disc membrane
Disc interior
Photopigment
Opsin
cis-Retinal
cGMP phospho-diesterase (inactive)
Guanylyl cyclase
Outer segment membrane
1
Transducin (inactive)
cGMP
2 High cGMP concentration
cGMP-gated channel
3
Na+
Cytosol
Large Na+ inflow
4
Depolarization
5
Ca2+
Voltage-gated Ca2+ channel
Synaptic vesicle
Neurotransmitter
Disc membrane
Disc interior
Photopigment
Opsin
trans-Retinal
cGMP phospho-diesterase (active)
Guanylyl cyclase
Outer segment membrane
1
2
3
cGMP
4
Transducin (active)
Light
Breakdown of cGMP, which lowers cGMP concentration
5
cGMP-gated channel
Na+
Cytosol
Decreased Na+ inflow
6
Hyperpolarizing receptor potential
7
Voltage-gated Ca2+ channel
Synaptic vesicle
Neurotransmitter

Sensory receptors

- (5) **chemoreceptors**, which detect taste, smell, oxygen level in the arterial blood, osmolality of the body fluids…



Axon
Olfactory receptor cell
Dendrite
Olfactory cilia
Extracellular fluid
Olfactory receptor protein
Odorant molecule
Adenylyl cyclase
Cation channel
Na+
Ca2+
G protein
ATP
cAMP
Opens cation channel
Depolarizing receptor potential
Action potential
Cytosol

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.

The labeled-line principle

- Despite the fact that we experience different modalities of sensation, nerve fibers transmit only impulses.

- 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.

The labeled-line principle

- 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.

- The specificity of nerve fibers for transmitting only one modality of sensation is called the **labeled line principle.**

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.

Questions? Feedback?

Thank you