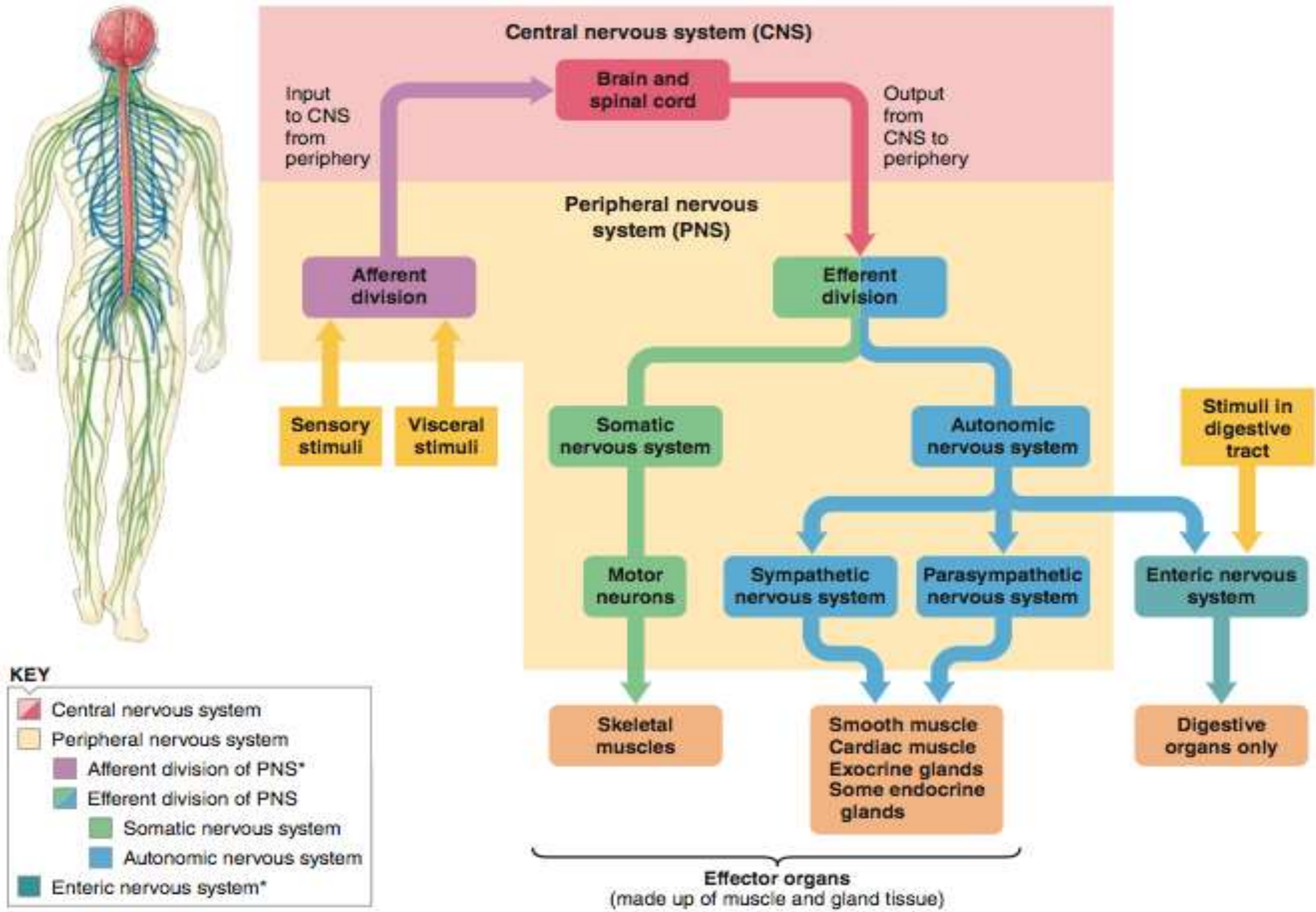
FISIOLOGI SSP

dr. Astri Handayani, M.Biomed



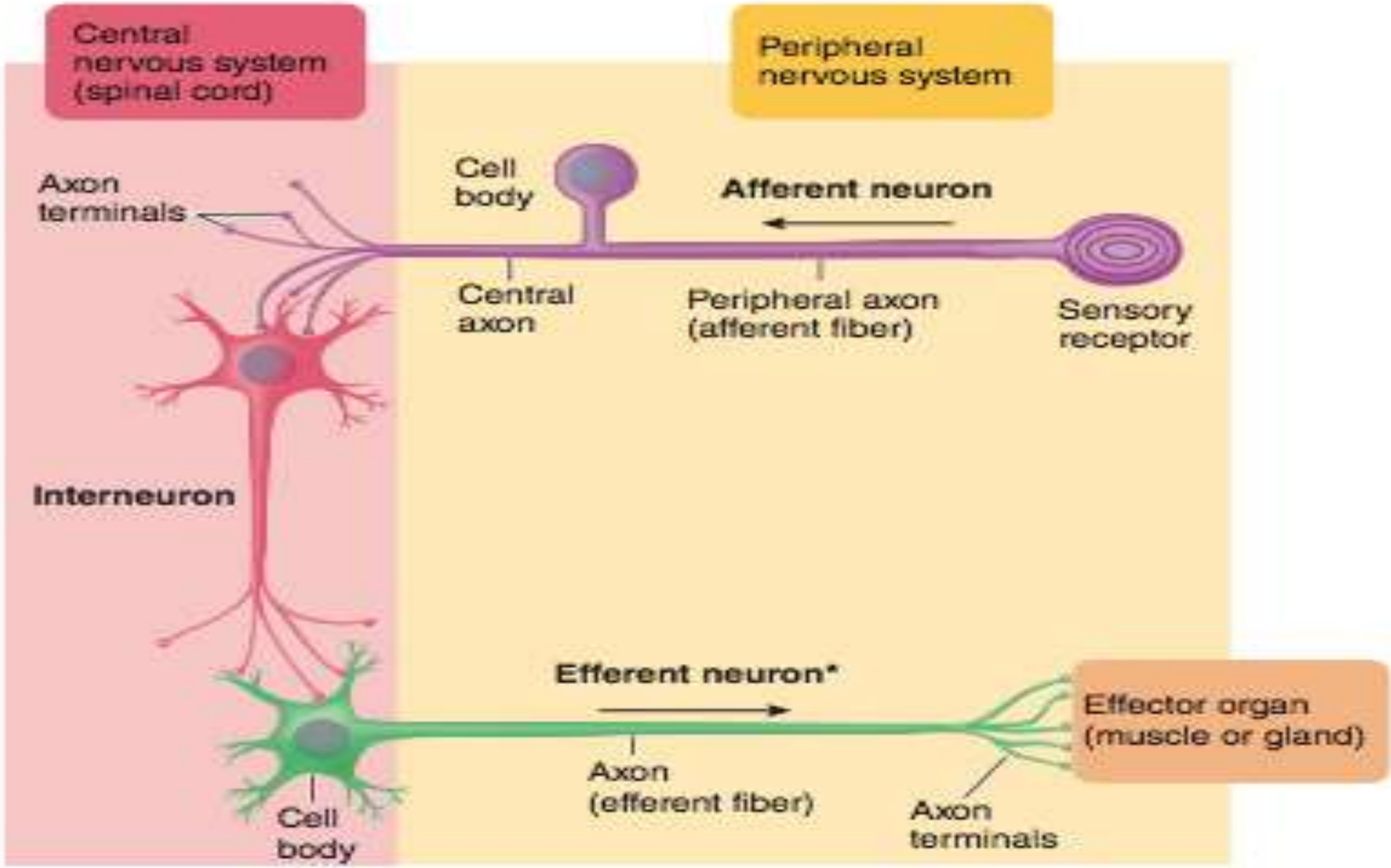
● **FIGURE 5-1 Organization of the nervous system.** *The afferent division of the PNS and the enteric nervous system are not shown in the human figure. Afferent fibers travel within the same nerves as efferent fibers but in the opposite direction. The enteric nervous system lies entirely within the wall of the digestive tract.

The nervous system :

- central nervous system
- peripheral nervous system.

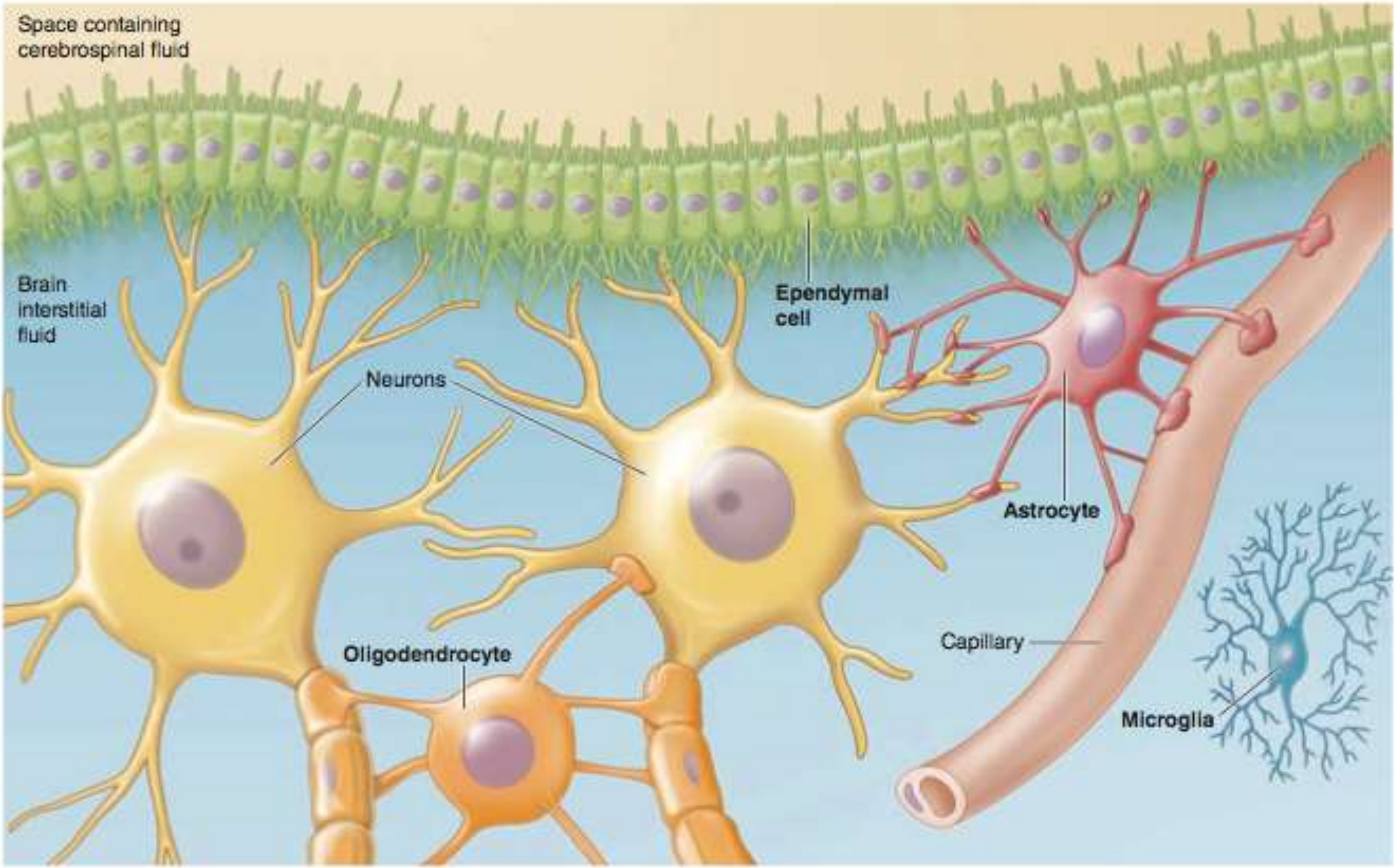
The three functional classes of neurons :

- Afferent
- Efferent
- interneurons



* Efferent autonomic nerve pathways consist of a two-neuron chain between the CNS and the effector organ.

● FIGURE 5-2 **Structure and location of the three functional classes of neurons.** Efferent autonomic nerve pathways consist of a two-neuron chain between the CNS and the effector organ.



● FIGURE 5-3 **Glial cells of the central nervous system.** The glial cells include the astrocytes, oligodendrocytes, microglia, and ependymal cells.

Astrocytes

Named for their starlike shape (astro means “star”; cyte means “cell”) astrocytes → most abundant glial cells.

They fill several critical functions:

- 1. hold the neurons together in proper spatial relationships.
- 2. a scaffold that guides neurons to their proper final destination during fetal brain development.
- 3. induce capillaries of the brain → blood– brain barrier
- 4. transfer nutrients from the blood to the neurons.

ASTROCYTES

- 5. repair brain injuries by forming neural scars.
- 6. take up and degrade some locally released neurotransmitters
- 7. take up excess K+ from the brain ECF → maintain the optimal ion conditions around neurons to sustain normal neural excitability.
- 8. Astrocytes communicate with neurons and with one another by means of chemical signals passing locally in both directions between these cell

Oligodendrocytes

- form the insulative myelin sheaths around axons in the CNS.
- The growth-inhibiting action of oligodendrocytes may thus stabilize the enormously complex structure of the CNS.
- Growth inhibition is a disadvantage, however, when central axons need to be mended, as when the spinal cord has been severed accidentally.

- **Schwann cells** → the myelin-forming cells of the PNS → regeneration tube and secrete nerve-growth-enhancing proteins that respectively guide and promote regrowth of damaged peripheral axons, as long as the cell body and dendrites remain intact

Microglia

- immune defense cells of the CNS → activated by an infection or injury.
- phagocytosis
- release destructive chemicals for assault against their target.
- excessive release of these chemicals → insidious neuronal damage

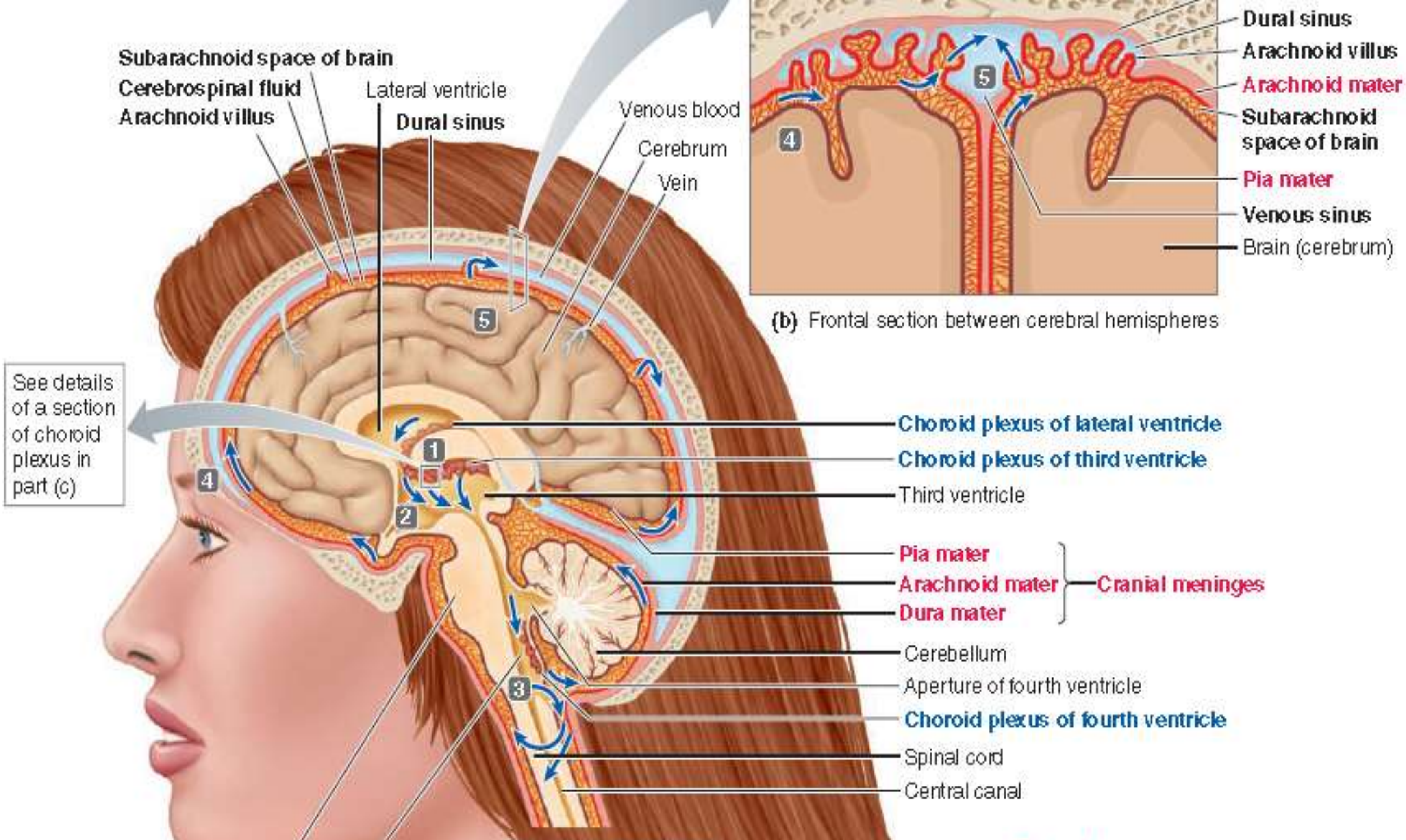
Ependymal Cells

- line the internal, fluid- filled cavities of the CNS.
- serve as neural stem cells → other glial cells, new neurons as well

Four major features help protect the CNS from injury:

- It is enclosed by hard, bony structures.
- Three protective and nourishing membranes, the meninges,
- The brain “floats” in CSF.
- A highly selective blood–brain barrier (BBB) regulates exchanges between the blood and the brain, thus limiting access of blood-borne materials into the vulnerable brain tissue.

PROTECTION AND NOURISHMENT OF THE BRAIN



Cerebrospinal fluid (CSF)

1 is produced by the choroid plexuses,

2 circulates throughout the ventricles,

3 exits the fourth ventricle at the base of the brain,

4 flows in the subarachnoid space between the meningeal layers, and

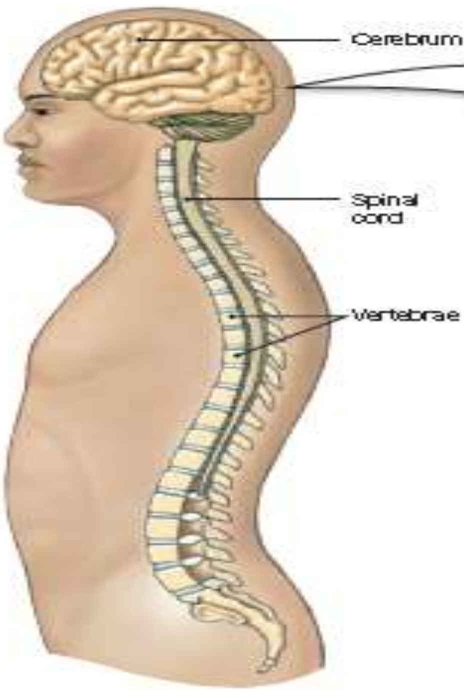
5 is finally reabsorbed from the subarachnoid space into the venous blood across the arachnoid villi.

PROTECTION AND NOURISHMENT OF THE BRAIN

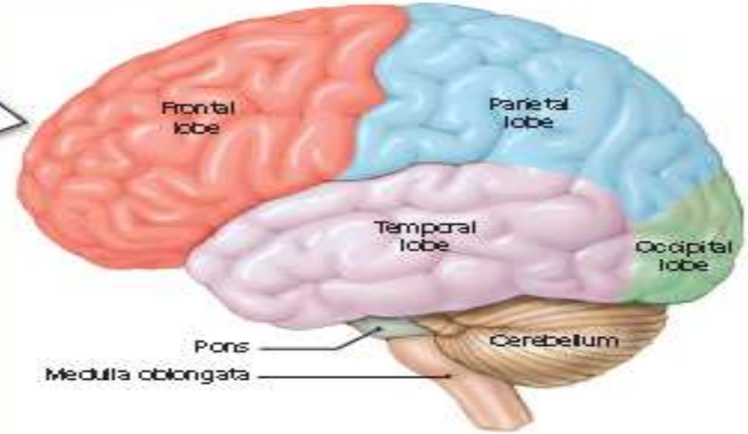
Central Nervous System

Anatomy of the Brain

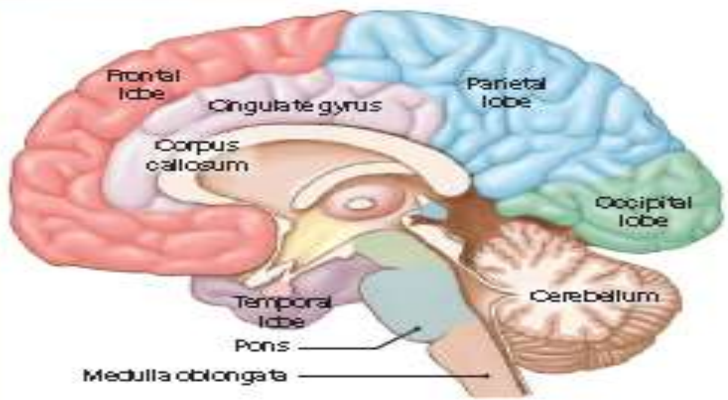
(a) Lateral View of the CNS



(b) Lateral View of Brain



(c) Mid-Sagittal View of Brain



(d) Diencephalon

Functions of the Cerebrum

Cerebral cortex
See Figure 9.13.

Sensory areas
- Perception [Fig. 10.3]

Motor areas
- Skeletal muscle movement

Association areas
- Integration of information and direction of voluntary movement [Ch. 13]

Basal ganglia (not shown)
See Figure 9.10.
- Movement [Ch. 13]

Limbic System (not shown)
See Figure 9.11.

Amygdala
- Emotion
- Memory

Hippocampus
- Learning
- Memory

Functions of the Cerebellum

- Movement coordination [Ch. 13]

Functions of the Diencephalon

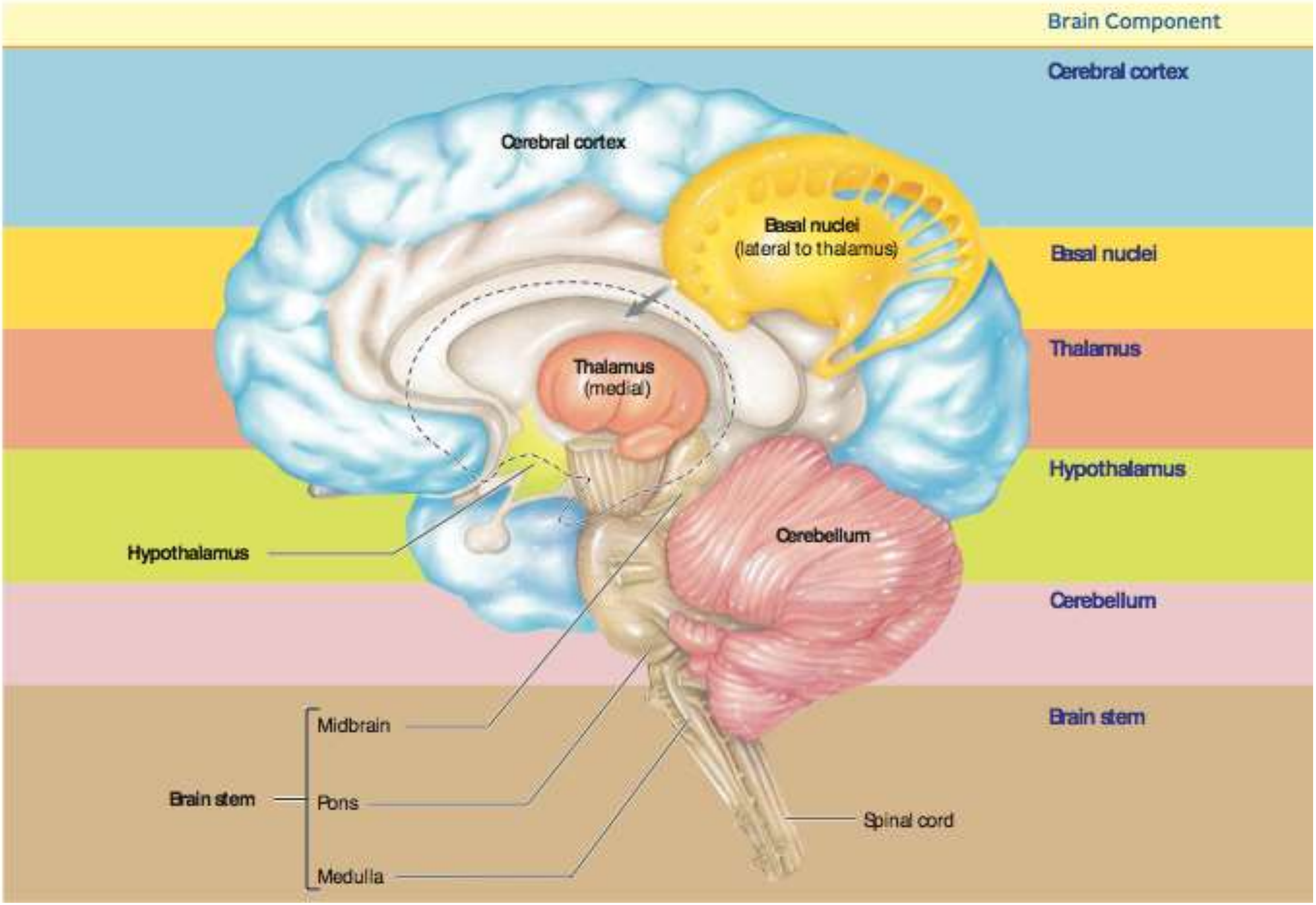
Thalamus
- Integrating center and relay station for sensory and motor information

Pineal gland
- Melatonin secretion [Fig. 7.16]

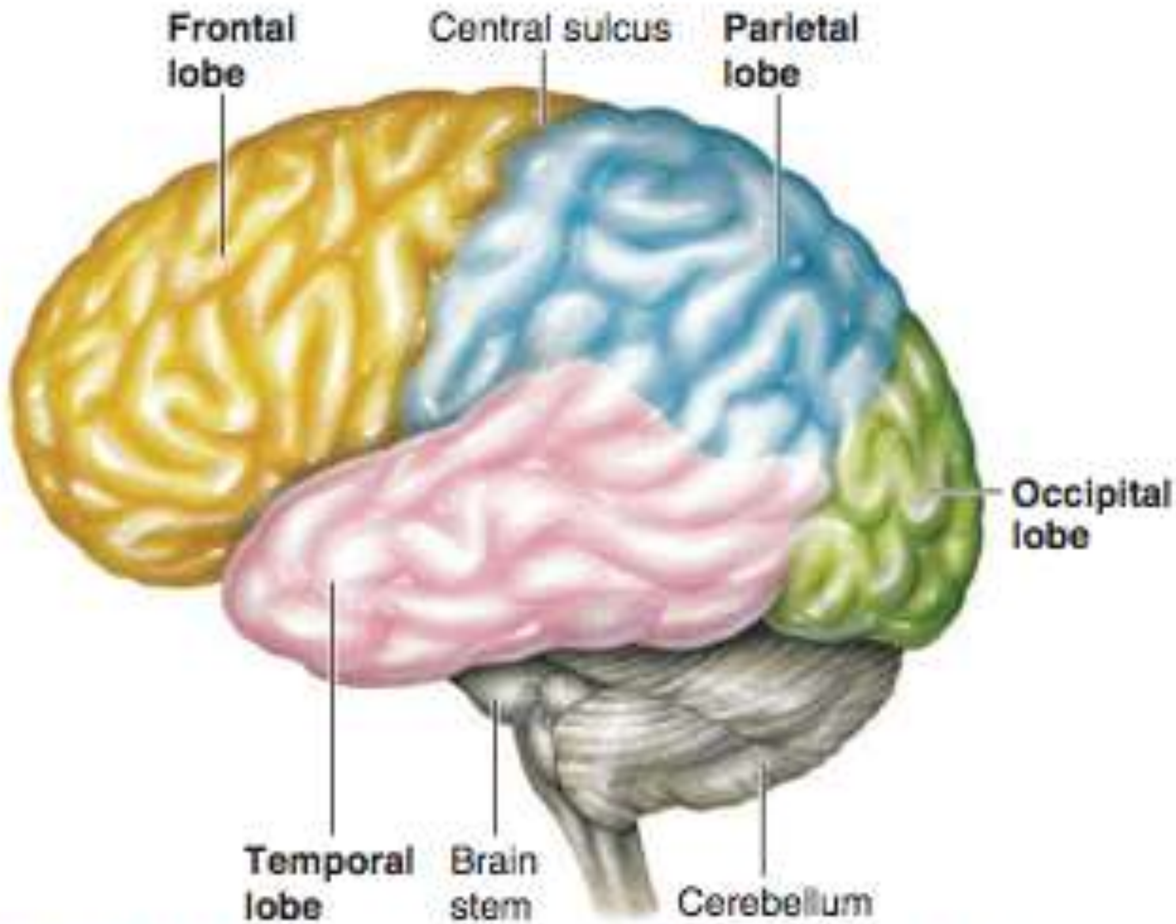
Hypothalamus
See Table 9.2.
- Homeostasis [Ch. 11]
- Behavioral drives

Pituitary gland
- Hormone secretion [Fig. 7.8]

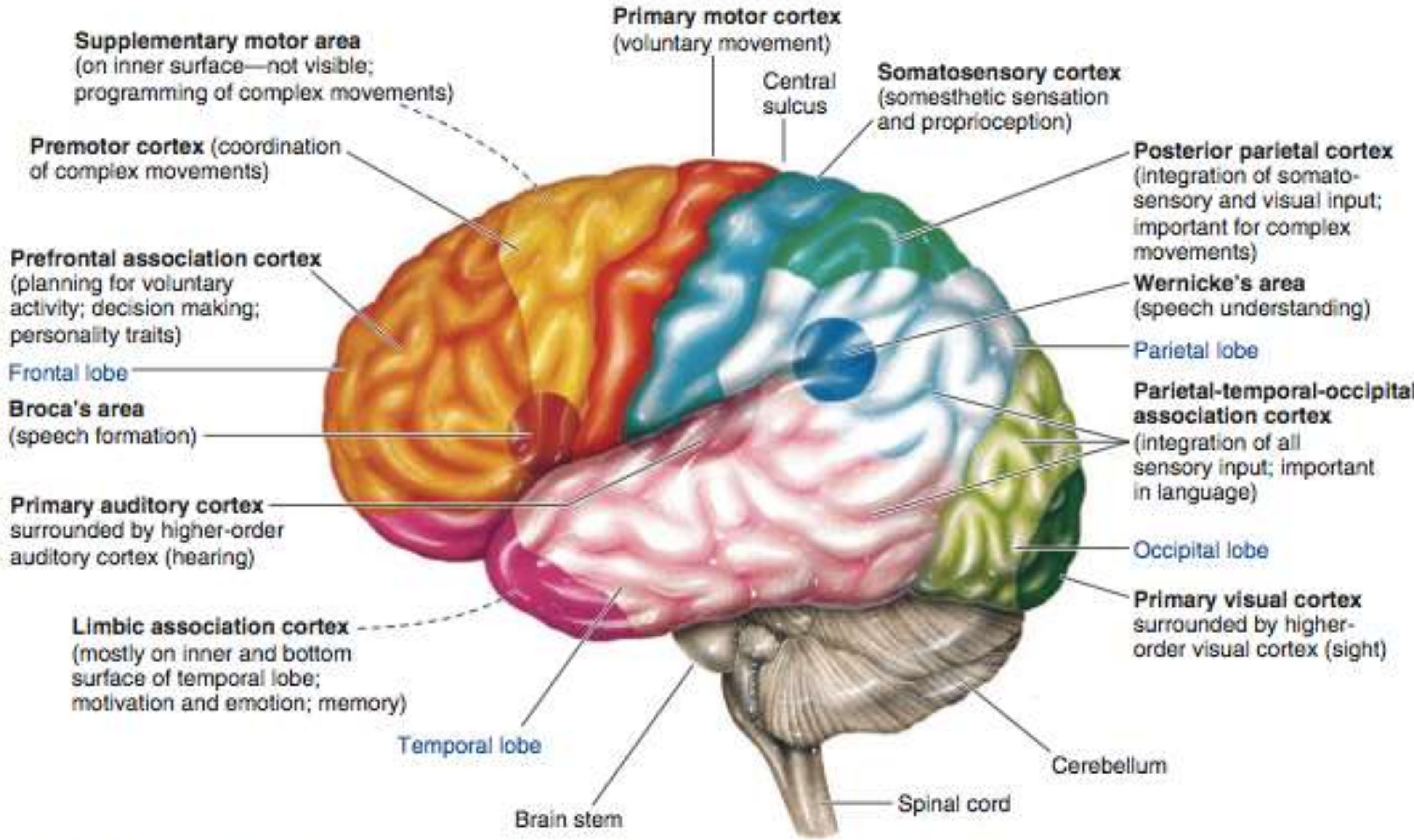
Table 5-1 Overview of Structures and Functions of the Major Components of the Brain



Major Functions
1. Sensory perception 2. Voluntary control of movement 3. Language 4. Personality traits 5. Sophisticated mental events, such as thinking, memory, decision making, creativity, and self-consciousness
1. Inhibition of muscle tone 2. Coordination of slow, sustained movements 3. Suppression of useless patterns of movement
1. Relay station for all synaptic input 2. Crude awareness of sensation 3. Some degree of consciousness 4. Role in motor control
1. Regulation of many homeostatic functions, such as temperature control, thirst, urine output, and food intake 2. Important link between nervous and endocrine systems 3. Extensive involvement with emotion and basic behavioral patterns 4. Role in sleep–wake cycle
1. Maintenance of balance 2. Enhancement of muscle tone 3. Coordination and planning of skilled voluntary muscle activity
1. Origin of majority of peripheral cranial nerves 2. Cardiovascular, respiratory, and digestive control centers 3. Regulation of muscle reflexes involved with equilibrium and posture 4. Reception and integration of all synaptic input from spinal cord; arousal and activation of cerebral cortex 5. Role in sleep–wake cycle



● FIGURE 5-7 **Cortical lobes.** Each half of the cerebral cortex is divided into the occipital, temporal, parietal, and frontal lobes, as depicted in this lateral view of the brain.



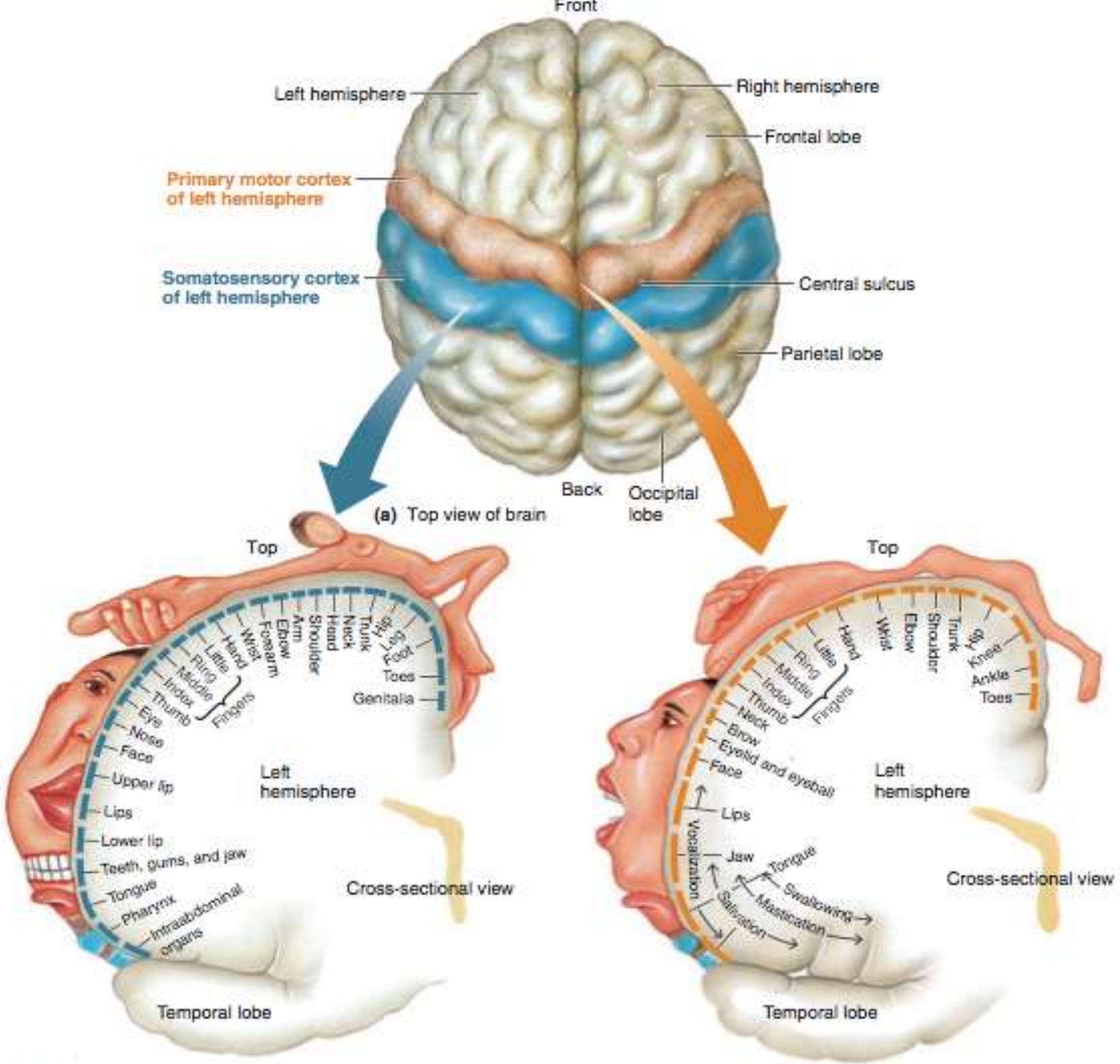
(a) Regions of the cerebral cortex responsible for various functions

Sensation from the surface of the body (ex touch, heat,etc) ➔ known as somesthetic sensation

This information is projected to

somatosensory cortex

The parietal lobes → somatosensory processing



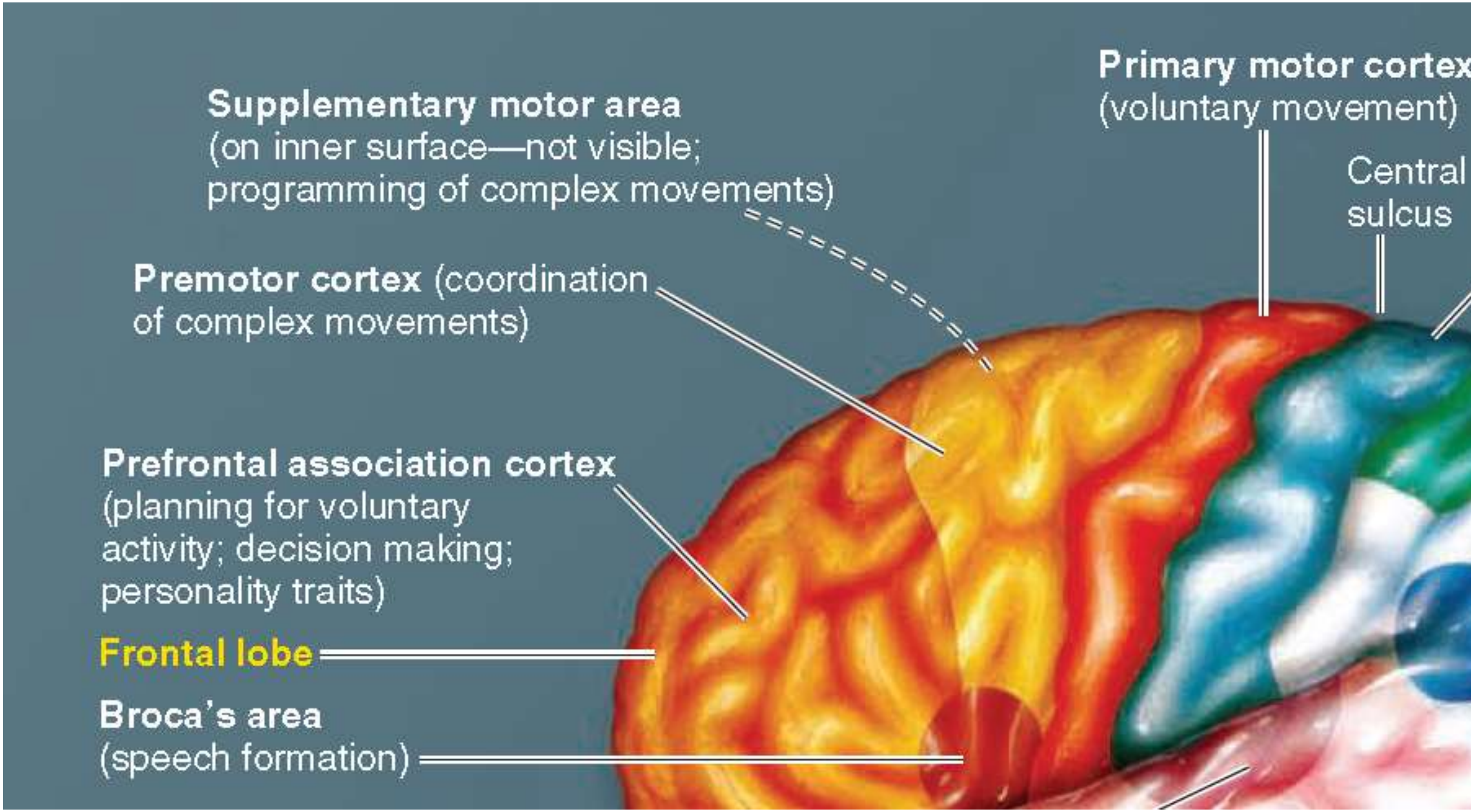
(b) Sensory homunculus

(c) Motor homunculus

● **FIGURE 5-9 Somatotopic maps of the somatosensory cortex and the primary motor cortex.** (a) Top view of cerebral hemispheres showing the somatosensory cortex and the primary motor cortex. (b) Sensory homunculus showing the distribution of sensory input to the somatosensory cortex from different parts of the body. The distorted graphic representation of the body parts indicates the relative proportion of the somatosensory cortex devoted to reception of sensory input from each area. (c) Motor homunculus showing the distribution of motor output from the primary motor cortex to different parts of the body. The distorted graphic representation of the body parts indicates the relative proportion of the primary motor cortex devoted to controlling skeletal muscles in each area.

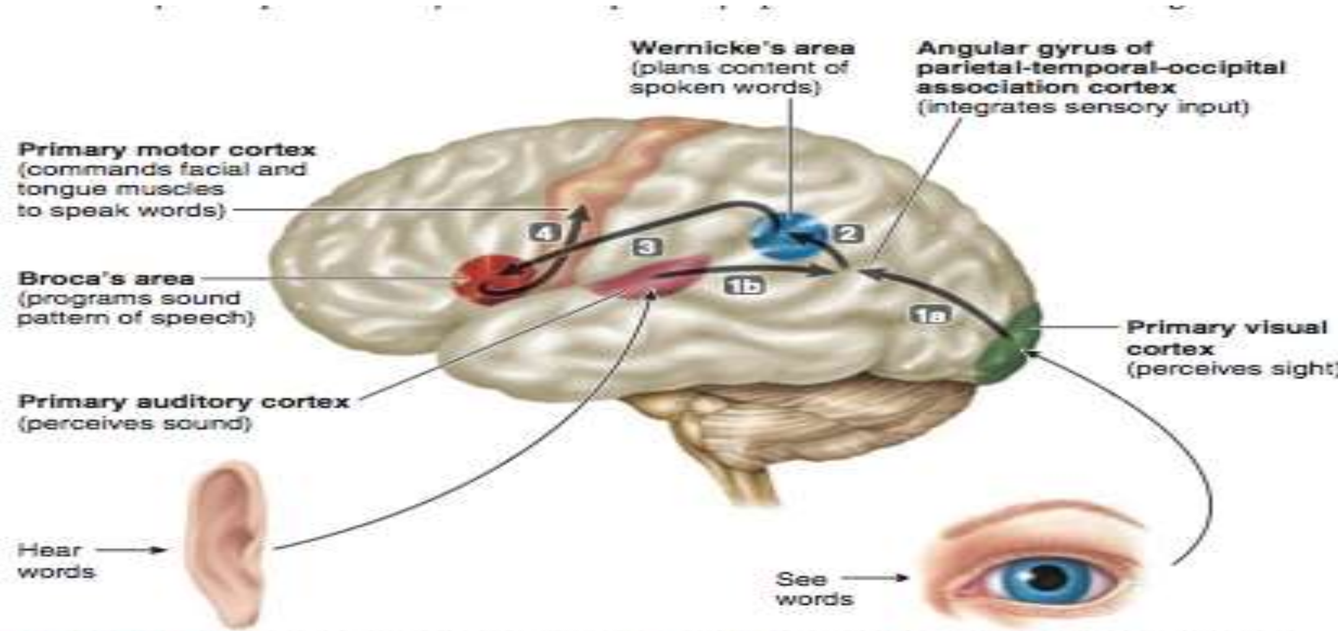
The somatosensory cortex on each side of the brain mostly receives sensory input from the opposite side of the body because most ascending pathways that carry sensory information up the spinal cord cross over to the opposite side before eventually terminating in the cortex

damage to the somatosensory cortex in the left hemisphere produces sensory deficits on the right side of the body, whereas sensory losses on the left side are associated with damage to the right half of the cortex.



The primary motor cortex located in the frontal lobes controls the skeletal muscles

the motor cortex on each
side of the brain primarily controls muscles on the opposite
side of the body.



● FIGURE 5-10 **Cortical pathway for speaking a word seen or heard.** The arrows and numbered steps show the pathway used to speak about something seen or heard. Similarly, appropriate muscles of the hand can be commanded to write the desired words.

Broca's area, which governs speaking ability, is located in the left frontal lobe in close association with the motor areas of the cortex that control the muscles necessary for speaking

Wernicke's area, located in the left cortex at the juncture of the parietal, temporal, and occipital lobes, is concerned with language comprehension. It plays a critical role in understanding both spoken and written messages.

There are three association areas:

(1) the prefrontal association cortex

(2) the parietal–temporal–occipital association cortex

(3) the limbic association cortex

The prefrontal association cortex → frontal lobe just ahead of the premotor cortex → "brainstorms" or thinks

- (1) planning for voluntary activity
- (2) decision making
- (3) creativity, and
- (4) personality traits.

The **parietal–temporal–occipital association cortex** lies at the interface of the three lobes for which it is named. In this strategic location, it pools and integrates somatic, auditory, and visual sensations projected from these three lobes for complex perceptual processing.

The **limbic association cortex** is located mostly on the bottom and adjoining inner portion of each temporal lobe. This area is concerned primarily with motivation and emotion and is extensively involved in memory.

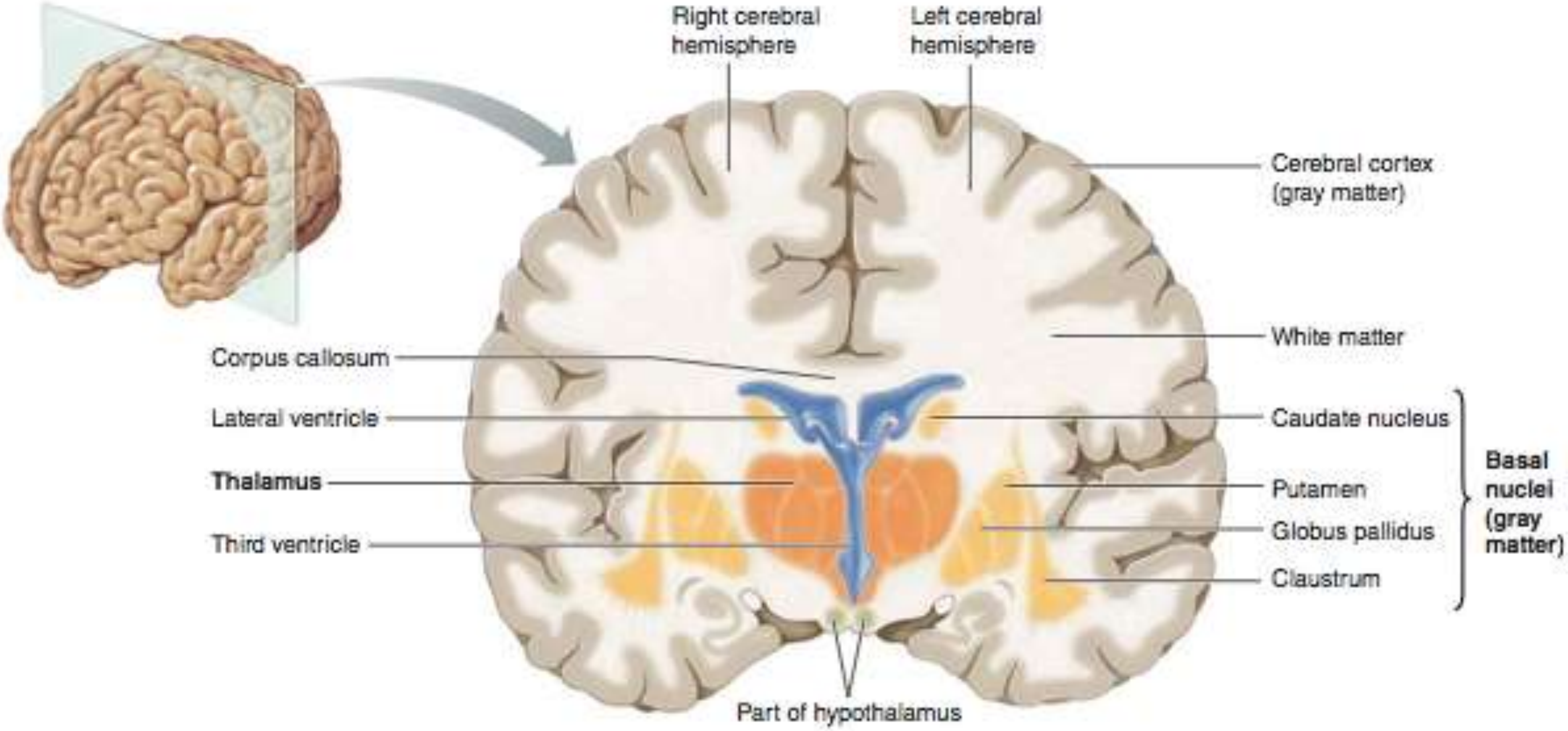
Basal Nuclei, Thalamus, and Hypothalamus

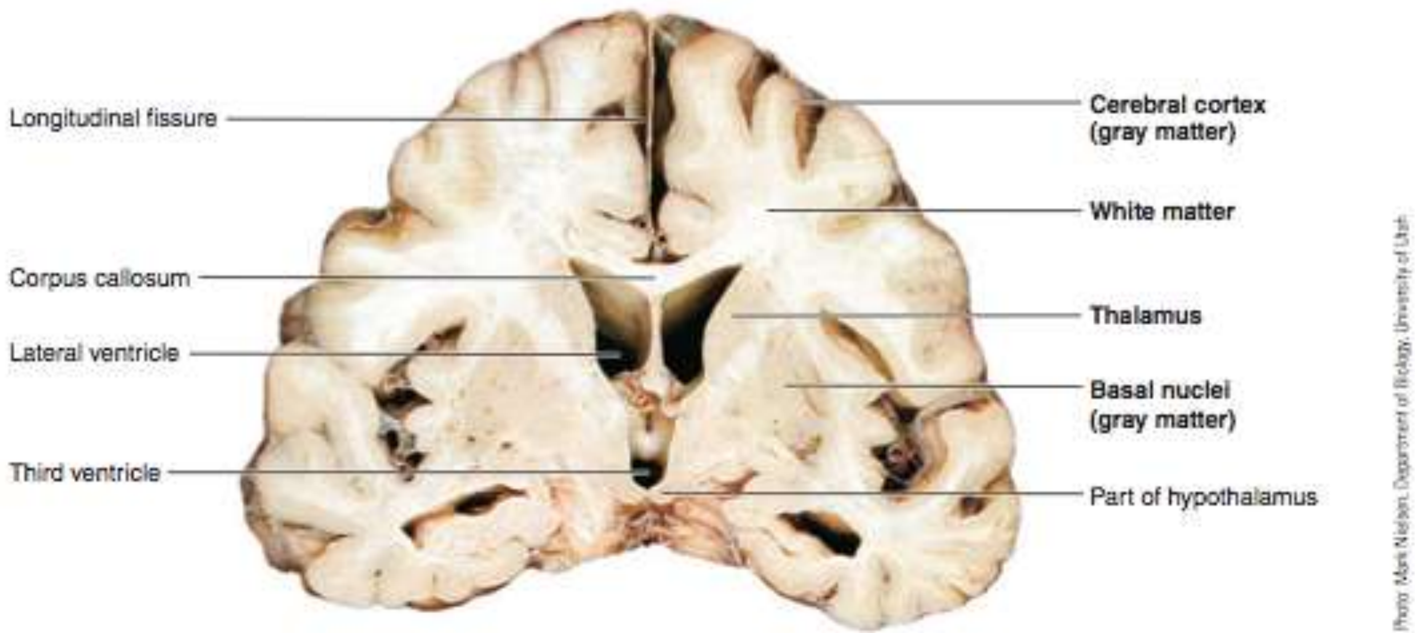
The basal nuclei play a complex role in controlling movement.

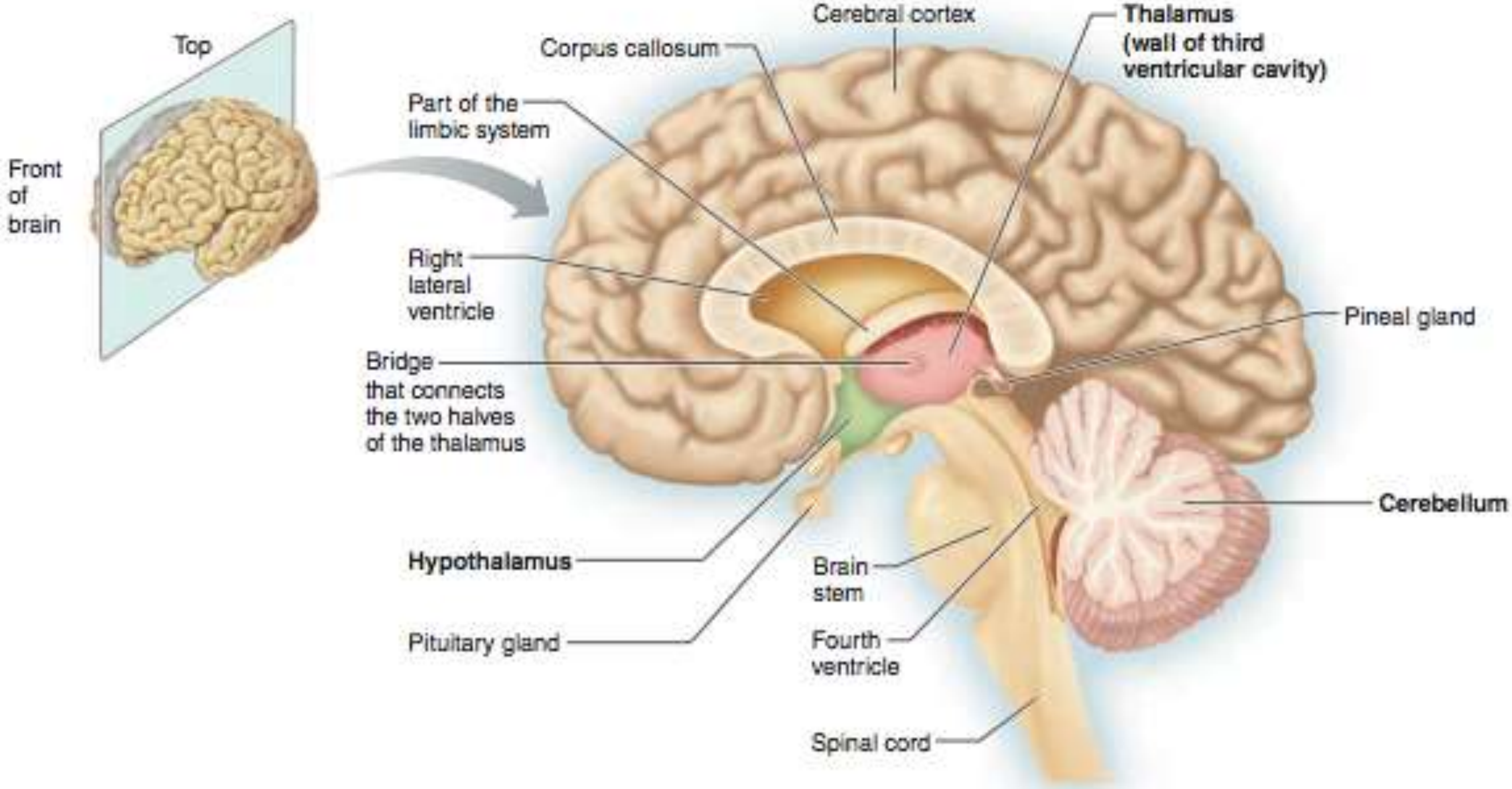
- (1) inhibiting muscle tone throughout the body ~ proper muscle tone
- (2) selecting and maintaining purposeful motor activity while suppressing useless or unwanted patterns of movement
- (3) helping monitor and coordinate slow, sustained contraction related to posture and support.

Parkinson's disease (PD) → gradual destruction of neurons that release dopamine in the basal Nuclei →

- (1) increased muscle tone, or rigidity
- (2) involuntary → resting tremors
- (3) slowness in initiating and carrying out different motor behaviors.


Right cerebral hemisphere
Left cerebral hemisphere
Cerebral cortex (gray matter)
White matter
Corpus callosum
Lateral ventricle
Caudate nucleus
Thalamus
Putamen
Globus pallidus
Third ventricle
Claustrum
Basal nuclei (gray matter)
Part of hypothalamus


Longitudinal fissure
Cerebral cortex (gray matter)
White matter
Corpus callosum
Thalamus
Lateral ventricle
Basal nuclei (gray matter)
Third ventricle
Part of hypothalamus
Photo: Mark Nielsen, Department of Biology, University of Utah



● FIGURE 5-13 **Location of the thalamus, hypothalamus, and cerebellum in sagittal section.**

Basal Nuclei, Thalamus, and Hypothalamus

The thalamus is a sensory relay station and is important in motor control.

The hypothalamus →

(1) controls body temperature

(2) controls thirst and urine output

(3) controls food intake

(4) controls anterior pituitary hormone secretion

Basal Nuclei, Thalamus, and Hypothalamus

(5) produces posterior pituitary hormones
(6) controls uterine contractions and milk ejection
(7) serves as a major autonomic nervous system coordinating center, which in turn affects all smooth muscle, cardiac muscle, and exocrine glands
(8) plays a role in emotional and behavioral patterns; and
(9) participates in the sleep–wake cycle.

EMOTION. BEHAVIOR, MOTIVATION

The limbic system plays a key role in emotion.

Emotional feelings and moods, overt physical responses associated with these feelings, and observable emotional expressions

Certain regions of the limbic system have been designated as “reward” and “punishment” centers, because stimulation in these respective areas gives rise to pleasant or unpleasant sensations.

EMOTION. BEHAVIOR, MOTIVATION

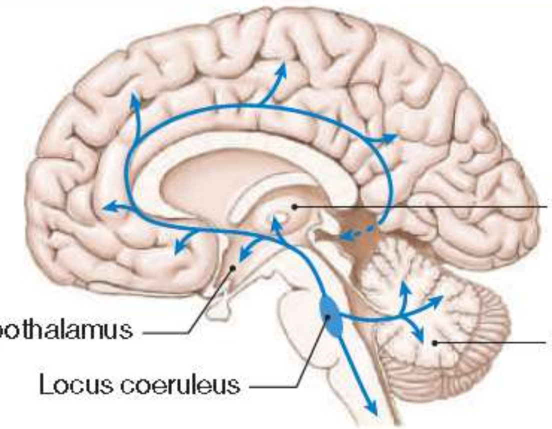
The behavioral state system is an important modulator of sensory and cognitive processing. Many neurons in the behavioral state system are found in regions of the brain outside the cerebral cortex, including parts of the reticular formation in the brain stem, the hypothalamus, and the limbic system

The neurons collectively known as the **diffuse modulatory systems** originate in the reticular formation in the brain stem and project their axons to large areas of the brain (F 9.16). There are four modulatory systems that are generally classified according to the neurotransmitter they secrete: *noradrenergic* (norepinephrine), *serotonergic* (serotonin), *dopaminergic* (dopamine), and *cholinergic* (acetylcholine). The diffuse modulatory systems regulate brain function by influencing attention, motivation, wakefulness, memory, motor control, mood, and metabolic homeostasis.

FIG. 9.16 Diffuse modulatory systems

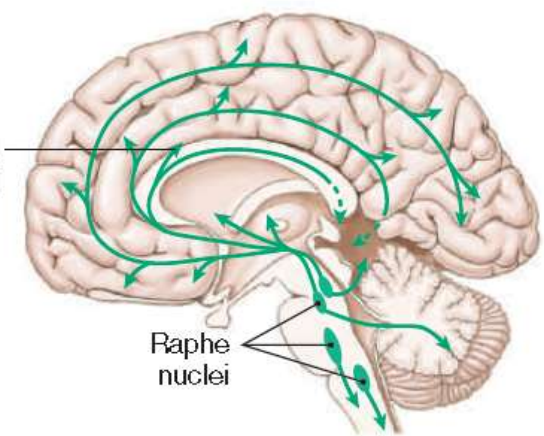
The neurons collectively known as the diffuse modulatory systems originate in the reticular formation of the brain stem and project their axons to large areas of the brain. The four systems are named for their neurotransmitters.

(a) Noradrenergic (Norepinephrine)



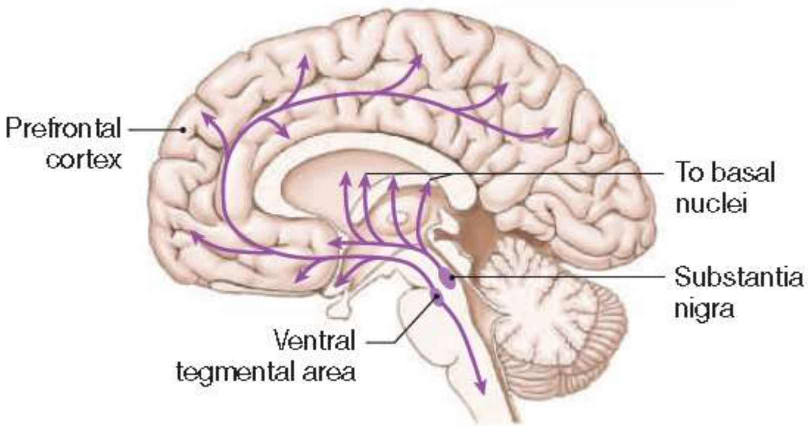
Functions:	Attention, arousal, sleep-wake cycles, learning, memory, anxiety, pain, and mood
Neurons Originate:	Locus coeruleus of the pons
Neurons Terminate:	Cerebral cortex, thalamus, hypothalamus, olfactory bulb, cerebellum, midbrain, spinal cord

(b) Serotonergic (Serotonin)



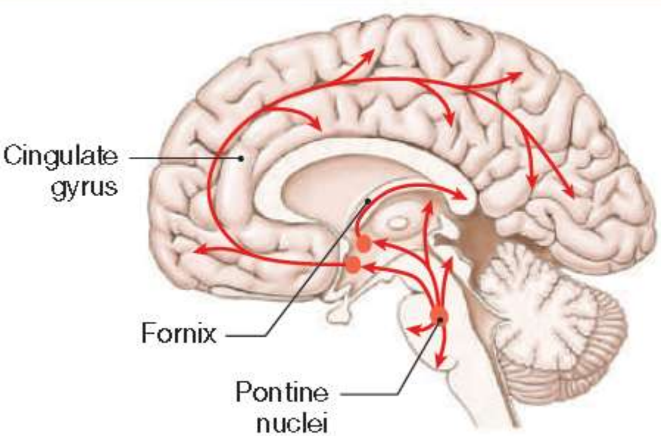
Functions:	1. Lower nuclei: Pain, locomotion 2. Upper nuclei: Sleep-wake cycle; mood and emotional behaviors, such as aggression and depression
Neurons Originate:	Raphe nuclei along brain stem midline
Neurons Terminate:	1. Lower nuclei project to spinal cord 2. Upper nuclei project to most of brain

(c) Dopaminergic (Dopamine)



Functions:	1. Motor control 2. "Reward" centers linked to addictive behaviors
Neurons Originate:	1. Substantia nigra in midbrain 2. Ventral tegmentum in midbrain
Neurons Terminate:	1. Cortex 2. Cortex and parts of limbic system

(d) Cholinergic (Acetylcholine)



Functions:	Sleep-wake cycles, arousal, learning, memory, sensory information passing through thalamus
Neurons Originate:	Base of cerebrum; pons and midbrain
Neurons Terminate:	Cerebrum, hippocampus, thalamus

LEARNING AND MEMORY

Short-term memory and long-term memory involve different molecular mechanisms.

- Short-term memory :

  - transient modifications in the function of preexisting synapses → amount of neurotransmitter released in response to stimulation

  - temporary increased responsiveness of the postsynaptic cell to the neurotransmitter within affected nerve pathways.

- Long-term memory storage :

  - activation of specific genes that control synthesis of proteins → structural or functional changes at specific synapses.

  - permanent physical changes in the brain.

▲Table 5-2 Comparison of Short-Term and Long-Term Memory

Characteristic	Short-Term Memory	Long-Term Memory
Time of storage after acquisition of new information	Immediate	Later; must be transferred from short-term to long-term memory through consolidation; enhanced by practice or recycling of information through short-term mode
Duration	Lasts for seconds to hours	Retained for days to years
Capacity of storage	Limited	Very large
Retrieval time (remembering)	Rapid retrieval	Slower retrieval, except for thoroughly ingrained memories, which are rapidly retrieved
Inability to retrieve (forgetting)	Permanently forgotten; memory fades quickly unless consolidated into long-term memory	Usually only transiently unable to access; relatively stable memory trace
Mechanism of storage	Involves transient modifications in functions of preexisting synapses, such as altering the amount of neurotransmitter released	Involves relatively permanent functional or structural changes between existing neurons, such as the formation of new synapses; synthesis of new proteins plays a key role

LEARNING AND MEMORY

Amnesia

retrograde (meaning "going backward") amnesia → inability to recall recent past events -- traumatic event → interferes with electrical activity of the brain, such as a concussion or stroke.

Anterograde (meaning "going forward") amnesia → inability to consolidate memory in long-term storage for later retrieval → lesions of the medial portions of the temporal lobes, which are generally considered critical regions for memory consolidation.

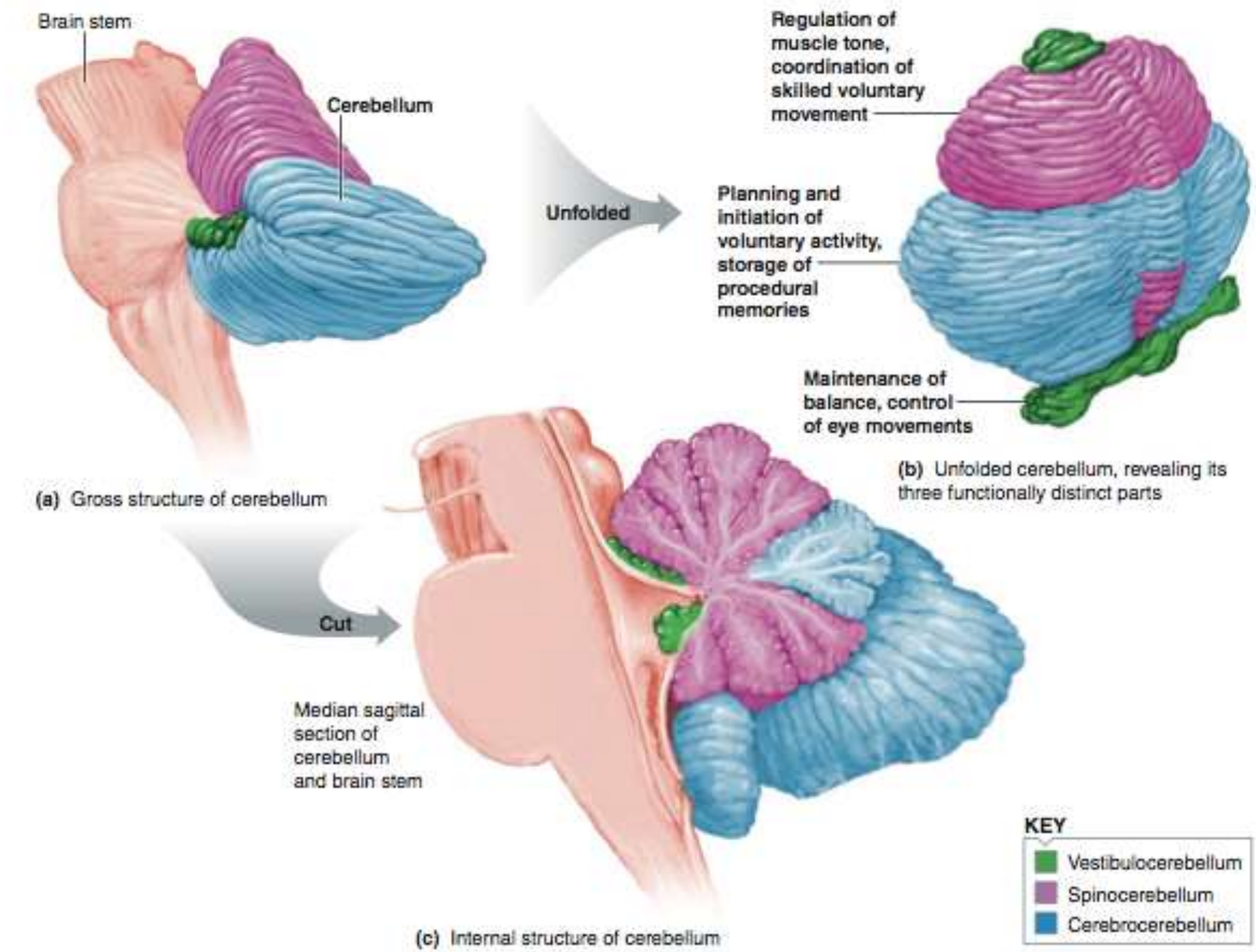
Cerebellum

Specifically, the different parts of the cerebellum perform the following functions:

1. The vestibulocerebellum → maintaining balance and controls eye movements.

2. The spinocerebellum → muscle tone and coordinates skilled, voluntary movements.

3. The cerebrocerebellum → planning and initiating voluntary activity by providing input to the cortical motor areas, stores procedural memories.



● FIGURE 5-15 **Cerebellum.**

BRAIN STEM

Consists of

- ➔ medulla
- ➔ Pons
- ➔ Midbrain

Functions :

1. Most of the 12 pairs of **cranial nerves** arise from the brain stem.
2. Collected within the brain stem are neuronal clusters or **centers** that control heart and blood vessel function, respiration, and many digestive activities
3. The brain stem helps regulate muscle reflexes involved in equilibrium and posture.
4. A widespread network of interconnected neurons called the **reticular formation** runs throughout the entire brain stem and into the thalamus.
5. The centers that govern sleep are housed within the brain stem and the hypothalamus.

TABLE 5-3 Functions of Cranial Nerves

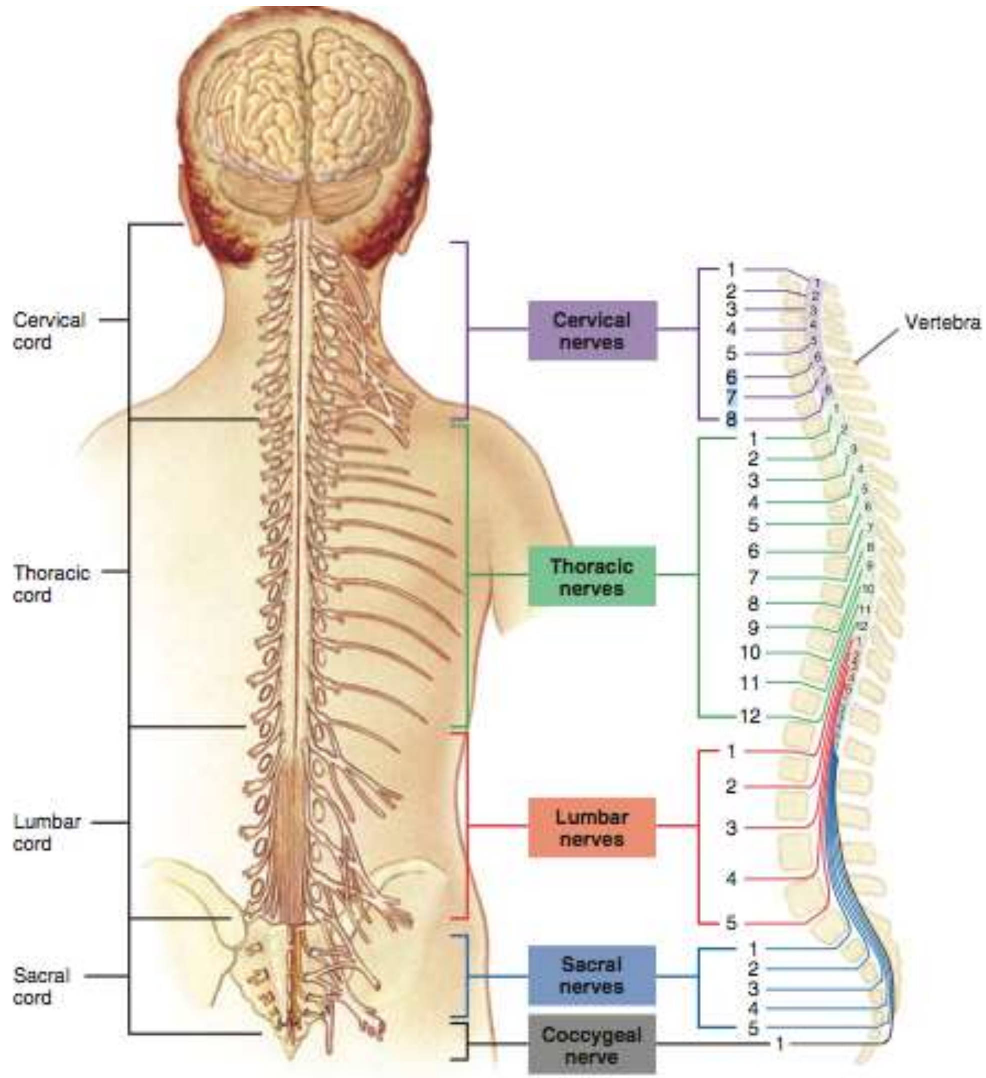
Number	Name	Fiber Types	Functions
I	Olfactory	Sensory	⊠ Smell
II	Optic	Sensory	⊠ Vision
III	Oculomotor	Mixed (mainly motor)	⊠ Eyeball and eyelid movement, pupil constriction, change of lens shape for near vision.
			⊠ Proprioception (awareness of position of body parts)
IV	Trochlear	Mixed (mainly motor)	⊠ Eyeball movement
			⊠ Proprioception
V	Trigeminal	Mixed	⊠ Chewing
			⊠ Somatic sensations (touch, pressure, pain, and temperature) of face and mouth
VI	Abducens	Mixed (mainly motor)	⊠ Eyeball movement
			⊠ Proprioception
VII	Facial	Mixed	⊠ Facial expression, secretion of saliva and tears
			⊠ Taste from front of tongue
VIII	Vestibulocochlear	Sensory	⊠ Hearing, sense of equilibrium
IX	Glossopharyngeal	Mixed	⊠ Swallowing, secretion of saliva
			⊠ Taste from back of tongue, somatic sensation of oral cavity, blood-pressure monitoring
X	Vagus	Mixed	⊠ Efferent output for skeletal muscles of pharynx (throat) and larynx (voice box) and for smooth muscle and glands of thoracic and abdominal organs and for cardiac muscle of heart
			⊠ Afferent input from thoracic and abdominal organs, blood-pressure monitoring
XI	Accessory	Motor	⊠ Efferent output for skeletal muscles of pharynx, larynx, neck, and shoulder
XII	Hypoglossal	Motor	⊠ Tongue movement

⊠ Carried by afferent fibers ⊠ Carried by efferent fibers

SPINAL CORD

The spinal cord is responsible for the integration of many basic reflexes. The spinal cord is strategically located between the brain and the afferent and efferent fibers of the PNS; this location enables the spinal cord to fulfill its two primary functions:

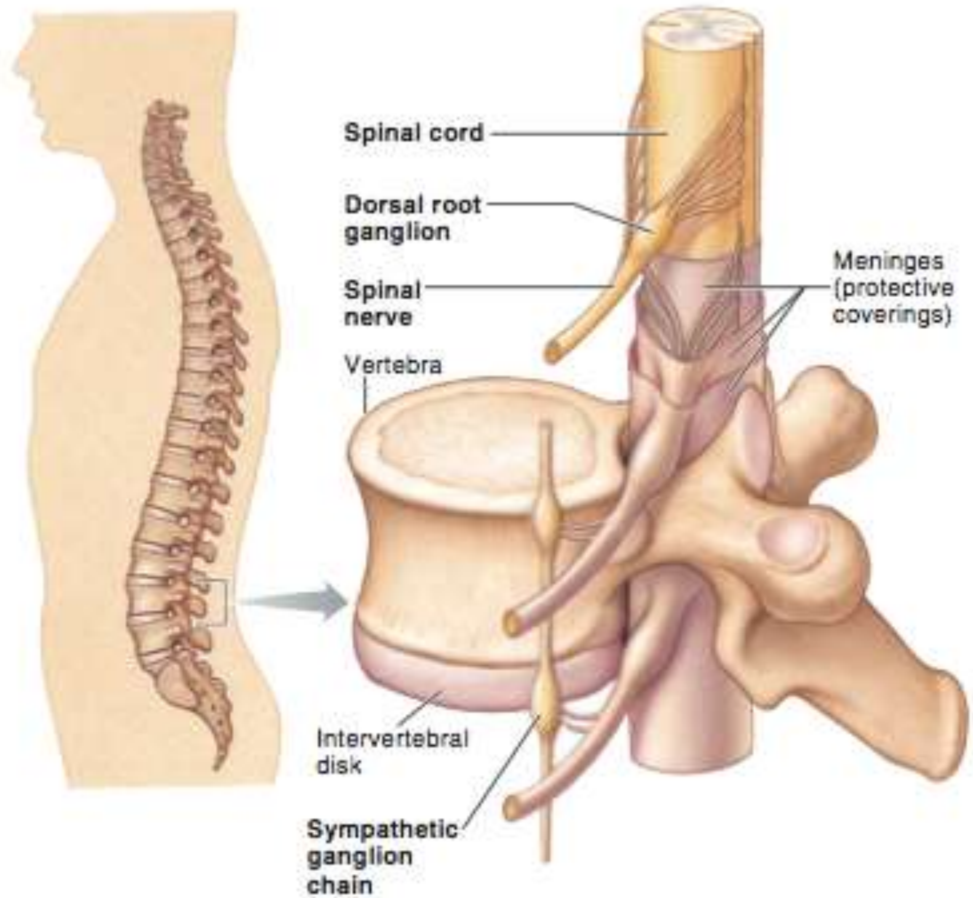
(1) serving as a link for transmission of information between the brain and the remainder of the body and (2) integrating reflex activity between afferent input and efferent output without involving the brain. This type of reflex activity is called a spinal reflex.



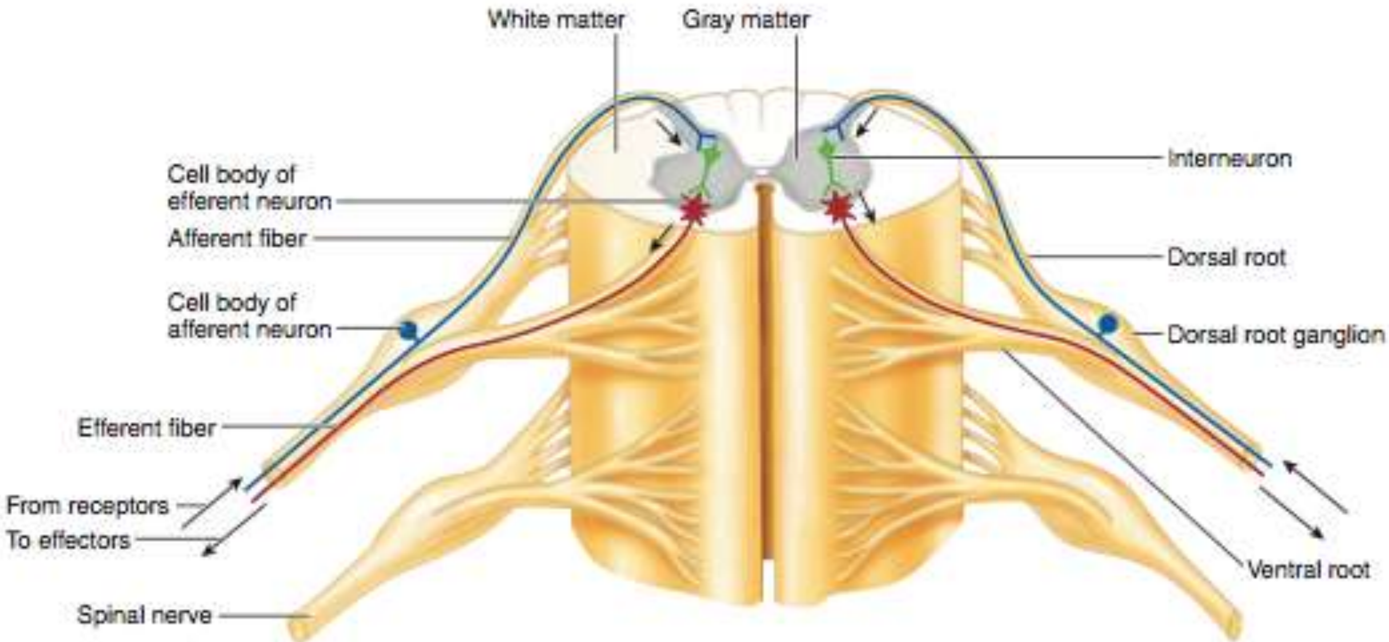
(a) Posterior view of spinal cord

(b) Lateral view of spinal cord

• FIGURE 5-19 **Spinal nerves.** The 31 pairs of spinal nerves are named according to the region of the vertebral column from which they emerge. Because the spinal cord is shorter than the vertebral column, spinal nerve roots must descend along the cord before emerging from the vertebral column at the corresponding intervertebral space, especially those beyond the level of the first lumbar vertebra (L1). (a) Posterior view of the brain, spinal cord, and spinal nerves (on the right side only). (b) Lateral view of the spinal cord and spinal nerves emerging from the vertebral column.



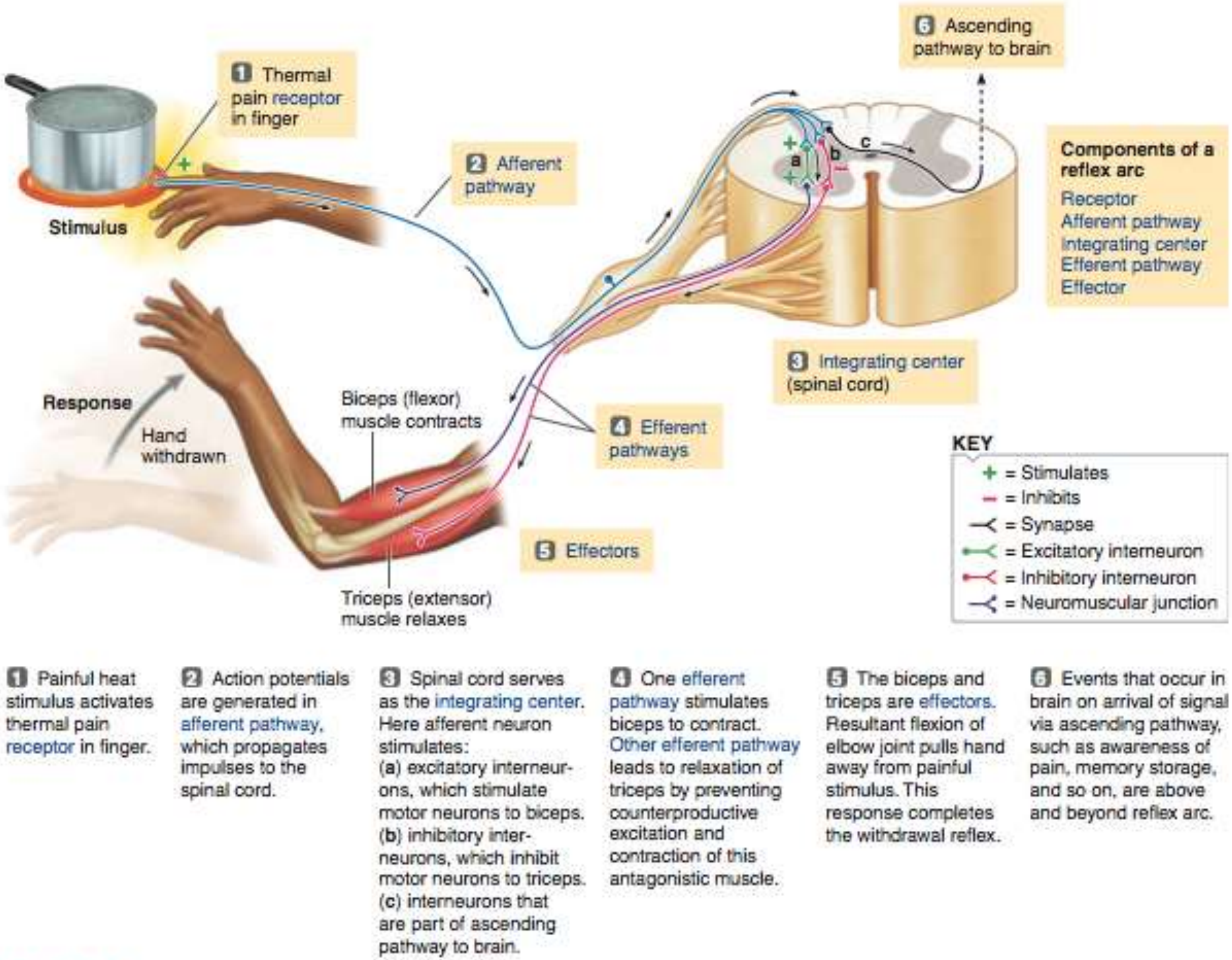
● FIGURE 5-18 Location of the spinal cord relative to the vertebral column.



● FIGURE 5-20 **Spinal cord in cross section.** The afferent fibers enter through the dorsal root, and the efferent fibers exit through the ventral root. Afferent and efferent fibers are enclosed together within a spinal nerve.

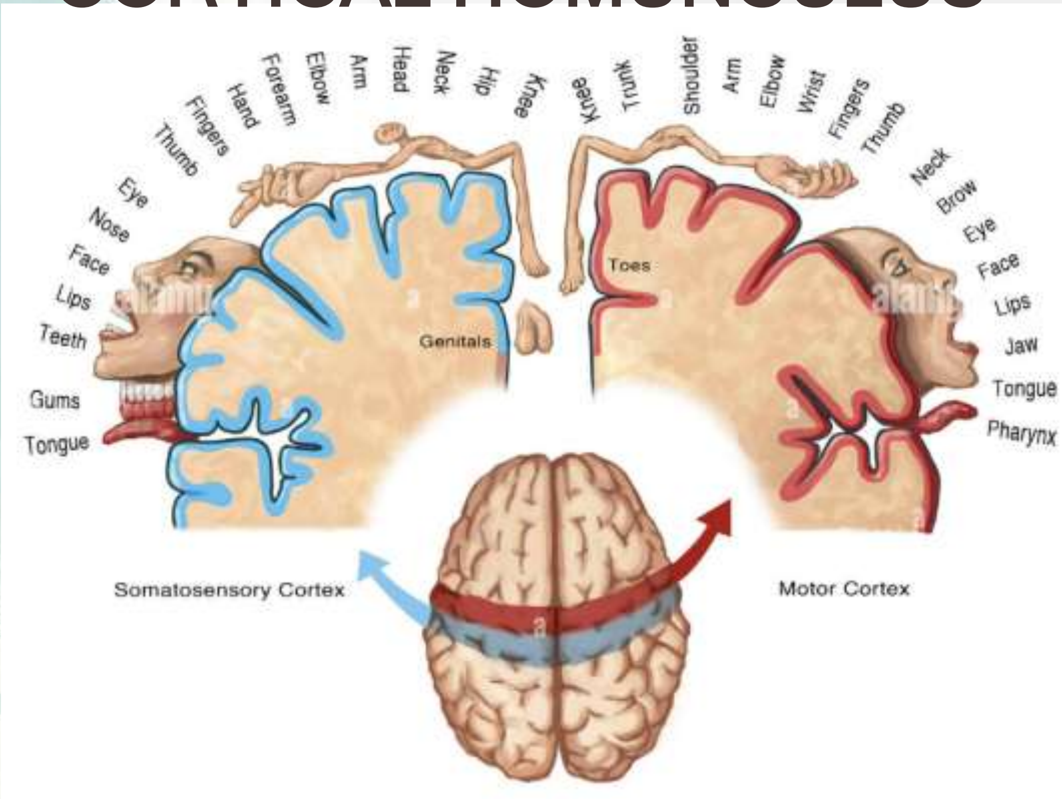
A reflex is any response that occurs automatically without conscious effort. There are two types of reflexes:

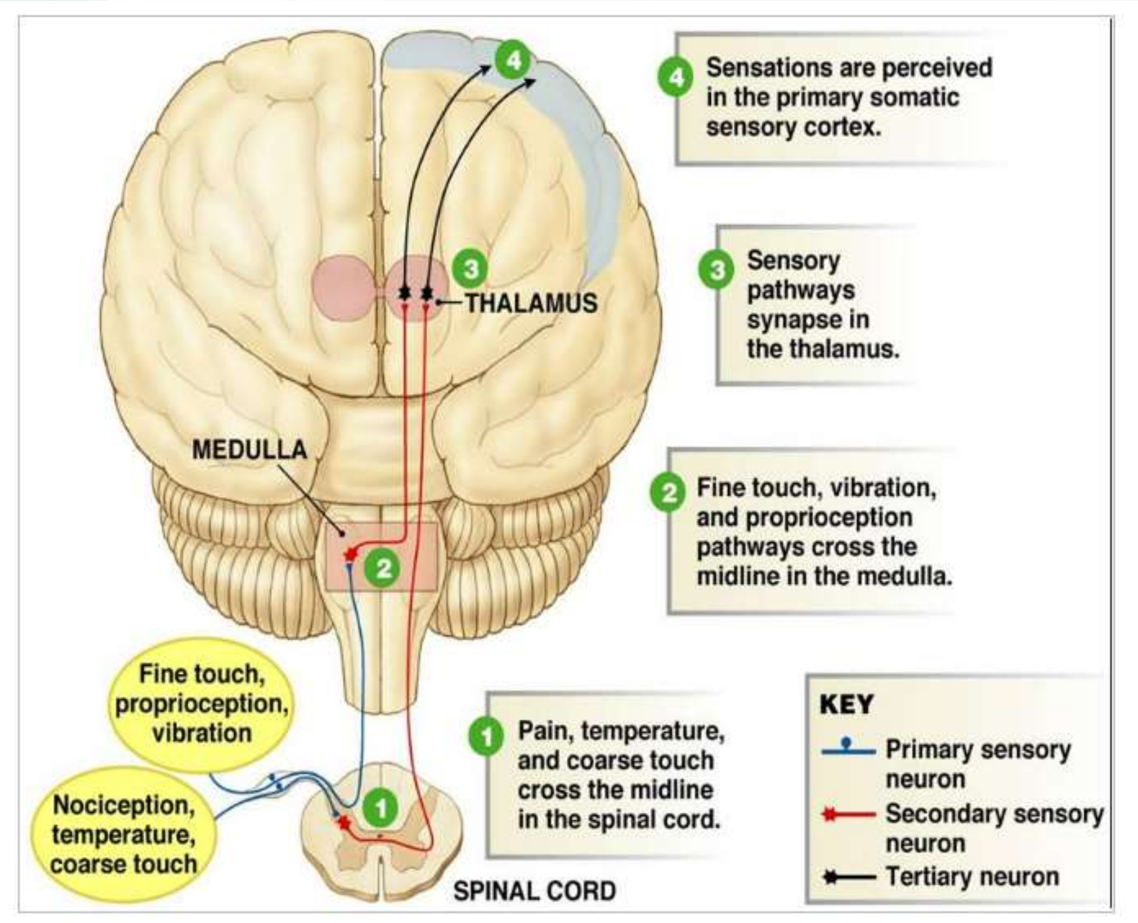
- (1) Simple, or basic, reflexes are built-in, unlearned responses, such as pulling the hand away from a burning hot object,
- (2) acquired, or conditioned, reflexes are a result of practice and learning, such as a pianist striking a particular key on seeing a given note on the music staff. The musician reads music and plays the notes automatically, but only after considerable conscious training effort.



● **FIGURE 5-21 The withdrawal reflex.**

CORTICAL HOMUNCULUS





Sensory pathways crosses the body's midline


PAIN

Definition of Pain

- Unpleasant sensory and emotional experience associated with actual or potential tissue damage.(IASP)
- Pain serves as important protective function, alerting us to injuries that required evasion or treatment
- Perception of pain is Subjective and influence by many factors.

Ganong, Review of Medical Physiology, 23rd ed,2010

Classification of Pain

- Based on Pathophysiology
  - ❖Nociceptive pain
    - Transient pain in response to noxious stimulus
    - Arises from a stimulus outside of the nervous system
    - Pain proportionate to the stimulation of nociceptors
    - Serves as a protective function
  - ❖Inflammatory pain
    - Initiated by tissue damage and/or inflammation
    - Arises from a stimulus that is outside of the nervous system
    - Spontaneous pain and hypersensitivity to noxious stimulus
    - Disproportionate to the stimulation of nociceptors
    - Serves no protective function
  - ❖Neuropathic pain
    - Initiated or caused by a primary lesion or dysfunction in the nervous system
    - No nociceptive stimulation
    - Disproportionate to the stimulation of receptors
    - Other evidence of nerve damage (eg, postherpetic neuralgia)

Woolf CJ. Ann Intern Med. 2004;140:441-451

Classification of Pain

Based on Pain duration

ACUTE PAIN

- Physiologic pain
- Sudden onset
- Recedes during the healing process
- "good Pain" as it serves an important protective mechanism
- pain of less than 3 to 6 months duration

CHRONIC PAIN

- Can result from nerve injuries (neuropathic pain)
- pain lasting for more than 3-6 months
- persisting beyond the course of an acute disease, or after tissue healing is complete

TABLE 6-2 Characteristics of Pain

Fast Pain	Slow Pain
Occurs on stimulation of mechanical and thermal nociceptors	Occurs on stimulation of polymodal nociceptors
Carried by small, myelinated A-delta fibers	Carried by small, unmyelinated C fibers
Produces sharp, prickling sensation	Produces dull, aching, burning sensation
Easily localized	Poorly localized
Occurs first	Occurs second; persists for longer time; more unpleasant

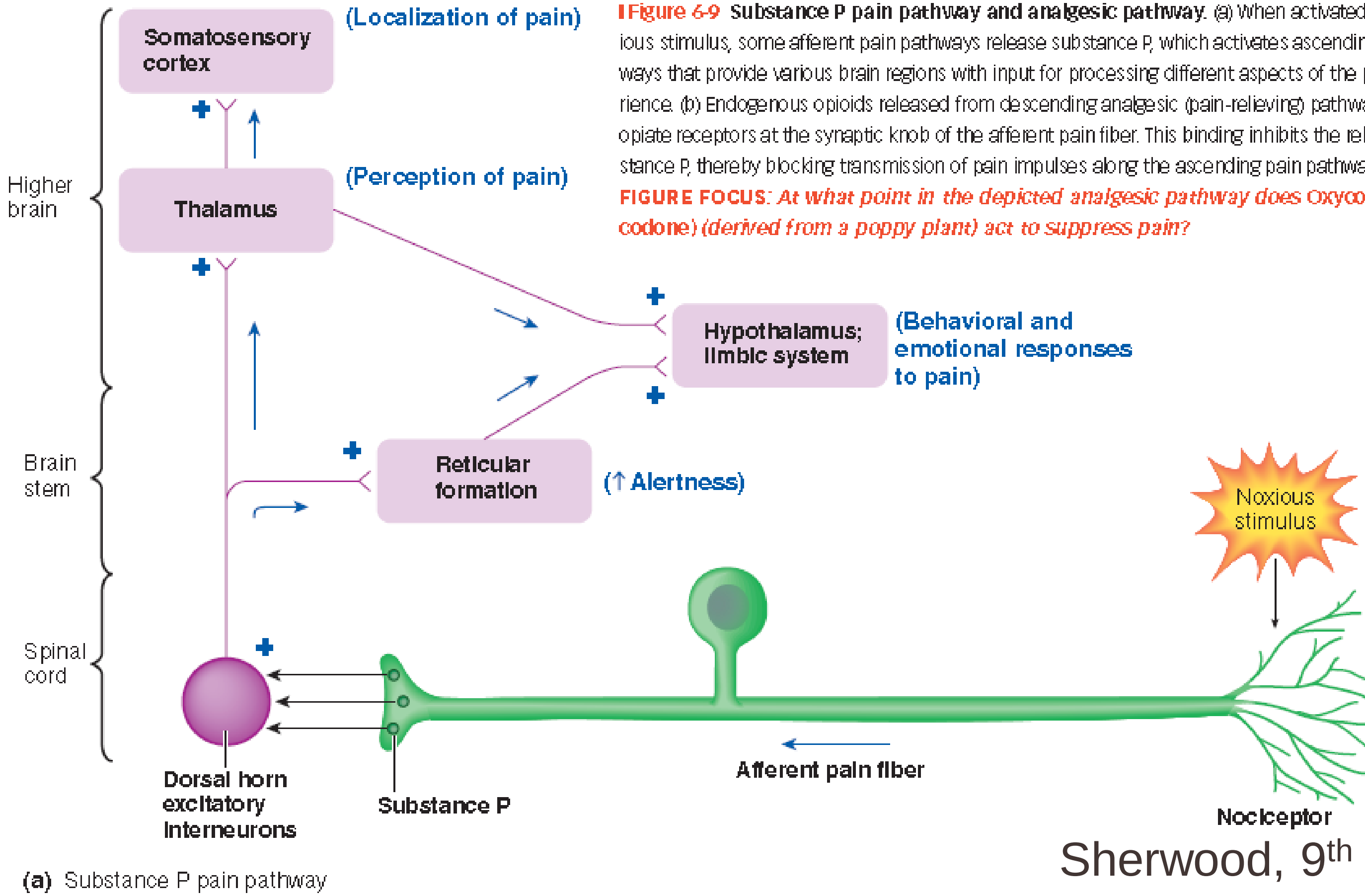
Sherwood, Principles of Human Physiology, 7th ed

Classes of Somatosensory Nerve Fibers

Table 10.3

Fiber Type	Fiber Characteristics	Speed of Conduction	Associated With
Aβ (beta)	Large, myelinated	30–70 m/sec	Mechanical stimuli
Aδ (delta)	Small, myelinated	12–30 m/sec	Cold, fast pain, mechanical stimuli
C	Small, unmyelinated	0.5–2 m/sec	Slow pain, heat, cold, mechanical stimuli

Silverthorne, Human Physiology Integrated Approach, 6th ed, 2013

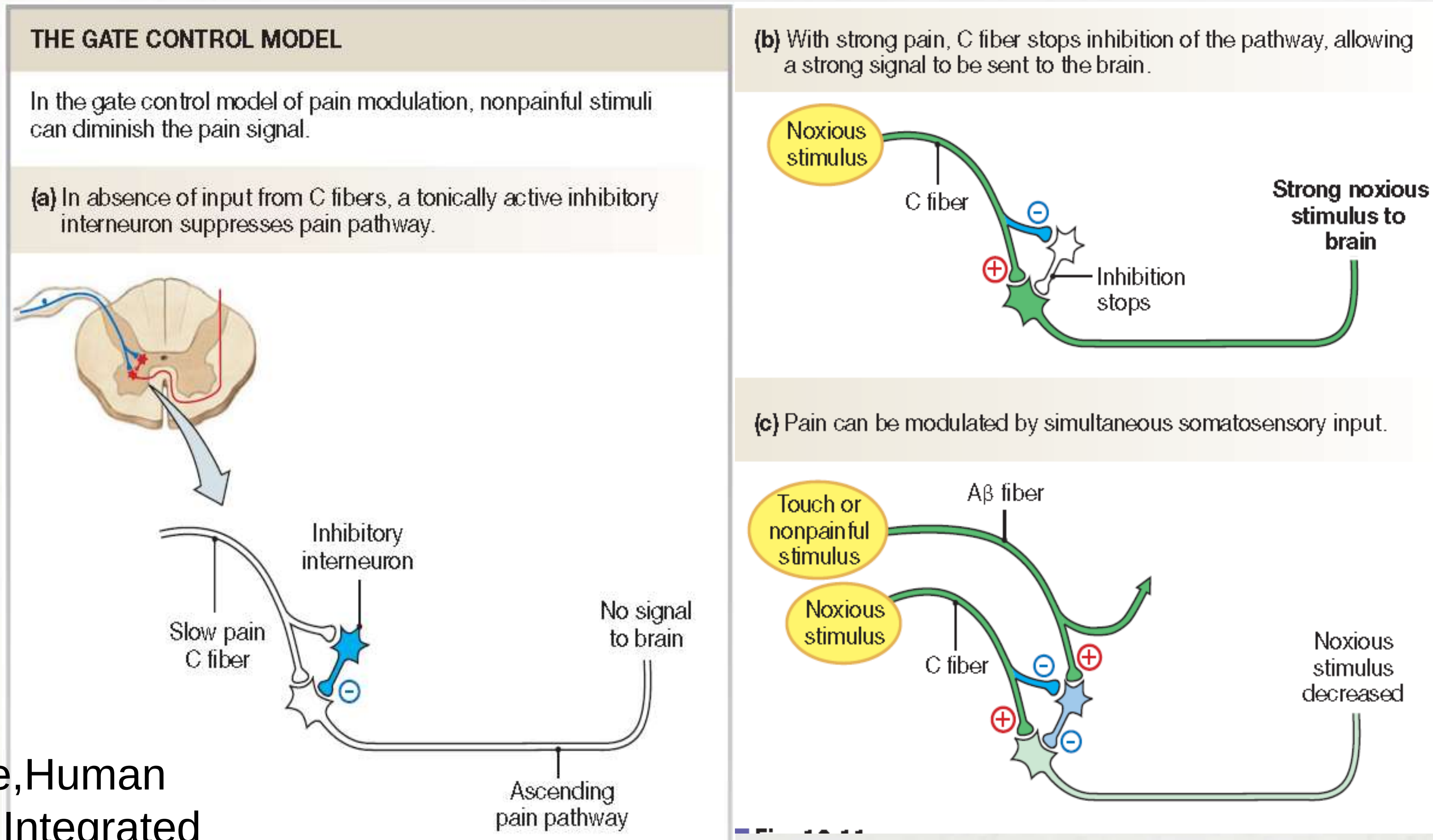


(a) Substance P pain pathway

Figure 6-9 Substance P pain pathway and analgesic pathway. (a) When activated by a noxious stimulus, some afferent pain pathways release substance P, which activates ascending pain pathways that provide various brain regions with input for processing different aspects of the painful experience. (b) Endogenous opioids released from descending analgesic (pain-relieving) pathways bind with opiate receptors at the synaptic knob of the afferent pain fiber. This binding inhibits the release of substance P, thereby blocking transmission of pain impulses along the ascending pain pathways.

FIGURE FOCUS: *At what point in the depicted analgesic pathway does Oxycontin (oxycodone) (derived from a poppy plant) act to suppress pain?*

Sherwood, 9th ed,2016

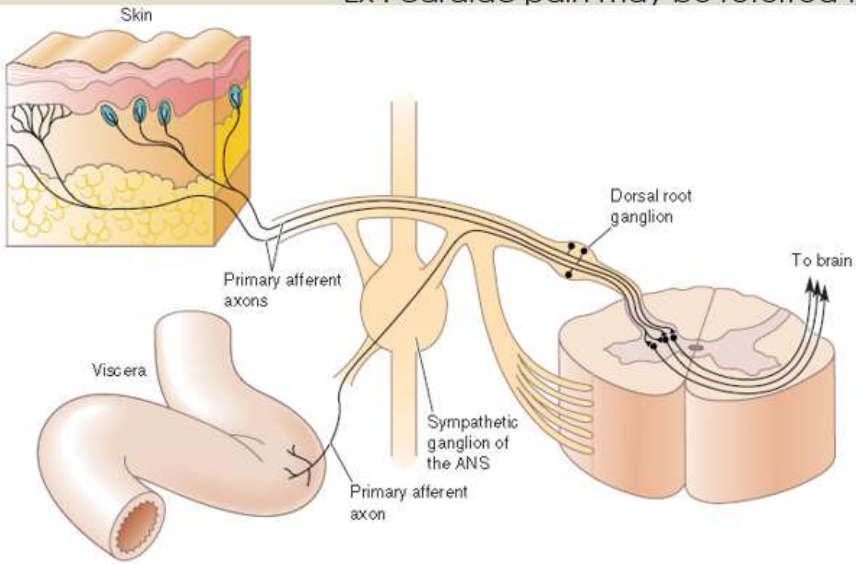


Silverthorne,Human Physiology Integrated Approach, 6th ed, 2013

REFERRED PAIN

Irritation of viceral organ frequently produces pain that is feel not at that site but in some somatic structure that may be considerable distant away.

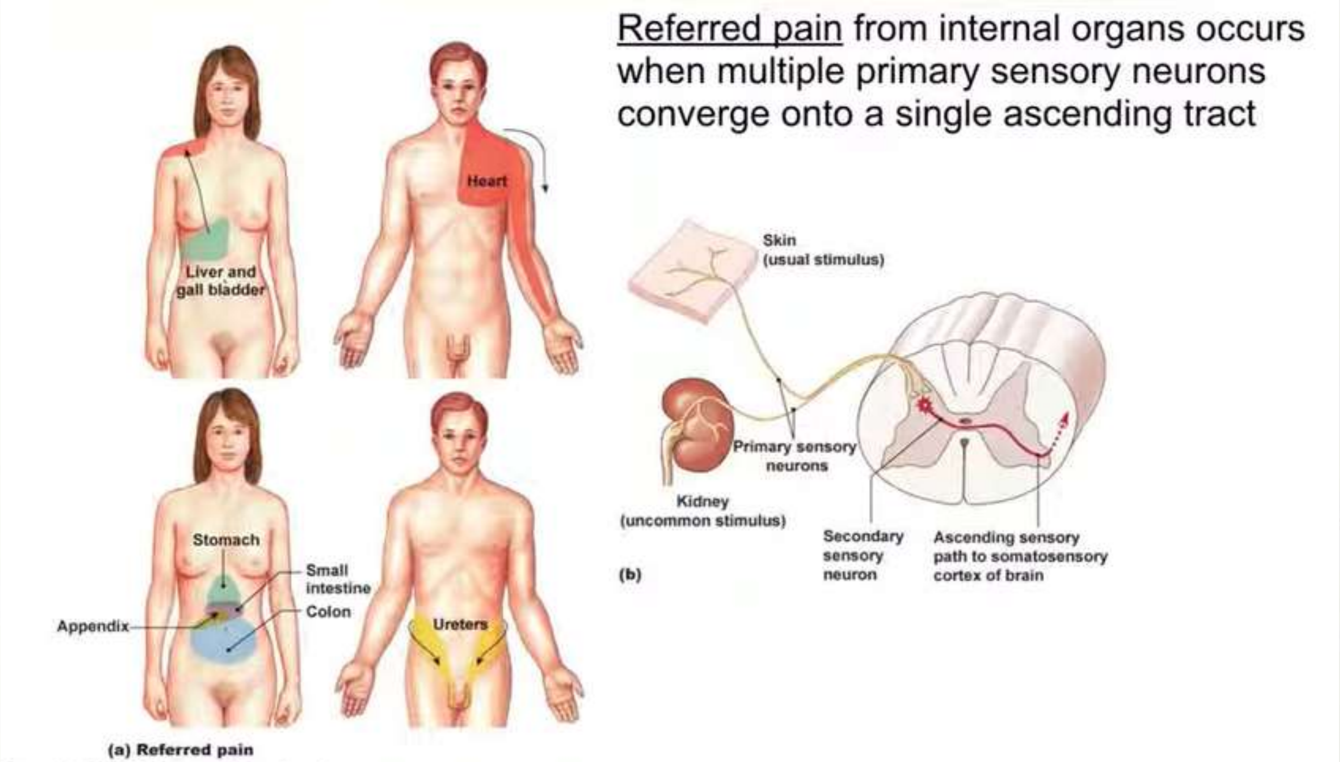
Ex : cardiac pain may be referred to the right arm.



▲ FIGURE 12.29
The convergence of nociceptor input from the viscera and the skin.

Bear,Neuroscience Exploring The Brain, 4th ed,2016

Referred Pain



Allodynia

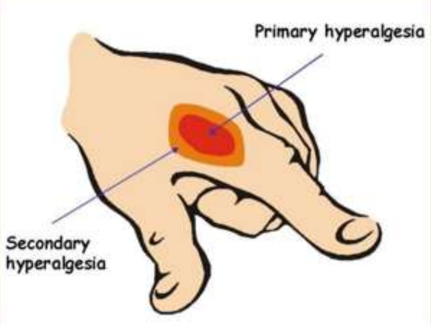
Patient with allodynia feel pain in response to stimuli that normally innocuous

Example :

- the movement of joints in patients with rheumatoid arthritis
- by the act of getting out of bed in the morning after a vigorous workout

Hyperalgesia

an exaggerated response to noxious stimuli—typically report persistent pain in the absence of sensory stimulate




THANK
YOU!