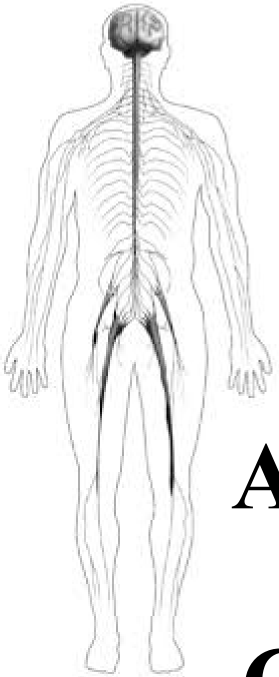
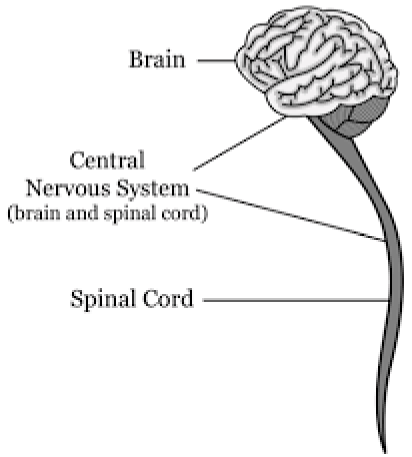


ANATOMY AND PHYSIOLOGY OF CENTRAL NERVOUS SYSTEM

Course Name: Anatomy and Physiology 2
Course Code: 0521215
Lecturer: Ms. Asma El-Shara'. MPH
Faculty Of Pharmacy,
Philadelphia University-Jordan

جامعـــــــة فيلادلفيـــــا
Philadelphia University



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Spinal Cord Anatomy: *Protective layers*

- ✓The first layer of protection for the central nervous system is **the hard bony skull and vertebral column**. The skull encases the brain and the vertebral column surrounds the spinal cord, providing strong protective defenses against damaging blows or bumps.
- ✓The second protective layer is the **meninges**, three membranes that lie between the bony encasement and the nervous tissue in both the brain and spinal cord.
- ✓Finally, a space between two of the meningeal membranes contains cerebrospinal fluid, a buoyant liquid that suspends the central nervous tissue in a weightless environment while surrounding it with a shock-absorbing, hydraulic cushion.

MENINGES

- The **meninges** (me-NIN-jēz; singular is meninx [MĒ -ninks]) are three protective, connective tissue coverings that encircle the spinal cord and brain.
- From superficial to deep they are:

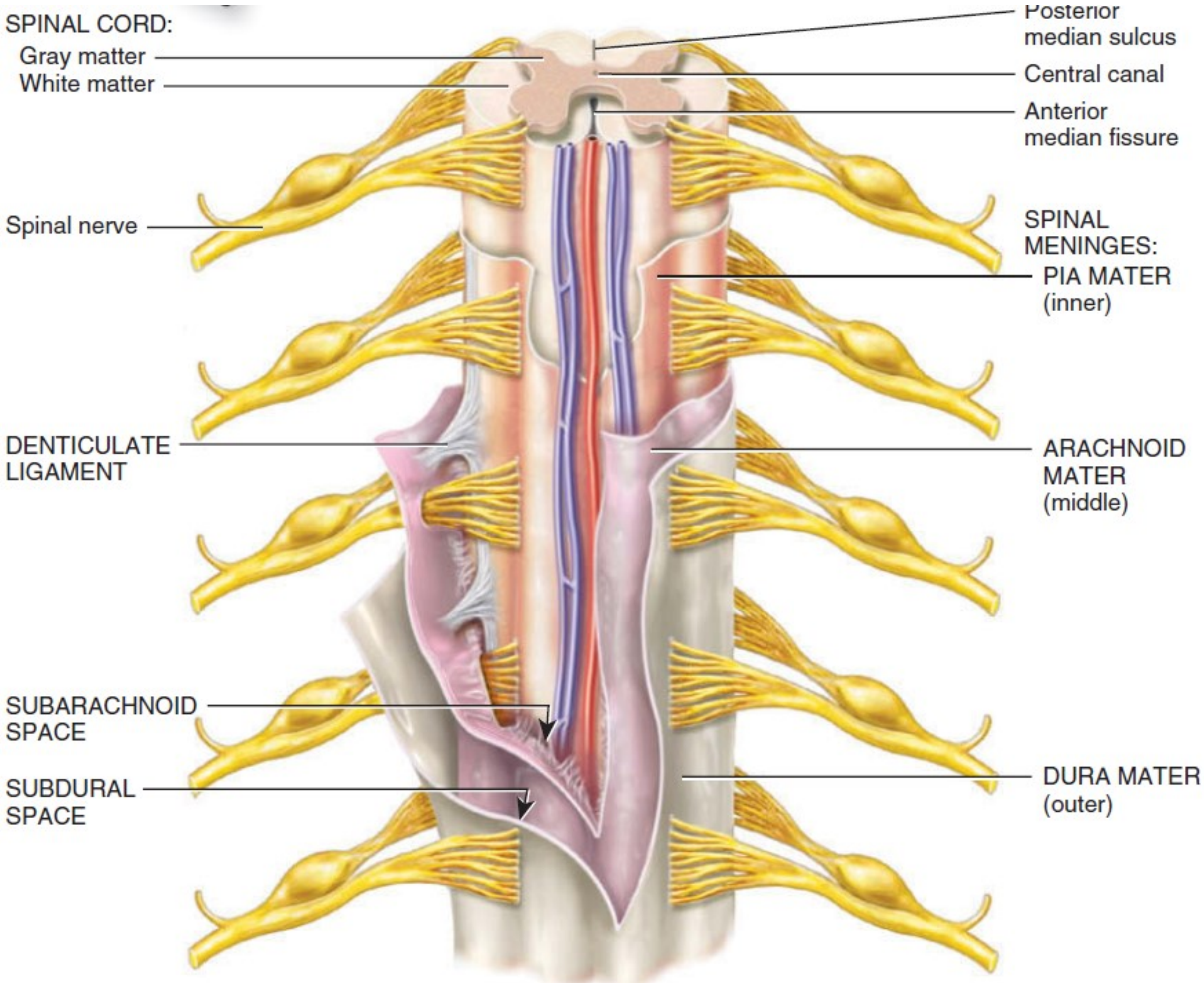
(1) <u>Dura mater</u>→ The most superficial of the three spinal meninges is a thick strong layer composed of dense irregular connective tissue.

(2) <u>Arachnoid mater</u>→ This layer, the middle of the meningeal membranes, is a thin, avascular covering comprised of cells and thin, loosely arranged collagen and elastic fibers. It is called the arachnoid mater because of its spider's web arrangement of delicate collagen fibers and some elastic fibers. Between the dura mater and the arachnoid mater is a thin **subdural space,** which contains interstitial fluid.

(3) <u>Pia mater</u>→ This innermost meninx is a thin transparent connective tissue layer that adheres to the surface of the spinal cord and brain. It consists of thin squamous to cuboidal cells within interlacing bundles of collagen fibers and some fine elastic fibers. Within the pia mater are many blood vessels that supply oxygen and nutrients to the spinal cord. Between the arachnoid mater and pia mater is a space, the **subarachnoid space,** which contains shock-absorbing cerebrospinal fluid.

- All three spinal meninges cover the spinal nerves up to the point where they exit the spinal column through the intervertebral foramina.
- The spinal cord is also protected by a cushion of fat and connective tissue located in the **epidural space** (ep-i-DOO-ral), a space between the dura mater and the wall of the vertebral canal.

Gross anatomy of the spinal cord. Meninges are connective tissue coverings that surround the spinal cord and brain.



External Anatomy of the Spinal Cord

- The **spinal cord** is roughly oval in shape, being flattened slightly anteriorly and posteriorly.
- In adults, it extends from the medulla oblongata, the inferior part of the brain, to the superior border of the second lumbar vertebra
- The length of the adult spinal cord ranges from 42 to 45 cm (16–18 in.). Its maximum diameter is approximately 1.5 cm (0.6 in.) in the lower cervical region and is smaller in the thoracic region and at its inferior tip.
- ***When the spinal cord is viewed externally, two conspicuous enlargements can be seen:***

1- The superior enlargement, the **cervical enlargement,** extends from the fourth cervical vertebra (C4) to the first thoracic vertebra (T1). Nerves to and from the upper limbs arise from the cervical enlargement.

2- The inferior enlargement, called the **lumbar enlargement,** extends from the ninth to the twelfth thoracic vertebra. Nerves to and from the lower limbs arise from the lumbar enlargement.

External Anatomy of the Spinal Cord (continued-1)

- **Spinal nerves** are the paths of communication between the spinal cord and specific regions of the body.

- The spinal cord appears to be segmented because the 31 pairs of spinal nerves emerge at regular intervals from intervertebral foramina.

- Each pair of spinal nerves is said to arise from a *spinal segment*. Within the spinal cord there is no obvious segmentation but, for convenience, the naming of spinal nerves is based on the segment in which they are located.

External Anatomy of the Spinal Cord (continued-2)

Segments of spinal cord:

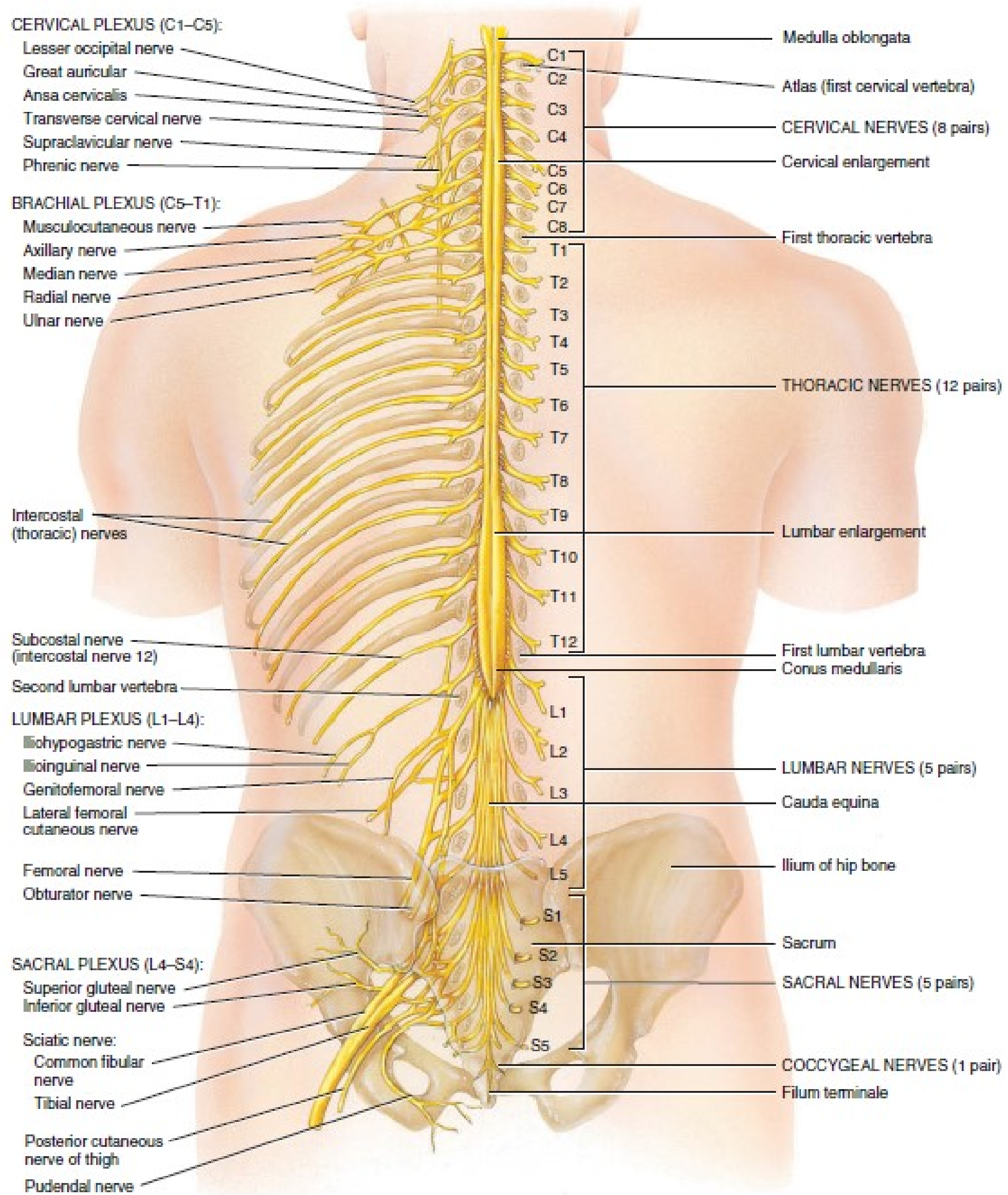
- **8 pairs of *cervical nerves* (C1–C8),**
- **12 pairs of *thoracic nerves* (T1–T12)**
- **5 pairs of *lumbar nerves* (L1–L5)**
- **5 pairs of *sacral nerves* (S1–S5),**
- **1 pair of *coccygeal nerves* (Co1).**

Two bundles of axons, called **roots:**

1- The **posterior** (*dorsal*) **root** and rootlets contain only sensory axons, which conduct nerve impulses from sensory receptors.

2- The **anterior** (*ventral*) **root** and rootlets contain axons of motor neurons, which conduct nerve impulses from the CNS to effectors (muscles and glands).

External anatomy of the spinal cord and spinal nerves.



Posterior view of entire spinal cord and portions of spinal nerves

Internal Anatomy of the Spinal Cord

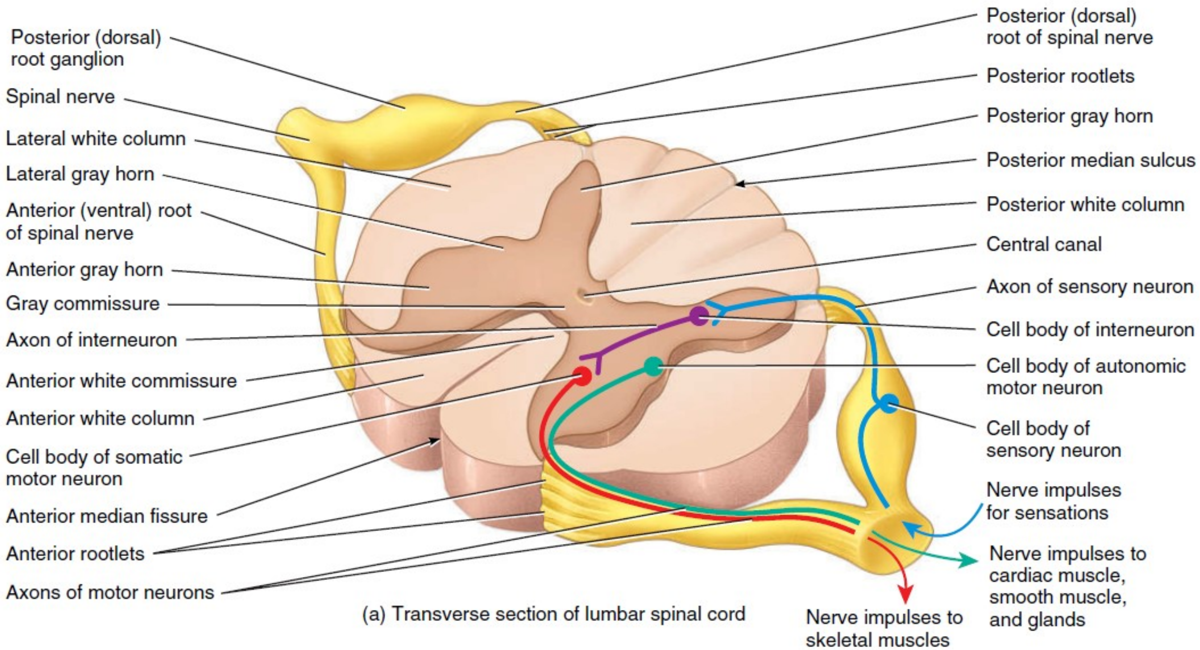
- A transverse section of the spinal cord reveals regions of white matter that surround an inner core of gray matter.
- The white matter of the spinal cord consists primarily of bundles of myelinated axons of neurons. For simplicity, dendrites are not shown in this illustration.

Blue*, *red*, *and green arrows indicate the direction of nerve impulse propagation.

→ The posterior gray horn contains axons of sensory neurons and cell bodies of interneurons;

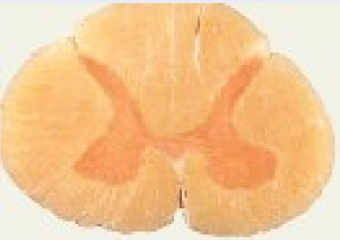
→ The lateral gray horn contains cell bodies of autonomic motor neurons;

→ and the anterior gray horn contains cell bodies of somatic motor neurons

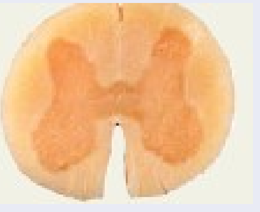


(a) Transverse section of lumbar spinal cord

Internal Anatomy of the Spinal Cord

Comparison of Various Spinal Cord Segments	
SEGMENT	**DISTINGUISHING CHARACTERISTICS**
Cervical 	Relatively large diameter, relatively large amounts of white matter, oval; in upper cervical segments (C1–C4), posterior gray horn is large but anterior gray horn is relatively small; in lower cervical segments (C5 and below), posterior gray horns are enlarged and anterior gray horns are well developed.
Thoracic 	Small diameter due to relatively small amounts of gray matter; except for first thoracic segment, anterior and posterior gray horns are relatively small; small lateral gray horn is present.

Internal Anatomy of the Spinal Cord

Comparison of Various Spinal Cord Segments	
SEGMENT	**DISTINGUISHING CHARACTERISTICS**
Lumbar 	Nearly circular; very large anterior and posterior gray horns; small lateral gray horn is present in upper segments; relatively less white matter than cervical segments.
Sacral 	Relatively small, but relatively large amounts of gray matter; relatively small amounts of white matter; anterior and posterior gray horns are large and thick.
Coccygeal	Resembles lower sacral spinal segments, but much smaller.

BRAIN (Introduction)

Brain vesicles give rise to adult brain structures:

- The **telencephalon** (tel-en-SEF-a-lon; *tel-* distant; *-encephalon* brain) develops into the *cerebrum* and *lateral ventricles*.
- The **diencephalon (**dı»-en-SEF-a-lon) forms the *thalamus, hypothalamus, epithalamus,* and *third ventricle.*
- The **mesencephalon** (mes-en-SEF-a-lon (*mes-* middle)), or midbrain, gives rise to the *midbrain* and *aqueduct of the midbrain (cerebral aqueduct).*
- The **metencephalon** (met-en-SEF-a-lon; *met-* after) becomes the *pons, cerebellum,* and *upper part of the fourth ventricle.*
- The **myelencephalon** (mı»-el-en-SEF-a-lon; *myel-* marrow) forms the *medulla oblongata* and *lower part of the fourth ventricle.*

- Most of the protective structures of the brain—that is, most of the bones of the skull, associated connective tissues, and meningeal membranes—arise from this expanded neural crest tissue.

Major Parts of the Brain

The adult brain consists of four major parts:

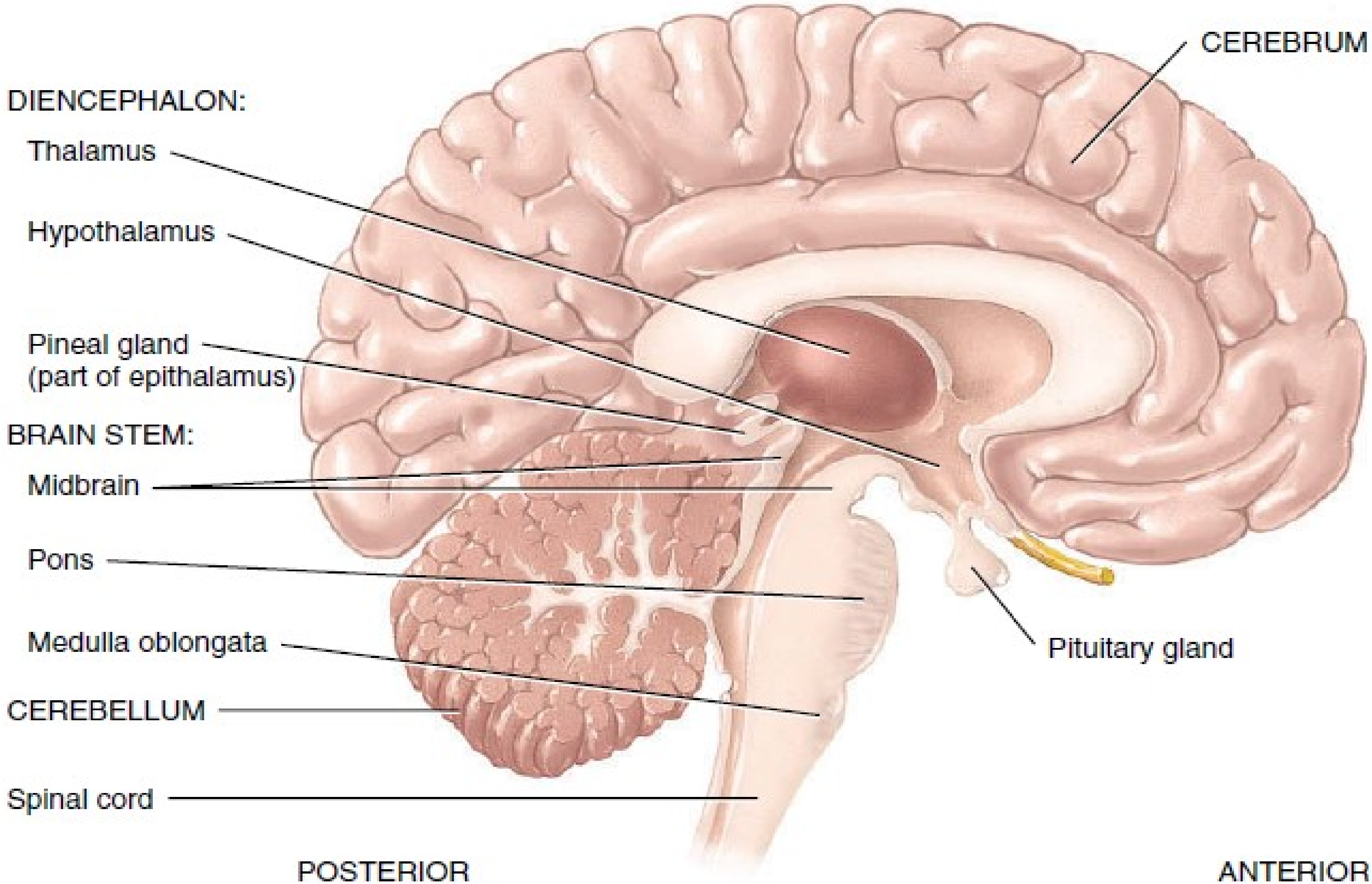
1- The **cerebrum** (se-RE»-brum brain), the largest part of the brain, supported on the diencephalon and brain stem

2- The **diencephalon** (*di-* through), superior to the brain stem, consists of the thalamus, hypothalamus, and epithalamus.

3- The **brain stem** is continuous with the spinal cord and consists of the medulla oblongata, pons, and midbrain.

4- the **cerebellum** (ser-e-BEL-um little brain), which is posterior to the brain stem.

Figure 14.1 **The brain.**



(a) Sagittal section, medial view

Protective Coverings of the Brain

- The cranium and the cranial meninges surround and protect the brain.
- The **cranial meninges** (me-NIN-je»z) are continuous with the spinal meninges, have the same basic structure, and bear the same names:

1- The outer **dura mater** (DOO-ra MA¯ -ter),

2- The middle **arachnoid mater** (a-RAK-noyd),

3- The inner **pia mater** (PE»-a or PI»-a).

NOTES:

✓ The cranial dura mater has two layers; the spinal dura mater has only one.

✓ The two dural layers are called the *periosteal layer* (which is external) and the *meningeal layer* (which is internal).

✓ The dural layers around the brain are fused together except where they separate to enclose the dural venous sinuses (endothelial-lined venous channels) that drain venous blood from the brain and deliver it into the internal jugular veins.

✓ Also, there is **no epidural space** around the brain.

Protective Coverings of the Brain (notes continued)

- ✓Blood vessels that enter brain tissue pass along the surface of the brain, and as they penetrate inward, they are sheathed by a loose-fitting sleeve of pia mater.

- ✓*Three extensions of the dura mater separate parts of the brain:*

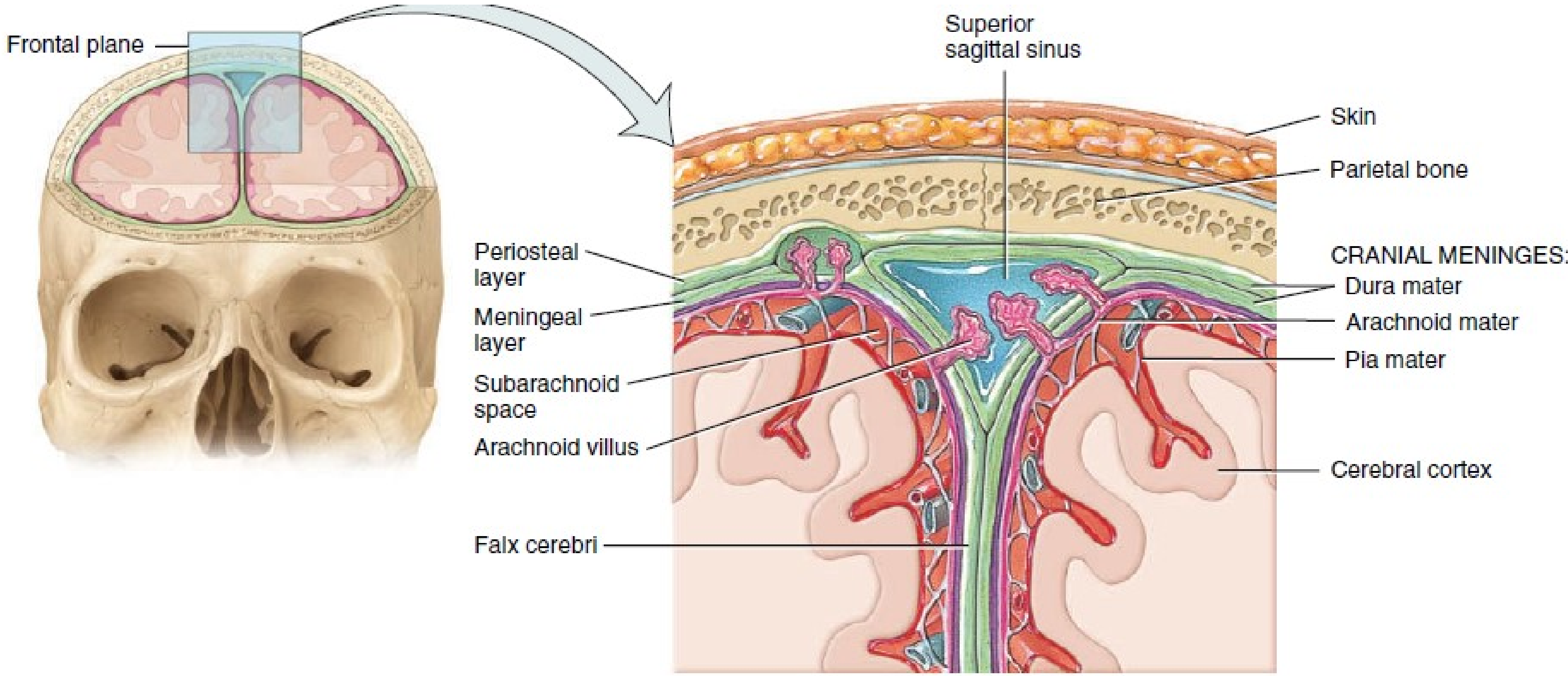
the cerebrum from the cerebellum

→(1) The **falx cerebri** (FALKS ser-i-BRE»; *falx* sickle-shaped) separates the two hemispheres (sides) of the cerebrum.

→(2) The **falx cerebelli** (ser- e-BEL-ı») separates the two hemispheres of the cerebellum.

→(3) The **tentorium cerebelli** (ten-TO» -re»-um tent) separates the cerebrum from the cerebellum.

Figure 14.2 The protective coverings of the brain

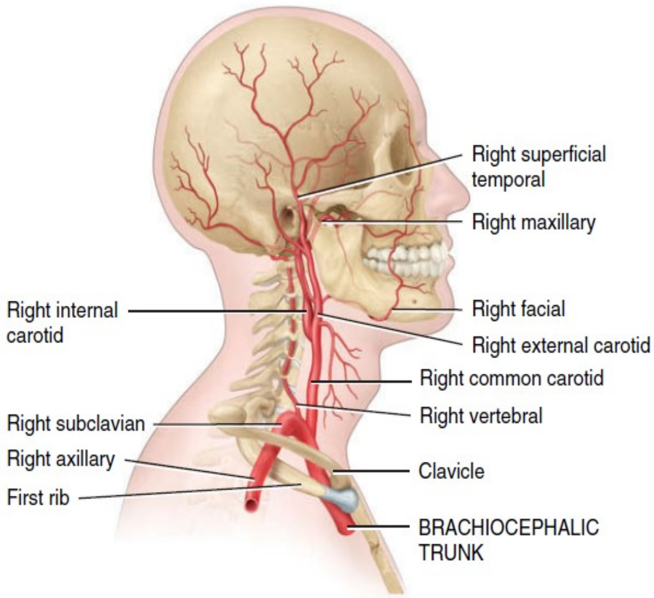


(a) Anterior view of frontal section through skull showing the cranial meninges

Brain Blood Flow

- Blood flows to the brain mainly via the internal carotid and vertebral arteries; the dural venous sinuses drain into the internal jugular veins to return blood from the head to the heart.

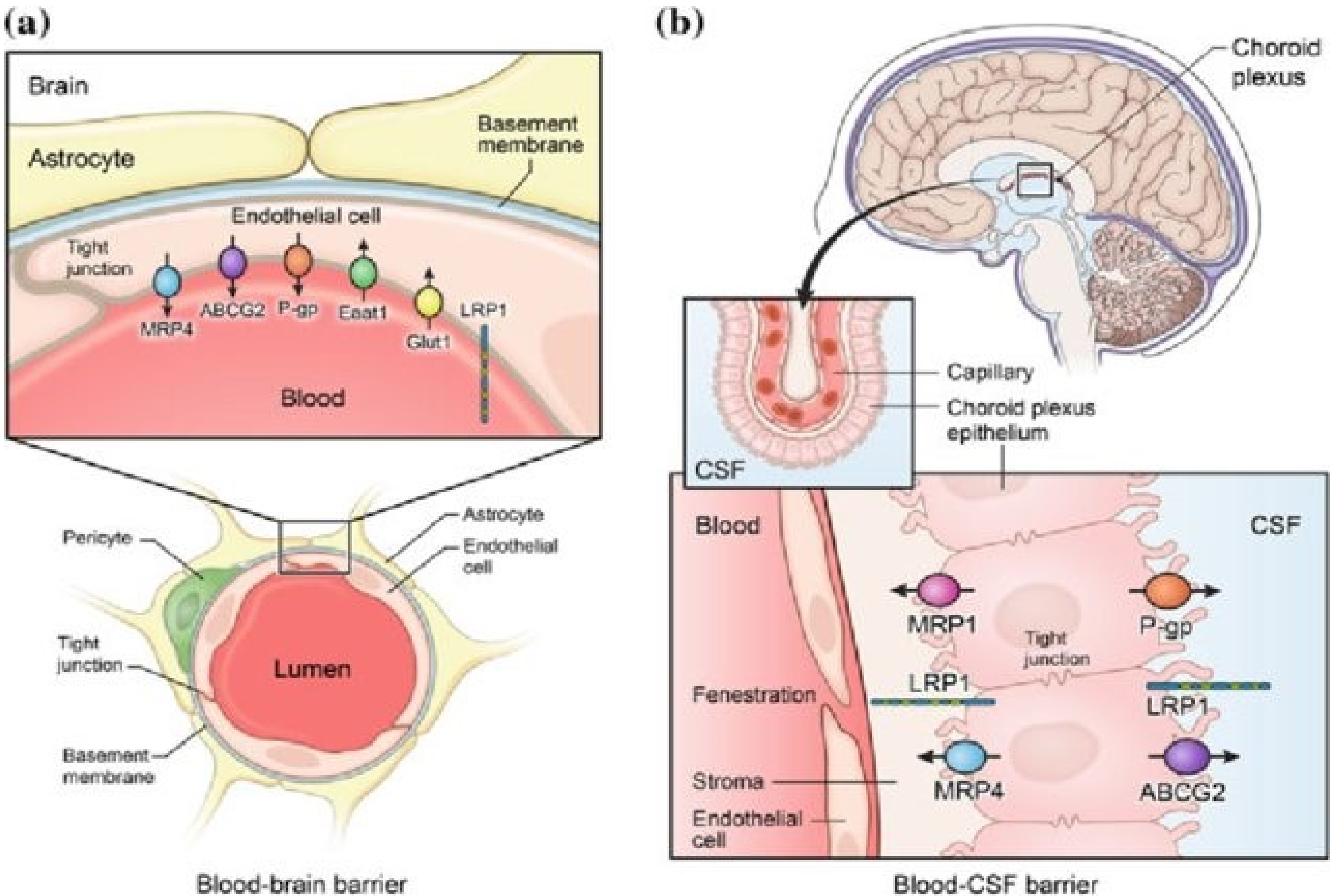
- Even a brief slowing of brain blood flow may cause disorientation or a lack of consciousness, such as when you stand up too quickly after sitting for a long period of time.



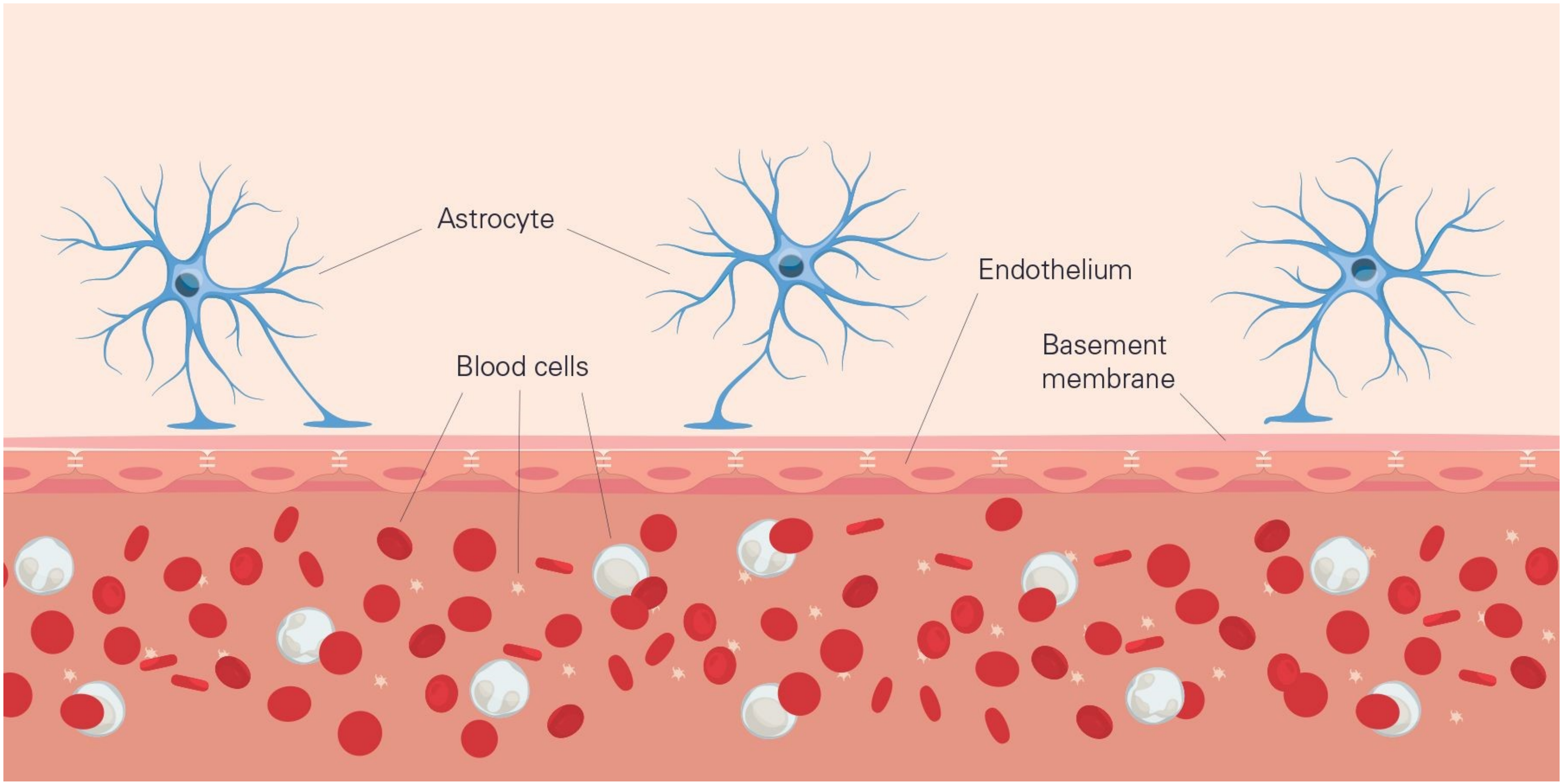
The Blood–Brain Barrier

- The **blood–brain barrier (BBB)** consists mainly of tight junctions that seal together the endothelial cells of brain blood capillaries and a thick basement membrane that surrounds the capillaries.
- Astrocytes are one type of neuroglia; the processes of many astrocytes press up against the capillaries and secrete chemicals that maintain the permeability characteristics of the tight junctions.
- Processes of astrocytes wrapped around blood capillaries isolate neurons of the CNS from various potentially harmful substances in blood by secreting chemicals that maintain the unique selective permeability characteristics of the endothelial cells of the capillaries. In effect, the endothelial cells create a *blood–brain barrier,* which restricts the movement of substances between the blood and interstitial fluid of the CNS.
- A few water-soluble substances, such as glucose, cross the BBB by active transport. Other substances, such as creatinine, urea, and most ions, cross the BBB very slowly.
- Still other substances—proteins and most antibiotic drugs—do not pass at all from the blood into brain tissue.
- However, lipid-soluble substances, such as oxygen, carbon dioxide, alcohol, and most anesthetic agents, are able to access brain tissue freely.
- Trauma, certain toxins, and inflammation can cause a breakdown of the blood–brain barrier.

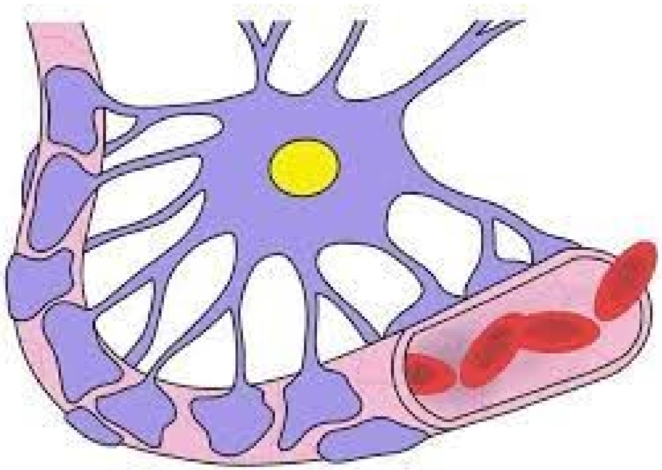
The Blood–Brain Barrier
image reference: DOI: 10.1007/978-3-319-23476-2_9



The Blood–Brain Barrier
image reference: https://www.drugdiscoverynews.com/engineers-developed-a-blood-brain-barrier-on-a-chip-15343



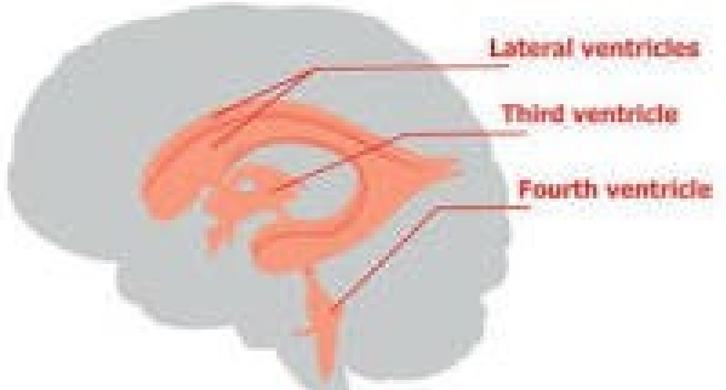
The Blood–Brain Barrier
image reference:
1- https://neuroscientificallychallenged.com/posts/know-your-brain-blood-brain-barrier
2- https://en.wikipedia.org/wiki/Blood%E2%80%93brain_barrier#/media/File:Blood_Brain_Barriere.jpg



Cerebrospinal Fluid

- ✓ **Cerebrospinal fluid (CSF)** is a clear, colorless liquid composed primarily of water that protects the brain and spinal cord from chemical and physical injuries.
- ✓ It also carries small amounts of oxygen, glucose, and other needed chemicals from the blood to neurons and neuroglia.
- ✓ CSF continuously circulates through cavities in the brain and spinal cord and around the brain and spinal cord in the subarachnoid space (the space between the arachnoid mater and pia mater).
- ✓ The total volume of CSF is 80 to 150 mL (3 to 5 oz) in an adult.
- ✓ CSF contains small amounts of glucose, proteins, lactic acid, urea, cations (Na, K, Ca2, Mg2), and anions (Cl– and HCO3); it also contains some white blood cells.

Cerebrospinal Fluid→ ORIGIN



- Four CSF-filled cavities within the brain, which are called **ventricles** (VEN-tri-kuls little cavities).

1 and 2- There is one **lateral ventricle** in each hemisphere of the cerebrum. (Think of them as ventricles 1 and 2.) Anteriorly, the lateral ventricles are separated by a thin membrane, the **septum pellucidum** (SEP-tum pe-LOO-si-dum; *pellucid* transparent).

3- The **third ventricle** is a narrow slit-like cavity along the midline superior to the hypothalamus and between the right and left halves of the thalamus.

4- The **fourth ventricle** lies between the brain stem and the cerebellum.

Functions of CSF

The CSF has three basic functions:

1. ***Mechanical protection.*** CSF serves as a shock-absorbing medium that protects the delicate tissues of the brain and spinal cord from jolts that would otherwise cause them to hit the bony walls of the cranial cavity and vertebral canal. The fluid also buoys the brain so that it "floats" in the cranial cavity.

2. ***Homeostatic function.*** The pH of the CSF affects pulmonary ventilation and cerebral blood flow, which is important in maintaining homeostatic controls for brain tissue. CSF also serves as a transport system for polypeptide hormones secreted by hypothalamic neurons that act at remote sites in the brain.

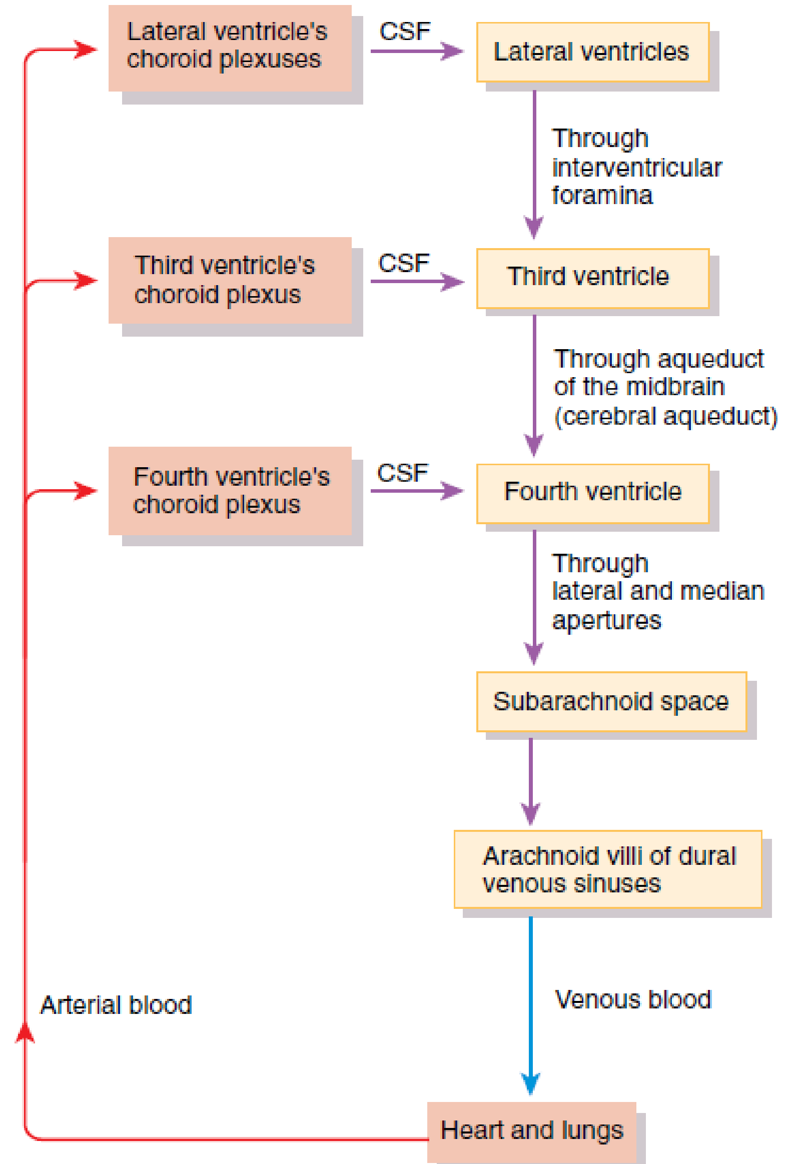
3. ***Circulation.*** CSF is a medium for minor exchange of nutrients and waste products between the blood and adjacent nervous tissue.

Formation of CSF in the Ventricles

- The majority of CSF production is from the **choroid plexuses** (KOˉ -royd membranelike), networks of blood capillaries in the walls of the ventricles (Figure 14.4a).
- Ependymal cells joined by tight junctions cover the capillaries of the choroid plexuses.
- Selected substances (mostly water) from the blood plasma, which are filtered from the capillaries, are secreted by the ependymal cells to produce the cerebrospinal fluid.
- This secretory capacity is bidirectional and accounts for continuous production of CSF and transport of metabolites from the nervous tissue back to the blood.

Circulation of CSF

- The CSF formed in the choroid plexuses of each lateral ventricle flows into the third ventricle.
- More CSF is added by the choroid plexus in the roof of the third ventricle.
- The fluid then flows through the **aqueduct of the midbrain** (*cerebral aqueduct*) (AK-we-dukt), which passes through the midbrain, into the fourth ventricle. The choroid plexus of the fourth ventricle contributes more fluid
- CSF is gradually reabsorbed into the blood through **arachnoid villi**, fingerlike extensions of the arachnoid mater that project into the dural venous sinuses,
- Because the rates of formation and reabsorption are the same, the pressure of CSF normally is constant. For the same reason, the volume of CSF remains constant.



(d) Summary of the formation, circulation, and absorption of cerebrospinal fluid (CSF)

The Brain Stem and Reticular Formation

The brain stem is the part of the brain between the spinal cord and the diencephalon.

It consists of three structures:

(1) Medulla oblongata,

(2) Pons

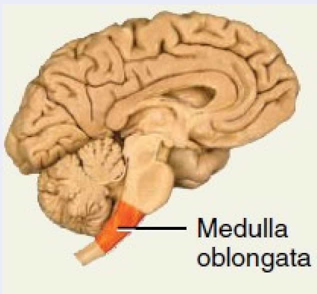
(3) Midbrain.

Extending through the brain stem is the **reticular formation**, a netlike region of interspersed gray and white matter.

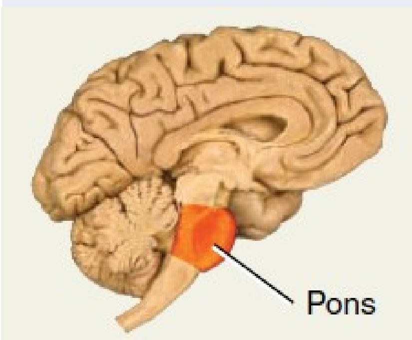
→ brain stem consists of small clusters of neuronal cell bodies (gray matter) interspersed among small bundles of myelinated axons (white matter).

→The broad region where white matter and gray matter exhibit a netlike arrangement is known as the **reticular formation** neurons within the reticular formation have both ascending (sensory) and descending (motor) functions.

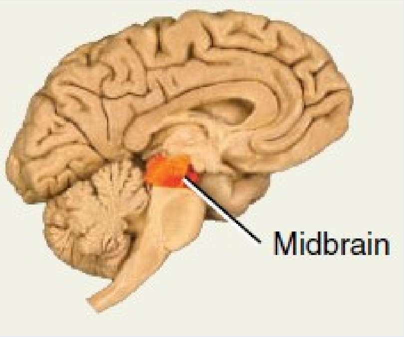
Summary of Functions of Principal Parts of the Brain -1

PART	FUNCTION
BRAIN STEM	
	***MEDULLA OBLONGATA:*** ✓ Contains sensory (ascending) and motor (descending) tracts. ✓ Cardiovascular center regulates heartbeat and blood vessel diameter. ✓ Medullary respiratory center (together with pons) regulates breathing. ✓ **Contains** gracile nucleus, cuneate nucleus, gustatory nucleus, cochlear nuclei, and vestibular nuclei (components of sensory pathways to brain). ✓ **Inferior olivary nucleus** provides instructions that cerebellum uses to adjust muscle activity when learning new motor skills. ✓ **Other nuclei** coordinate vomiting, swallowing, sneezing, coughing, and hiccupping. ✓ **Contains nuclei of origin for** vestibulocochlear (VIII), glossopharyngeal (IX), vagus (X), accessory (XI), and hypoglossal (XII) nerves. ✓ **Reticular formation** (also in pons, midbrain, and diencephalon) functions in consciousness and arousal.

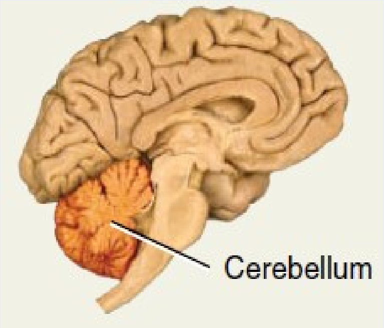
Summary of Functions of Principal Parts of the Brain -2

PART	FUNCTION
BRAIN STEM	
	***PONS:*** ✓ **Contains** sensory and motor tracts. → Pontine nuclei relay nerve impulses from motor areas of cerebral cortex to cerebellum. ✓ **Contains** vestibular nuclei (along with medulla) that are part of equilibrium pathway to brain. ✓ Pontine respiratory group (together with the medulla) helps control breathing. ✓ **Contains** nuclei of origin for trigeminal (V), abducens (VI), facial (VII), and vestibulocochlear (VIII) nerves.

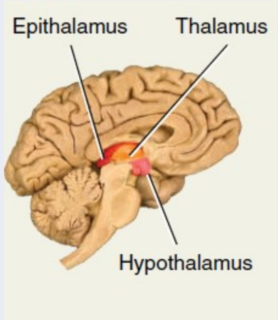
Summary of Functions of Principal Parts of the Brain -3

PART	FUNCTION
BRAIN STEM	
	***MIDBRAIN:*** ✓ **Contains** sensory and motor tracts. ✓ Superior colliculi coordinate movements of head, eyes, and trunk in response to visual stimuli. ✓ Inferior colliculi coordinate movements of head, eyes, and trunk in response to auditory stimuli. ✓ Substantia nigra and red nucleus contribute to control of movement. ✓ **Contains** nuclei of origin for oculomotor (III) and trochlear (IV) nerves.

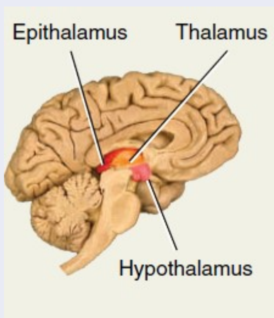
Summary of Functions of Principal Parts of the Brain -4

PART	FUNCTION
CEREBELLUM	
	***CEREBELLUM:*** ✓ Smooths and coordinates contractions of skeletal muscles. ✓ Regulates posture and balance. ✓ May have role in cognition and language processing.

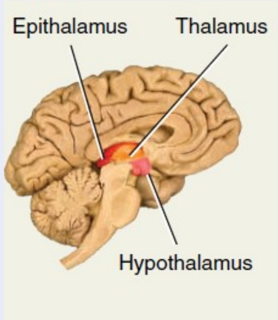
Summary of Functions of Principal Parts of the Brain-5

PART	FUNCTION
DIENCEPHALON	
	***THALAMUS:*** ✓ Relays almost all sensory input to cerebral cortex. ✓ Contributes to motor functions by transmitting information from cerebellum and basal nuclei to primary motor area of cerebral cortex. ✓ Plays role in maintenance of consciousness.

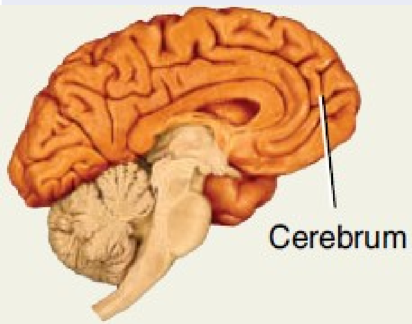
Summary of Functions of Principal Parts of the Brain-6

PART	FUNCTION
DIENCEPHALON	
	***HYPOTHALAMUS:*** ✓ Controls and integrates activities of autonomic nervous system. ✓ Produces hormones, including releasing hormones, inhibiting hormones, oxytocin, and antidiuretic hormone (ADH). ✓ Regulates emotional and behavioral patterns (together with limbic system). ✓ Contains feeding and satiety centers (regulate eating), thirst center (regulates drinking), and suprachiasmatic nucleus (regulates circadian rhythms). ✓ Controls body temperature by serving as body's thermostat.

Summary of Functions of Principal Parts of the Brain-7

PART	FUNCTION
DIENCEPHALON	
	***EPITHALAMUS:*** Consists of pineal gland (secretes melatonin) and habenular nuclei (involved in olfaction).

Summary of Functions of Principal Parts of the Brain -8

PART	FUNCTION
CEREBRUM	
	***CEREBRUM*** ✓ Sensory areas of cerebral cortex are involved in perception of sensory information; motor areas control execution of voluntary movements; association areas deal with more complex integrative functions such as memory, personality traits, and intelligence. ✓ Basal nuclei help initiate and terminate movements, suppress unwanted movements, and regulate muscle tone. ✓ Limbic system promotes range of emotions, including pleasure, pain, docility, affection, fear, and anger.

The Cerebrum

- The cerebrum consists of:

A- Outer cerebral cortex

B- Internal region of cerebral white matter, and gray matter nuclei deep within the white matter.

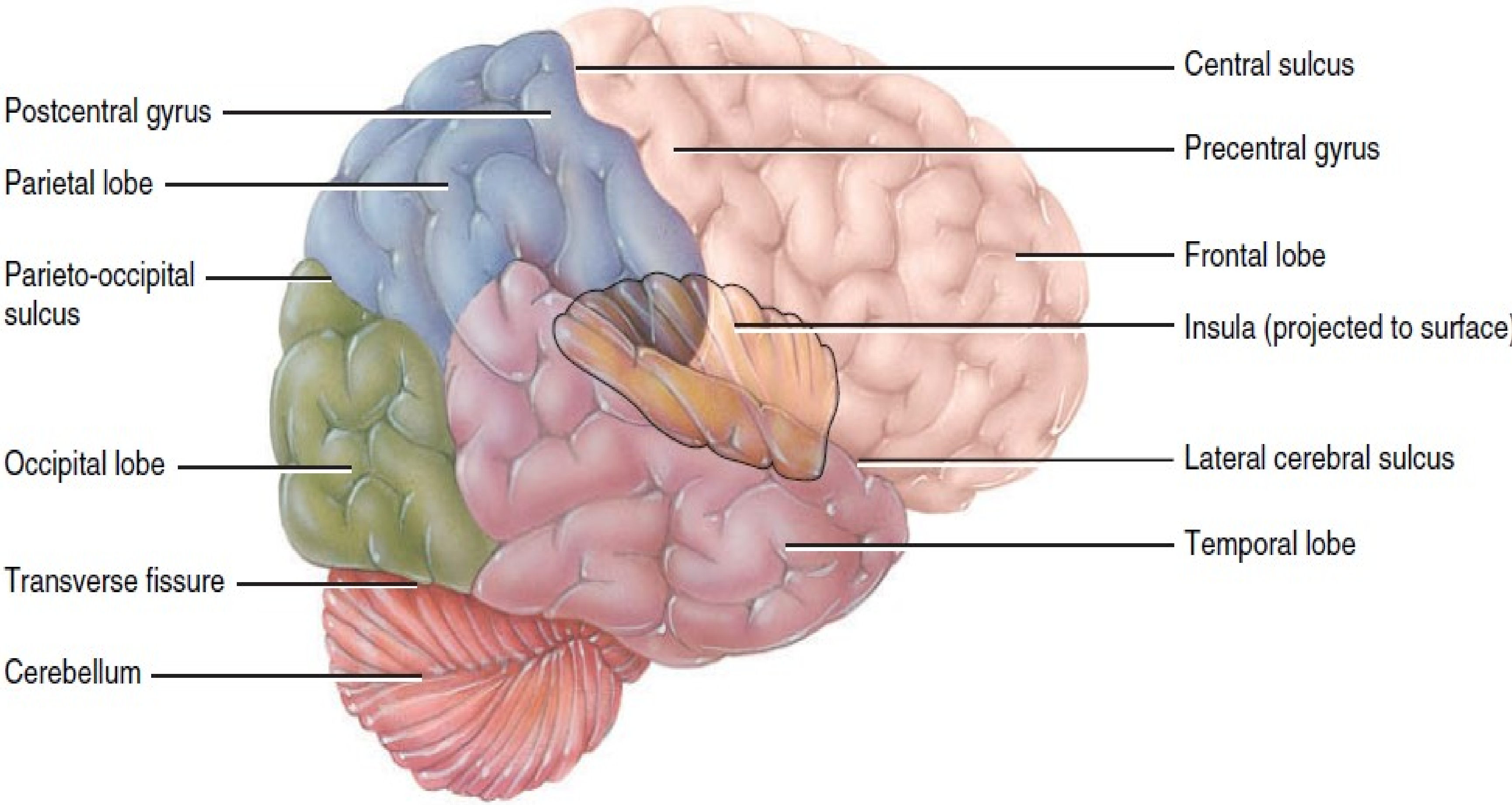
A- Cerebral Cortex

- The **cerebral cortex** (*cortex* rind or bark) is a region of gray matter that forms the outer rim of the cerebrum (Figure 14.11a).
- Although only 2–4 mm (0.08–0.16 in.) thick, the cerebral cortex contains billions of neurons arranged in layers.
- *During embryonic development*, when brain size increases rapidly, the gray matter of the cortex enlarges much faster than the deeper white matter. As a result, the cortical region rolls and folds on itself.
- The folds are called **gyri** (JI» -rı» circles; singular is *gyrus*) or **convolutions** (kon-vo¯ -LOO-shuns) .
- The deepest grooves between folds are known as **fissures;** the shallower grooves between folds are termed **sulci** (SUL-sı» grooves; singular is *sulcus*).
- The most prominent fissure, the **longitudinal fissure**, separates the cerebrum into right and left halves called **cerebral hemispheres**. Within the longitudinal fissure between the cerebral hemispheres is the **falx cerebri**.
- The cerebral hemispheres are connected internally by the **corpus callosum** (kal-LO» -sum; *corpus* body; *callosum* hard), a broad band of white matter containing axons that extend between the hemispheres

Lobes of the Cerebrum

- The lobes are named after the bones that cover them: frontal, parietal, temporal, and occipital lobes (see Figure 14.11).
- The **central sulcus** (SUL-kus) separates the **frontal lobe** from the **parietal lobe**
- A major gyrus, the **precentral gyrus**—located immediately anterior to the central sulcus— contains the primary motor area of the cerebral cortex.
- Another major gyrus, the **postcentral gyrus**, which is located immediately posterior to the central sulcus, contains the primary somatosensory area of the cerebral cortex.
- The **lateral cerebral sulcus** (*fissure*) separates the frontal lobe from the **temporal lobe**.
- The **parieto-occipital sulcus** separates the parietal lobe from the **occipital lobe**.
- A fifth part of the cerebrum, the **insula**, cannot be seen at the surface of the brain because it lies within the lateral cerebral sulcus, deep to the parietal, frontal, and temporal lobes

Lobes of the Cerebrum



(b) Right lateral view

B- Cerebral White Matter and Basal Nuclei

- The **cerebral white matter** consists primarily of myelinated axons in three types of tracts, contain axons that conduct nerve impulses between different part of brain.

Basal Nuclei

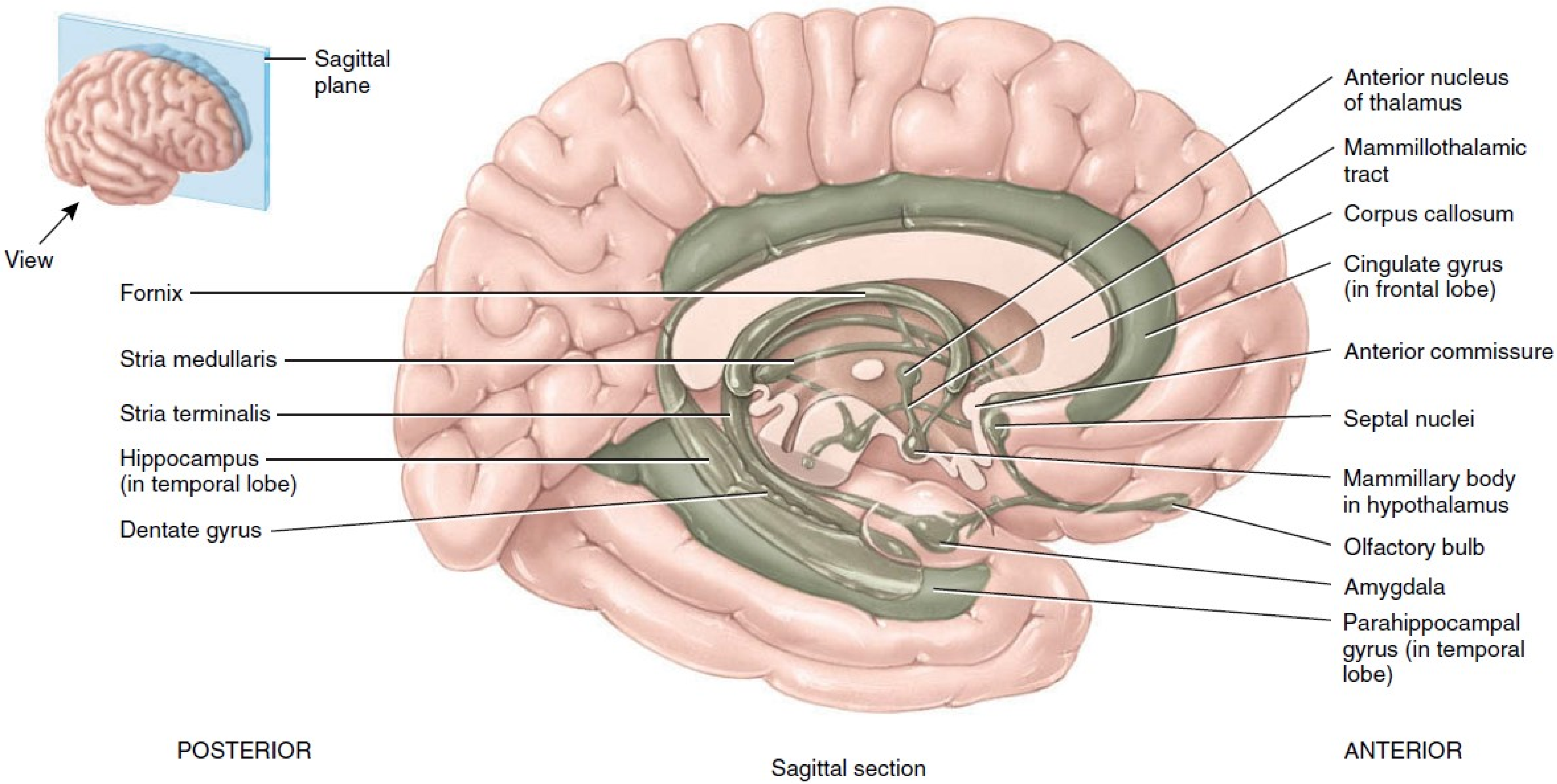
- Deep within each cerebral hemisphere are three nuclei (masses of gray matter) that are collectively termed the **basal nuclei**.
- The basal nuclei receive input from the cerebral cortex and provide output to motor parts of the cortex via the medial and ventral group nuclei of the thalamus.
- In addition, the basal nuclei have extensive connections with one another.
- A major function of the basal nuclei is to **help regulate initiation and termination of movements**.

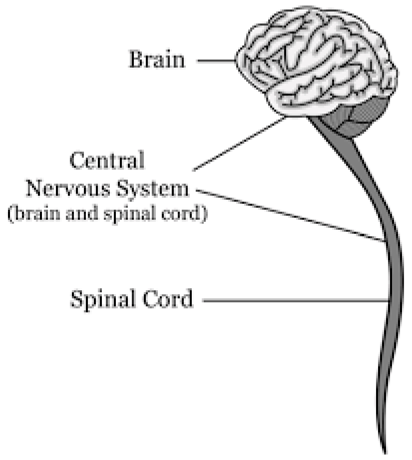
The limbic system

- The limbic system is sometimes called the “emotional brain” because it plays a primary role in a range of emotions, including pain, pleasure, docility, affection, and anger. It also is involved in olfaction (smell) and memory.
- Experiments have shown that when different areas of animals’ limbic systems are stimulated, the animals’ reactions indicate that they are experiencing intense pain or extreme pleasure.
- Together with parts of the cerebrum, the limbic system also functions in memory; damage to the limbic system causes memory impairment.
- One portion of the limbic system, the hippocampus, is seemingly unique among structures of the central nervous system—it has cells reported to be capable of mitosis. Thus, the portion of the brain that is responsible for some aspects of memory may develop new neurons, even in the elderly.

- → The **amygdala** (a-MIG-da-la; *amygda-* almond-shaped) is composed of several groups of neurons located close to the tail of the caudate nucleus. It is thought that it involves in the processing of emotions and memories associated with fear.

Components of the limbic system (shaded green) and surrounding structures.





PHYSIOLOGY
OF
CENTRAL NERVOUS SYSTEM

Course Name: Anatomy and Physiology 2
Course Code: 0521215
Lecturer: Ms. Asma El-Shara’. MPH
Faculty Of Pharmacy,
Philadelphia University-Jordan

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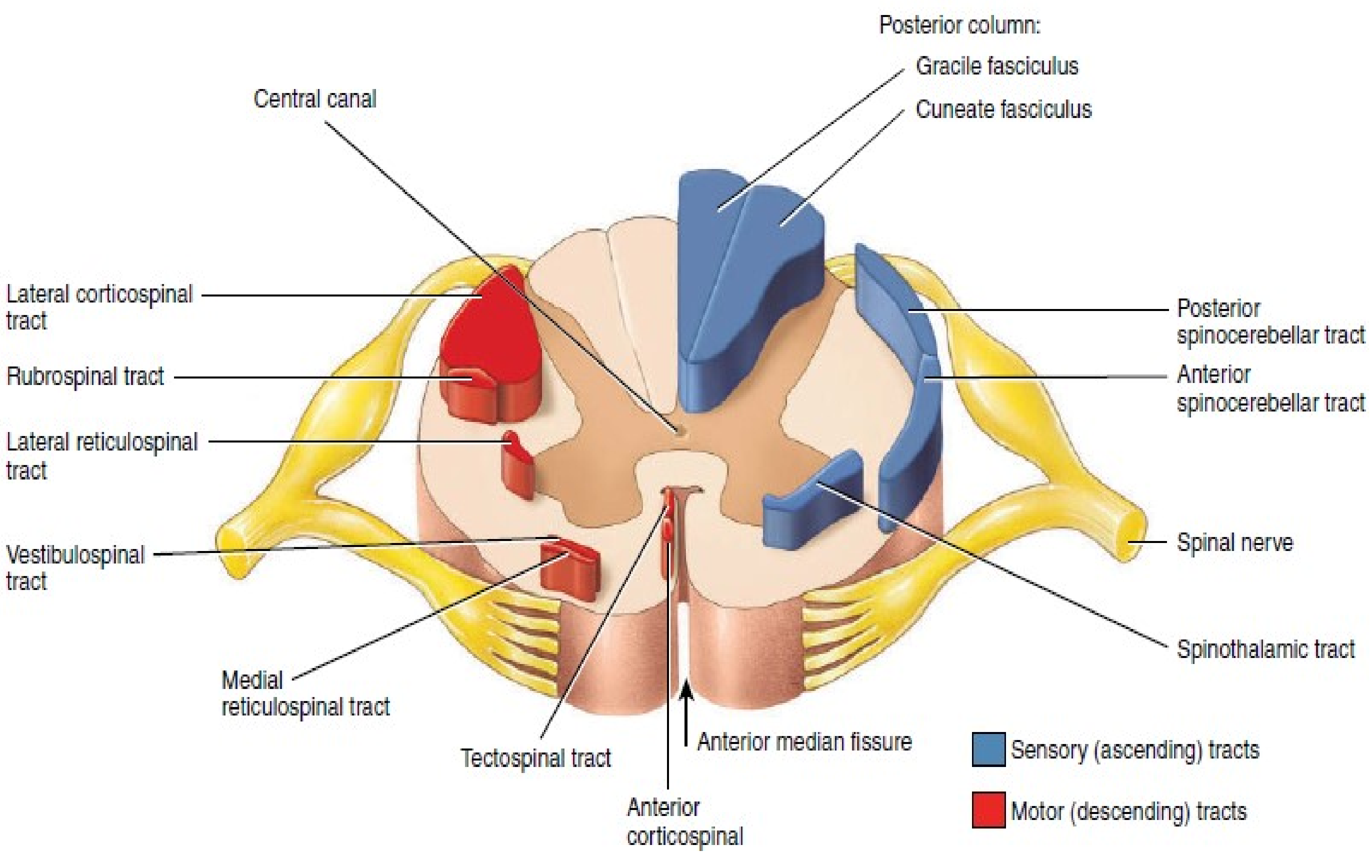
Philadelphia University

SPINAL CORD PHYSIOLOGY



Introduction

The spinal cord has two principal functions in maintaining homeostasis:

Nerve impulse **propagation** and **integration** of information.

- The *white matter tracts* in the spinal cord are highways for nerve impulse **propagation**. Sensory input travels along these tracts toward the brain, and motor output travels from the brain along these tracts toward skeletal muscles and other effector tissues.
- The *gray matter* of the spinal cord receives and **integrates** incoming and outgoing information.

Sensory and Motor Tracts

Nerve impulses from **sensory receptors** propagate up the spinal cord to the brain along two main routes on each side:

<u>1- The spinothalamic tract</u> (spı¯-no¯-tha-LAM-ik)

- It is a sensory tract that carries nociceptive, temperature, crude touch, and pressure from our skin to the somatosensory area of the thalamus
- The **spinothalamic tract** conveys nerve impulses for sensing pain, warmth, coolness, itching, tickling, deep pressure, and crude touch.

<u>2- The posterior column</u>

- Consists of two tracts: the **gracile fasciculus** (GRAS-ı¯l fa-SIK-u¯-lus) and the **cuneate fasciculus** (KU¯ -ne¯-a¯t).
- The posterior column tracts convey nerve impulses for discriminative touch, light pressure, vibration, and conscious proprioception (the awareness of the positions and movements of muscles, tendons, and joints).

Sensory and Motor Tracts (continued-1)

- The sensory systems keep the CNS informed of changes in the external and internal environments.
- The sensory information is integrated (processed) by **interneurons** in the spinal cord and brain.
- *Responses* to the integrative decisions are brought about by motor activities (muscular contractions and glandular secretions).
- **The cerebral cortex**, the outer part of the brain, plays a major role in controlling precise voluntary muscular movements.
- **Other brain regions** provide important integration for regulation of automatic movements.

Sensory and Motor Tracts (continued-2)

- **Motor output** to skeletal muscles travels down the spinal cord in two types of descending pathways: **direct and indirect**.

1- The direct motor pathways include:

a. The lateral corticospinal (kor-ti-kō-spī-nal),

b. Anterior corticospinal,

c. Corticobulbar tracts (kor-ti-kō-bul-bar). → a white matter pathway connecting the cerebral cortex to the brainstem

→ They convey nerve impulses that originate in the cerebral cortex and are destined to cause *voluntary* movements of skeletal muscles.

Sensory and Motor Tracts (continued-3)

<u>2- Indirect motor pathways include</u>

a. The rubrospinal (ROO-brō-spī-nal)→ *beginning as axons of the neurons present in the red nucleus and terminates by synapsing with the interneurons in the spinal cord.*

b. Tectospinal (TEKtō-spī-nal)→ *[1] It is involved in orienting the eyes and the head towards sounds as part of the auditory and visual reflex.[2] It originates from the superior colliculus, which is involved in both the auditory and visual pathways.*

c. Vestibulospinal (ves-TIB-ū-lō-spī-nal),

d. Lateral reticulospinal (re-TIK-ū-lō-spī-nal), → *medullary*

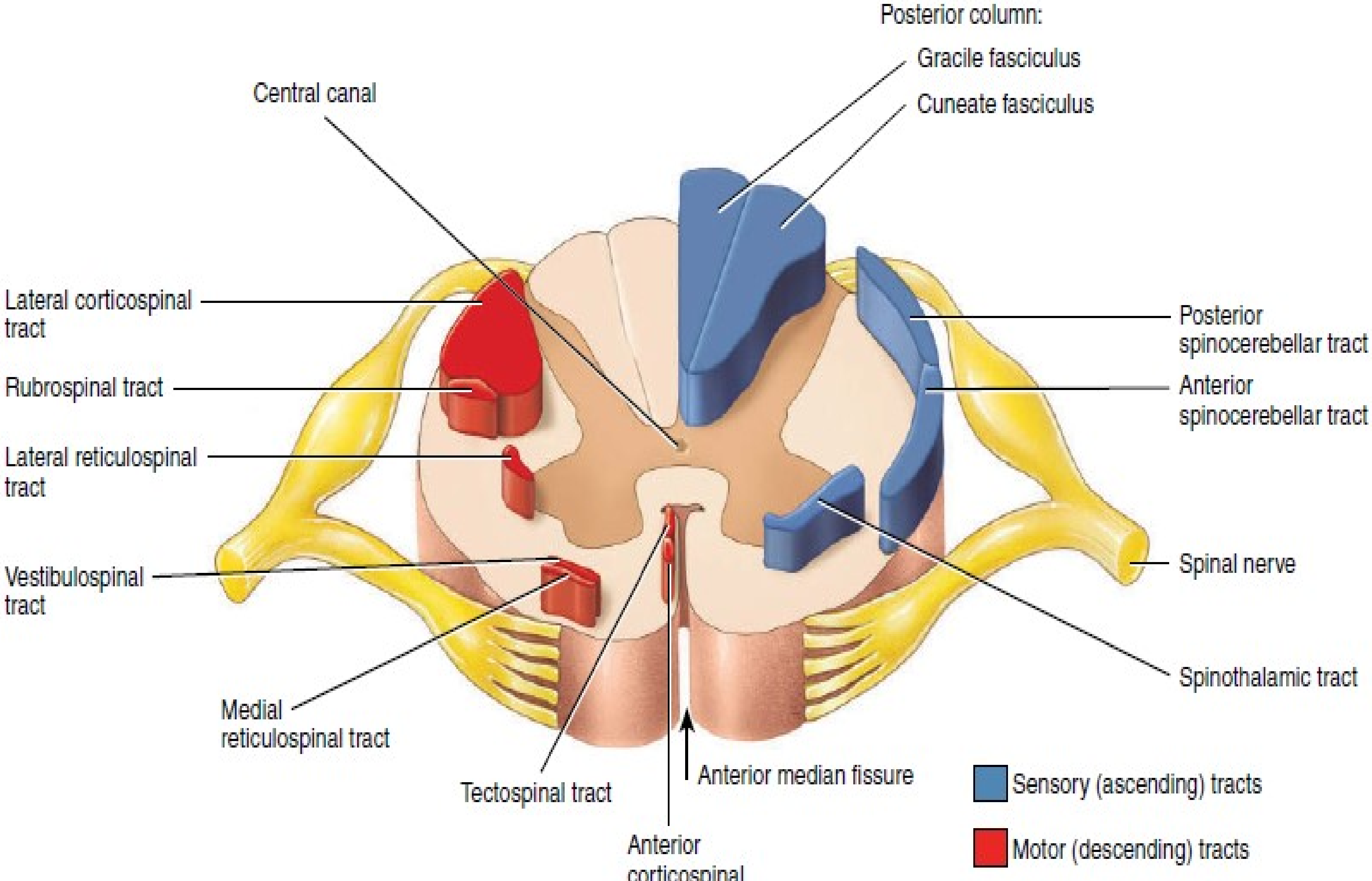
e. Medial reticulospinal tracts→ *pontine (both reticulospinal tracts are responsible for posture and locomotion*

→These tracts convey nerve impulses from the brain stem to cause *<u>automatic movements</u>* and help coordinate body movements with visual stimuli.

→Indirect pathways also maintain skeletal muscle tone, sustain contraction of postural muscles, and play a major role in equilibrium by regulating muscle tone in response to movements of the head.

Figure 13.12 Locations of major sensory and motor tracts, shown in a transverse section of the spinal cord. Sensory tracts are indicated on one half and motor tracts on the other half of the cord, but actually all tracts **are present on both sides**.

→ *<u>The name of a tract often indicates its location in the white matter and where it begins and ends.</u>*



Reflexes and Reflex Arcs

- The second way the spinal cord promotes homeostasis is by serving as an integrating center for some reflexes.

- A **reflex** is a fast, involuntary, unplanned sequence of actions that occurs in response to a particular stimulus.

- Some reflexes are inborn, such as pulling your hand away from a hot surface before you even feel that it is hot.

- Other reflexes are learned or acquired. For instance, you learn many reflexes while acquiring driving expertise. Slamming on the brakes in an emergency is one example.

Reflexes and Reflex Arcs (continued-1)

- When integration takes place in the spinal cord gray matter, the reflex is a **spinal reflex**. → An example is the familiar patellar reflex (knee jerk).
- If integration occurs in the brain stem rather than the spinal cord, the reflex is called a **cranial reflex.** → An example is the tracking movements of your eyes as you read this sentence.

REFLEX ARCS HAVE TWO TYPES: (not consciously perceived)

1-Somatic reflexes, which involve contraction of skeletal muscles.

2- Autonomic (visceral) reflexes They involve responses of smooth muscle, cardiac muscle, and glands. Body functions such as heart rate, digestion, urination, and defecation are controlled by the autonomic nervous system through autonomic reflexes.

Reflexes and Reflex Arcs (continued-2)

- Nerve impulses propagating into, through, and out of the CNS follow specific pathways, depending on the kind of information, its origin, and its destination.

- The pathway followed by nerve impulses that produce a reflex is a **reflex arc** (*reflex circuit*).

- A reflex arc includes the following five functional components (Figure 13.13)

Figure 13.13 General components of a reflex arc. Arrows show the direction of nerve impulse propagation.

→ A reflex is a fast, predictable sequence of involuntary actions that occur in response to certain changes in the environment.

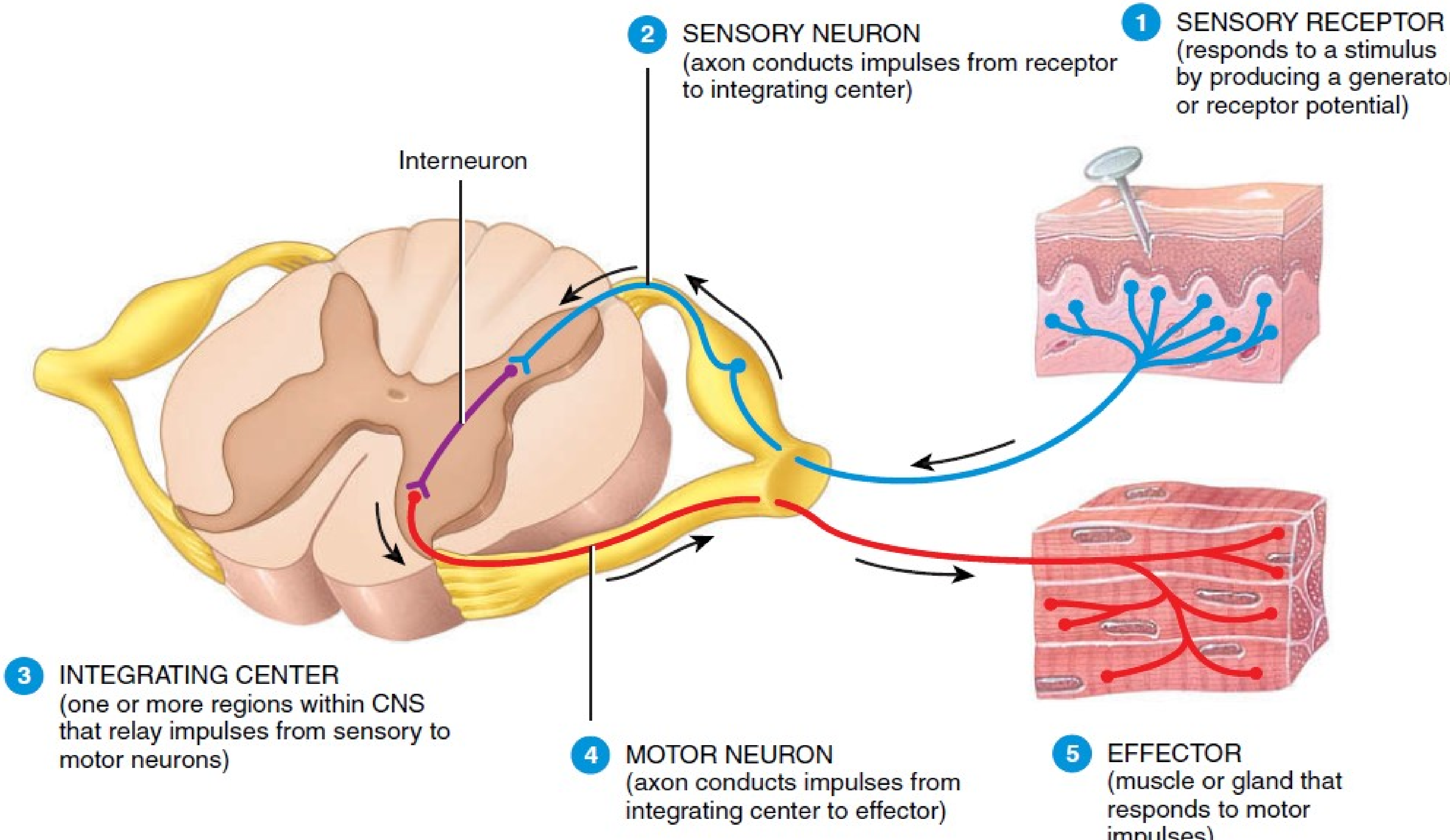


Figure 13.13 General components of a reflex arc. (NOTES)

Integrating center. One or more regions of gray matter within the CNS acts as an integrating center.

- In the simplest type of reflex, the integrating center is a single synapse between a sensory neuron and a motor neuron. A reflex pathway having only one synapse in the CNS is termed a **monosynaptic reflex arc** (mono¯-si-NAP-tik; *mono-* one).
- More often, the integrating center consists of one or more interneurons, which may relay impulses to other interneurons as well as to a motor neuron. A **polysynaptic reflex arc** (*poly-* many) involves more than two types of neurons and more than one CNS synapse.

Effector. The part of the body that responds to the motor nerve impulse, such as a muscle or gland, is the effector.

- Its action is called a reflex.
- If the effector is skeletal muscle, the reflex is a **somatic reflex**.
- If the effector is smooth muscle, cardiac muscle, or a gland, the reflex is an **autonomic** (*visceral*) **reflex**.

Reflexes and Reflex Arcs (continued-3)

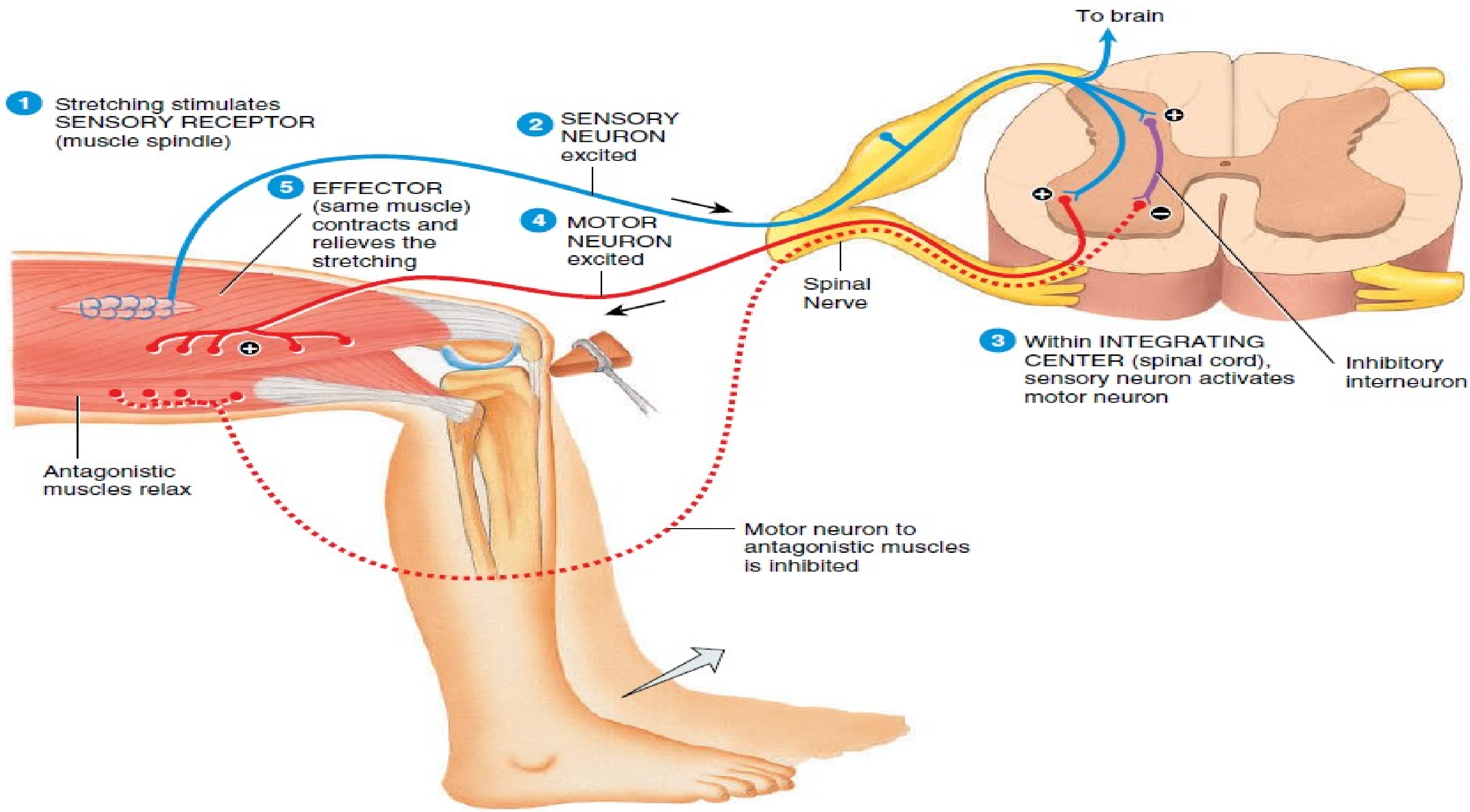
In case of injury, we examine four important somatic spinal reflexes:

1. ***The Stretch Reflex***
2. ***The Tendon Reflex***
3. ***The Flexor (withdrawal) Reflex***
4. ***Crossed Extensor Reflexes***

1. The Stretch Reflex

- A **stretch reflex** causes contraction of a skeletal muscle (the effector) in response to stretching of the muscle.
- This type of reflex occurs via a monosynaptic reflex arc.
- The reflex can occur by activation of a single sensory neuron that forms one synapse in the CNS with a single motor neuron.
- Stretch reflexes can be elicited by tapping on tendons attached to muscles at the elbow, wrist, knee, and ankle joints.
- An example of a stretch reflex is the patellar reflex (knee jerk),

Figure 13.14 Stretch reflex. This monosynaptic reflex arc has only one synapse in the CNS—between a single sensory neuron and a single motor neuron. A polysynaptic reflex arc to antagonistic muscles that includes two synapses in the CNS and one interneuron is also illustrated. Plus signs (+) indicate excitatory synapses; the minus sign (-) indicates an inhibitory synapse.
→ *The stretch reflex causes contraction of a muscle that has been stretched.*



In the reflex arc just described, sensory nerve impulses enter the spinal cord on the same side from which motor nerve impulses leave it. This arrangement is called an **ipsilateral reflex** (ip-si-LAT-er-al same side). All monosynaptic reflexes are ipsilateral.

2. The Tendon Reflex

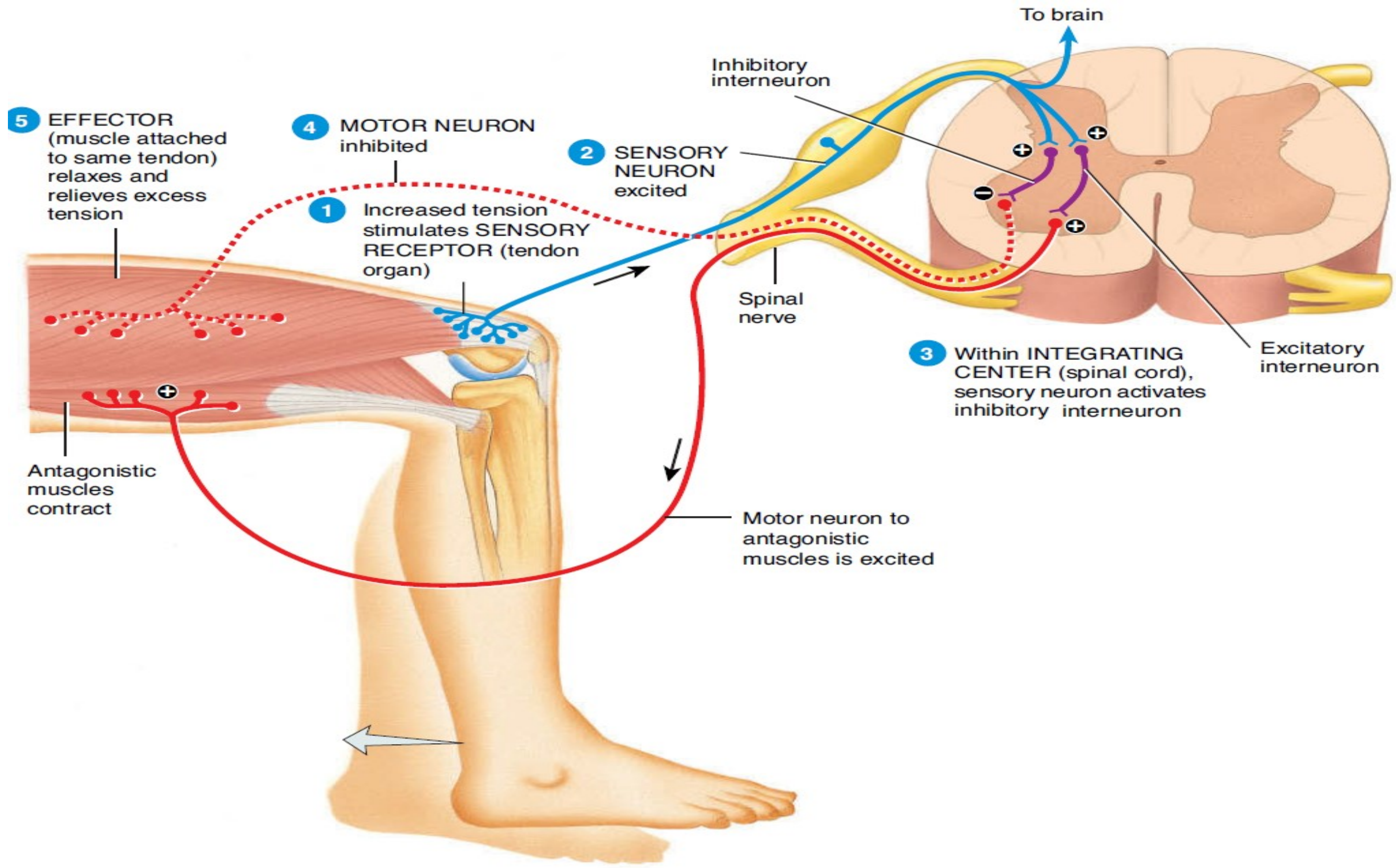
- The **tendon reflex** operates as a feedback mechanism to control muscle *tension* by causing muscle relaxation before muscle force becomes so great that tendons might be torn.

- Although the tendon reflex is <u>less</u> sensitive than the stretch reflex, it can override the stretch reflex when tension is great.

- EXAMPLE: It makes you drop a very heavy weight.

Figure 13.15 Tendon reflex. This reflex arc is polysynaptic—more than one CNS synapse and more than two different neurons are involved in the pathway. The sensory neuron synapses with two interneurons. An inhibitory interneuron causes relaxation of the effector, and a stimulatory interneuron causes contraction of the antagonistic muscle. Plus signs (+) indicate excitatory synapses; the minus sign (-) indicates an inhibitory synapse.

→ The tendon reflex causes relaxation of the muscle attached to the stimulated tendon organ.



3. The Flexor Reflex

- Another reflex involving a polysynaptic reflex arc results when, for instance, you step on a tack. In response to such a painful stimulus, you immediately withdraw your leg. This reflex, called the **flexor** or *withdrawal reflex*
- Moving your entire lower or upper limb away from a painful stimulus involves contraction of more than one muscle group.
- Hence, several motor neurons must simultaneously convey impulses to several limb muscles. Because nerve impulses from one sensory neuron ascend and descend in the spinal cord and activate interneurons in several segments of the spinal cord, this type of reflex is called an **intersegmental reflex arc** (in-ter-seg-MEN-tal; *inter-* between).
- Through **intersegmental** reflex arcs, a single sensory neuron can activate several motor neurons, thereby *stimulating more than one effector*.
- The monosynaptic stretch reflex, in contrast, involves muscles receiving nerve impulses from one spinal cord segment only.

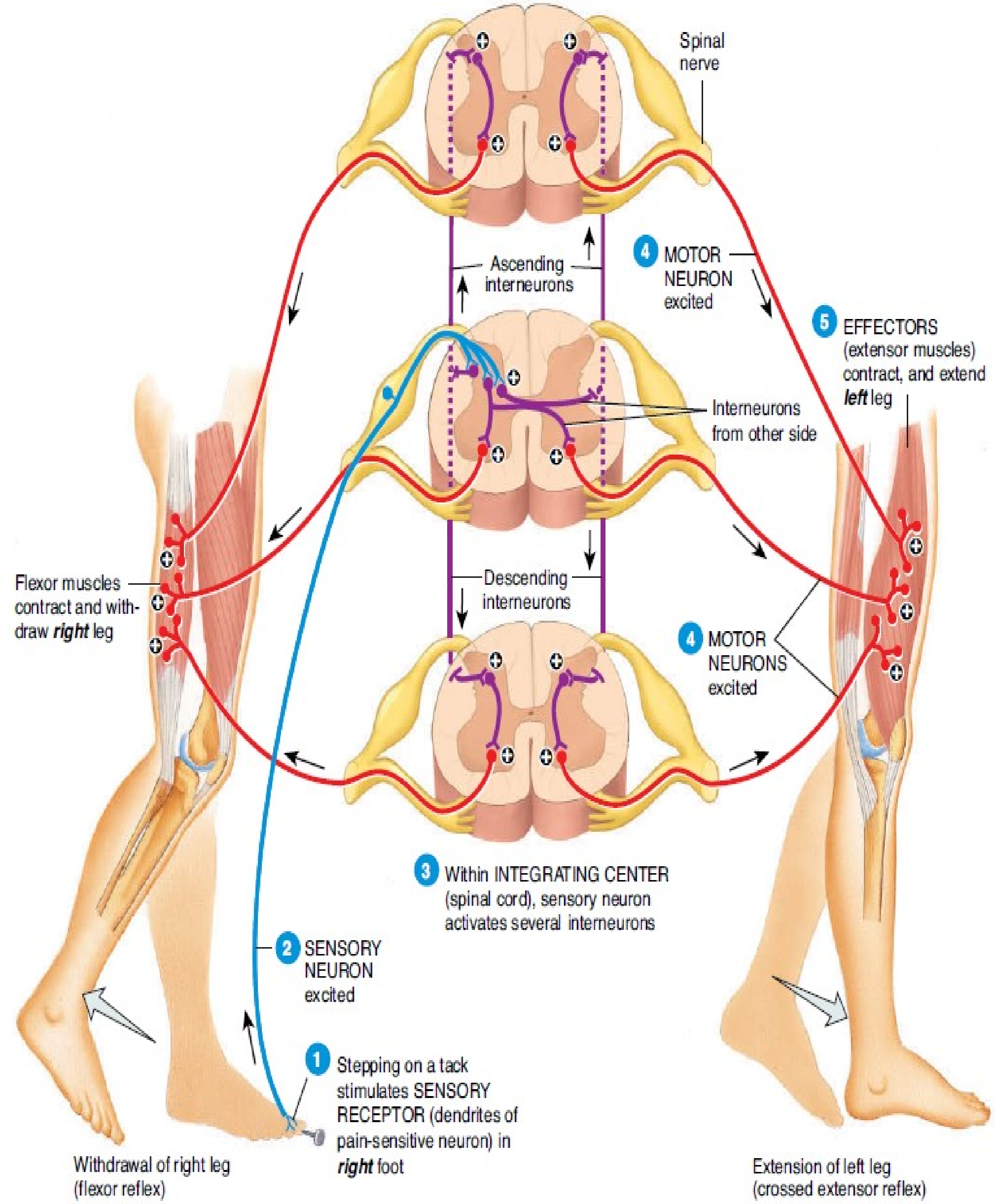
4. Crossed Extensor Reflexes

- Something else may happen when you step on a tack: You may start to lose your balance as your body weight shifts to the other foot.

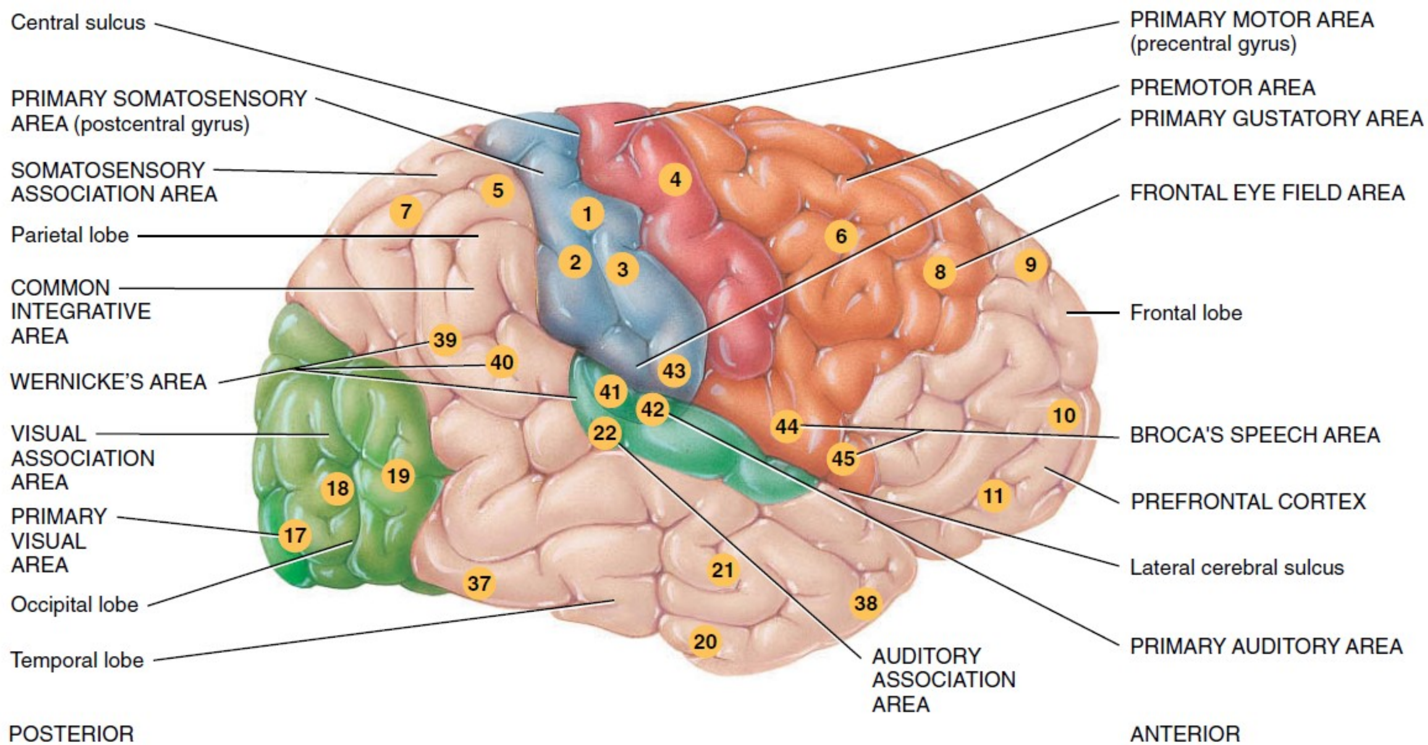
- Besides initiating the flexor reflex that causes you to withdraw the limb, the pain impulses from stepping on the tack also initiate a **crossed extensor reflex** to help you maintain your balance.

Figure 13.17 Crossed extensor reflex. The flexor reflex arc is shown (at left) for comparison with the crossed extensor reflex arc. Plus signs (+) indicate excitatory synapses.

→ A crossed extensor reflex causes contraction of muscles that extend joints in the limb opposite a painful stimulus. *Unlike the flexor reflex, which is an ipsilateral reflex, the crossed extensor reflex involves a **contralateral reflex arc** (kontra- LAT-er-al opposite side): Sensory impulses enter one side of the spinal cord and motor impulses exit on the opposite side.*



BRAIN PHYSIOLOGY



Lateral view of right cerebral hemisphere

Functional Organization of the Cerebral Cortex

Specific types of sensory, motor, and integrative signals are processed in certain regions of the cerebral cortex (Figure 14.15).

1- **Sensory areas** receive sensory information and are involved in **perception**, the conscious awareness of a sensation;

2- **Motor areas** control the **execution** of voluntary movements;

3- **Association areas** deal with more **complex integrative** functions such as memory, emotions, reasoning, will, judgment, personality traits, and intelligence.

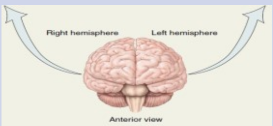
Hemispheric Lateralization

- Although the brain is almost symmetrical on its right and left sides, subtle anatomical differences between the two hemispheres exist.
- For example, in about two-thirds of the population, the planum temporale, a region of the temporal lobe that includes Wernicke's area, is 50% larger on the left side than on the right side.
- This asymmetry appears in the human fetus at about 30 weeks gestation.
- Physiological differences also exist; although the two hemispheres share performance of many functions, each hemisphere also specializes in performing certain unique functions.
- This functional asymmetry is termed **hemispheric lateralization**.

TABLE 14.3

Functional Differences between Right and Left Hemispheres

RIGHT HEMISPHERE FUNCTIONS	LEFT HEMISPHERE FUNCTIONS
1. Receives somatic sensory signals from, and controls muscles on, left side of body. 2. Musical and artistic awareness. 3. Space and pattern perception. 4. Recognition of faces and emotional content of facial expressions. 5. Generating emotional content of language. 6. Generating mental images to compare spatial relationships. 7. Identifying and discriminating among odours. ✓ Patients with damage in right hemisphere regions that correspond to Broca’s and Wernicke’s areas in the left hemisphere speak in a monotonous voice, having lost the ability to impart emotional inflection to what they say.	1. Receives somatic sensory signals from, and controls muscles on, right side of body. 2. Reasoning. 3. Numerical and scientific c skills. 4. Ability to use and understand sign language. 5. Spoken and written language. ✓ Persons with damage in the left hemisphere often exhibit aphasia (loss of ability to understand or express speech, caused by brain damage.)



Clinical Importance

Broca's speech area (BRO» -kaz) (Motor Areas)

→ (areas 44 and 45) is located in the frontal lobe close to the lateral cerebral sulcus.

→ *Speaking and understanding language are complex activities that involve several sensory, association, and motor areas of the cortex.*

Wernicke's area (VER-ni-ke»z) Association Areas

→ *Posterior language area*; area 22, and possibly areas 39 and 40, a broad region in the *left* temporal and parietal lobes

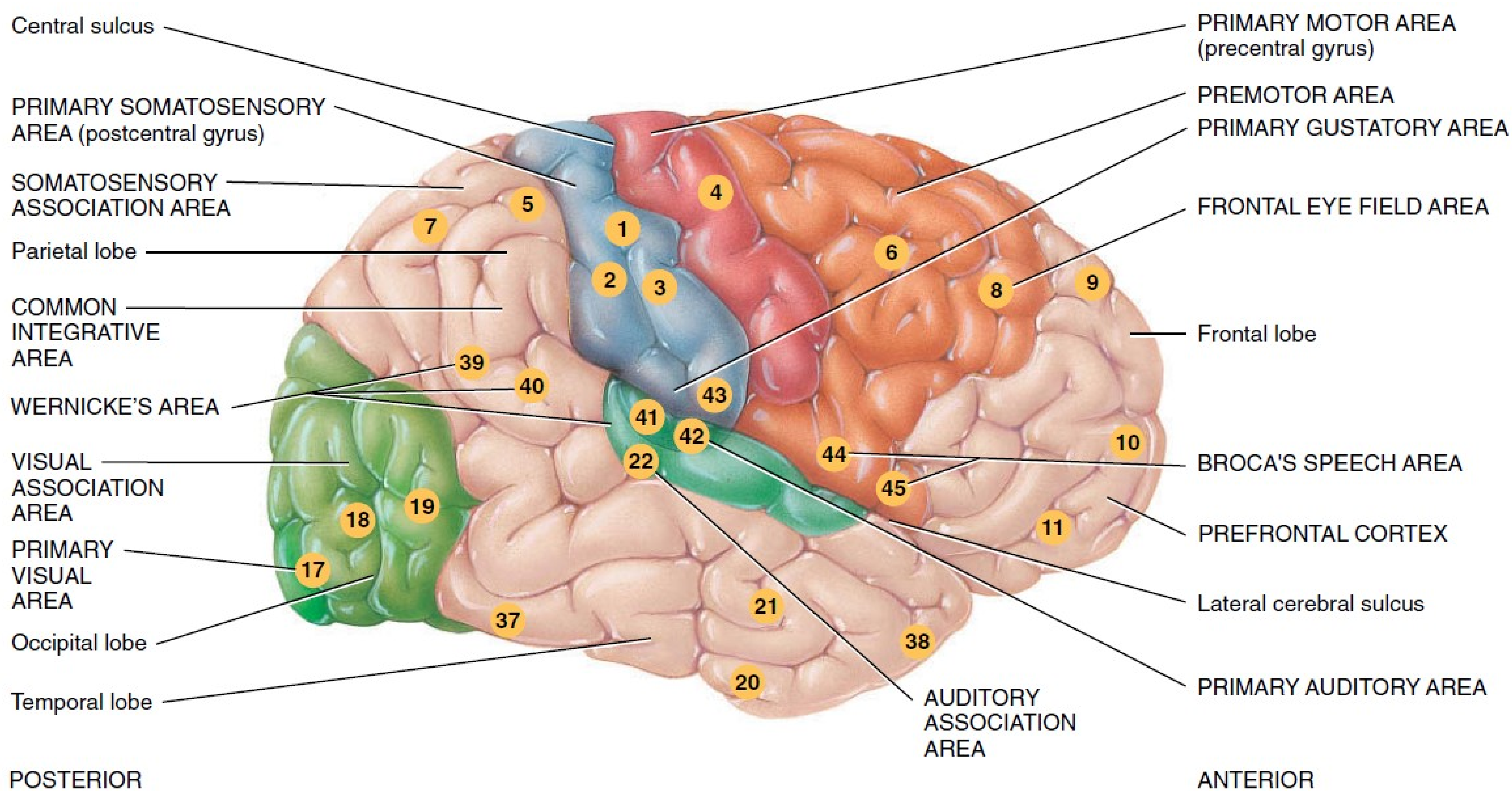
→ *Interprets the meaning of speech by recognizing spoken words. It is active as you translate words into thoughts*.

→ The regions in the *right* hemisphere that correspond to Broca's and Wernicke's areas in the left hemisphere also contribute to verbal communication by adding emotional content, such as anger or joy, to spoken words.

→ Unlike those who have Cerebrovascular Accident (CVAs) in Broca's area, people who suffer strokes in Wernicke's area can still speak, but cannot arrange words in a coherent fashion (fluent aphasia, or "word salad")

Figure 14.15 Functional areas of the cerebrum. Broca's speech area and Wernicke's area are in the left cerebral hemisphere of most people; they are shown here to indicate their relative locations. The numbers, still used today, are from K. Brodmann's map of the cerebral cortex, first published in 1909

→ Particular areas of the cerebral cortex process sensory, motor, and integrative signals.



Lateral view of right cerebral hemisphere

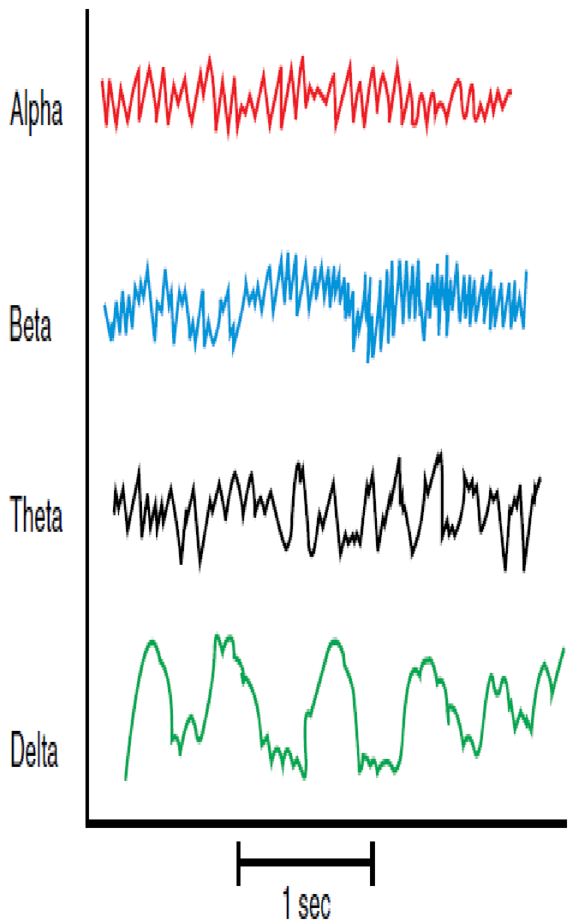
Brain Waves

- At any instant, brain neurons are generating millions of nerve impulses (action potentials).
- Taken together, these electrical signals are called **brain waves**.
- Brain waves generated by neurons close to the brain surface, mainly neurons in the cerebral cortex, can be detected by sensors called electrodes placed on the forehead and scalp.
- A record of such waves is called an **electroencephalogram EEG** (e-lek-tro¯-en-SEF-a-lo¯-gram; *electro-* electricity; *-gram* recording).
- Electroencephalograms are useful both in studying normal brain functions, such as changes that occur during sleep, and in diagnosing a variety of brain disorders, such as epilepsy, tumors, trauma, hematomas, metabolic abnormalities, sites of trauma, and degenerative diseases. The EEG is also utilized to determine if "life" is present, that is, to establish or confirm that brain death has occurred.

Figure 14.16 **Types of brain waves recorded in an electroencephalogram (EEG).**

→ Brain waves indicate electrical activity of the cerebral cortex.

WAVE	INTERPRETATION
1. Alpha waves.	present in the EEGs of nearly all normal individuals when they are awake and resting with their eyes closed. These waves disappear entirely during sleep.
2. Beta waves.	generally appear when the nervous system is active—that is, during periods of sensory input and mental activity.
3. Theta waves.	These waves normally occur in children and adults experiencing emotional stress. They also occur in many disorders of the brain.
4. Delta waves.	occur during deep sleep in adults, but they are normal in awake infants. When produced by an awake adult, they indicate brain damage.



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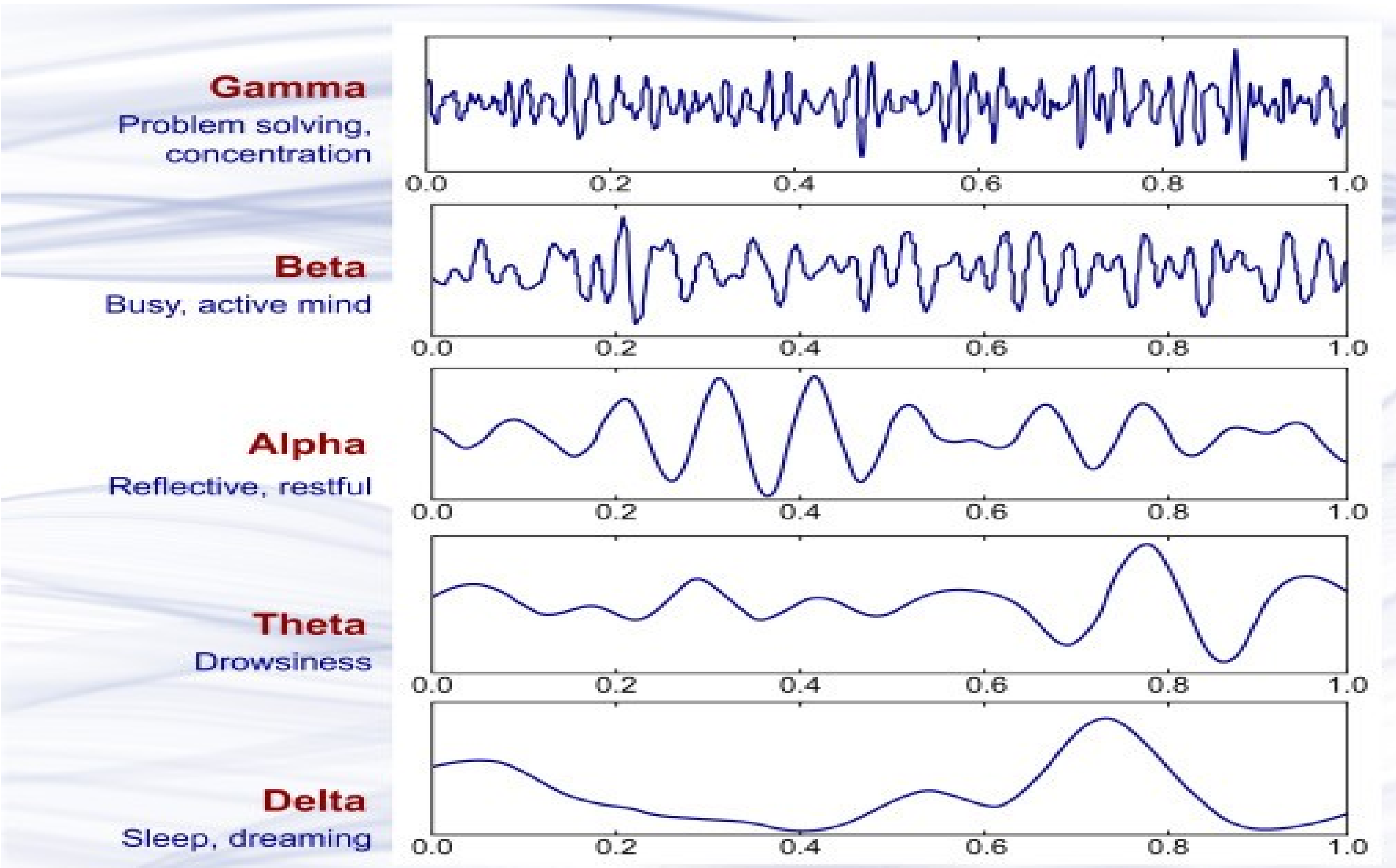

Cranial Nerves (TABLE 14.4) Summary of Cranial Nerves - 1

CRANIAL NERVE	COMPONENTS	PRINCIPAL FUNCTIONS
Olfactory (I)	***Special sensory***	✓ Olfaction (smell).
Optic (II)	***Special sensory***	✓ Vision (sight).
Oculomotor (III)	***Motor*** Somatic	✓ Movement of eyeballs and upper eyelid
	Motor (autonomic)	✓ Adjusts lens for near vision (accommodation). ✓ Constriction of pupil.
Trochlear (IV)	***Motor*** Somatic	✓ Movement of eyeballs.
Trigeminal (V)	***Mixed***	
	Sensory	✓ Touch, pain, and thermal sensations from scalp, face, and oral cavity (including teeth and anterior two-thirds of tongue).
	Motor (branchial)	✓ Chewing and controls middle ear muscle.

Cranial Nerves (TABLE 14.4) Summary of Cranial Nerves - 2

CRANIAL NERVE	COMPONENTS	PRINCIPAL FUNCTIONS
Abducens (VI)	***Motor*** Somatic	✓ Movement of eyeballs.
Facial (VII)	***Mixed***	
	Sensory	✓ Taste from anterior two-thirds of tongue. ✓ Touch, pain, and thermal sensations from skin in external ear canal.
	Motor (branchial)	✓ Control of muscles of facial expression and middle ear muscle.
	Motor (autonomic)	✓ Secretion of tears and saliva.
Vestibulocochlear (VIII)	***Special sensory***	✓ Hearing and equilibrium.

Cranial Nerves (TABLE 14.4) Summary of Cranial Nerves - 3

CRANIAL NERVE	COMPONENTS	PRINCIPAL FUNCTIONS
Glossopharyngeal (IX)	***Mixed***	
	Sensory	✓ Taste from posterior one-third of tongue. ✓ Proprioception in some swallowing muscles. ✓ Monitors blood pressure and oxygen and carbon dioxide levels in blood. ✓ Touch, pain, and thermal sensations from skin of external ear and upper pharynx.
	Motor (branchial)	✓ Assists in swallowing.
	Motor (autonomic)	✓ Secretion of saliva.

Cranial Nerves (TABLE 14.4) Summary of Cranial Nerves - 4

CRANIAL NERVE	COMPONENTS	PRINCIPAL FUNCTIONS
Vagus (X)	***Mixed***	
	Sensory	✓ Taste from epiglottis. ✓ Proprioception from throat and voice box muscles. ✓ Monitors blood pressure and oxygen and carbon dioxide levels in blood. ✓ Touch, pain, and thermal sensations from skin of external ear. ✓ Sensations from thoracic and abdominal organs.
	Motor (branchial)	✓ Swallowing, vocalization, and coughing.
	Motor (autonomic)	✓ Motility and secretion of gastrointestinal organs. ✓ Constriction of respiratory passageways. ✓ Decreases heart rate.
Accessory (XI)	***Motor*** Branchial	✓ Movement of head and pectoral girdle.
Hypoglossal (XII)	***Motor*** Somatic	✓ Speech, manipulation of food, and swallowing.

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