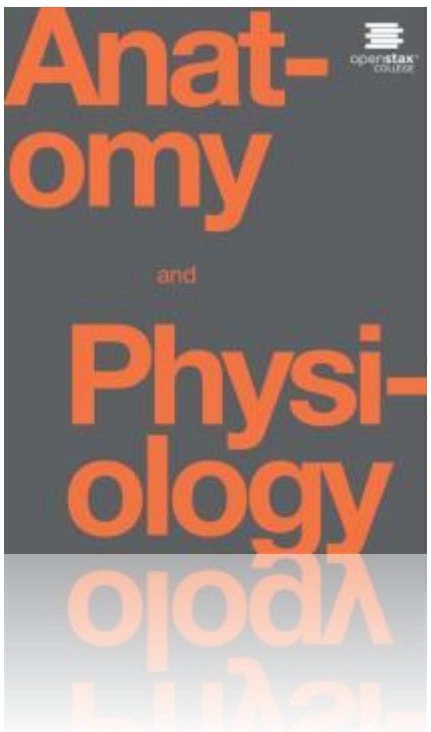
ANATOMY & PHYSIOLOGY

Chapter 13 ANATOMY OF NERVOUS SYSTEM

PowerPoint Image Slideshow



N.B.: <u>Exercises 14 and 15</u> of your lab manual are mandatory complements for this chapter.

MAJOR CHAPTER OBJECTIVES

- Relate the developmental processes of the embryonic nervous system to the adult structures
- Name the major regions of the adult nervous system
- Locate regions of the cerebral cortex on the basis of anatomical landmarks common to all human brains
- Describe the regions of the spinal cord in cross-section
- List the cranial nerves in order of anatomical location and provide the central and peripheral connections
- List the spinal nerves by vertebral region and by which nerve plexus each supplies

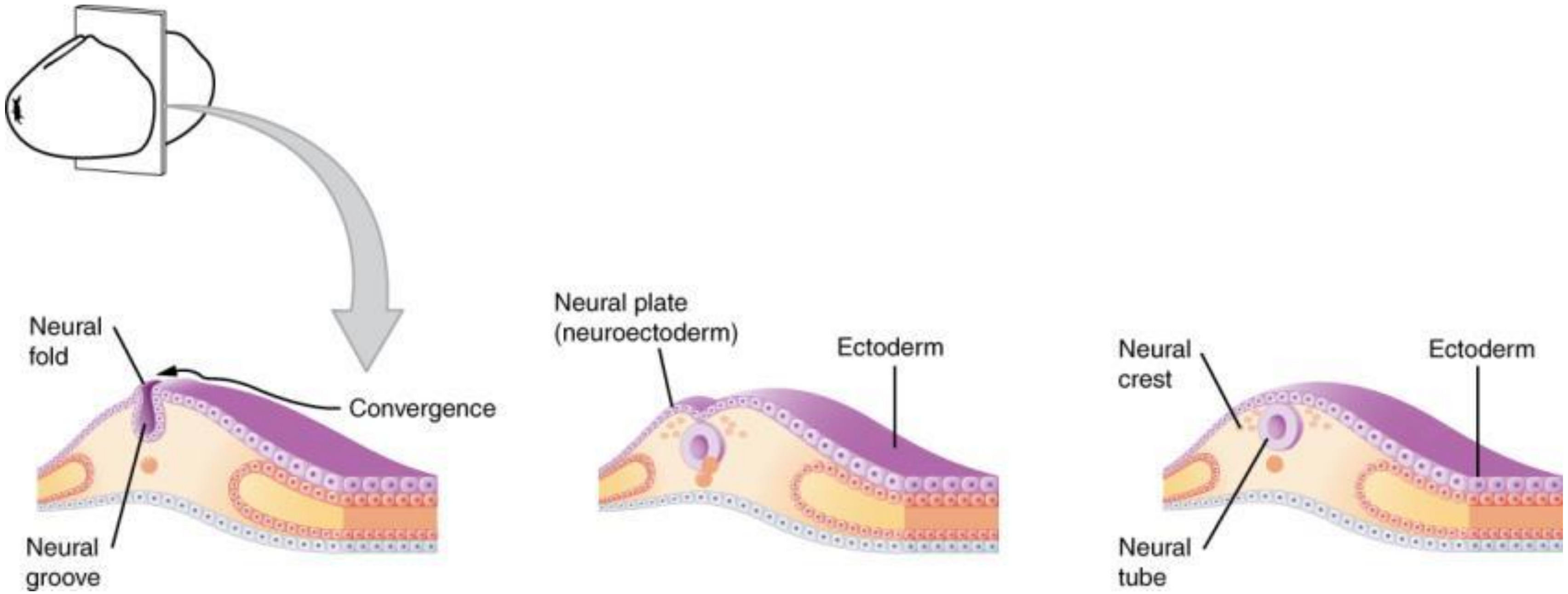
Add:

- Explain and illustrate the concept of somatotopy (associated to that of “localization of function”)
- Be able to discuss normal development and selected aging issues
- Be able to discuss selected, associated disorders

13.1 THE EMBRYOLOGIC PERSPECTIVE
MAJOR SECTION OBJECTIVES

- Describe the growth and differentiation of the neural tube
- Relate the different stages of development to the adult structures of the central nervous system
- Explain the expansion of the ventricular system of the adult brain from the central canal of the neural tube
- Describe the connections of the diencephalon and cerebellum on the basis of patterns of embryonic development

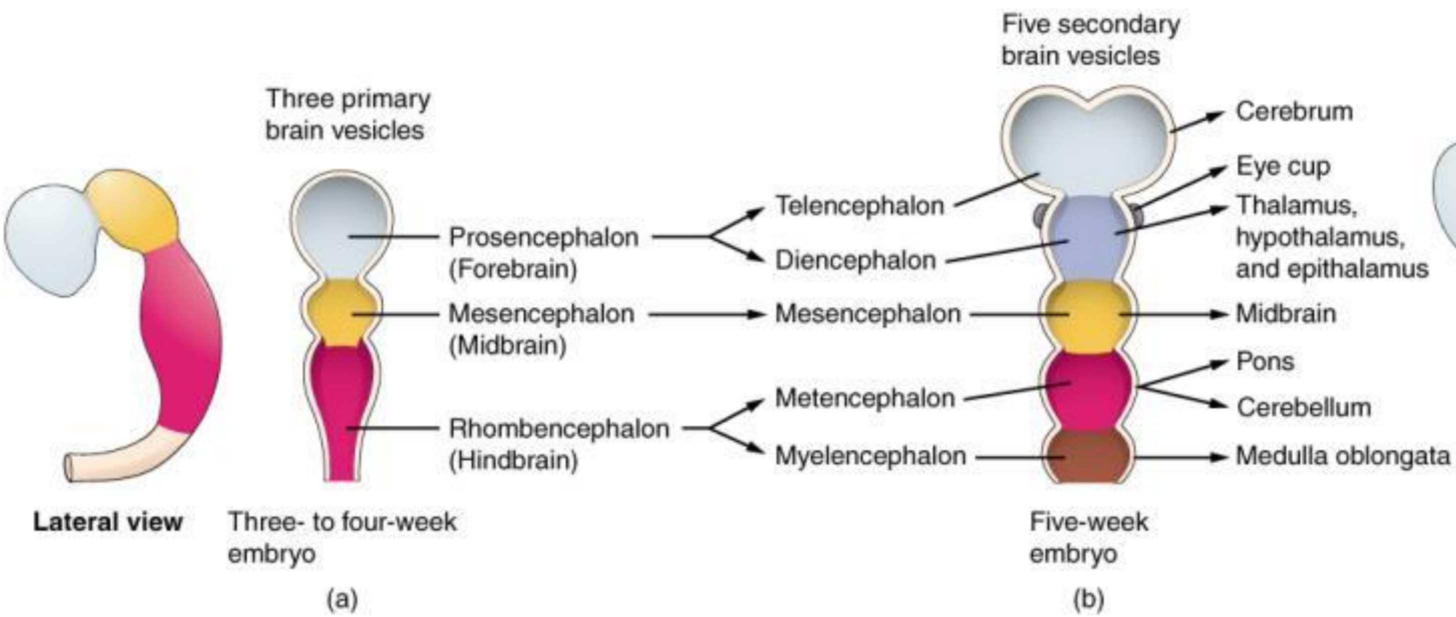
FIGURE 13.2



Early Embryonic Development of Nervous System (at about 16 days)

The neuroectoderm begins to fold inward to form the neural groove. As the two sides of the neural groove converge, they form the neural tube, which lies beneath the ectoderm. The anterior end of the neural tube will develop into the brain, and the posterior portion will become the spinal cord. The neural crest develops into peripheral structures.

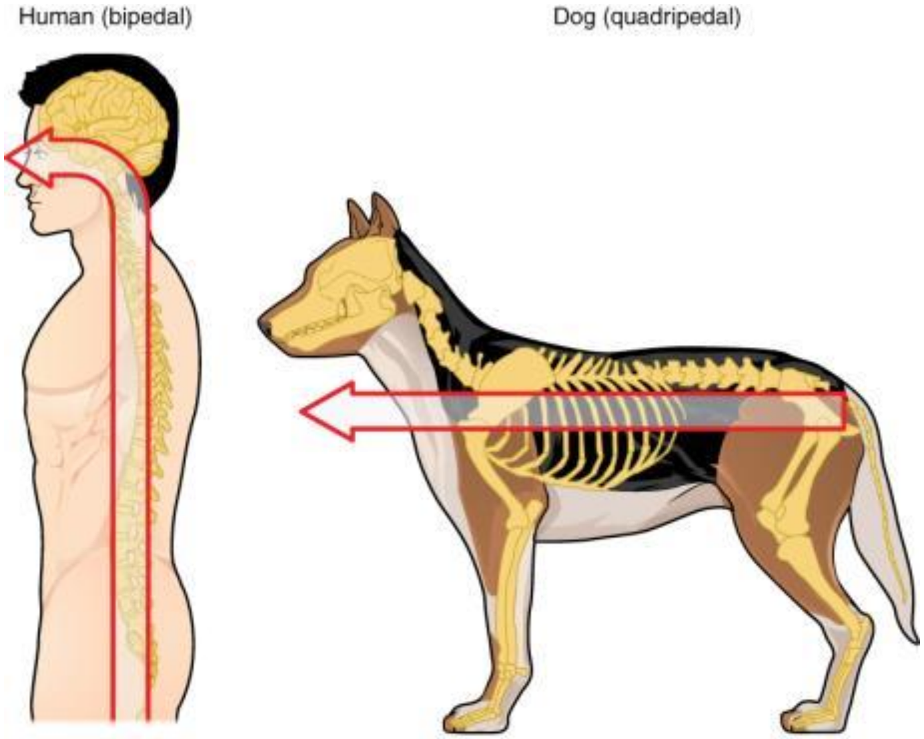
FIGURE 13.3



Primary and Secondary Vesicle Stages of Development

The embryonic brain develops complexity through enlargements of the neural tube called vesicles; (a) The primary vesicle stage has three regions, and (b) the secondary vesicle stage has five regions.

FIGURE 13.4



Human Neuraxis

The mammalian nervous system is arranged with the neural tube running along an anterior to posterior axis, from nose to tail for a four-legged animal like a dog. Humans, as two-legged animals, have a bend in the neuraxis between the brain stem and the diencephalon, along with a bend in the neck, so that the eyes and the face are oriented forward.

TABLE 13.1

Stages of Embryonic Development

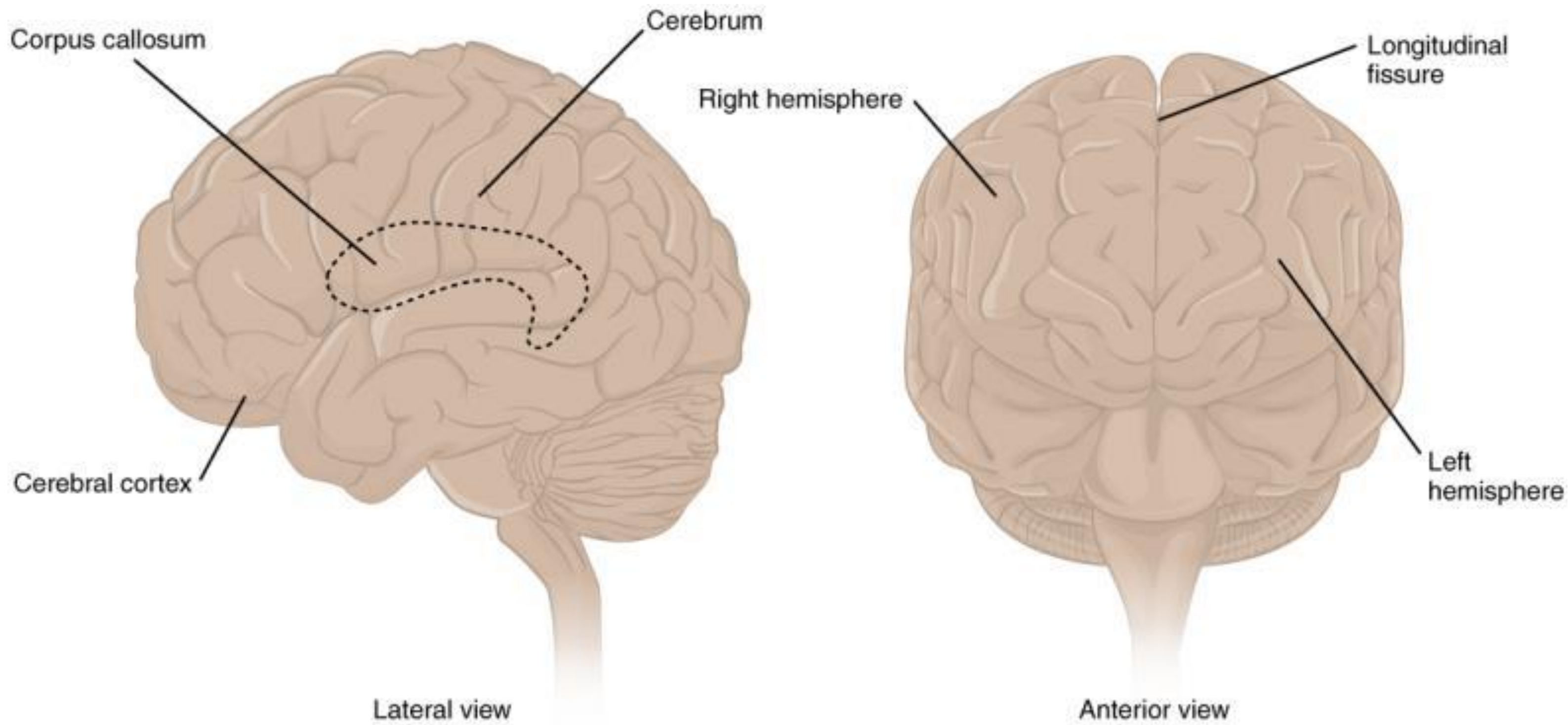
Neural tube	Primary vesicle stage	Secondary vesicle stage	Adult structures	Ventricles
Anterior	Prosencephalon	Telencephalon	• Cerebrum	Lateral ventricles (I and II)
Anterior	Prosencephalon	Diencephalon	• Diencephalon	Third - III
Anterior	Mesencephalon	Mesencephalon	• Midbrain	Cerebral aqueduct
Anterior	Rhombencephalon	Metencephalon	• Pons, cerebellum	Fourth - IV
Anterior	Rhombencephalon	Myelencephalon	• Medulla	Fourth - IV
Posterior	-	-	• Spinal cord	Central canal

N.B. A synonym for “cerebral aqueduct” is “aqueduct of Sylvius”.

13.2 THE CENTRAL NERVOUS SYSTEM
MAJOR SECTION OBJECTIVES

- Name the major regions of the adult brain
- Describe the connections between the cerebrum and brain stem through the diencephalon, and from those regions into the spinal cord
- Recognize the complex connections within the subcortical structures of the basal nuclei
- Explain the arrangement of gray and white matter in the spinal cord

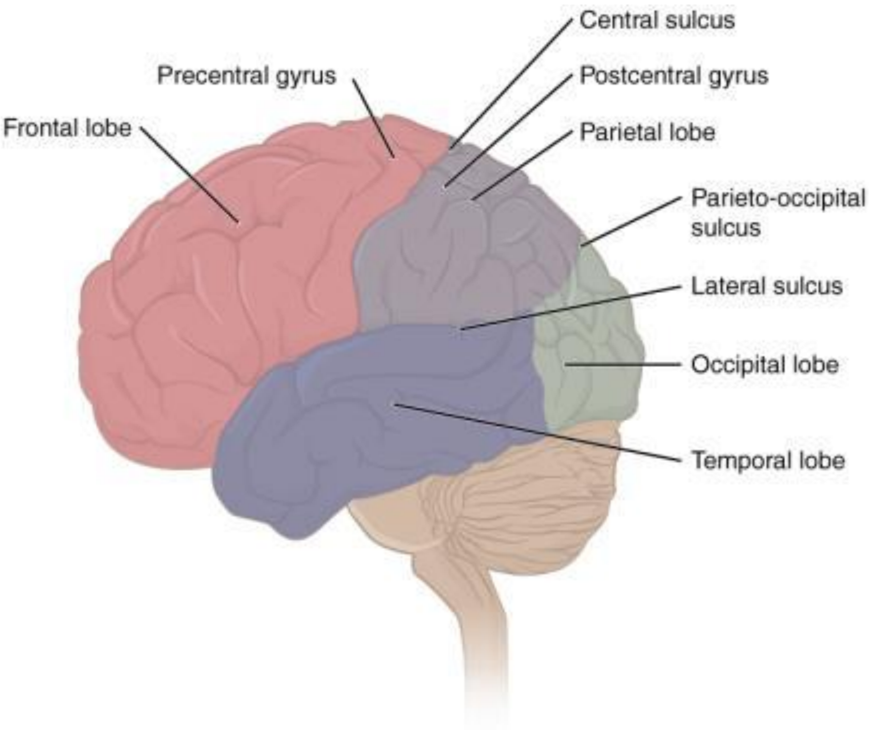
FIGURE 13.6



The Cerebrum

The cerebrum is a large component of the CNS in humans, and the most obvious aspect of it is the folded surface called the cerebral cortex.

FIGURE 13.7

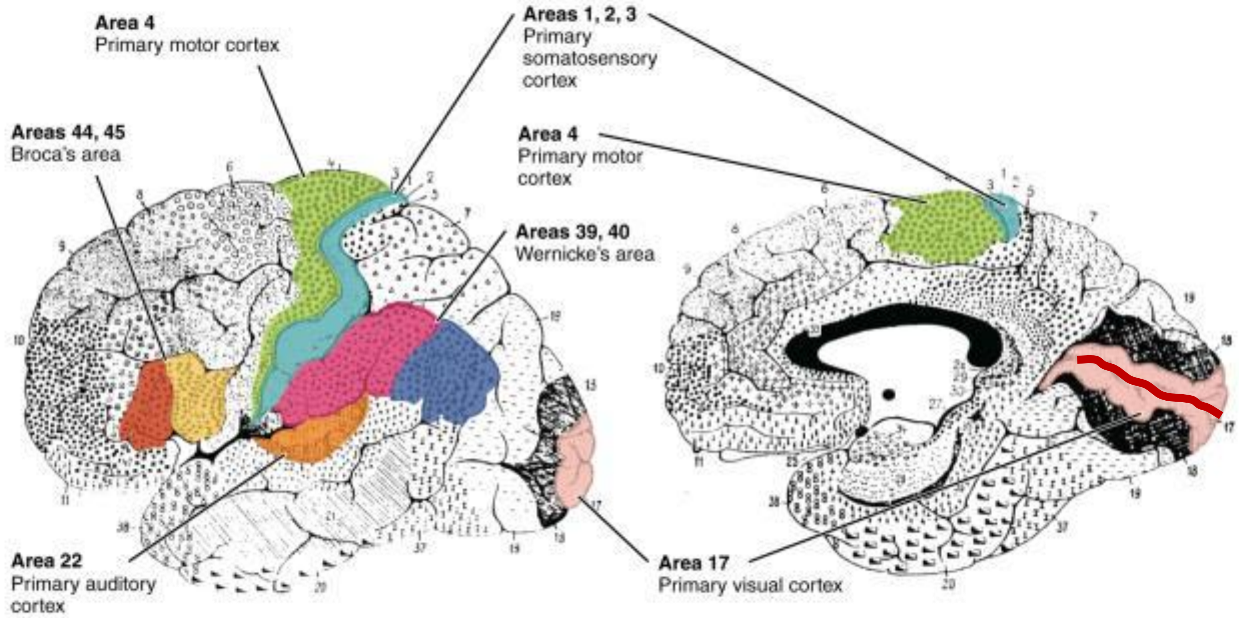


Lobes of the Cerebral Cortex

The cerebral cortex is divided into ~~four~~ **five** lobes. Extensive folding increases the surface area available for cerebral functions.

Omisson in text and figures:
The cerebrum is divided in **five** lobes: frontal, parietal, temporal, occipital and the **insula**, buried within the temporal lobe on each side.

FIGURE 13.8



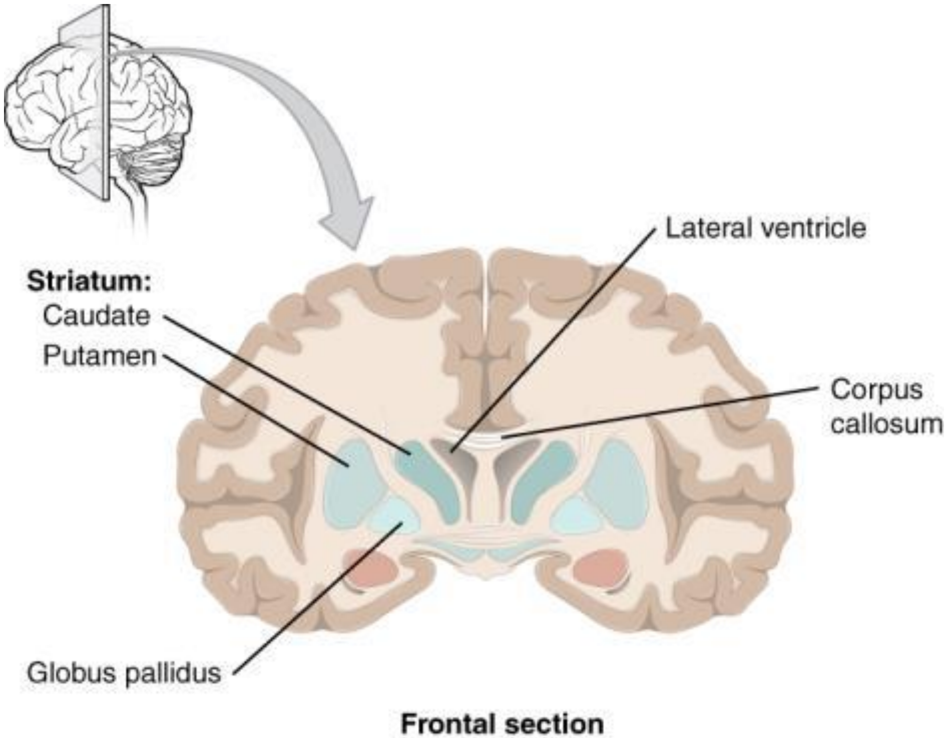
Brodmann's cytotechtonic map (1909):
Lateral surface

Brodmann's cytotechtonic map (1909):
Medial surface

Brodmann's Areas of the Cerebral Cortex

Brodmann mapping of functionally distinct regions of the cortex was based on its cytoarchitecture at a microscopic level.

FIGURE 13.9

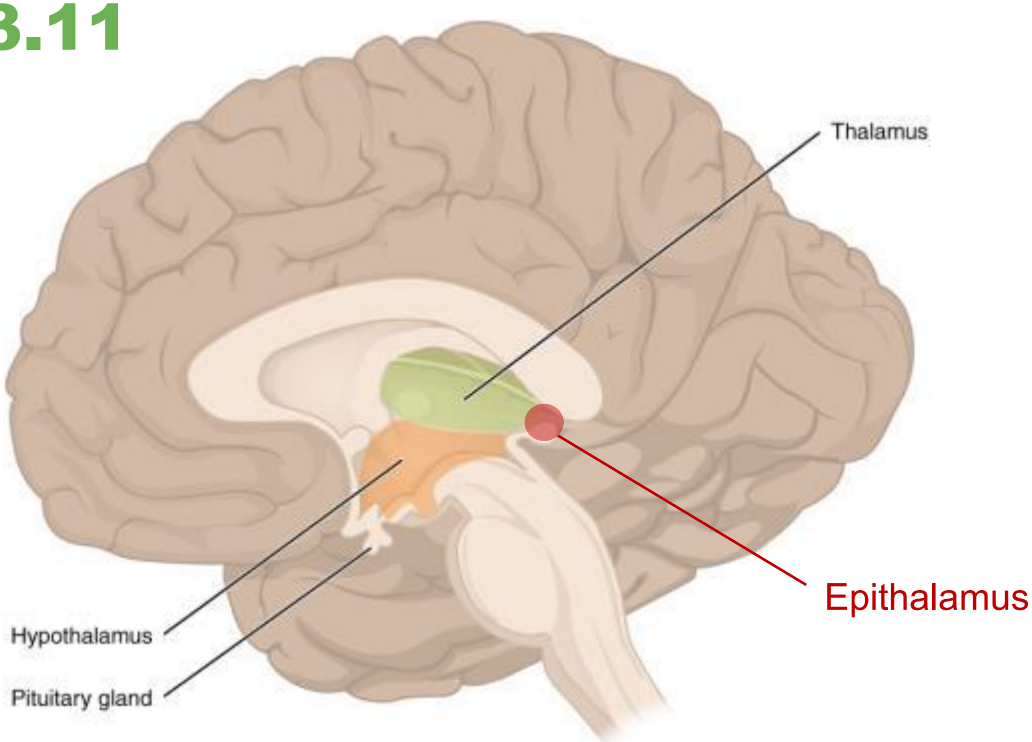


Frontal Section of Cerebral Cortex and Basal Nuclei

The major components of the basal nuclei, shown in a frontal section of the brain, are the caudate (just lateral to the lateral ventricle), the putamen (inferior to the caudate and separated by the large white-matter structure called the internal capsule), and the globus pallidus (medial to the putamen).

BIO229: You are expected to learn to name and recognize the basal nuclei and explain their general functions, but NOT expected to memorize the details found below Fig. 13.9, on p. 562 of your textbook, or in Fig. 13.10.

FIGURE 13.11



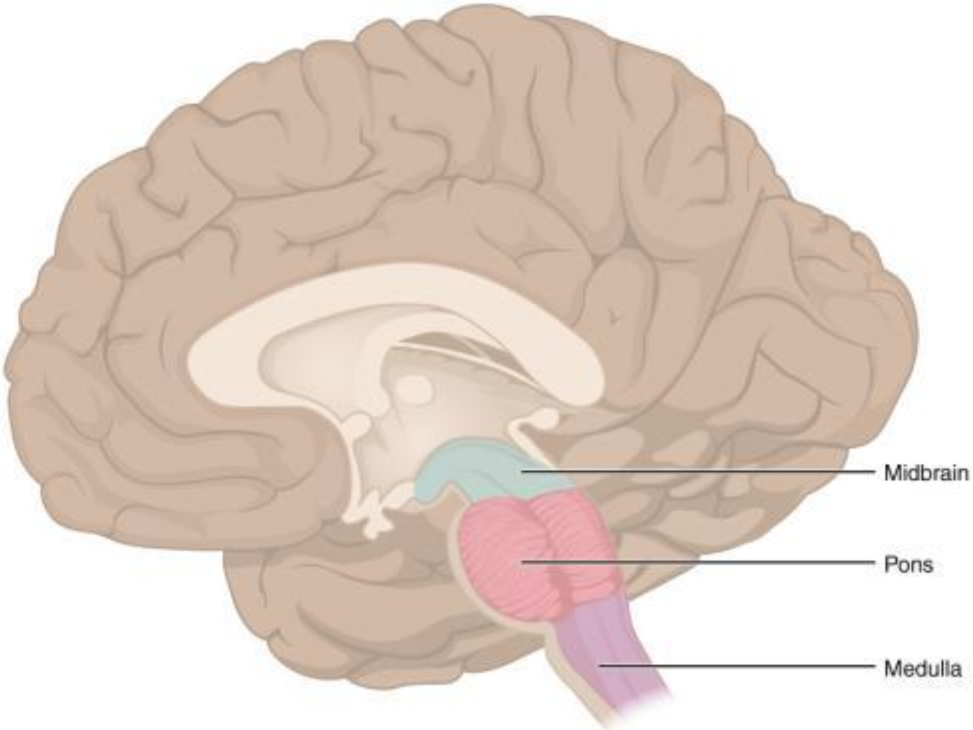
Add

The Diencephalon

The diencephalon is composed primarily of the **thalamus** and **hypothalamus**, which together define the walls of the third ventricle. The thalami are two elongated, ovoid structures on either side of the midline that make contact in the middle. The hypothalamus is inferior and anterior to the thalamus, culminating in a sharp angle to which the pituitary gland is attached.

Add: The epithalamus contains, mostly, the pineal gland.

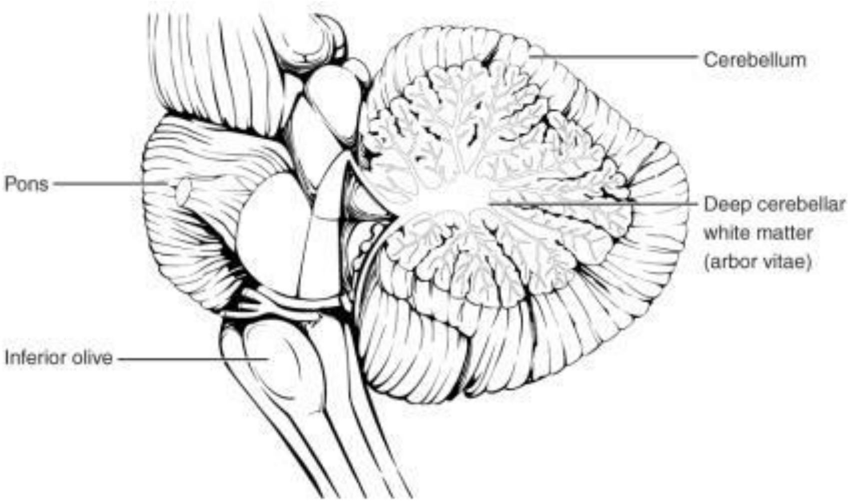
FIGURE 13.12

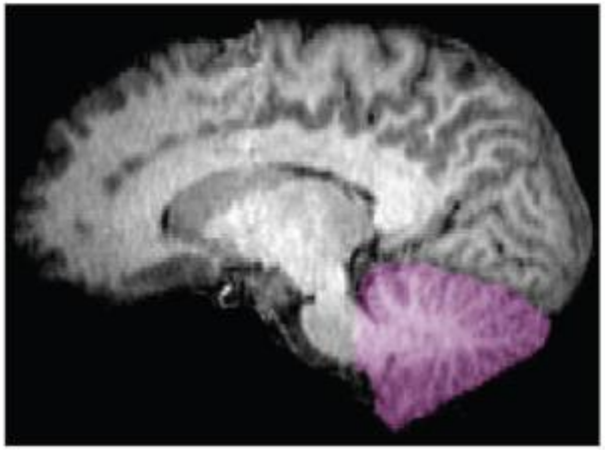


The Brain Stem

The brain stem comprises three regions: the midbrain, the pons, and the medulla.

FIGURE 13.13





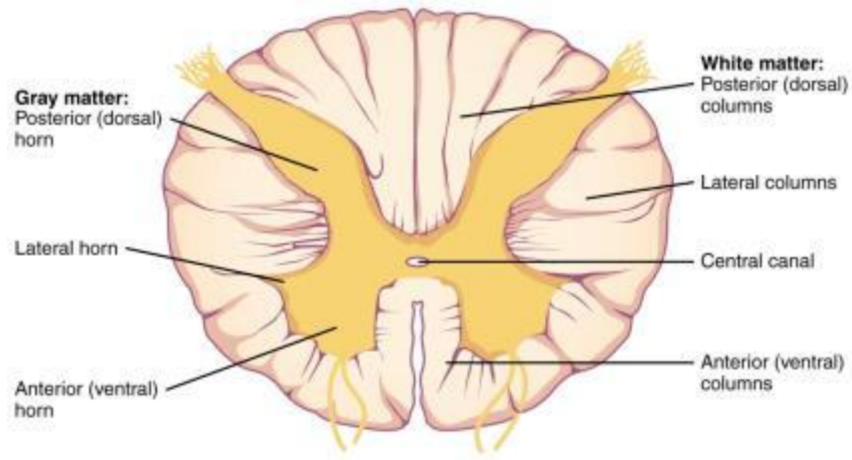
The Cerebellum

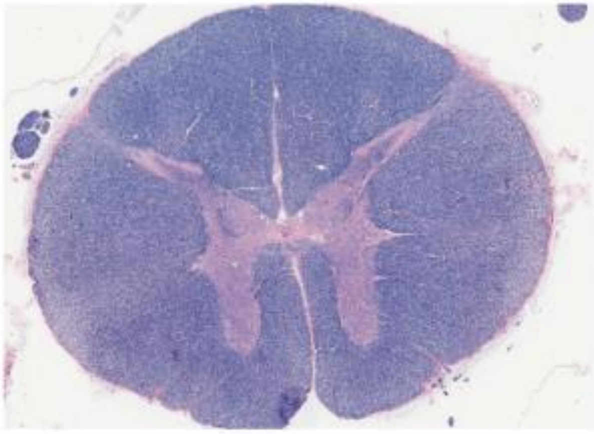
The cerebellum is situated on the posterior surface of the brain stem. Descending input from the cerebellum enters through the large white matter structure of the pons. Ascending input from the periphery and spinal cord enters through the fibers of the inferior olive. Output goes to the midbrain, which sends a descending signal to the spinal cord.

FIGURE 13.14

Cross-section of Spinal Cord

The cross-section of a thoracic spinal cord segment shows the posterior, anterior, and lateral horns of gray matter, as well as the posterior, anterior, and lateral columns of white matter. LM × 40. (Micrograph provided by the Regents of University of Michigan Medical School © 2012)





N.B. Each white column can also be called a “funiculus” (plural: funiculi).

13.3 CIRCULATION IN THE CENTRAL NERVOUS SYSTEM
MAJOR SECTION OBJECTIVES

- Describe the vessels that supply the CNS with blood
- Name the components of the ventricular system and the regions of the brain in which each is located
- Explain the production of cerebrospinal fluid and its flow through the ventricles
- Explain how a disruption in circulation would result in a stroke

FIGURE 13.15

Circle of Willis

The blood supply to the brain enters through the internal carotid arteries and the vertebral arteries, eventually giving rise to the circle of Willis.

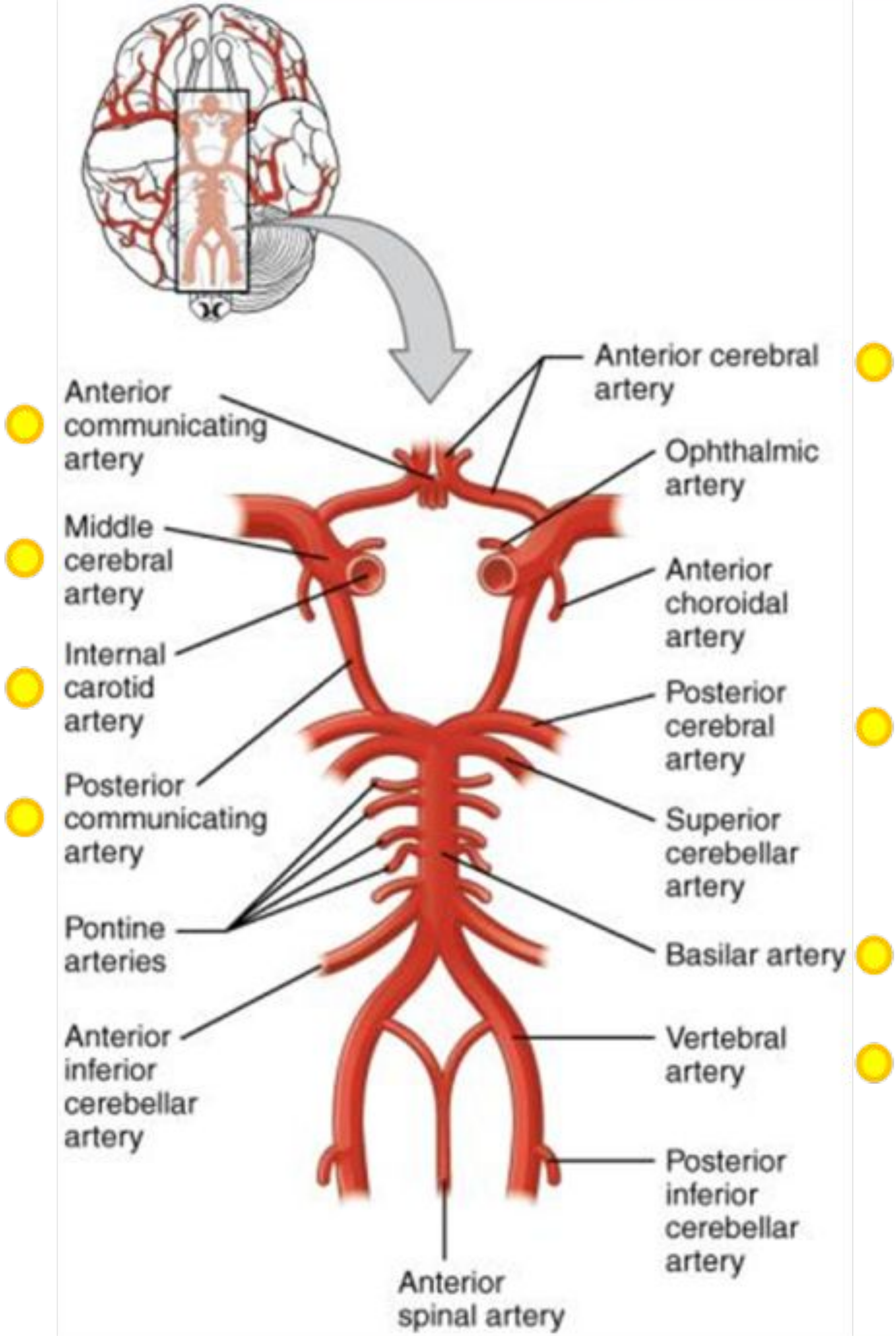


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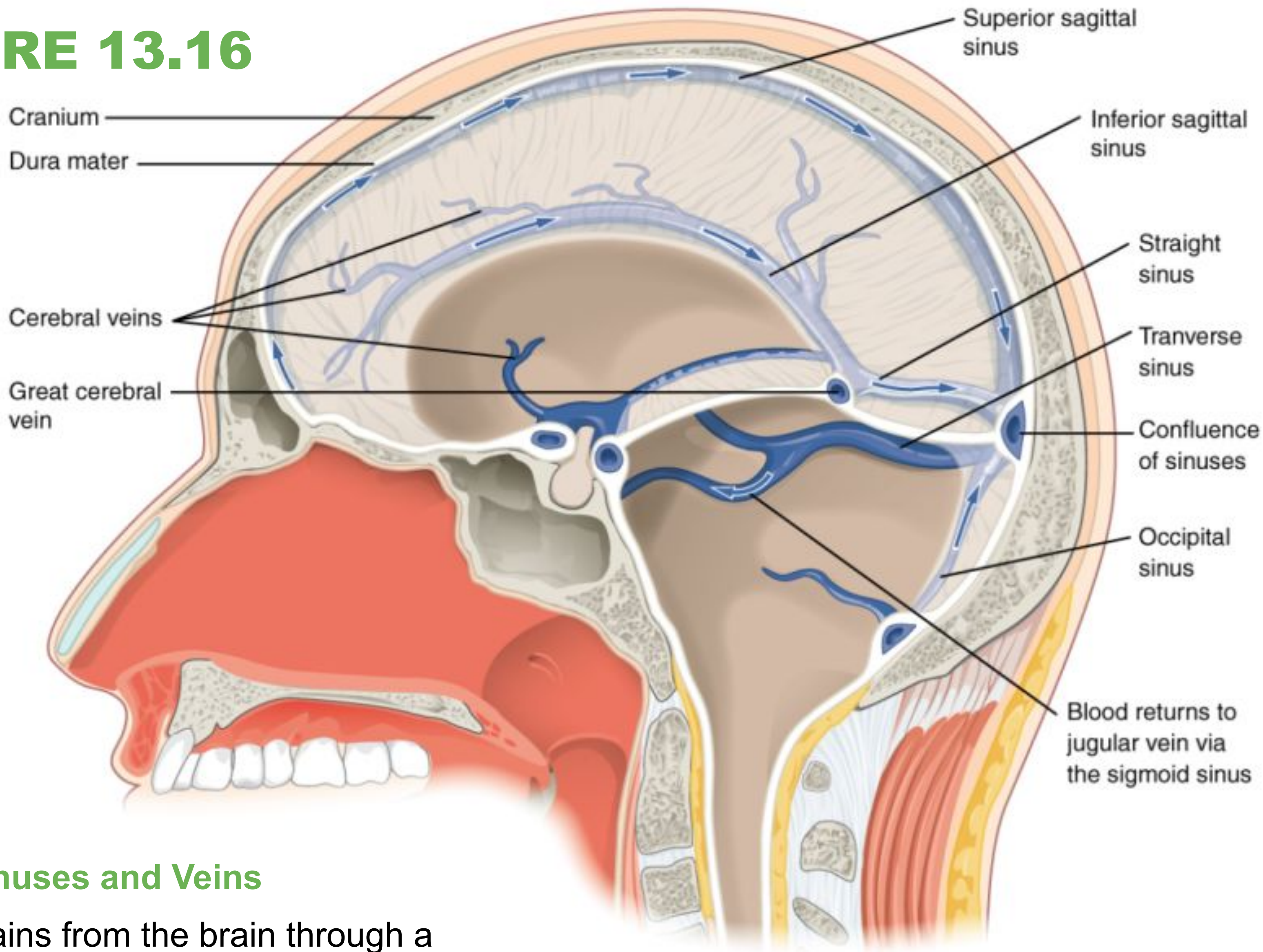
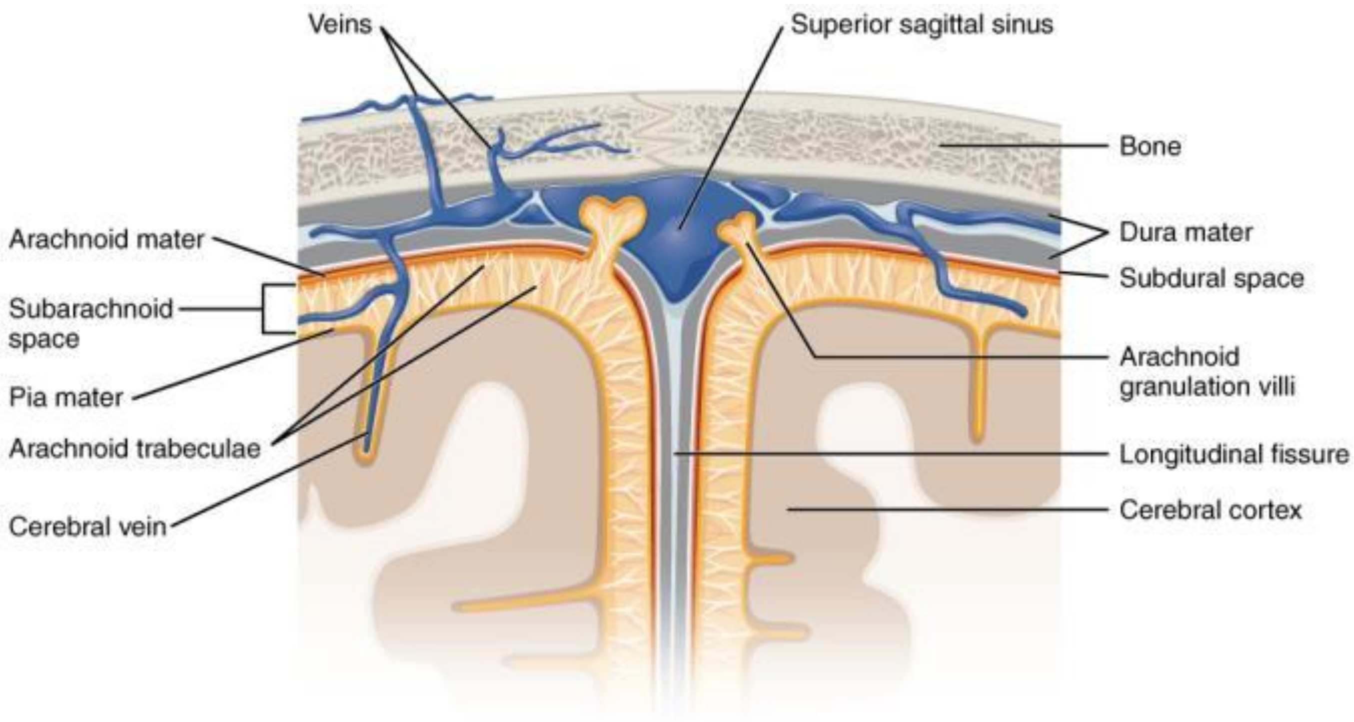
FIGURE 13.16



Dural Sinuses and Veins

Blood drains from the brain through a series of sinuses that connect to the jugular veins.

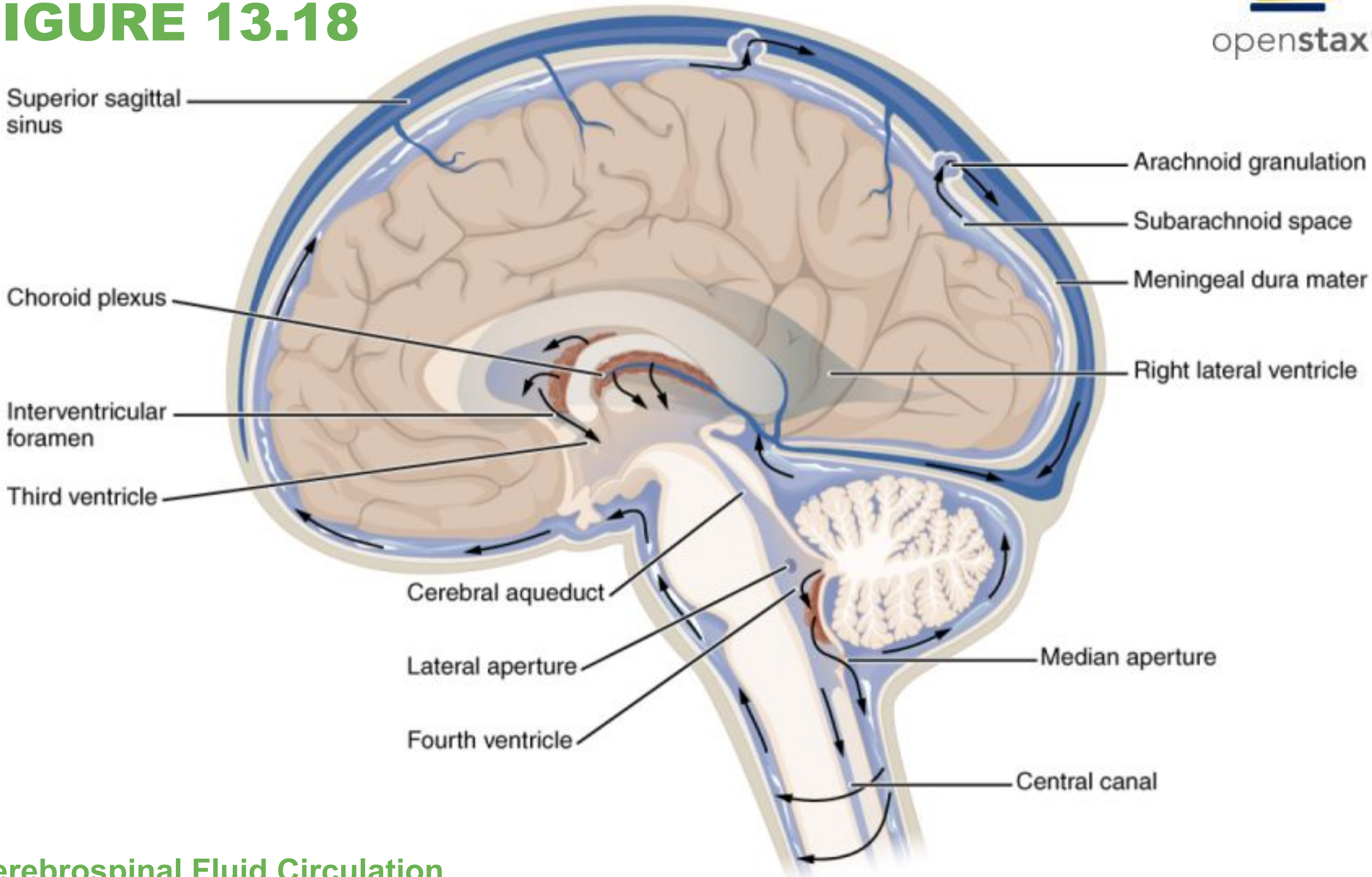
FIGURE 13.17



Meningeal Layers of Superior Sagittal Sinus

The layers of the meninges in the longitudinal fissure of the superior sagittal sinus are shown, with the dura mater adjacent to the inner surface of the cranium, the pia mater adjacent to the surface of the brain, and the arachnoid and subarachnoid space between them. An arachnoid villus is shown emerging into the dural sinus to allow CSF to filter back into the blood for drainage.

FIGURE 13.18



Cerebrospinal Fluid Circulation

The choroid plexus in the four ventricles produce CSF, which is circulated through the ventricular system and then enters the subarachnoid space through the median and lateral apertures. The CSF is then reabsorbed into the blood at the arachnoid granulations, where the arachnoid membrane emerges into the dural sinuses.

MODIFIED TABLE 13.2

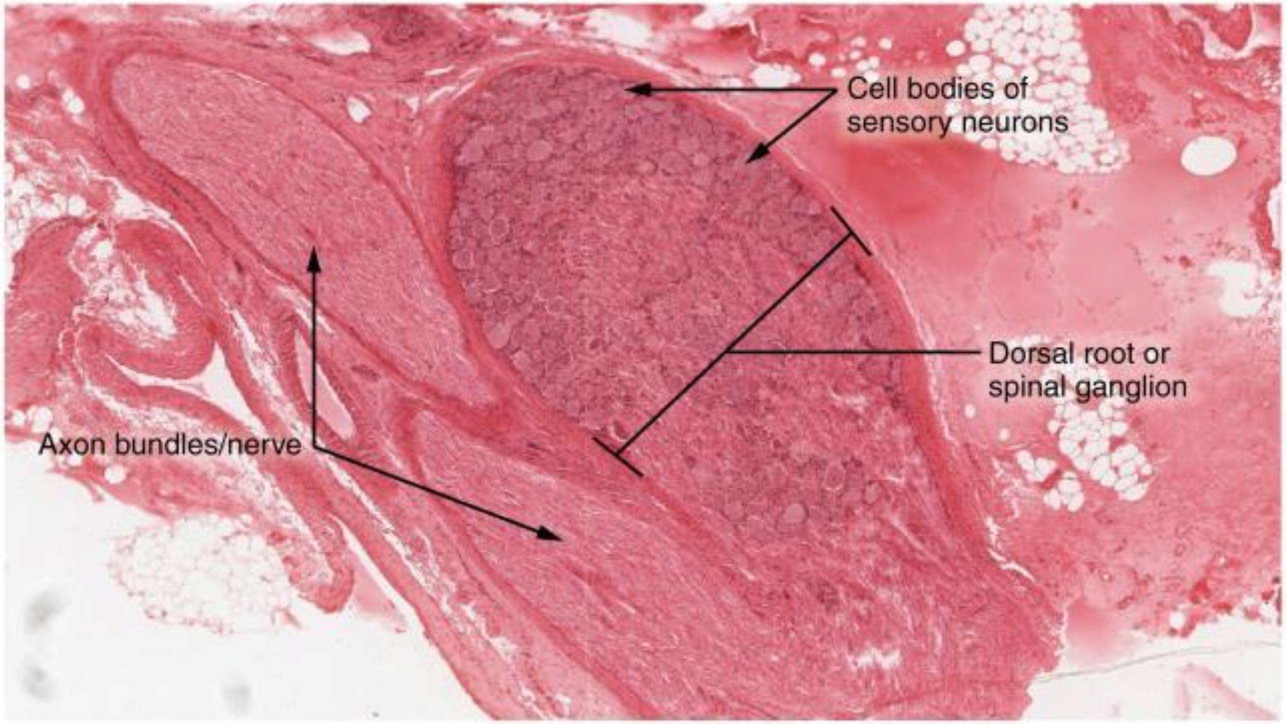
Components of CSF Circulation

Component	Location in CNS	Blood vessel structure
Lateral ventricle – I	Cerebrum, left hemisphere	Choroid plexus
Lateral ventricle – II	Cerebrum, right hemisphere	Choroid plexus
Third ventricle – III	Diencephalon	Choroid plexus
Cerebral aqueduct	Midbrain	None
Fourth ventricle – IV	Between pons, upper medulla and cerebellum	Choroid plexus
Central canal	Spinal cord	None
Subarachnoid space	External to the entire CNS	Arachnoid granulations projecting into dural sinuses

13.4 THE PERIPHERAL NERVOUS SYSTEM MAJOR SECTION OBJECTIVES

- Describe the structures found in the PNS
- Distinguish between somatic and autonomic structures, including the special peripheral structures of the enteric nervous system
- Name the twelve cranial nerves and explain the functions associated with each
- Describe the sensory and motor components of spinal nerves and the plexuses that they pass through

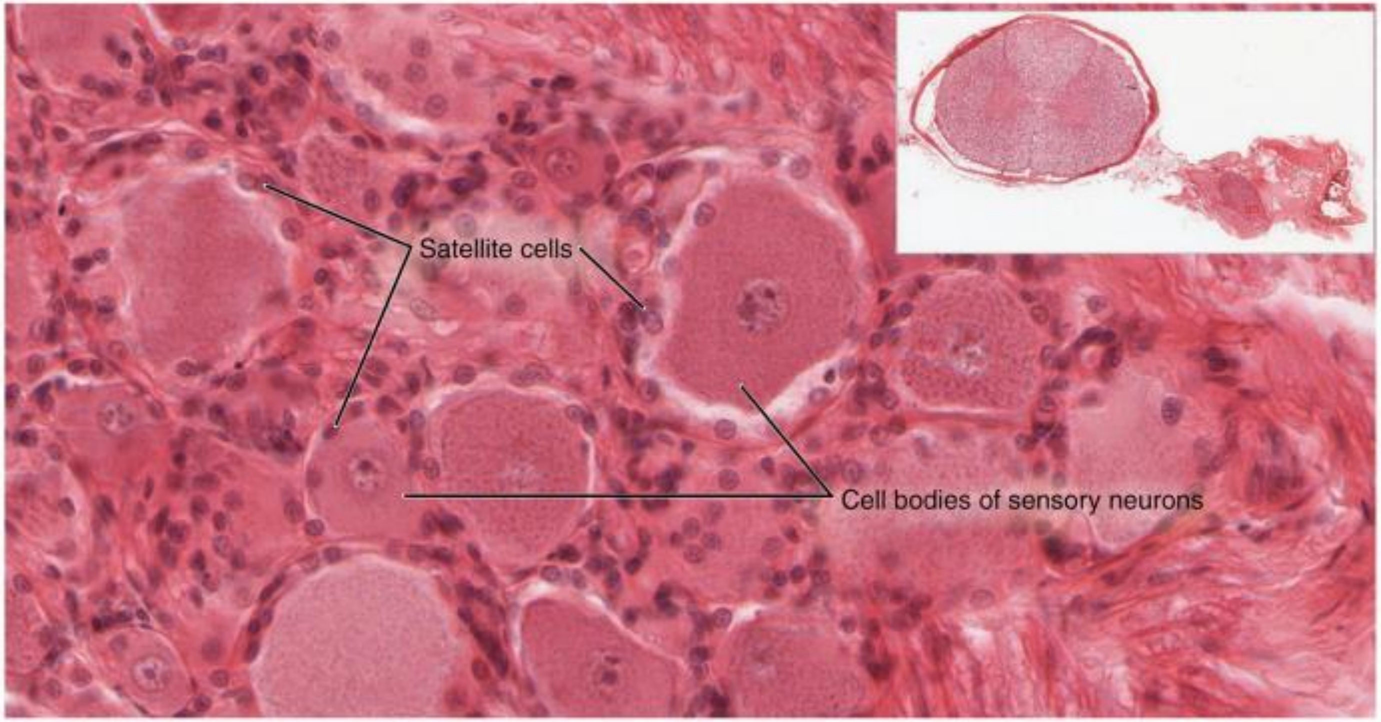
FIGURE 13.19



Dorsal Root Ganglion

The cell bodies of sensory neurons, which are unipolar neurons by shape, are seen in this photomicrograph. Also, the fibrous region is composed of the axons of these neurons that are passing through the ganglion to be part of the dorsal nerve root (tissue source: canine). LM × 40. (Micrograph provided by the Regents of University of Michigan Medical School © 2012)

FIGURE 13.20



Spinal Cord and Root Ganglion

The slide includes both a cross-section of the lumbar spinal cord and a section of the dorsal root ganglion (see also Figure 13.19) (tissue source: canine). LM × 1600. (Micrograph provided by the Regents of University of Michigan Medical School © 2012)

FIGURE 13.21

Nerve Structure

The structure of a nerve is organized by the layers of connective tissue on the outside, around each fascicle, and surrounding the individual nerve fibers (tissue source: simian). LM × 40. (Micrograph provided by the Regents of University of Michigan Medical School © 2012)

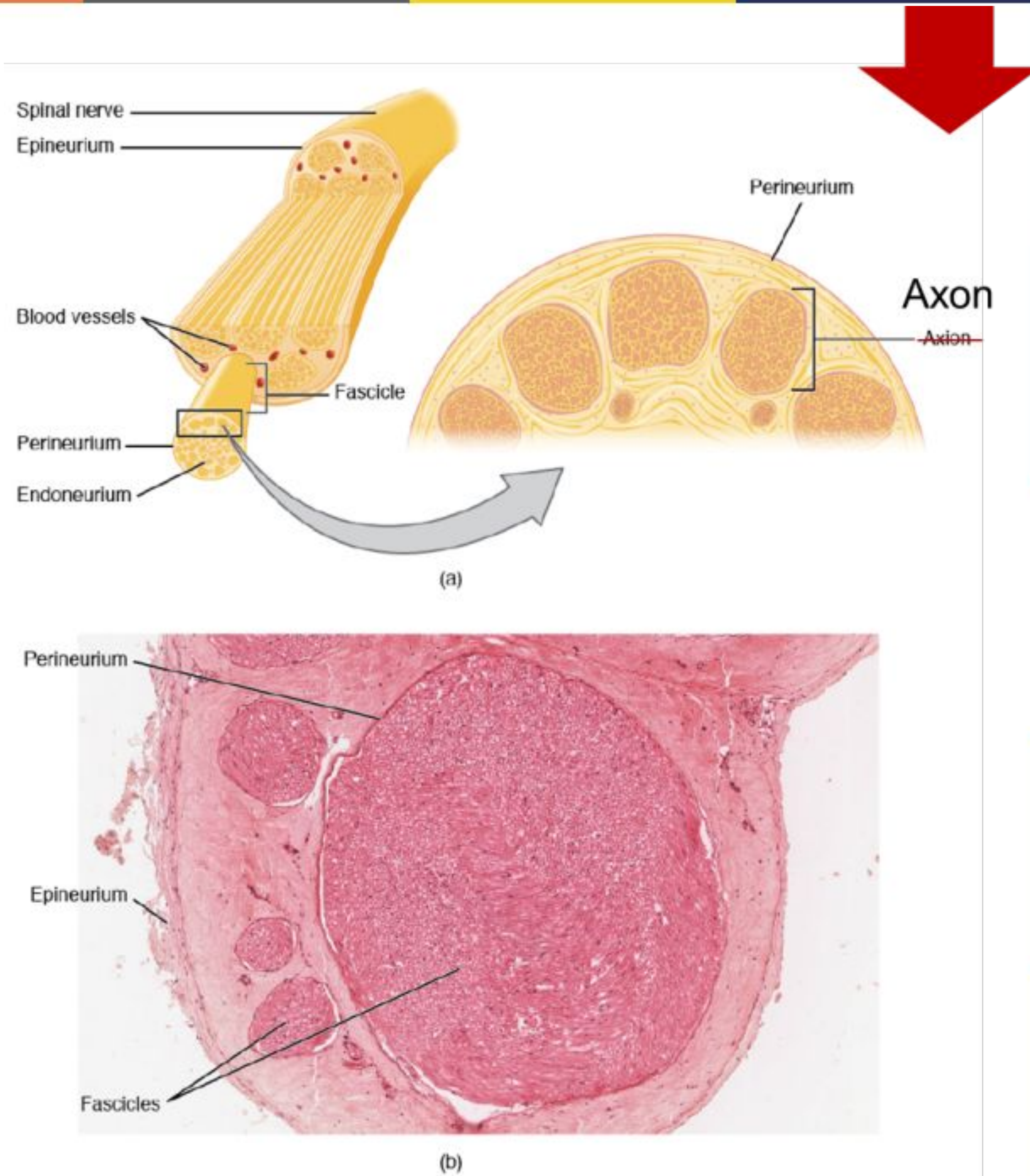


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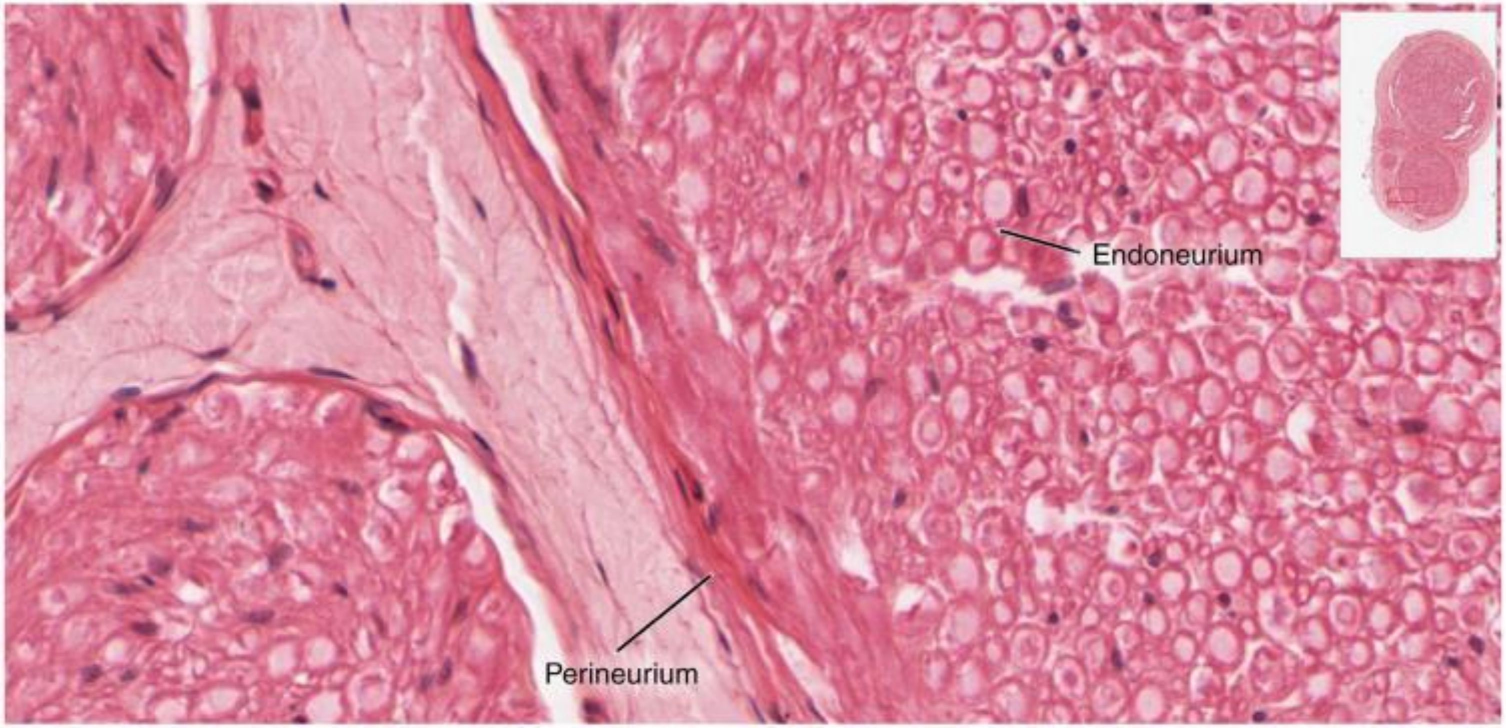
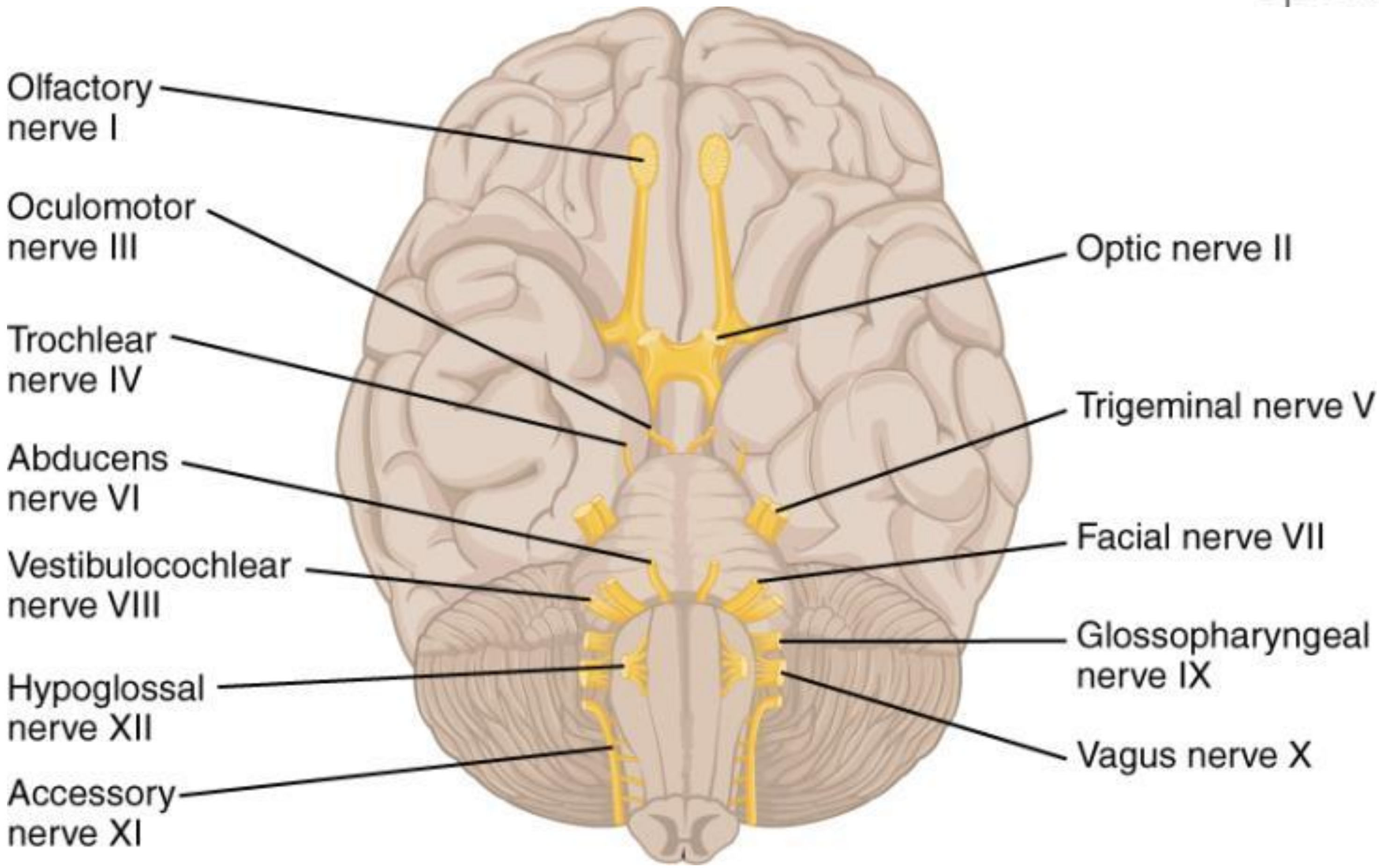
FIGURE 13.22



Close-Up of Nerve Trunk

Zoom in on this slide of a nerve trunk to examine the endoneurium, perineurium, and epineurium in greater detail (tissue source: simian). LM × 1600. (Micrograph provided by the Regents of University of Michigan Medical School © 2012)

FIGURE 13.23



The Cranial Nerves

The anatomical arrangement of the roots of the cranial nerves observed from an inferior view of the brain.

MODIFIED TABLE 13.3

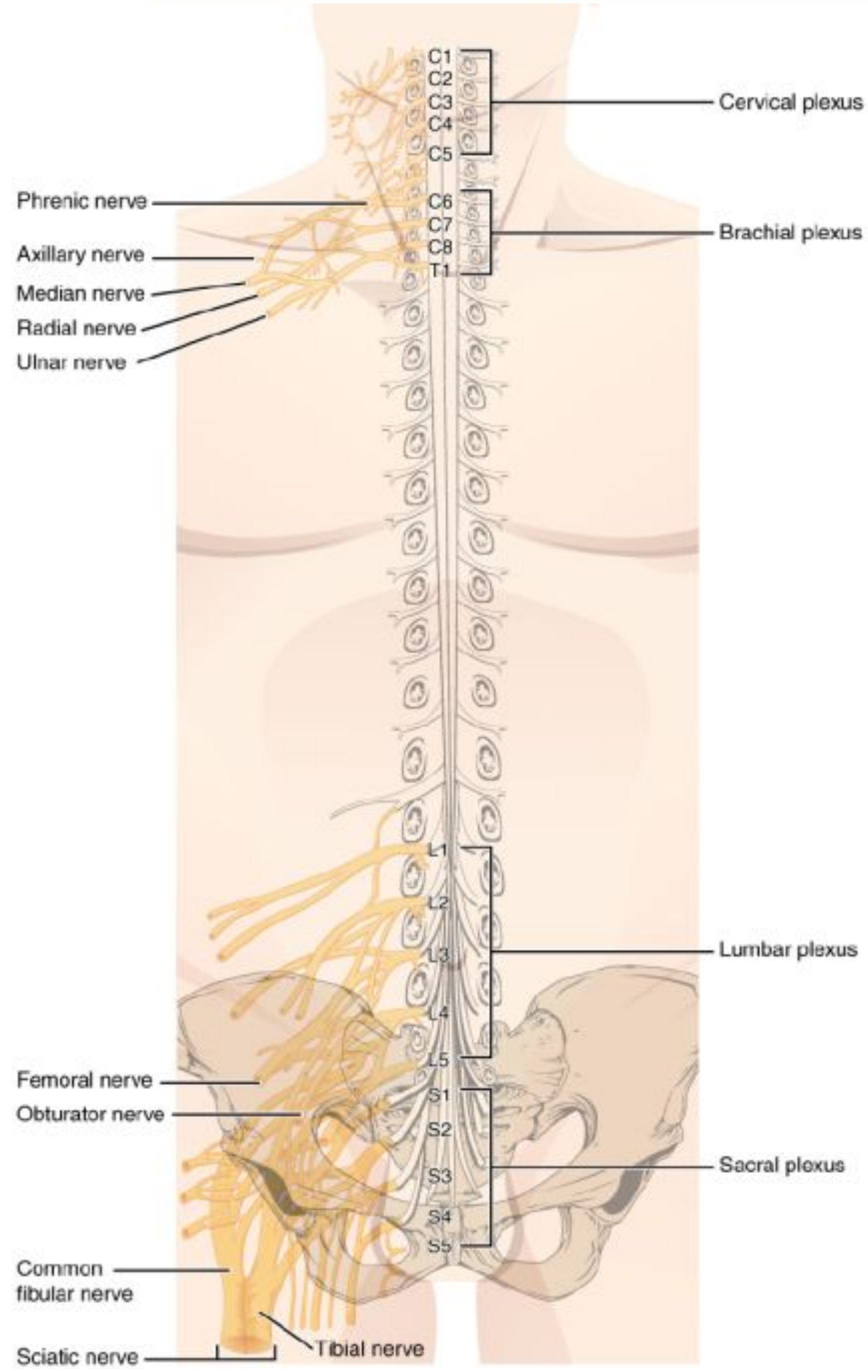
Cranial Nerves

#	Name(s)	Function (S/M/B)	Peripheral connection
I	Olfactory	Smell (S)	Olfactory epithelium
II	Optic	Vision (S)	Retina
III	Oculomotor	Eye mvmnts (M)	Orbit, eye muscles
IV	Trochlear	Eye mvmnts (M)	Superior oblique m.
V	Trigeminal	Sensory/Motor face (B)	Many in V1, V2, V3
VI	Abducens	Eye mvmnts (M)	Lateral rectus m.
VII	Facial	Motor face, taste (B)	Facial muscles, ganglia
VIII	Vestibulochoclear (Auditory)	Hearing and Balance (S)	Spiral ganglion Vestibular ganglion
IX	Glossopharyngeal	Motor throat, taste (B)	Pharynx muscles, ganglia
X	Vagus	Sensory/Motor viscera (B)	Ganglia (thorax, abdomen)
XI	Accessory (Spinal)	Motor head/neck (M)	Neck muscles
XII	Hypoglossal	Motor lower throat (M)	Larynx, low pharynx muscles

FIGURE 13.24

Nerve Plexuses of the Body

There are four main nerve plexuses in the human body. The cervical plexus supplies nerves to the posterior head and neck, as well as to the diaphragm. The brachial plexus supplies nerves to the arm. The lumbar plexus supplies nerves to the anterior leg. The sacral plexus supplies nerves to the posterior leg.



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TYPOS

N.B. Nerves do not *enervate* targets!
To enervate means to make weak, tired…

Nerves **innervate** targets.

DEVELOPMENT

- Embryonic Germ Layers - Review
  - To begin, a sperm cell and an egg cell fuse to become a fertilized egg. The fertilized egg cell, or zygote, starts dividing to generate the cells that make up an entire organism. Sixteen days after fertilization, the developing embryo's cells belong to one of three germ layers that give rise to the different tissues in the body.
    - The **endoderm**, or inner tissue, is responsible for generating the lining tissues of various spaces within the body, such as the mucosae of the digestive and respiratory systems.
    - The **mesoderm**, or middle tissue, gives rise to most of the muscle and connective tissues.
    - Finally the **ectoderm**, or outer tissue, develops into the integumentary system (the skin) and the nervous system.

DEVELOPMENT

- Neural Tube Formation
    - Early formation of the nervous system depends on the formation of the neural tube. A groove forms along the dorsal surface of the embryo, which becomes deeper until its edges meet and close off to form the tube. If this fails to happen, especially in the posterior region where the spinal cord forms, a developmental defect called spina bifida occurs. The closing of the neural tube is important for more than just the proper formation of the nervous system. The surrounding tissues are dependent on the correct development of the tube. The connective tissues surrounding the CNS can be involved as well.

AGING

- **Anosmia**
  - The sensory neurons of the olfactory epithelium have a limited lifespan of approximately one to four months, and new ones are made on a regular basis. The new neurons extend their axons into the CNS by growing along the existing fibers of the olfactory nerve.
  - Anosmia is the loss of the sense of smell.
  - Anosmia is often the result of the olfactory nerve being severed, usually because of blunt force trauma to the head. Following the damage, new neurons cannot regrow without intact fibers to follow.
  - The ability of these neurons to be replaced is also lost with age. Age-related anosmia is hence a slow loss of the sensory neurons responsible for olfaction, with no new neurons born to replace them.

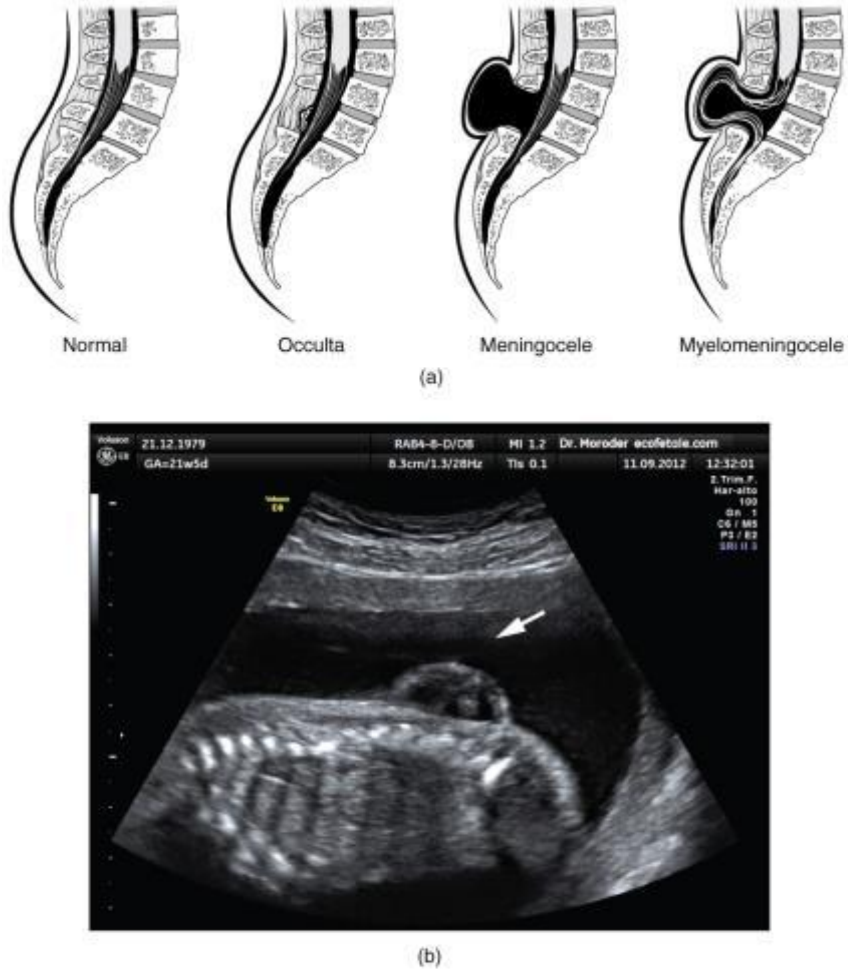
EVERYDAY CONNECTIONS

- **Left Brain/Right Brain**
  - To say that people are “right-brained” or “left-brained” is an oversimplification of an important concept about the cerebral hemispheres.
  - There is some **lateralization of function**, in which the left side of the brain is devoted to language function and the right side is devoted to spatial and nonverbal reasoning in most individuals.
  - But whereas these functions are predominantly associated with those sides of the brain, there is no monopoly by either side on these functions. Many pervasive functions, such as language, are distributed globally around the cerebrum.
  - The term “cerebral dominance” is nonetheless still used to describe the side of the cerebrum where the language of Broca and Wernicke are found (nothing to do with being right- or left-handed!).

DISORDERS & HOMEOSTATIC IMBALANCES

- **Spina Bifida**
  - Results from a failure of the neural tube to close.Two forms present with an external cyst, this mass forming a “second head” that gave this condition its name (bi-fida = two heads).
  - There are three classes of this disorder: occulta, meningocele, and myelomeningocele.
    - Spina bifida occulta, is the mildest because the vertebral bones do not fully surround the spinal cord, but the spinal cord itself is not affected. No functional differences may be noticed, which is what the word occulta means; it is hidden spina bifida.
  - The other two types both involve the formation of a cyst—a fluid-filled sac of the connective tissues that cover the spinal cord called the meninges. Surgery to close the opening or to remove the cyst is necessary; the earlier that it can be performed, the better the chances of controlling or limiting further damage or infection at the opening.
    - “Meningocele” means that the meninges protrude through the spinal column but nerves may not be involved and few symptoms are present, though complications may arise later in life.
    - “Myelomeningocele” means that the meninges protrude and spinal nerves are involved, and therefore severe neurological symptoms can be present.

FIGURE 13.5



Spinal Bifida

(a) Spina bifida is a birth defect of the spinal cord caused when the neural tube does not completely close, but the rest of development continues. The result is the emergence of meninges and neural tissue through the vertebral column.

(b) Fetal myelomeningocele is evident in this ultrasound taken at 21 weeks.

DISORDERS & HOMEOSTATIC IMBALANCES

- **Basal Nuclei and Parkinson's Disease**
  - Parkinson's disease is a disorder of the basal nuclei, specifically of the substantia nigra. As the dopamine-producing neurons in the substantia nigra pars compacta die, they fail to modulate the activity of the basal nuclei properly – causing too much inhibition of cortical activity which results in a *hypokinetic* disorder.
  - Parkinson's disease is neurodegenerative, meaning that neurons die that cannot be replaced, so there is no cure for the disorder.
  - Treatments for Parkinson's disease are aimed at increasing dopamine levels among basal nuclei by providing the amino acid L-DOPA, which is a precursor to the neurotransmitter dopamine that can cross the blood-brain barrier (dopamine cannot).
  - Unfortunately, patients become less responsive to L-DOPA treatment as time progresses - and the increased dopamine levels created elsewhere in the brain can be associated with psychosis or schizophrenia.

DISORDERS & HOMEOSTATIC IMBALANCES

- **Meningitis**
  - Meningitis is an inflammation of the meninges, the three layers of fibrous membrane that surround the CNS, and can be caused by infection by bacteria or viruses. The particular pathogens are not special to meningitis.
  - Symptoms of meningitis include: fever, chills, nausea, vomiting, light sensitivity, soreness of the neck, or severe headache, but also changes in mental state (confusion, memory deficits, etc.).
  - The primary test for meningitis is a **lumbar puncture**.
  - Viral meningitis is usually the result of common enteroviruses (such as those that cause intestinal disorders), but may be the result of the herpes virus or West Nile virus. Viral meningitis cannot be treated with antibiotics but fortunately, viral forms tend to be milder.
  - Bacterial meningitis can be caused by *Streptococcus* or *Staphylococcus*, among many others. It is treated by antibiotics. Bacterial meningitis tends to be more severe, with **fatality** in 5 to 40 percent of children and 20 to 50 percent of adults.

DISORDERS & HOMEOSTATIC IMBALANCES

- **CNS Perfusion Disorders**
  - Without a steady supply of oxygen, and to a lesser extent glucose, the nervous tissue in the brain cannot keep up its extensive electrical activity. These nutrients get into the brain through the blood, and if blood flow is interrupted, neurological function is compromised.
  - A **stroke** (disruption of blood supply to the brain) is caused by a blockage to an artery from some type of embolus: a blood clot, a fat embolus, or an air bubble.
  - When the blood cannot travel through the artery, the surrounding tissue that is deprived starves and dies. Strokes will often result in the loss of very specific functions.
  - Related to strokes are **transient ischemic attacks** (**TIAs**) - “mini-strokes” - in which a physical blockage may temporarily affect a region. Lost neurological function may return.
  - Sometimes, treatment with blood-thinning drugs can alleviate the problem, and recovery is possible.
  - Because the nervous system is adaptable, even with neuron death, victims of strokes can recover, or more accurately relearn, some functions with physical, occupational, and speech therapy.

INTERACTIVE LINKS

- Watch this animation http://openstaxcollege.org/l/braindevel to examine the development of the brain, starting with the neural tube.
- Watch this video http://openstaxcollege.org/l/whitematter to learn about the white matter in the cerebrum that develops during childhood and adolescence.
- FYI only BIO229: The videos http://openstaxcollege.org/l/basalnuclei1 and http://openstaxcollege.org/l/basalnuclei2 describe two basal nuclei-related pathways that process information within the cerebrum.
- Watch this video http://openstaxcollege.org/l/graymatter to learn about the gray matter of the spinal cord that receives input from fibers of the dorsal (posterior) root and sends information out through the fibers of the ventral (anterior) root.
- Visit this site http://openstaxcollege.org/l/parkinsons for a thorough explanation of Parkinson's disease.
- Read this article http://openstaxcollege.org/l/hugebrain in which the author explores the current understanding of what might have happened to increase the size of the human brain relative to that of the chimpanzee.

INTERACTIVE LINKS

- Watch this animation http://openstaxcollege.org/l/bloodflow1 to see how blood flows to the brain and passes through the circle of Willis before being distributed through the cerebrum.
- Watch this video http://openstaxcollege.org/l/lumbarpuncture that describes the procedure known as the lumbar puncture, a medical procedure used to sample the CSF.
- Watch this animation http://openstaxcollege.org/l/CSFflow that shows the flow of CSF through the brain and spinal cord, and how it originates from the ventricles and then spreads into the space within the meninges, where the fluids then move into the venous sinuses to return to the cardiovascular circulation.
- Explore a section of spinal cord and a dorsal root ganglion at http://openstaxcollege.org/l/spinalroot.
- Explore a section of nerve trunk at http://openstaxcollege.org/l/nervetrunk.

INTERACTIVE LINKS

- Visit this site http://openstaxcollege.org/l/NYTmeningitis to read about a man who wakes with a headache and a loss of vision caused by meningitis.

ERRORS IN CHAPTER REVIEW

N.B. The cerebrum is now considered to have five rather than four lobes: frontal, parietal, temporal, occipital, **insula**.

Last modified: 09/2017 / Dr. F. Jolicoeur