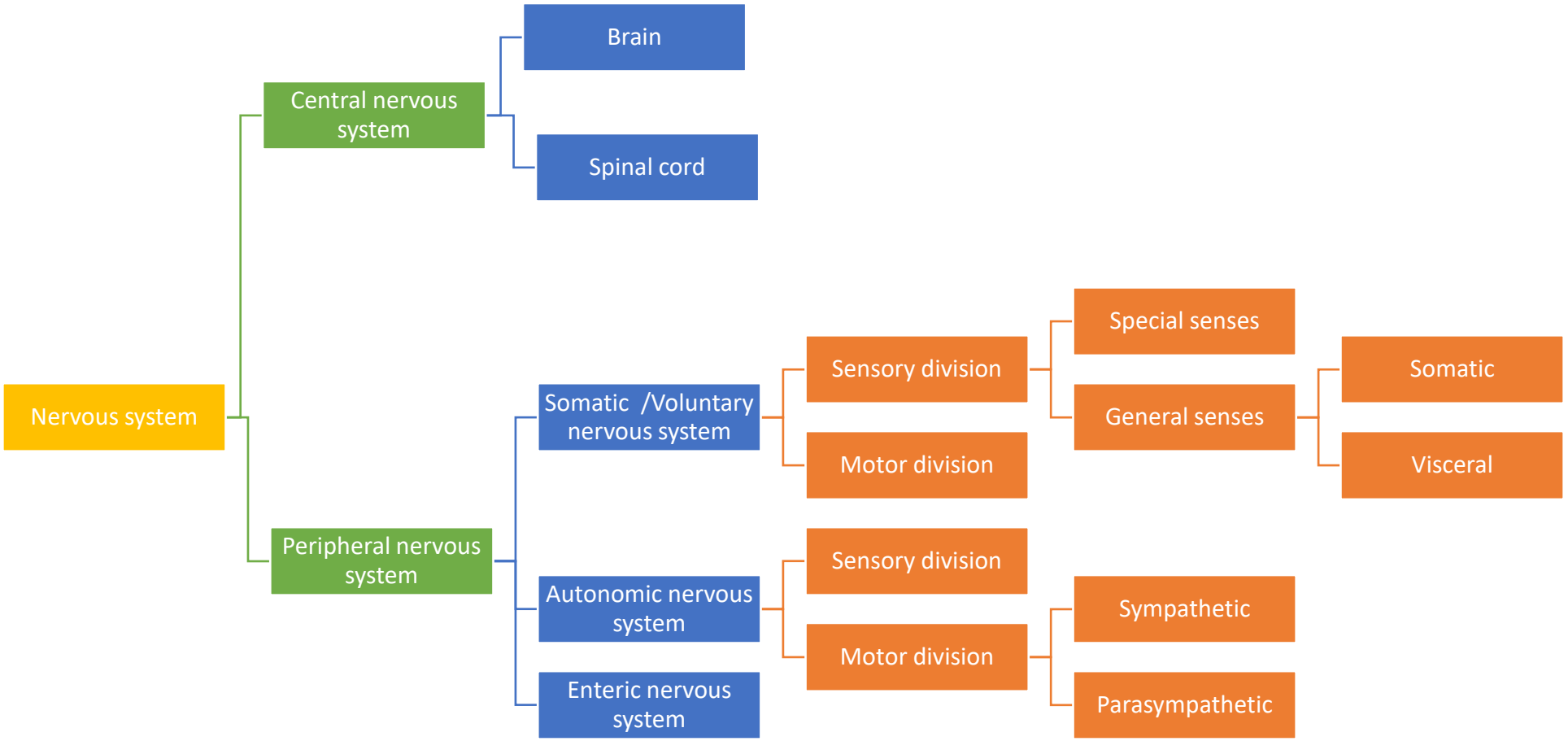
Nervous system

Organization of nervous system



Nervous system

- The system which regulate the body responses to internal and external stimuli

- Nervous system has two divisions
  - ❑ **Central Nervous System**
    - Present in the midline performs the integratory role
    - It has anatomic components
    - **Brain**: Part of the CNS contained in skull and made up of over 100 billion neurons
    - **Spinal Cord**: Part of CNS contained in vertebral column, made up of about 100 million neurons

Peripheral Nervous system

- All nervous tissue outside CNS is called PNS
- It is made up of nerves, ganglia, enteric plexus and sensory receptors
- It has three divisions:
  - Somatic nervous system
  - Autonomic nervous system
  - Enteric nervous system

Histology of nervous system

Nervous tissue comprises two types of cell:

- **Neurons**
- **Neuroglia .**

- Combine in different ways in the brain, spinal cord and periphery to generate different functions

Neurons / Nerve cells

- Structural and functional unit of nervous system

- Structurally neuron has two parts:
  - The cell body
  - The neuronal processes

- The cell body is the control center of neuron and is responsible for receiving, integrating, and sending nerve impulses

- The cell body is enclosed by a plasma membrane and contains cytoplasm surrounding a nucleus with its nucleolus

- The cytoplasm of the cell body is called perikaryon

- Cell bodies also contain free ribosomes and prominent clusters of rough endoplasmic reticulum, termed Nissl bodies

- The cytoskeleton includes both microtubules and neurofibrils.

- The cluster of cell bodies in the CNS is called nuclei while cluster of cell bodies in PNS is called ganglia

- The cell processes are extensions of cytoplasm that emerges from cell body
- It may an axon or dendrite
- Dendrites are the receiving or input portion of neuron
- They are short extensions
- They respond to specific stimuli and conduct impulses to the cell body.
- The more dendrites a neuron has, the more information it can receive from other cells.
- Axons are relatively long, cylindrical process that conducts impulses away from the cell body.
- Axons vary in length from a few millimeters in the CNS to over a meter between the distal portions of the extremities and the spinal cord.
- The axon connects to the cell body at a triangular region called the axon hillock
- Side branches called **collateral branches extend a short distance from the axon.**

- The axon and its collaterals end by dividing into many fine processes called axon terminals (telodendria)

- The extreme tips of these fine extensions are slightly expanded regions called synaptic knobs

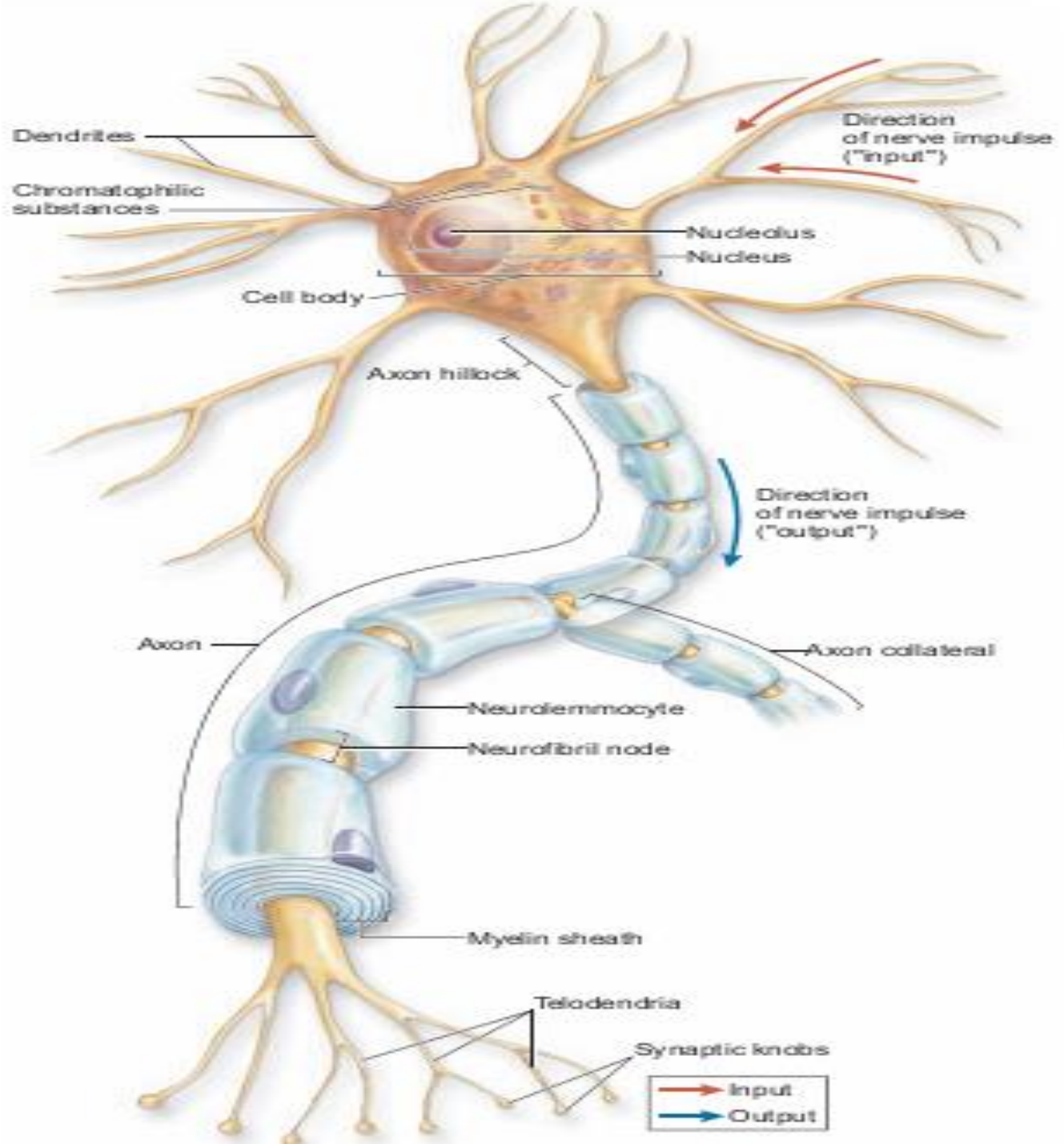

Dendrites
Chromatophilic substances
Direction of nerve impulse ("input")
Nucleolus
Nucleus
Cell body
Axon hillock
Direction of nerve impulse ("output")
Axon
Axon collateral
Neurolemmocyte
Neurofibril node
Myelin sheath
Telodendria
Synaptic knobs
Input
Output

Table 14.2	Parts of a Neuron
Category/Structure	**Description**
Neuron	Structural and functional cell of the nervous system; sometimes called a nerve cell
Cell body	Nucleus and surrounding cytoplasm of a neuron (excluding its dendrites and axon)
Perikaryon	Most often refers to the cytoplasm within the cell body. Sometimes used to describe the entire cell body
Neurotubules	Microtubules that form the cytoskeleton
Neurofilaments	Intermediate filaments that aggregate to form bundles called neurofibrils
Neurofibrils	Aggregates of neurofilaments that extend as a complex network into dendrites and axons, their tensile strength provides support for these processes
Dendrites	Neuron processes that conduct information to the cell body ("input")
Axon	Neuron process that conducts nerve impulses away from the cell body ("output")
Axon hillock	Triangular region connecting axon to cell body
Axon collaterals	Side branches of an axon
Telodendria	Fine terminal branches of an axon or axon collateral
Synaptic knobs	Slightly expanded regions at the tips of telodendria

Classification of neurons

- There are two ways two ways to classify neurons

1. Structural classification

2. Functional classification

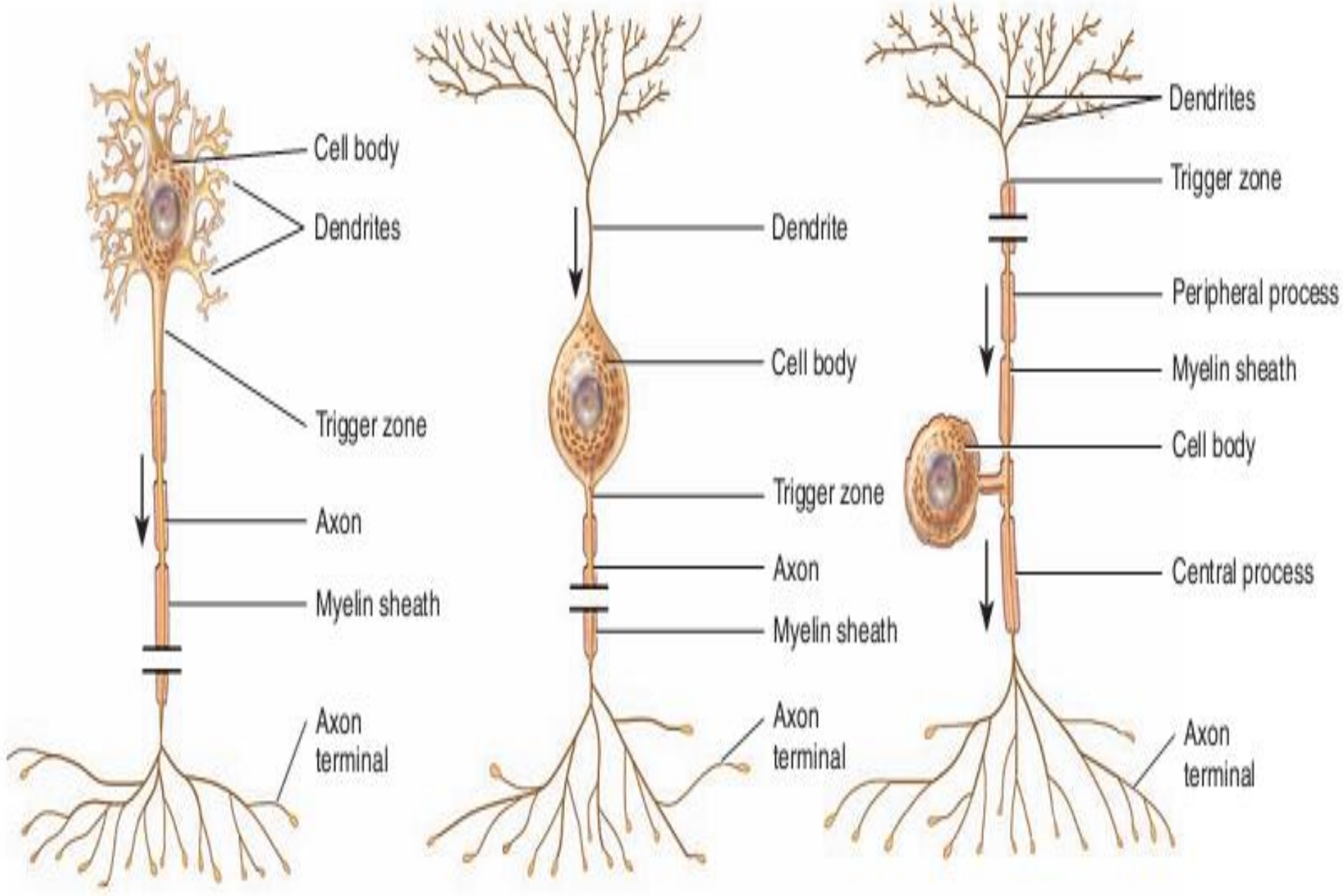
Structural classification

- Structurally, neurons are classified according to the number of processes extending from the cell body

- **Multipolar neurons :** neurons having several dendrites and one axon. Most neurons in the brain and spinal cord and motor neurons are of this type.

- **Bipolar neurons: neurons** having one main dendrite and one axon. Forexample neuron found in the retina of the eye, the inner ear, and the olfactory area of the brain.

- **Unipolar neurons :** neurons having dendrites and one axon that are fused together to form a continuous process that emerges from the cell body. These neurons are also called as pseudounipolar neurons because they begin in the embryo as bipolar neurons. During development, the dendrites and axon fuse together and become a single process



(a) Multipolar neuron (b) Bipolar neuron (c) Unipolar neuron

Functional classification

- Functional classification of neurons is based on the direction in which the impulse is directed

- **Sensory or afferent neurons :** convey action potential towards central nervous system . Most sensory neurons are unipolar in structure.

- **Motor or efferent neurons:** convey action potentials away from the CNS to effectors (muscles and glands). Motor neurons are multipolar in structure.

- **Interneurons or association neurons:** mainly located within the CNS between sensory and motor neurons. Interneurons integrate (process) incoming sensory information from sensory neurons and then elicit a motor response by activating the appropriate motor neurons. Most interneurons are multipolar in structure.

NEUROGLIA

- Glia is from glue – cells which hold the neurons together and provides supportive framework
- Present both in CNS and PNS, smaller than neurons but numerous than them, account for half of the volume of nervous system
- Have the capacity of mitosis
- Six type of glial cells are found in nervous system; four of them are found in CNS while two are found in PNS

Neuroglia of CNS

- Classified on the basis of size, cytoplasmic processes, and intracellular organization

ASTROCYTES

- Most abundant type of glial cells found in CNS
- Have star shaped cells having many processes. These processes extends to the capillaries and neurons
- Performs important functions for CNS:
  - Formation of BBB
  - Maintenance of chemical environment of CNS
  - Neuronal development in embryo
  - Support to neurons through its cytoskeleton
  - Replacing the damaged neurons

Oligodendrocytes

- These are large cells with a bulbous body and slender cytoplasmic extensions. Resemble astrocytes but have fewer extensions
- Oligodendrocyte processes are responsible for forming and maintaining the myelin sheath around CNS axons

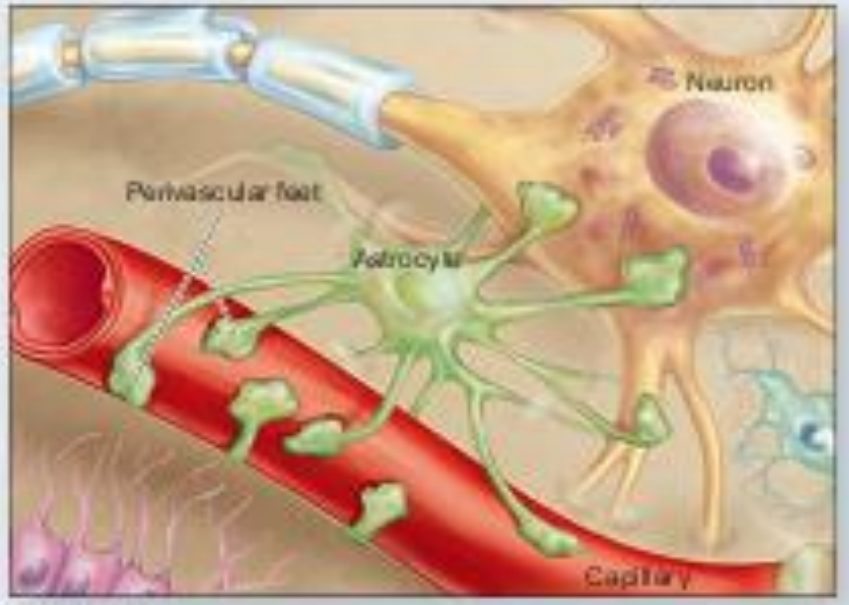
Ependymal cells

- cuboidal epithelial cells that line the ventricles of the brain and the central canal of the spinal cord
- form a single layer and possess micovilli and cilia
- Ependymal cells produce and assist in the circulation of cerebrospinal fluid

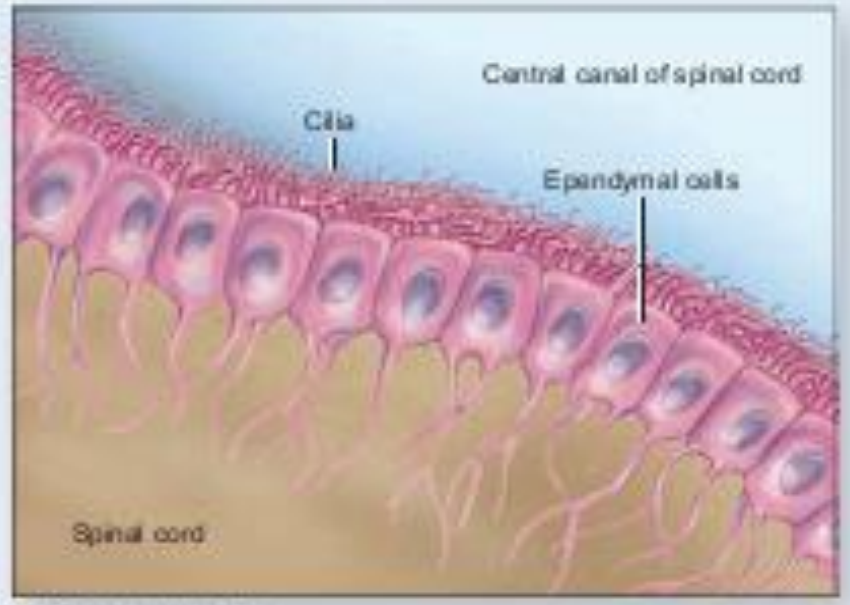
Microglia

- Are small macrophages that develop from white blood cells called monocytes.
- They wander through the CNS and phagocytize dead nervous tissue, microorganisms, and other foreign matter.
- They become concentrated in areas damaged by infection, trauma, or stroke.

CNS Glial Cells

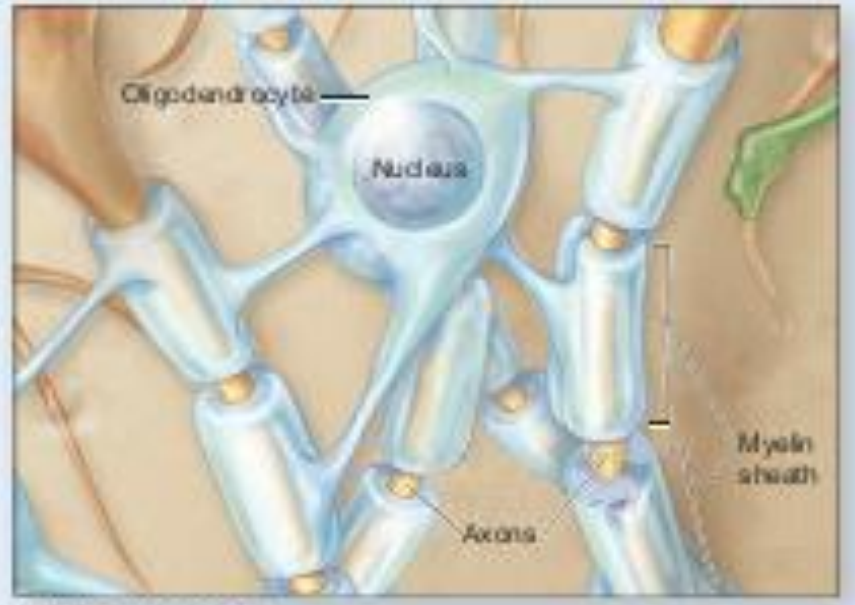


(a) Astrocyte



(b) Ependymal cells

(c) Microglial cell



(d) Oligodendrocyte

Neuroglia of PNS

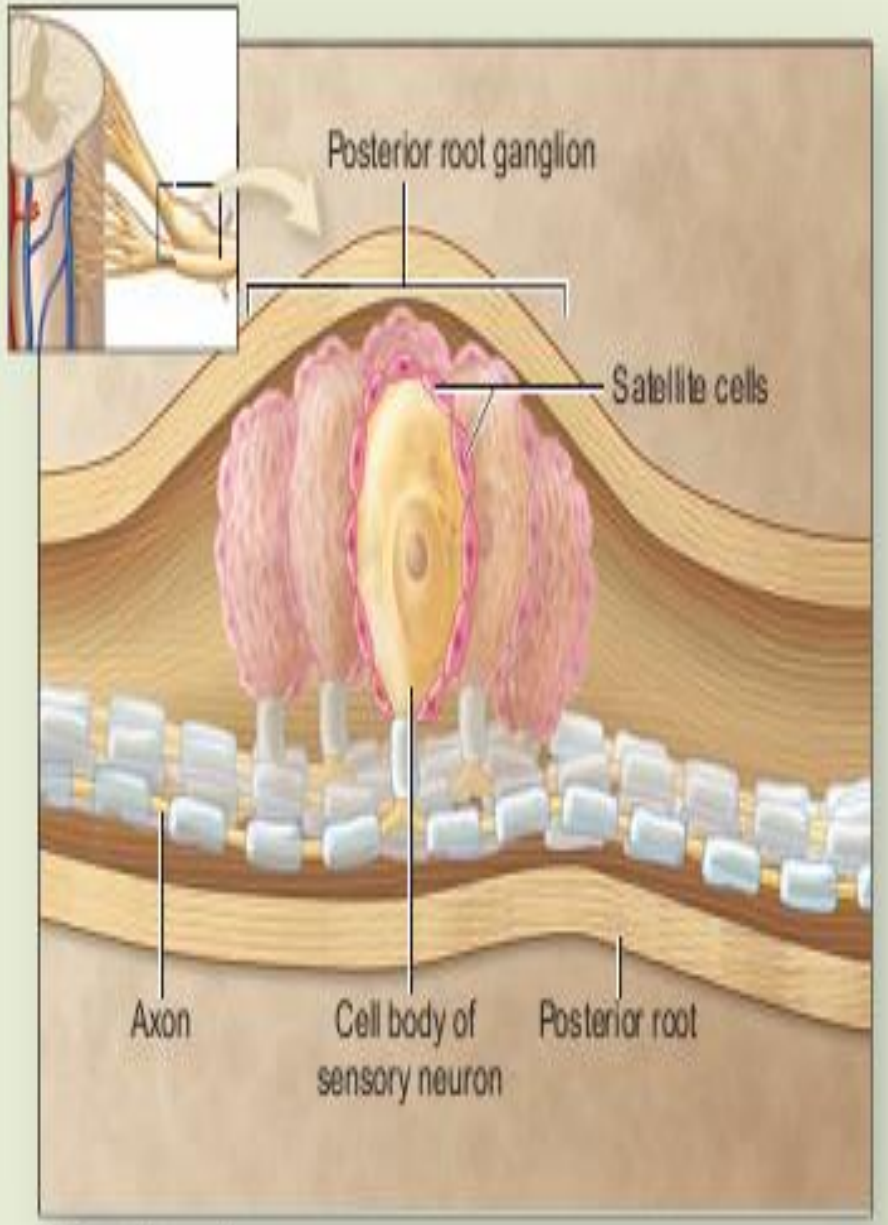
Shwann cells

- These cells encircle PNS axons.
- They are involved in formation of myelin sheath around axons.
- A single oligodendrocyte myelinates several axons, but each Schwann cell myelinates a single axon
- They are also present around unmyelinated axons
- Have role in axonal regeneration

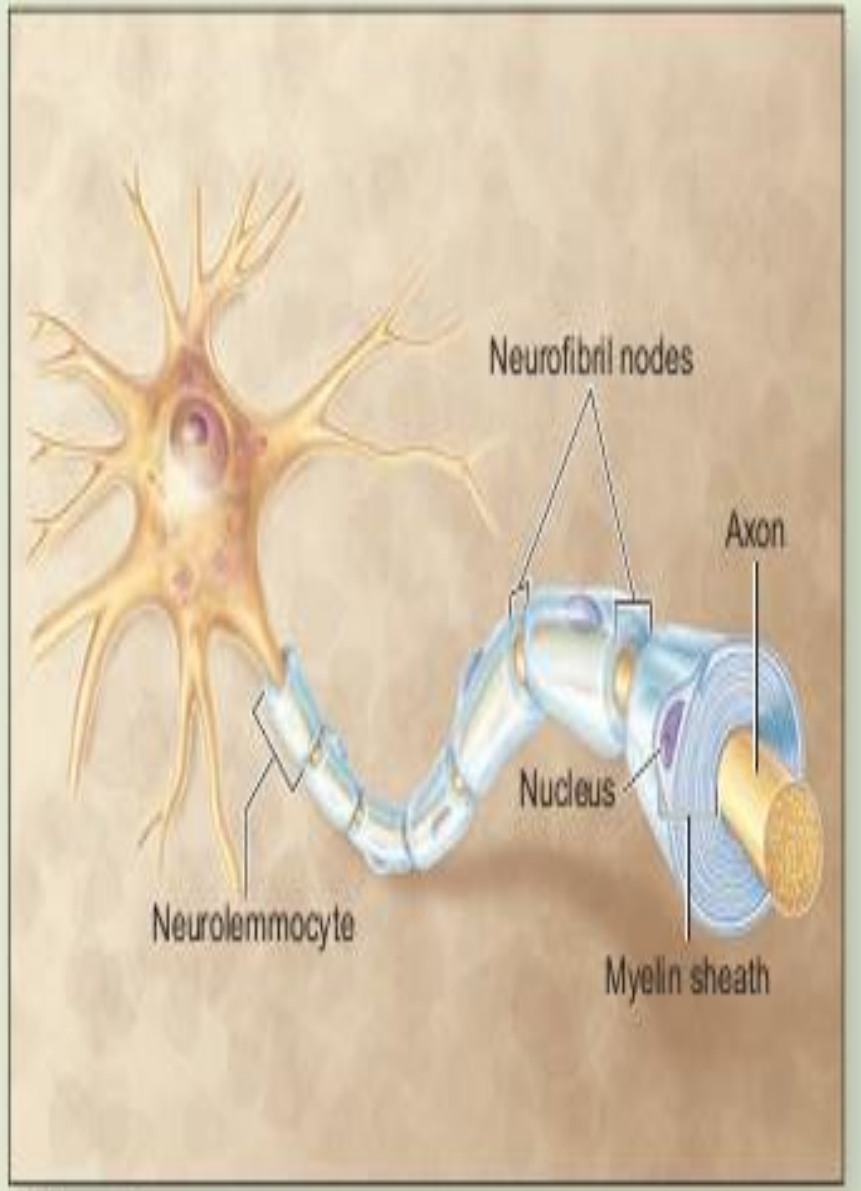
Satellite cells

- flat cells surrounds ganglia
- Provide structural support and help in exchange of materials between cell bodies and interstitial fluid

PNS Glial Cells



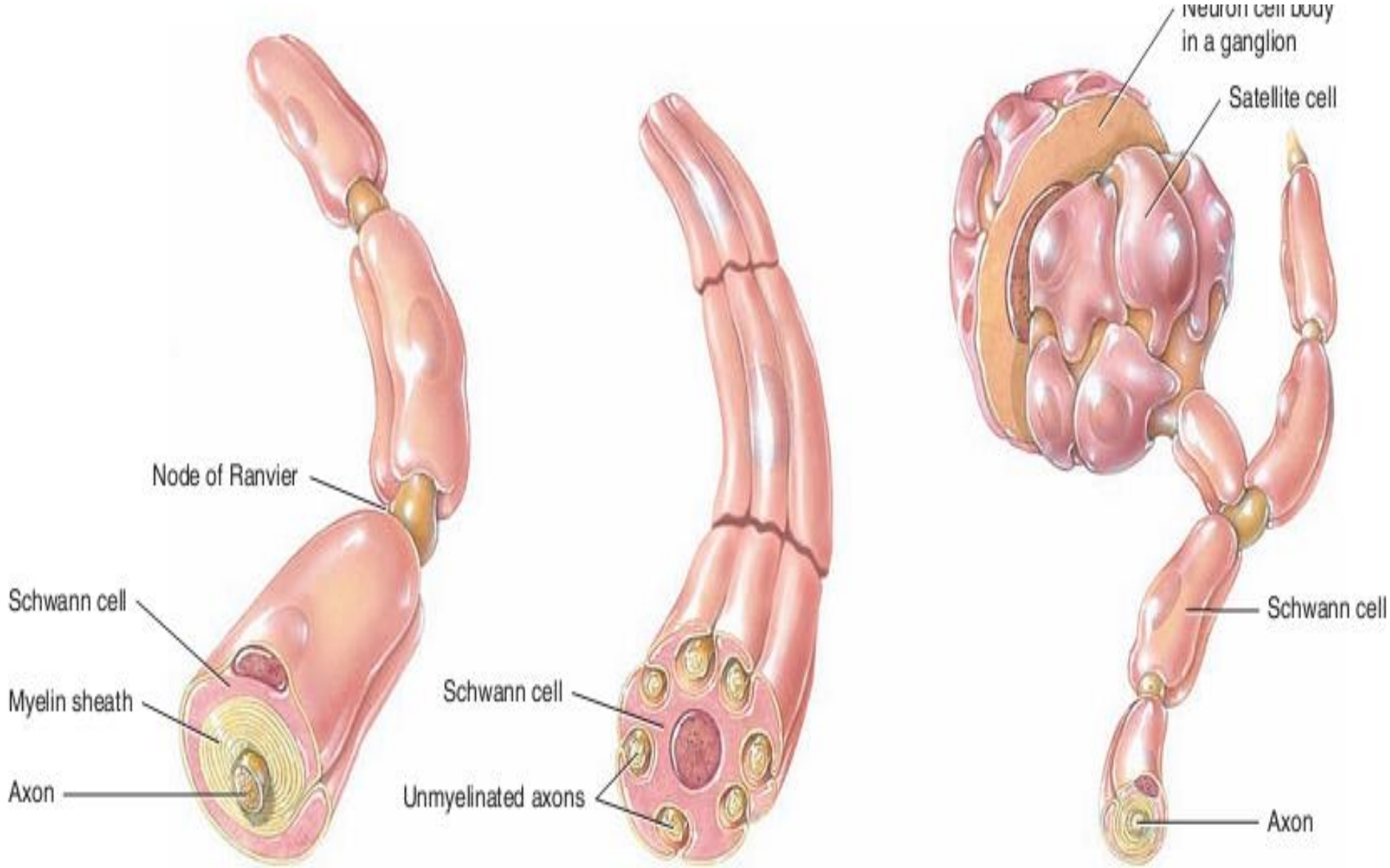
(e) Satellite cells

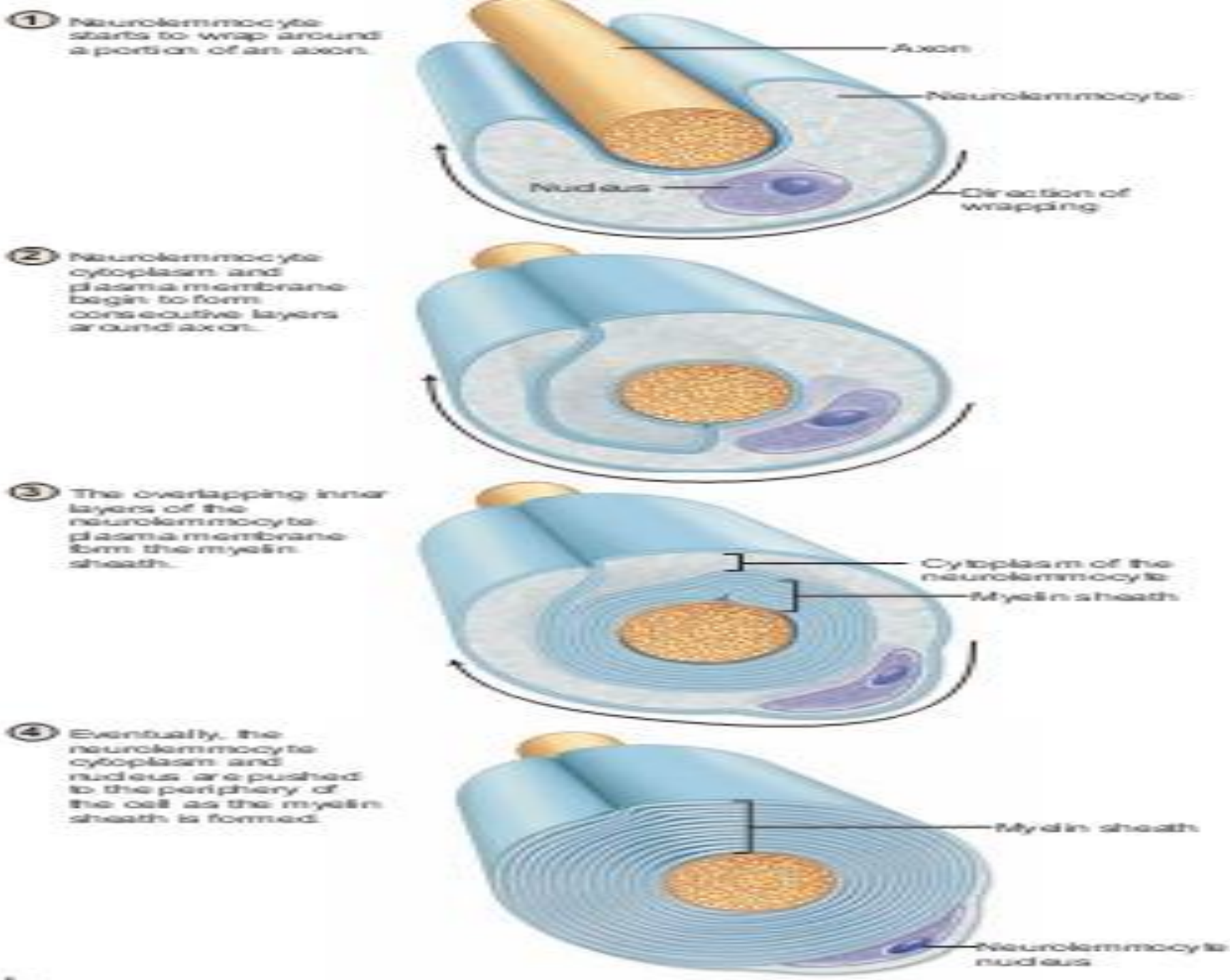


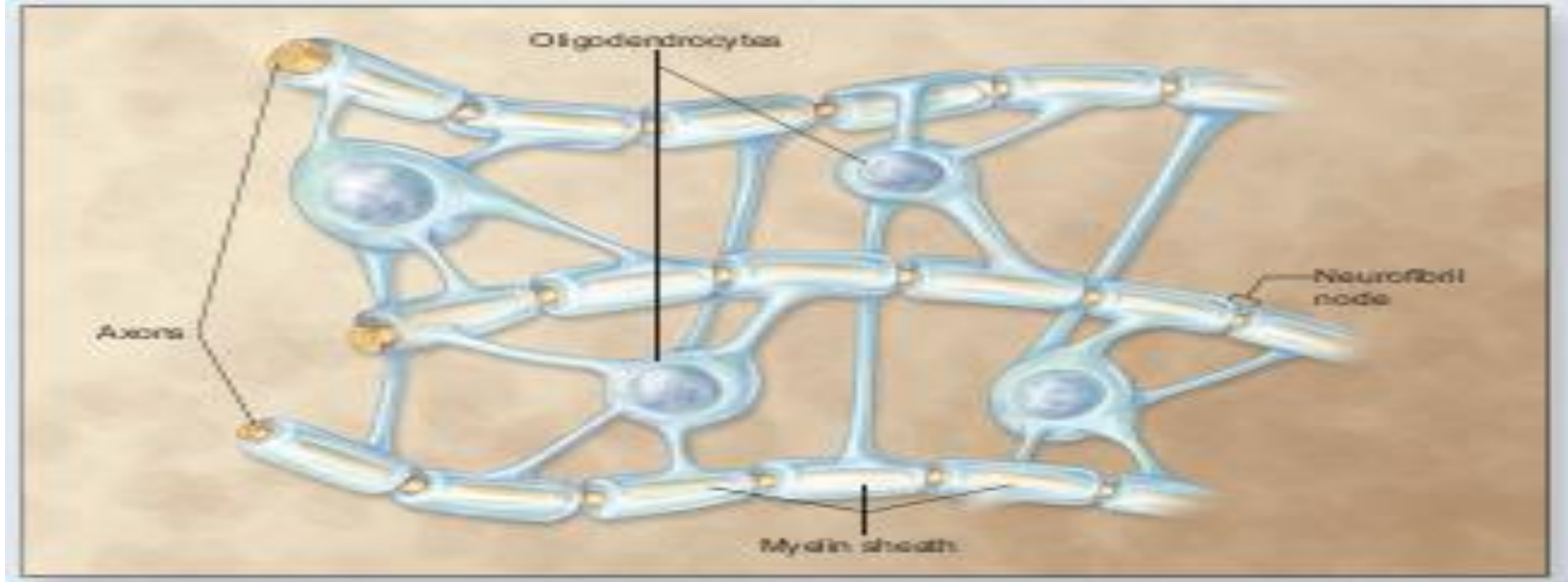
(f) Neurolemmocytes

Myelination

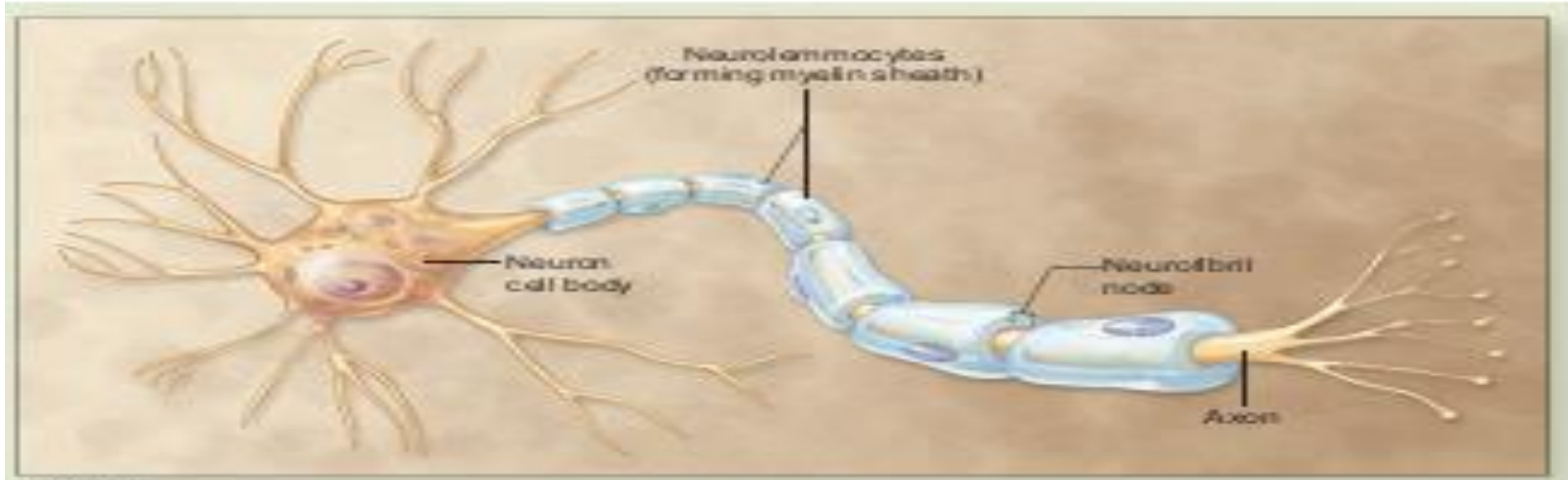
- Neurons are covered by in insulating layer of lipid and protein called myelin sheath
- Two types of neuroglia produce myelin sheaths: Schwann cells in the PNS and oligodendrocytes in the CNS
- There are gaps in the myelin sheath called nodes of Raniver


Node of Ranvier
Schwann cell
Myelin sheath
Axon
Schwann cell
Unmyelinated axons
Neuron cell body
in a ganglion
Satellite cell
Schwann cell
Axon


1 Neurolemmocyte starts to wrap around a portion of an axon.
Axon
Neurolemmocyte
Nucleus
Direction of wrapping
2 Neurolemmocyte cytoplasm and plasma membrane begin to form consecutive layers around axon.
3 The overlapping inner layers of the neurolemmocyte plasma membrane form the myelin sheath.
Cytoplasm of the neurolemmocyte
Myelin sheath
4 Eventually, the neurolemmocyte cytoplasm and nucleus are pushed to the periphery of the cell as the myelin sheath is formed.
Myelin sheath
Neurolemmocyte nucleus


Oligodendrocytes
Axons
Neurofibril node
Myelin sheath

(a) CNS


Neurolemmocytes (forming myelin sheath)
Neuron cell body
Neurofibril node
Axon

(b) PNS

Collection of nervous tissue

Collection of cell bodies

- Nucleus: cluster of neuronal cell bodies located in the CNS
- Ganglia: cluster of neuronal cell bodies located in the PNS

Collection of axons

- Tracts: bundle of axons that is located in the CNS .
- Nerve: bundle of axons that is located in the PNS .
- Gray matter
- White matter

Meninges

- The entire CNS is protected by a **bony encasement**, the cranium, surrounding the brain and the vertebral column surrounding the spinal cord.

- It is also protected by three membranous connective tissue coverings called the **meninges.**

- **Meninges perform the protective functions like:**
  - ❑ **separate the soft tissue of the brain from the bones of the cranium**
  - ❑ **enclose and protect blood vessels that supply the brain**
  - ❑ **contain and circulate cerebrospinal fluid**
  - ❑ **some parts of the cranial meninges form some of the veins that drain blood from the brain**

- Three layers of meninges from deep to superficial are:
  - ❑ Pia mater
  - ❑ Arachnoid
  - ❑ Dura mater

Pia mater

- The innermost of the three layers of the meninges
- It is composed of loose connective tissue
- It is highly vascular
- It is tightly connected to brain
- Lateral extensions of the pia matter along the spinal cord form the ligamentum denticulatum, which attaches the spinal cord to the dura mater

Arachnoid

- The arachnoid mater lies external to the pia mater
- The arachnoid is not completely applied on the pia matter and have space called subarachnoid space which is filled with CSF
- The subarachnoid space is maintained by delicate web of collagen and elastic fibers, termed the arachnoid trabeculae
- Arachnoid is avascular covering comprised of cells and thin, loosely arranged collagen and elastic fibers

Dura mater

- The dura mater is an outermost tough layer
- It is made up of dense connective tissue
- Between the arachnoid mater and the overlying dura mater is a potential space, the subdural space
- The cranial dura matter is double layered structure
  - ❑ The outer **periosteal layer** applied to the cranium
  - ❑ The inner **meningeal layer** present next to the arachnoid
- The spinal dura mater is a single layered structure which is similar to the meningeal layer of the cranial dura mater.

- The meningeal layer is usually fused to the periosteal layer

- In specific areas however the two layers separate to form large, blood-filled spaces called dural venous sinuses which collect venous blood and drain it to the internal jugular veins of the neck.

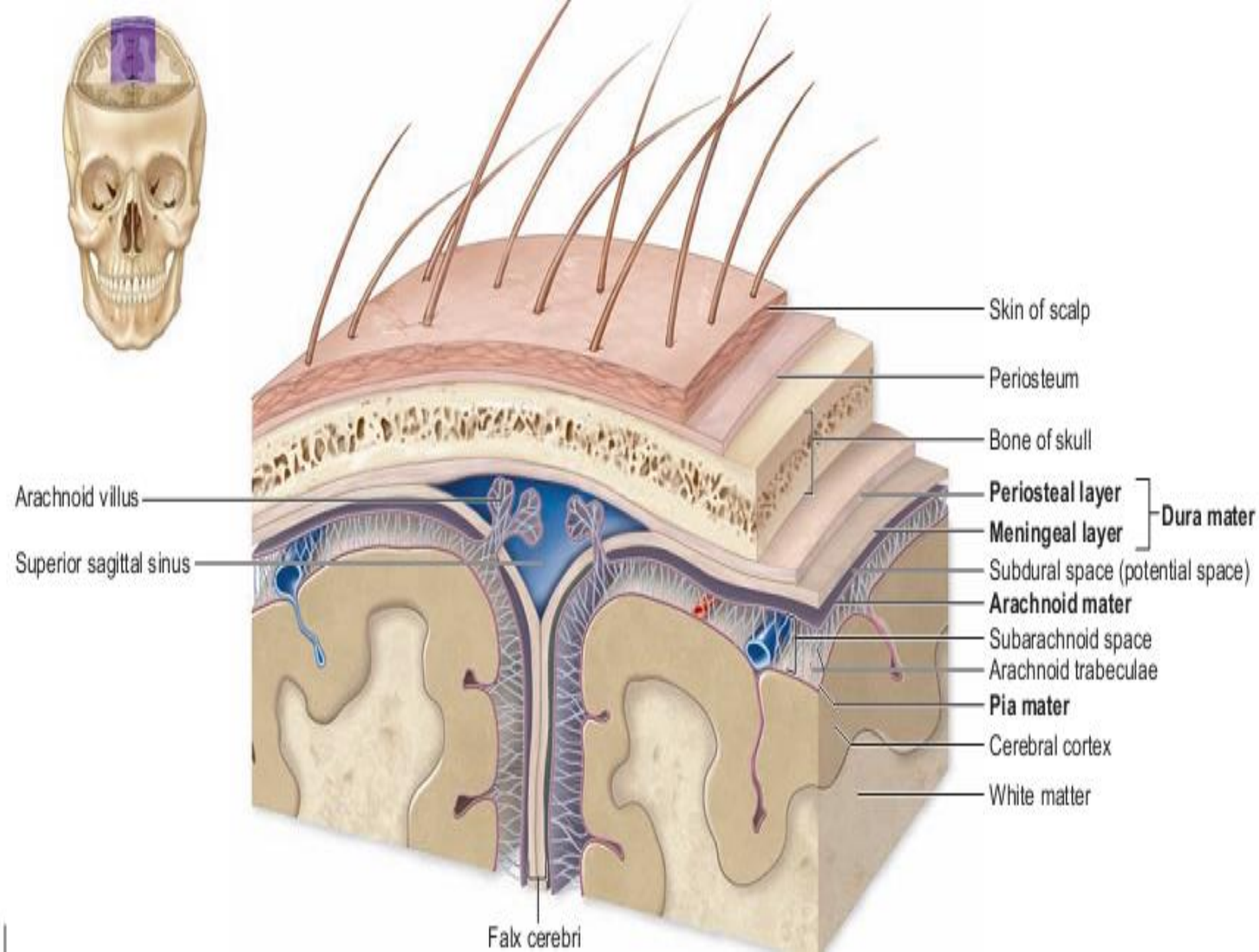
- The dura mater and the bones of the skull may be separated by the potential epidural space, which contains the arteries and veins that nourish the meninges and bones of the cranium

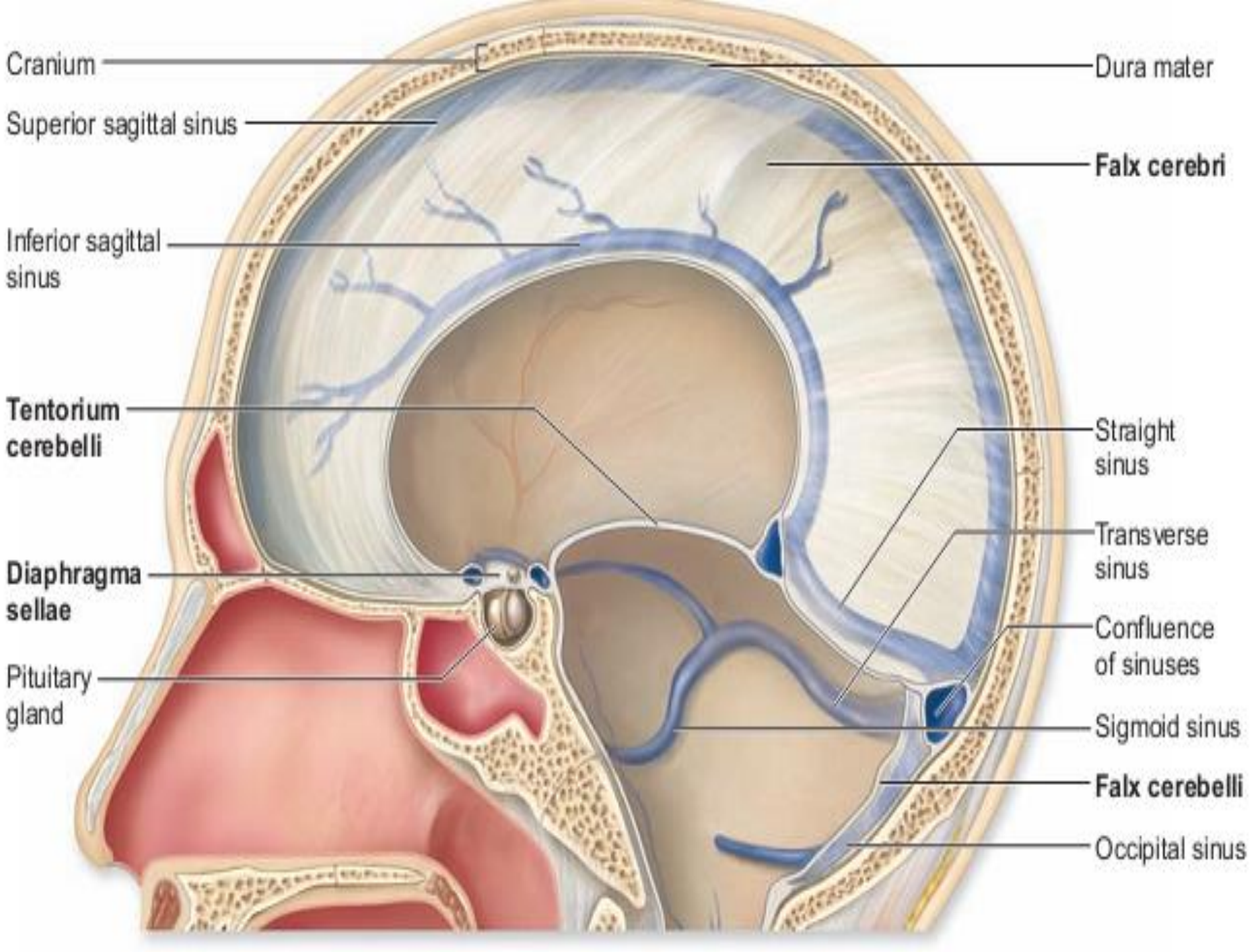
- In certain places, the meningeal layer of the dura mater folds inward which is called dural septa that separate major parts of the brain:

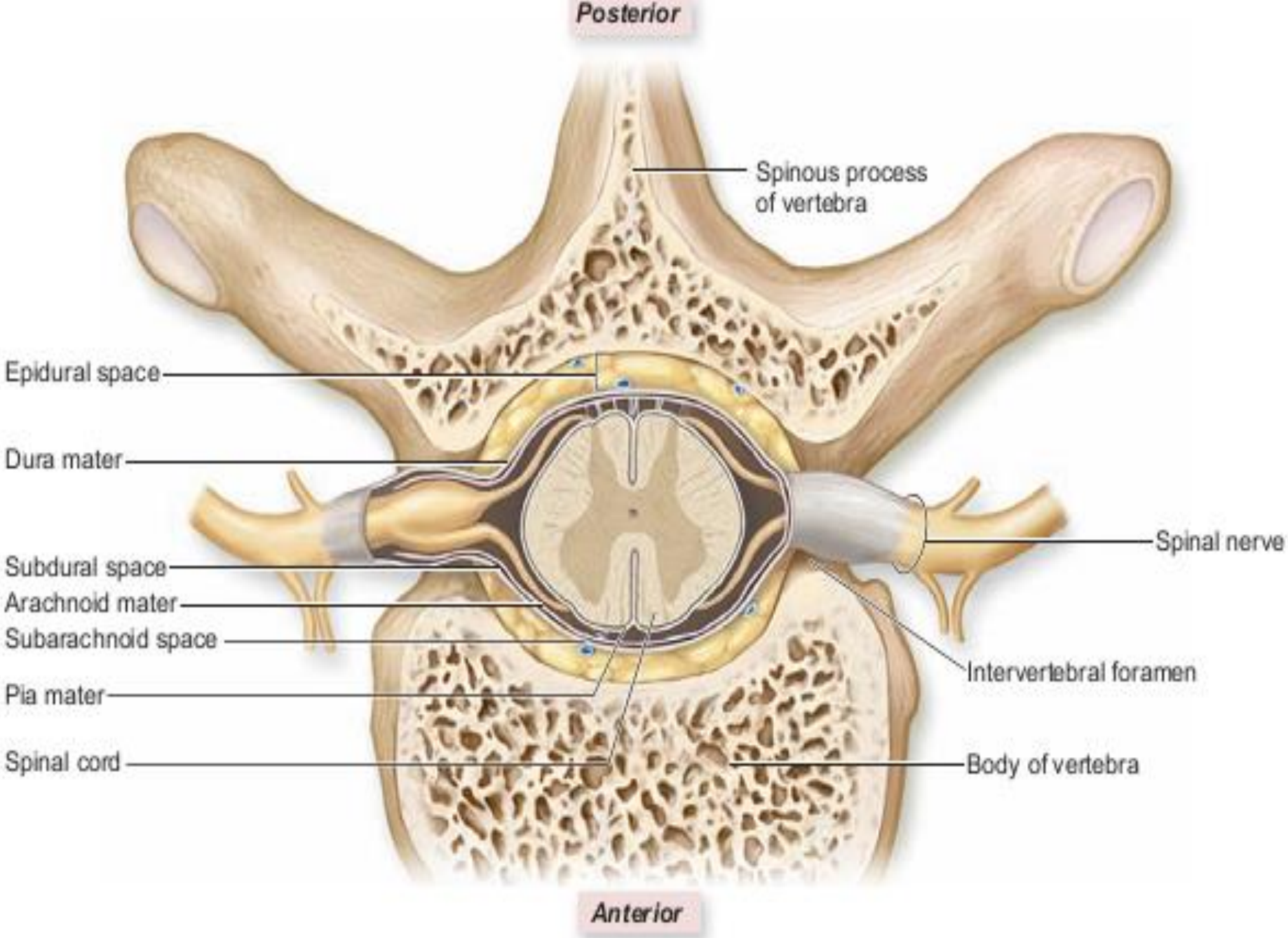
  1:Falx cerebri extends into the longitudinal fissure between the right and left cerebral hemispheres;

  2: Tentorium cerebelli stretches like a roof over the posterior cranial fossa and separates the cerebellum from the overlying cerebrum;

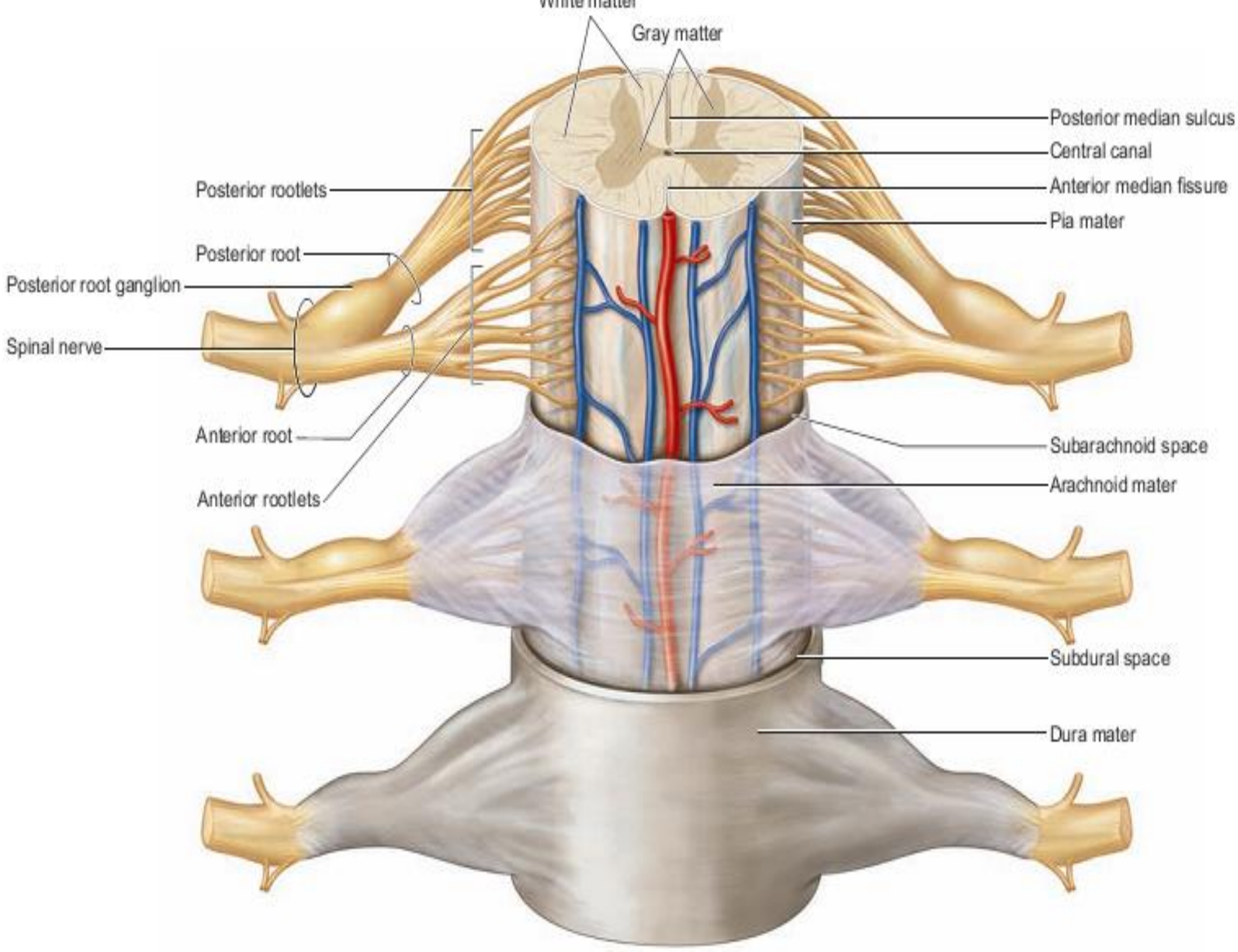
  3. Diaphragma sellae which forms a “roof” over the sella turcica of the sphenoid bone. A small opening within it allows for the passage of a thin stalk, called the infundibulum, that attaches the pituitary gland to the base of the hypothalamus


Skin of scalp
Periosteum
Bone of skull
Periosteal layer
Meningeal layer
Dura mater
Arachnoid villus
Superior sagittal sinus
Subdural space (potential space)
Arachnoid mater
Subarachnoid space
Arachnoid trabeculae
Pia mater
Cerebral cortex
White matter
Falx cerebri


Cranium
Superior sagittal sinus
Inferior sagittal sinus
Tentorium cerebelli
Diaphragma sellae
Pituitary gland
Dura mater
Falx cerebri
Straight sinus
Transverse sinus
Confluence of sinuses
Sigmoid sinus
Falx cerebelli
Occipital sinus

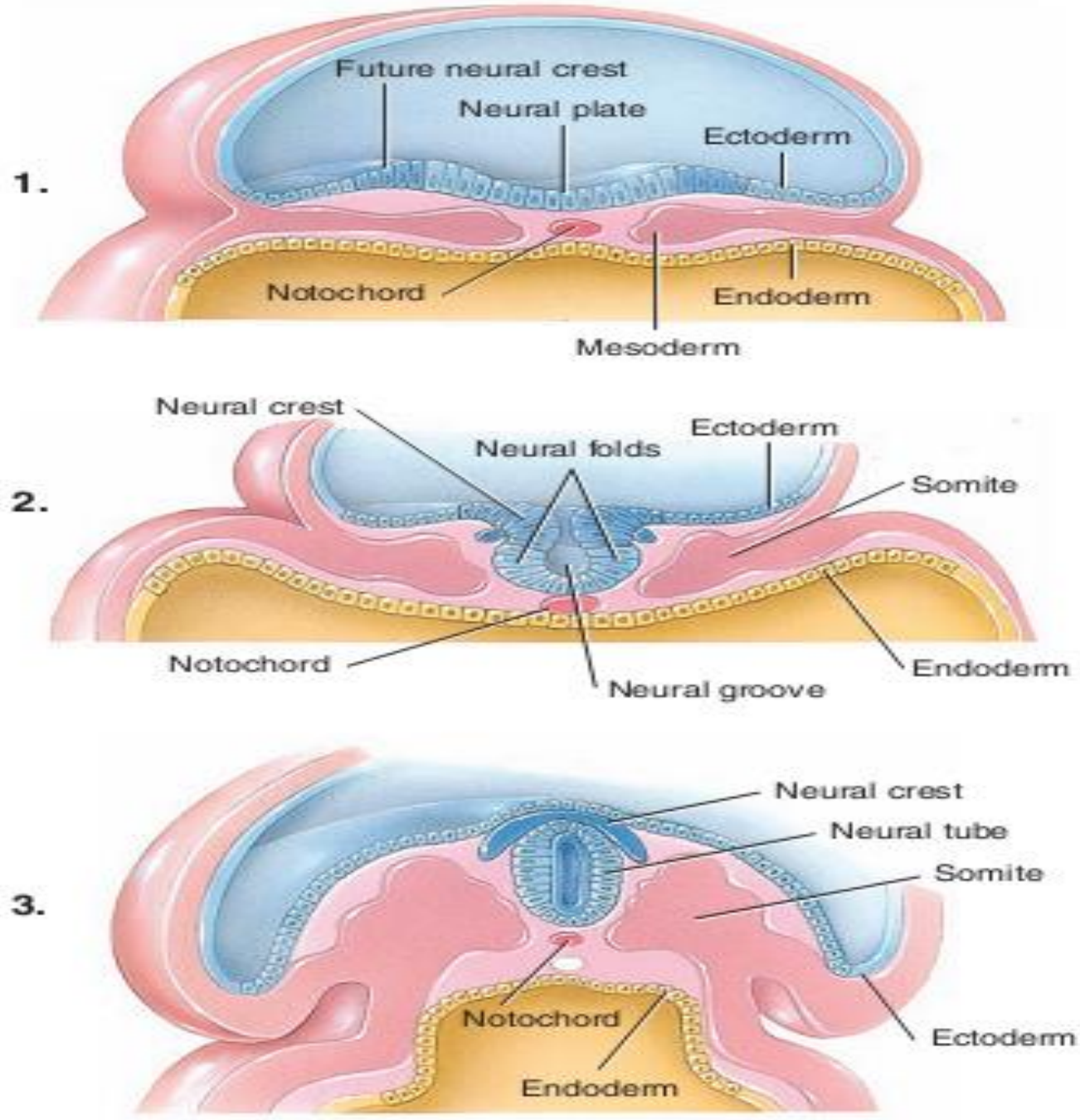


(a) Cross section of vertebra and spinal cord


White matter
Gray matter
Posterior median sulcus
Central canal
Anterior median fissure
Pia mater
Posterior rootlets
Posterior root
Posterior root ganglion
Spinal nerve
Anterior root
Anterior rootlets
Subarachnoid space
Arachnoid mater
Subdural space
Dura mater

Embryonic development of nervous system

- Starts in the third week of gestation
- First thickening appear on the ectoderm called **neural plate**.
- The neural plate then divide and differentiates to make the entire nervous system
- The first change in neural plate is that it invaginates inward making a groove called **neural groove**.
- The thick raised lateral margins of the groove are called **neural folds.**
- The neural folds raise further ultimately meets to form a tube called **neural tube**
- The neural tube is open both cranially and caudally till fourth week, the openings are called **neural pores**. At fourth week neural pores close off
- The neural tube then separates from surface ectoderm and forms CNS
- The **neural crest** forms from the neural folds as they fuse longitudinally along the dorsal midline. Most of the peripheral nervous system (cranial and spinal nerves) forms from the neural crest



(b) Transverse sections

Embryonic development of brain

- The brain begins its embryonic development as the cephalic end of the neural tube as it starts to grow rapidly and differentiate.

- By the middle of the fourth week, three distinct swellings called primary brain vesicles are evident which are named according to their relative positions:

  - the **prosencephalon***) (forebrain),*
  - *the **mesencephalon (midbrain),*** and
  - the **rhombencephalon (hindbrain).**

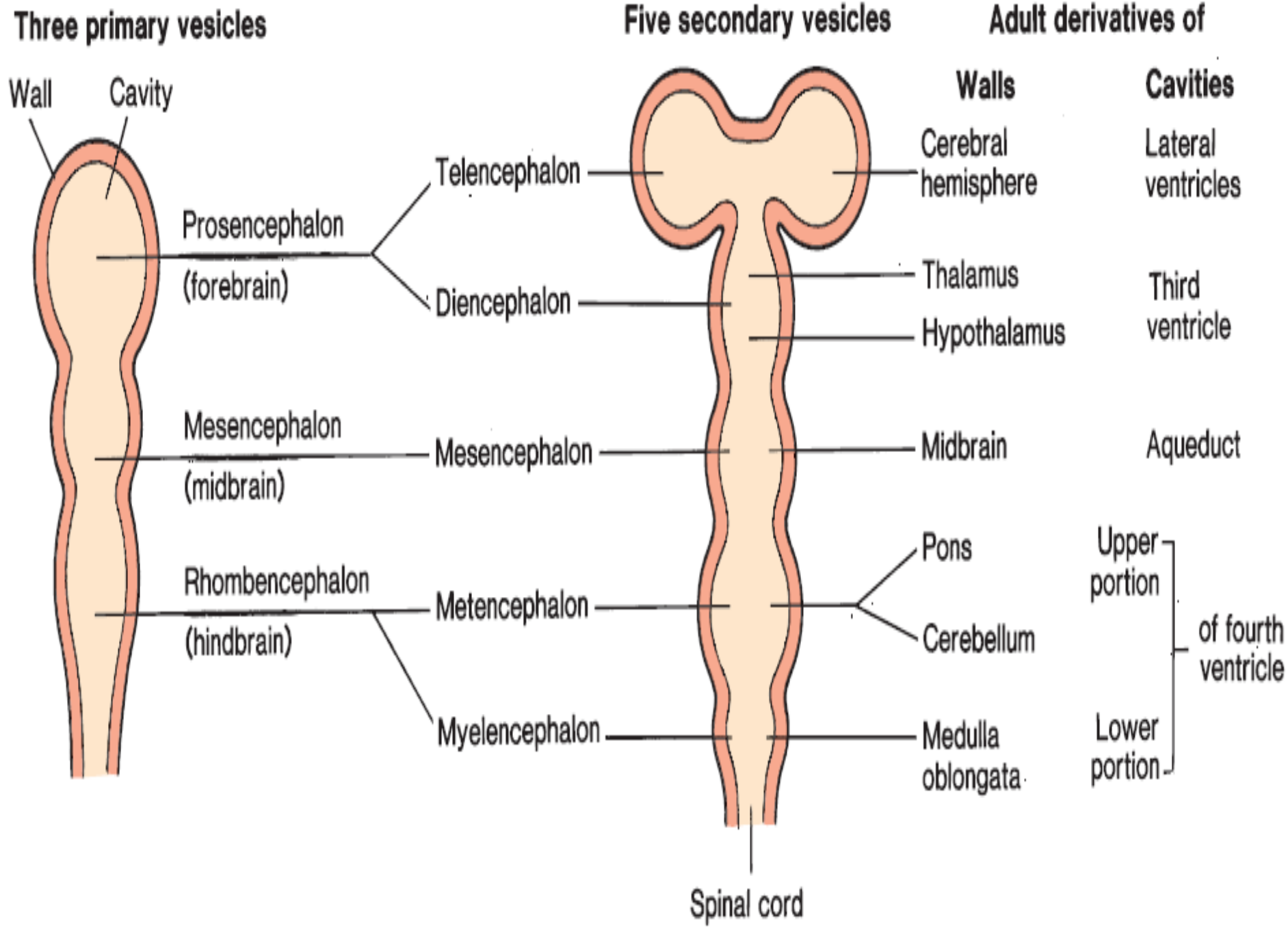
- **Further development** during the fifth week results in the formation of secondary brain vesicles

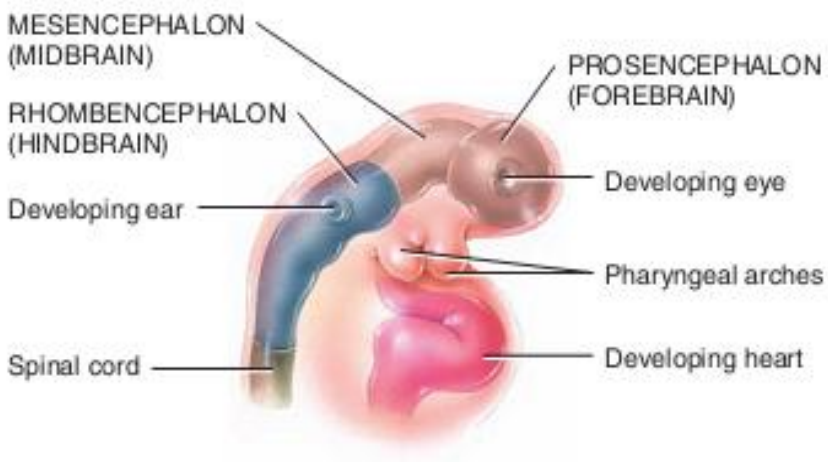
  - The **telencephalon and the diencephalon** derive from the forebrain,
  - the mesencephalon remains unchanged,
  - the **metencephalon and myelencephalon form** from the hindbrain.

- The caudal portion of the myelencephalon is continuous with and resembles the spinal cord.

TABLE 11.3 Derivation and Functions of the Major Brain Structures

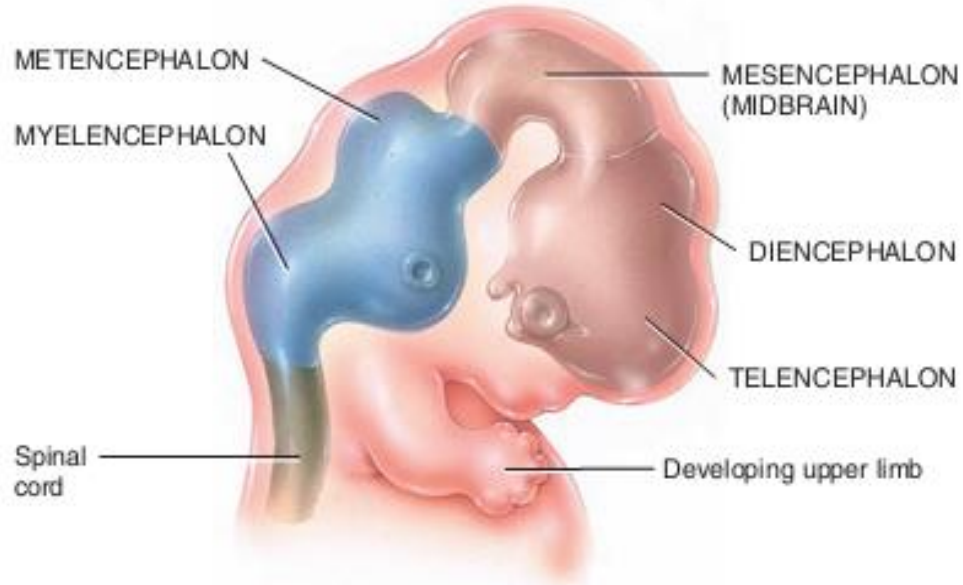
Developmental Region	Adult Region	Structure	Function
Prosencephalon (forebrain)	Telencephalon	Cerebrum	Control of most sensory and motor activities; reasoning, memory, intelligence, etc.; instinctual and limbic functions
	Diencephalon	Thalamus	Relay center; all impulses (except olfactory) going into the cerebrum synapse here; some sensory interpretation; initial autonomic response to pain
		Hypothalamus	Regulation of food and water intake, body temperature, heartbeat, etc.; control of secretory activity in anterior pituitary gland; instinctual and limbic functions
		Pituitary gland	Regulation of other endocrine glands
Mesencephalon (midbrain)	Mesencephalon	Superior colliculi	Visual reflexes (eye-hand coordination)
		Inferior colliculi	Auditory reflexes
		Cerebral peduncles	Reflex coordination; contain many motor fibers
Rhombencephalon (hindbrain)	Metencephalon	Cerebellum	Balance and motor coordination
		Pons	Relay center; contains nuclei (pontine nuclei)
	Myelencephalon	Medulla oblongata	Relay center; contains many nuclei; visceral autonomic center (e.g., respiration, heart rate, vasoconstriction)


Three primary vesicles
Five secondary vesicles
Adult derivatives of
Wall
Cavity
Walls
Cavities
Prosencephalon
(forebrain)
Telencephalon
Cerebral hemisphere
Lateral ventricles
Diencephalon
Thalamus
Hypothalamus
Third ventricle
Mesencephalon
(midbrain)
Mesencephalon
Midbrain
Aqueduct
Rhombencephalon
(hindbrain)
Metencephalon
Pons
Cerebellum
Upper portion
Lower portion
of fourth ventricle
Myelencephalon
Medulla oblongata
Spinal cord

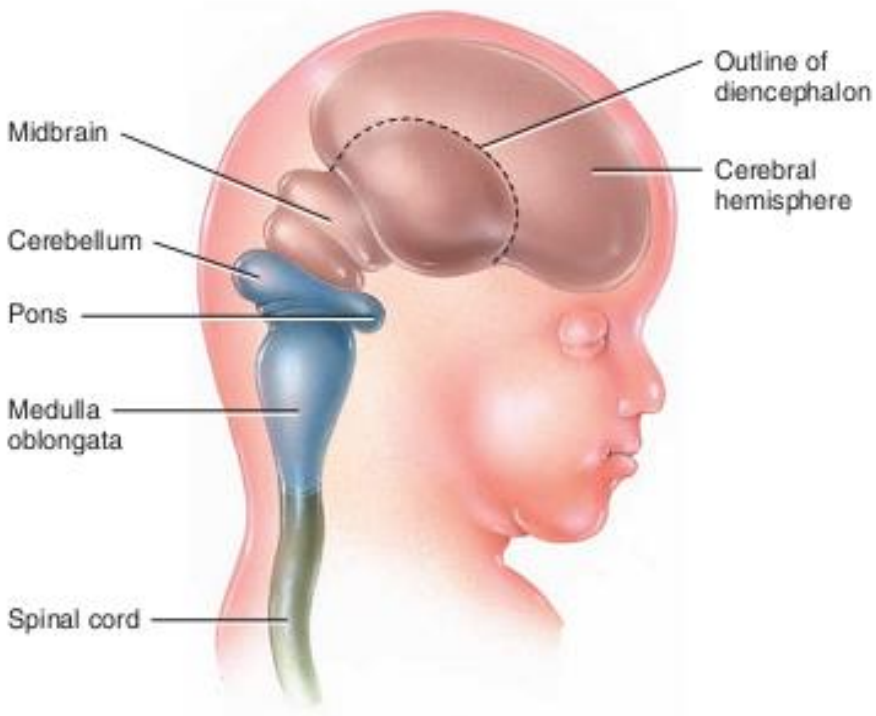


Lateral view of right side

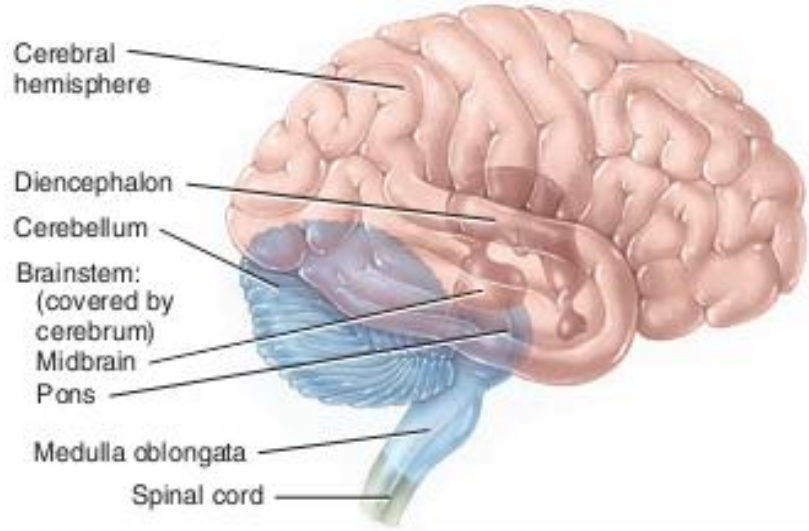
(a) Three- to four-week embryo showing primary brain vesicles



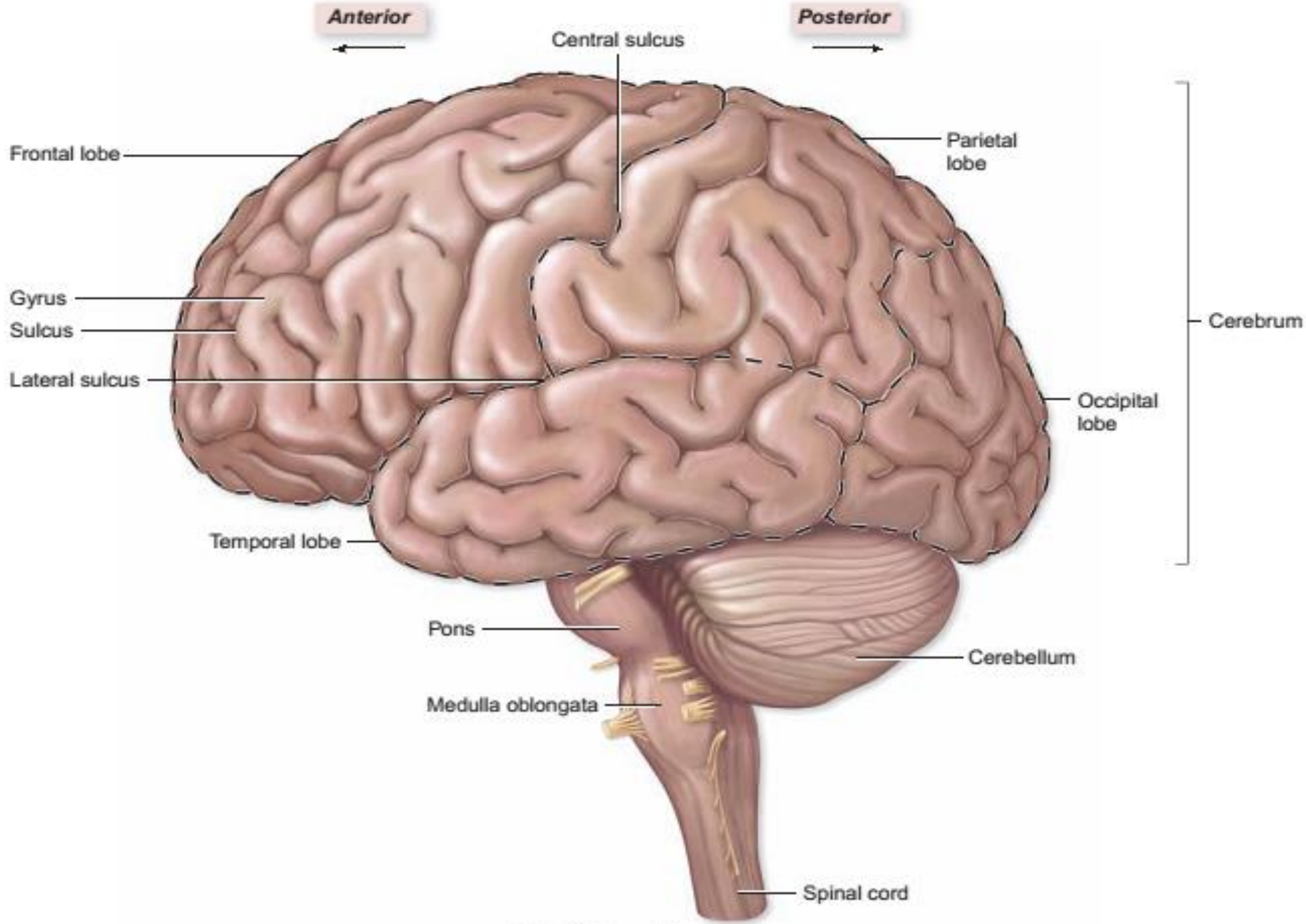
(b) Seven-week embryo showing secondary brain vesicles



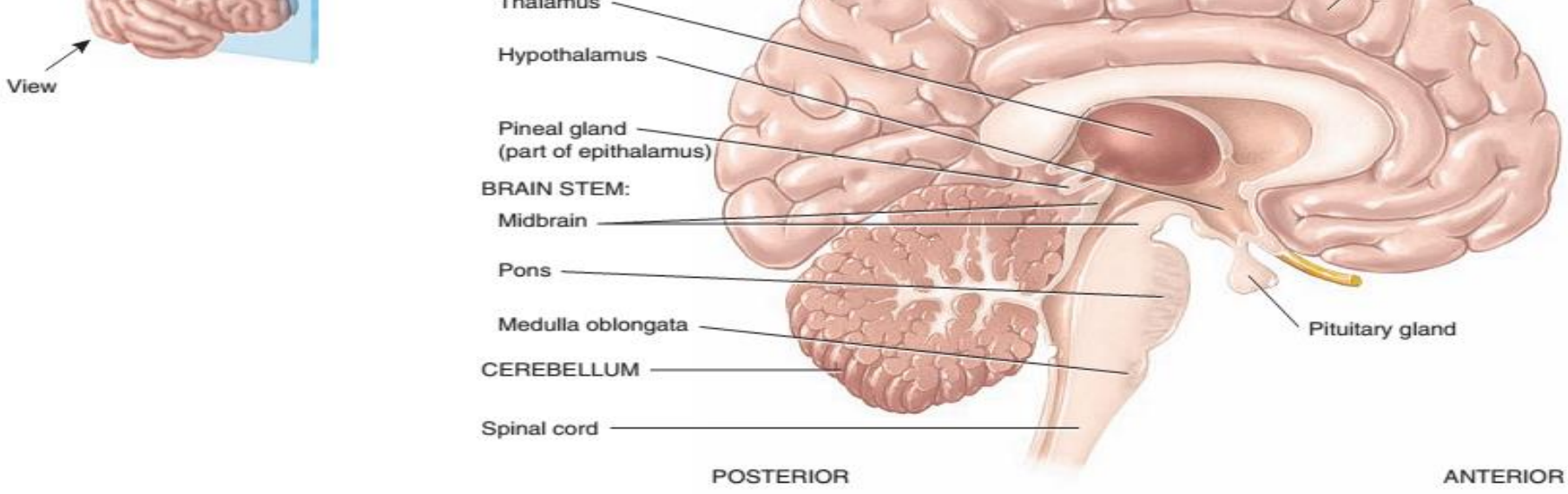
(c) Eleven-week fetus showing expanding cerebral hemispheres overgrowing the diencephalon



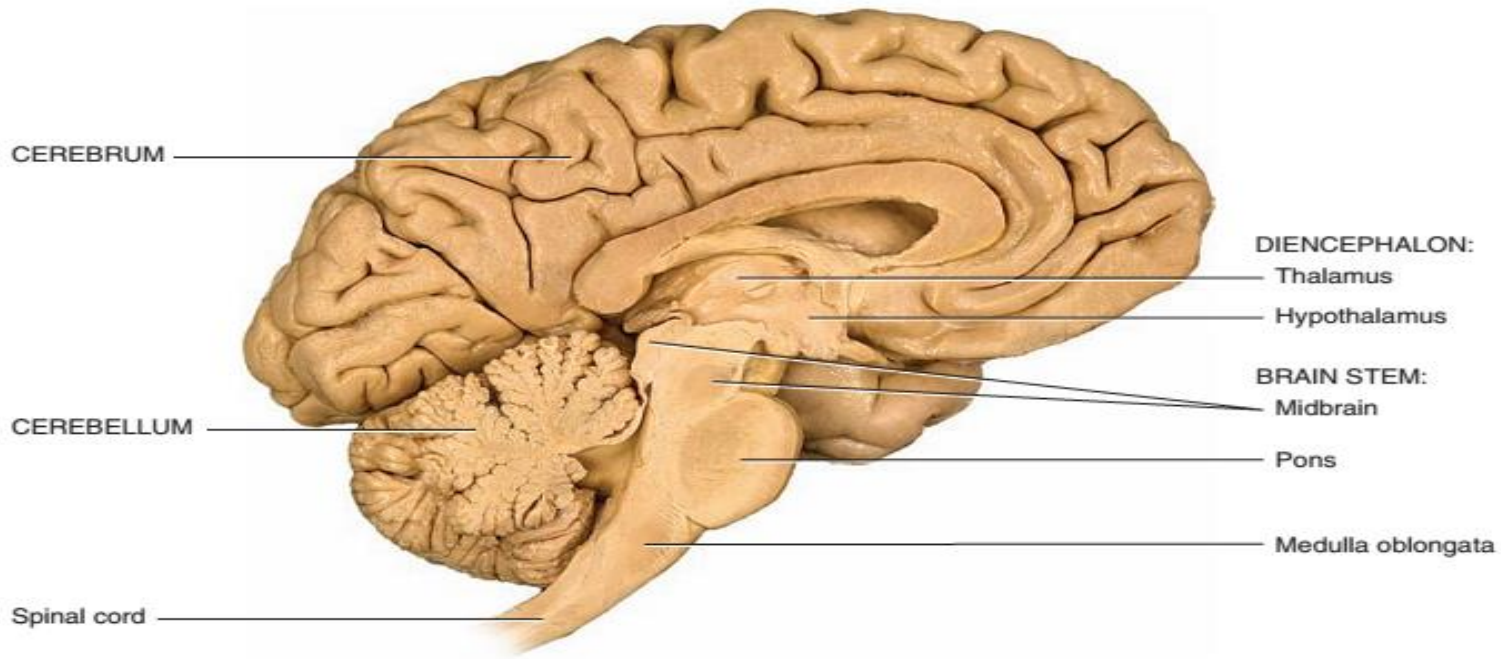
(d) Brain at birth (diencephalon and superior portion of brain stem projected to surface)



(a) Left lateral view



(a) Sagittal section, medial view



(b) Sagittal section, medial view