Anatomy of Meninges and the Spinal Cord

Meninges

3 layers-

- Dura mater:
  - outer layer
- Arachnoid mater:
  - middle layer
- Pia mater:
  - inner layer

SPINAL MENINGES

The meninges are three connective tissue coverings that encircle the spinal cord and brain. The spinal meninges surround the spinal cord and are continuous with the cranial meninges.

1. **Dura mater- most superficial layer (tough mother), is composed of dense, irregular connective tissue.**

It forms a sac from the level of the foramen magnum, where it is continuous with the dura mater of the brain, to the second sacral vertebra.

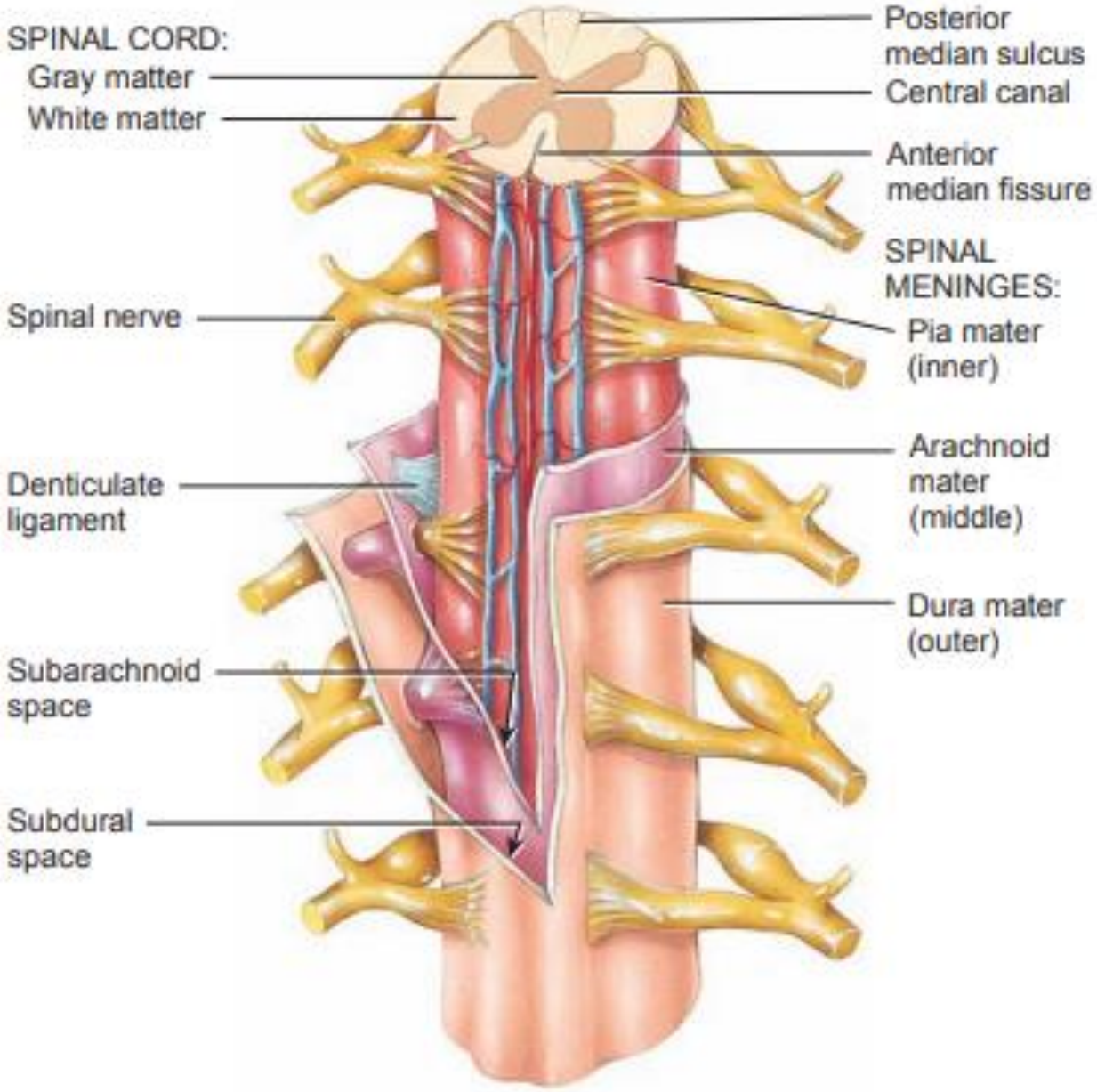
The spinal cord is also protected by a cushion of fat and connective tissue located in the epidural space, a space between the dura mater and the wall of the vertebral canal.

2. **Arachnoid mater- middle layer, is an avascular covering. It is deep to the dura mater and is continuous with the arachnoid mater of the brain. Between the dura mater and the arachnoid mater is a thin subdural space, which contains interstitial fluid.**

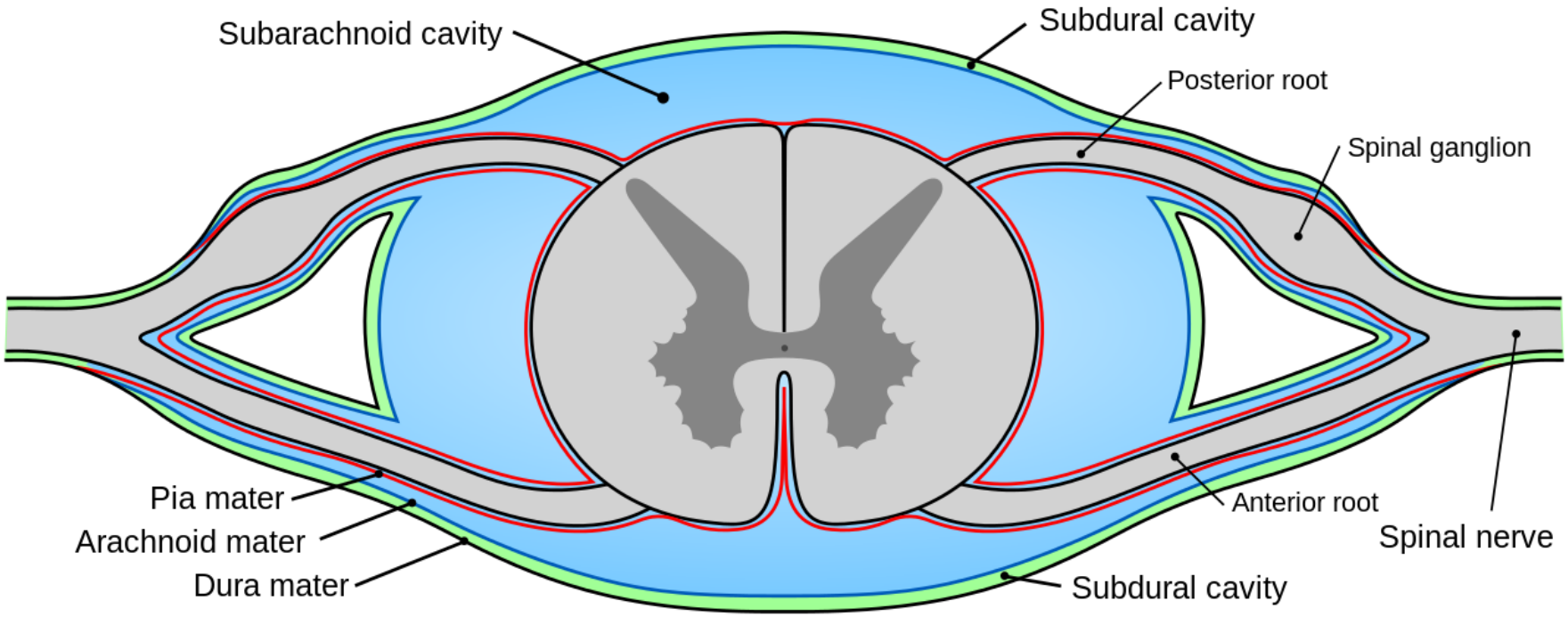
3. **Pia mater- innermost layer (pia delicate), a thin transparent connective tissue layer that adheres to the surface of the spinal cord and brain.**

It consists of squamous to cuboidal cells, 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 the pia mater is the subarachnoid space, which contains cerebrospinal fluid that serves as a shock absorber and suspension system for the spinal cord and brain.

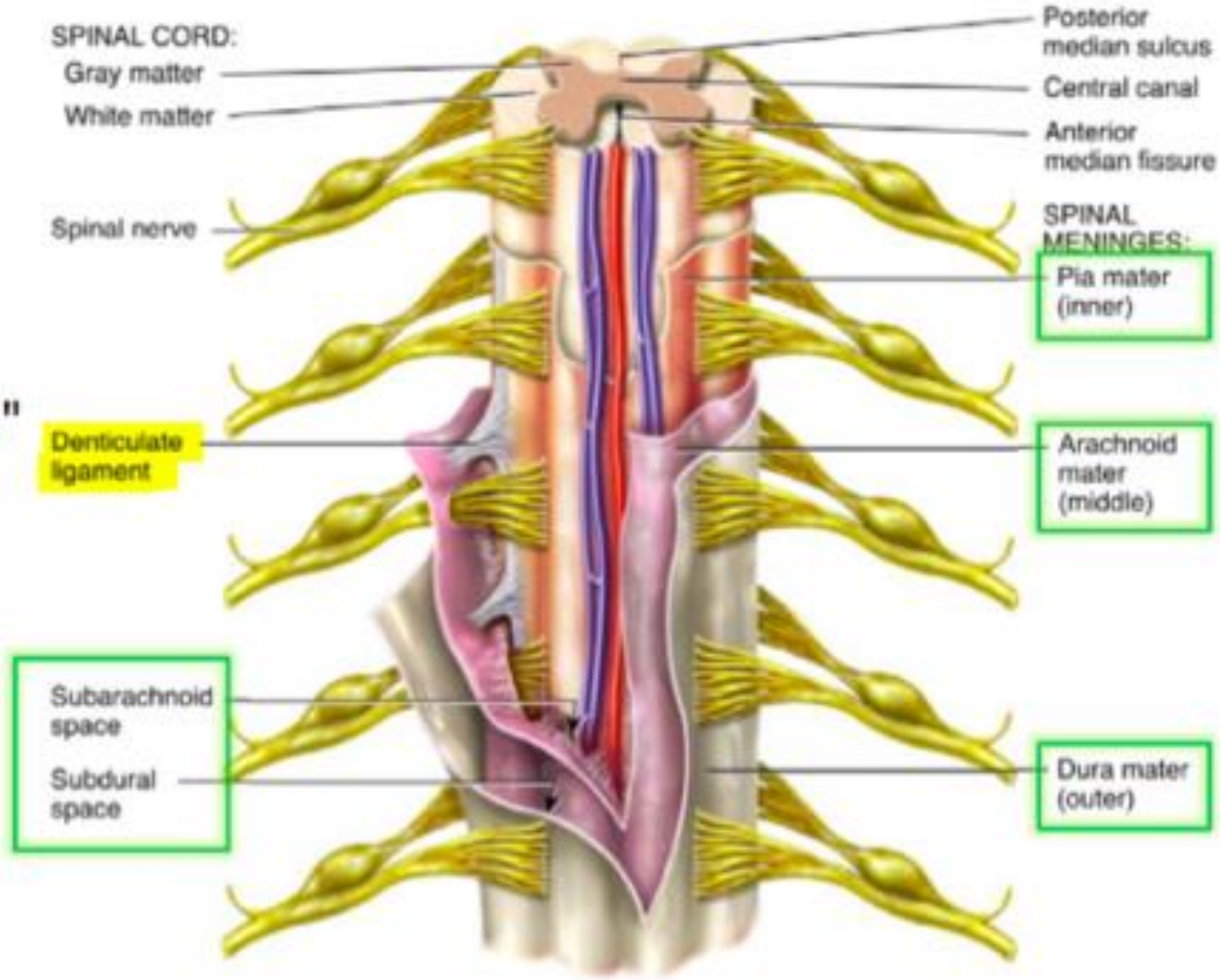

SPINAL CORD:
Gray matter
White matter
Spinal nerve
Denticulate ligament
Subarachnoid space
Subdural space
Posterior median sulcus
Central canal
Anterior median fissure
SPINAL MENINGES:
Pia mater (inner)
Arachnoid mater (middle)
Dura mater (outer)

All three spinal meninges cover the spinal nerve roots up to the point where they exit the spinal column through the intervertebral foramina.


Subarachnoid cavity
Subdural cavity
Posterior root
Spinal ganglion
Pia mater
Arachnoid mater
Dura mater
Anterior root
Spinal nerve
Subdural cavity

- **Triangular-shaped membranous extensions of the pia mater suspend the spinal cord in the middle of its dural sheath. These extensions, called denticulate ligaments, are thickenings of the pia mater. They project laterally and fuse with the arachnoid mater and inner surface of the dura mater between the anterior and posterior nerve roots of spinal nerves on either side.**

- **Extending all along the length of the spinal cord, the denticulate ligaments protect the spinal cord against sudden displacement that could result in shock.**


SPINAL CORD:
Gray matter
White matter
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Central canal
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SPINAL MENINGES:
Pia mater (inner)
Arachnoid mater (middle)
Dura mater (outer)
Denticulate ligament
Subarachnoid space
Subdural space

"tooth"

CRANIAL MENINGES

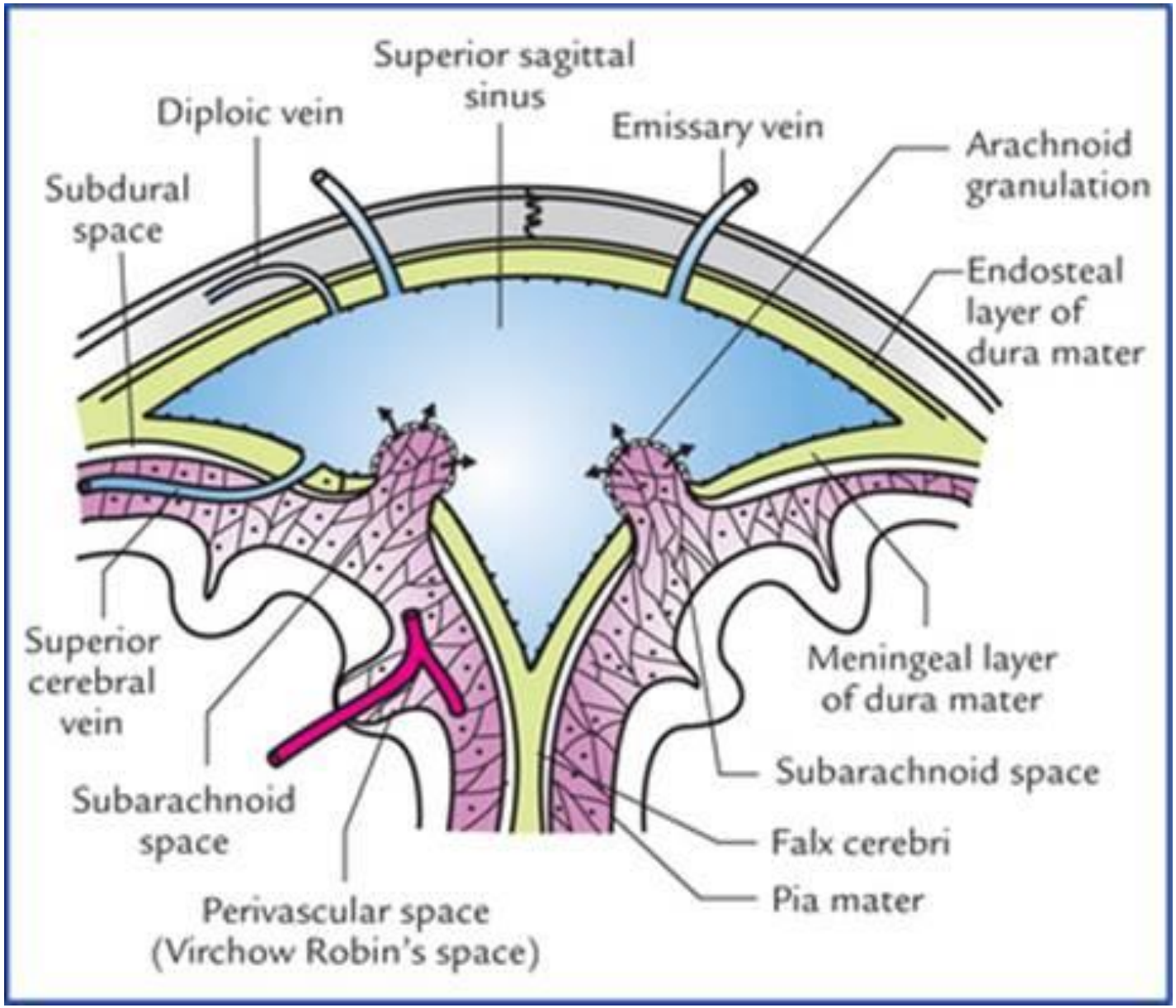
The cranial meninges are continuous with the spinal meninges.

1. **outer dura mater**
2. **middle arachnoid mater**
3. **inner pia mater**

Cranial dura mater has two layers-

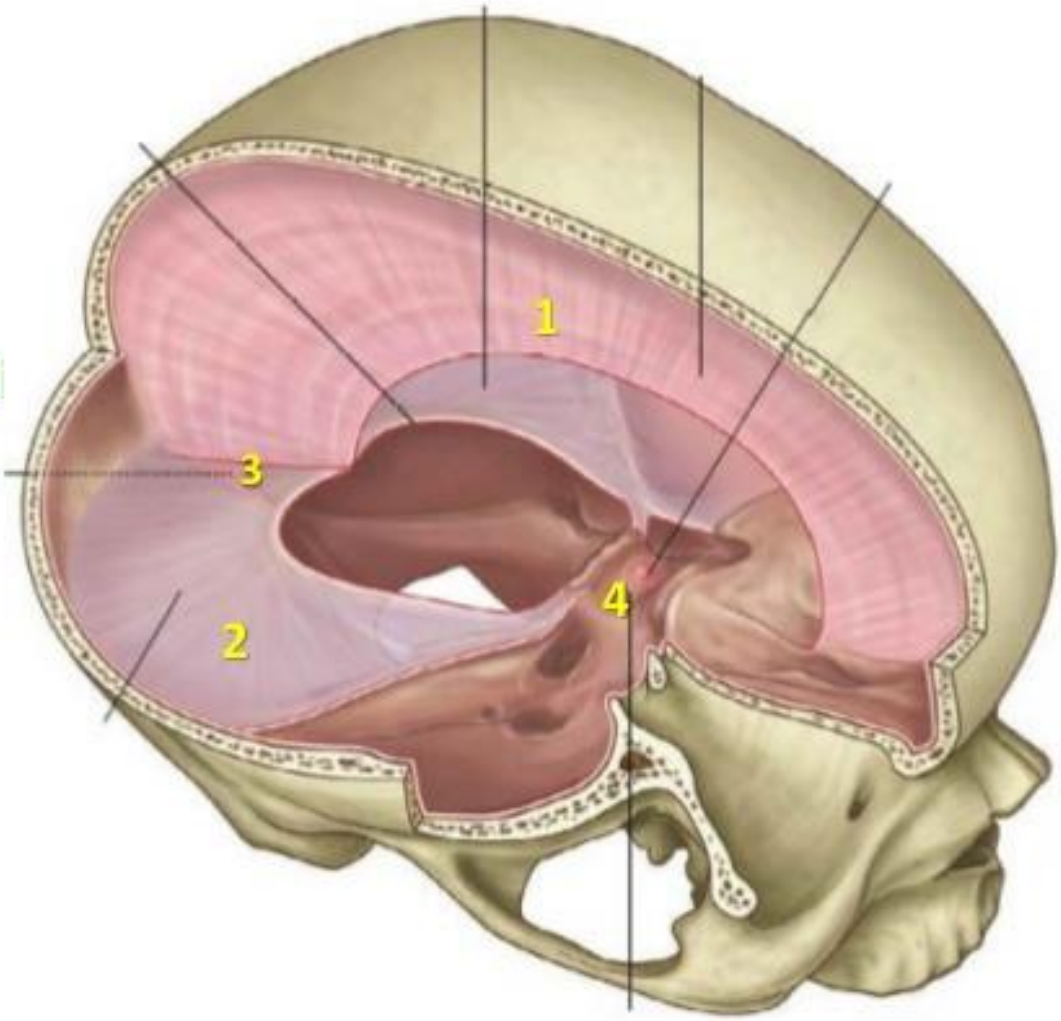
1. **Meningeal layer-inner**
2. **Periosteal or endosteal layer-outer**

The two dural layers around the brain are fused together except where they separate to enclose the dural venous sinuses that drain venous blood from the brain and deliver it into the internal jugular veins.

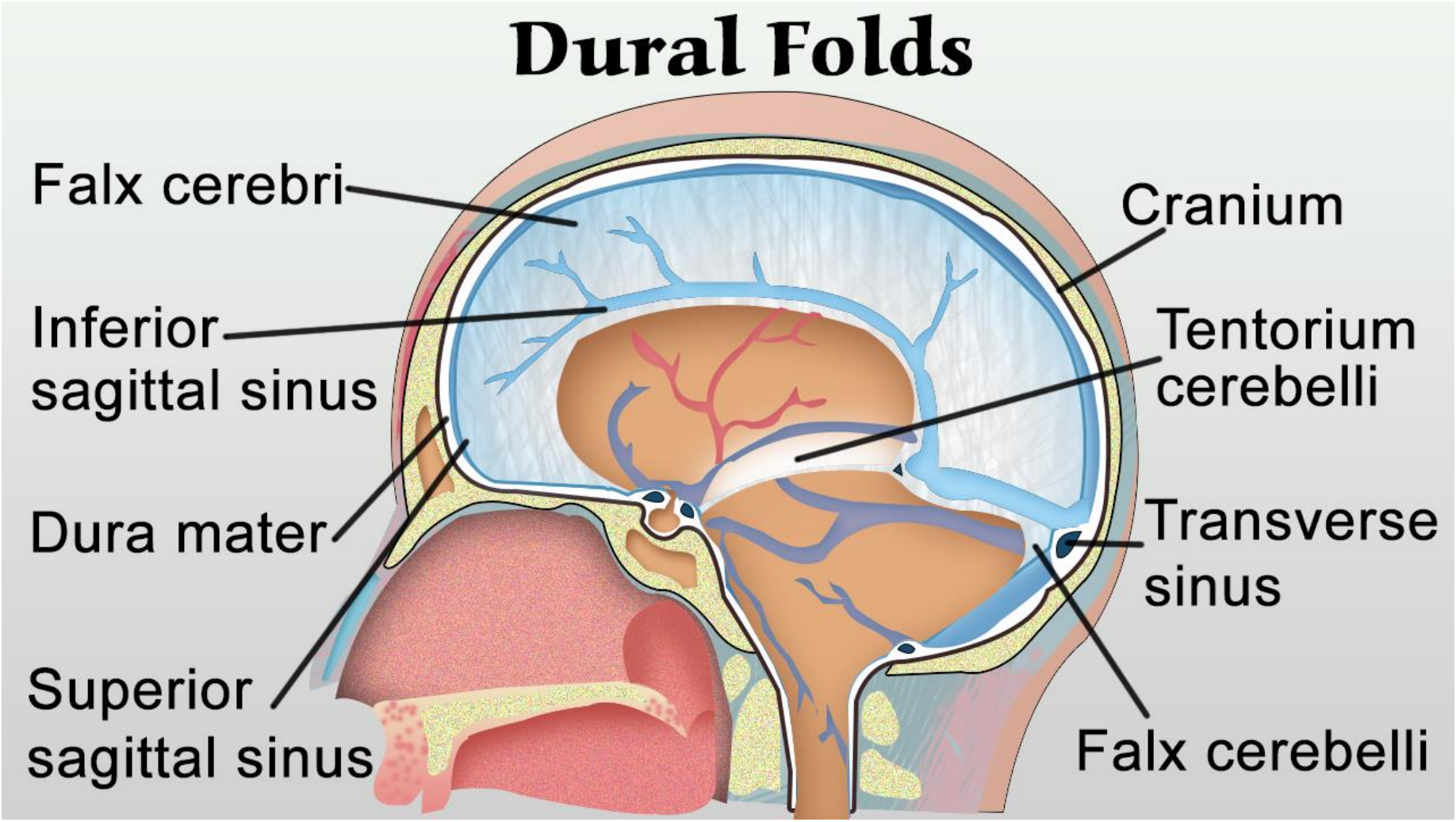

Superior sagittal sinus
Diploic vein
Emissary vein
Arachnoid granulation
Subdural space
Endosteal layer of dura mater
Superior cerebral vein
Meningeal layer of dura mater
Subarachnoid space
Subarachnoid space
Falx cerebri
Pia mater
Perivascular space (Virchow Robin's space)

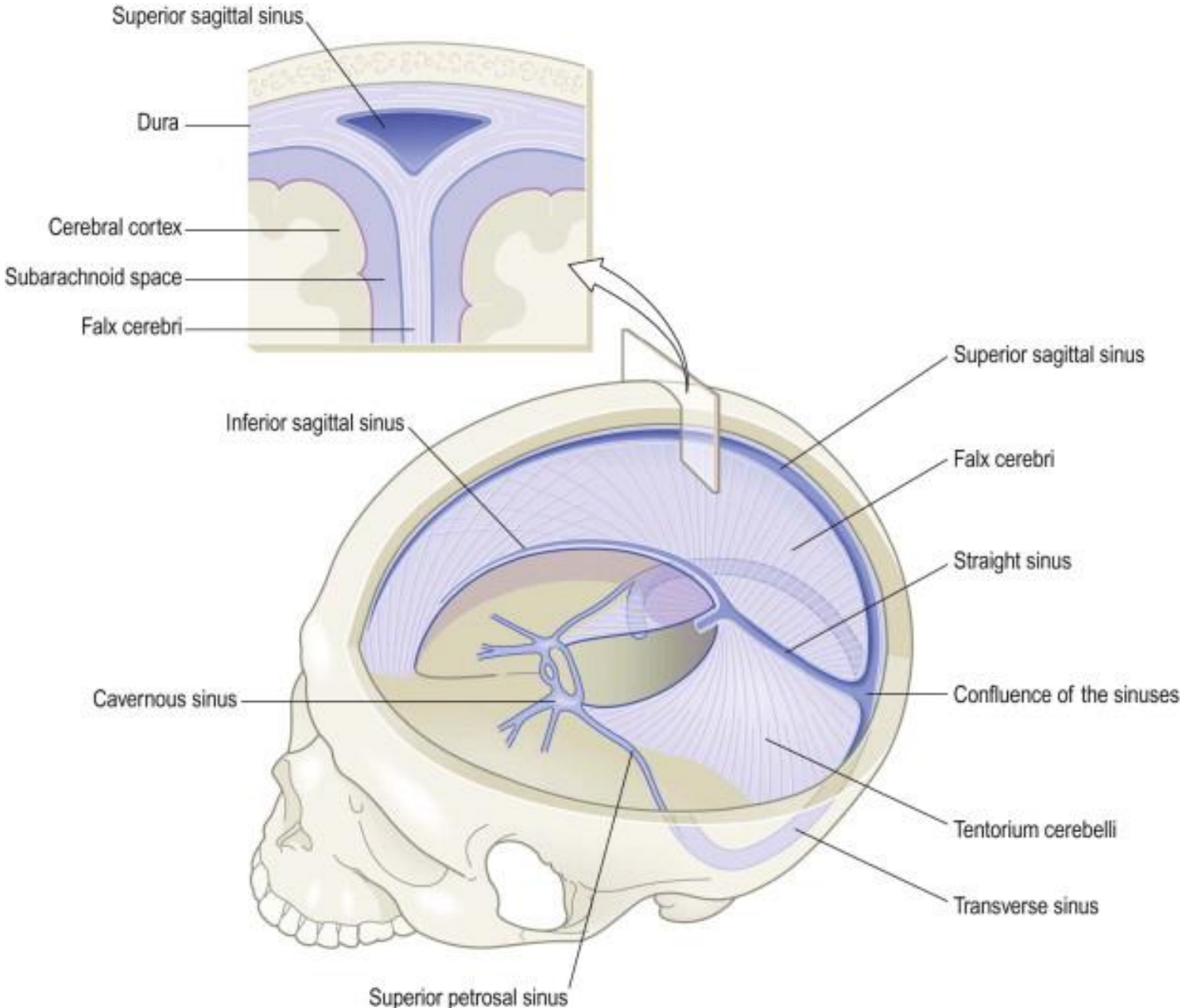
Dural partitions

1. Falx cerebri
2. Tentorium cerebell
3. Falx cerebelli
4. Diaphragm sellae



Dural Folds


Falx cerebri
Inferior sagittal sinus
Dura mater
Superior sagittal sinus
Cranium
Tentorium cerebelli
Transverse sinus
Falx cerebelli


Superior sagittal sinus
Dura
Cerebral cortex
Subarachnoid space
Falx cerebri
Superior sagittal sinus
Inferior sagittal sinus
Falx cerebri
Straight sinus
Cavernous sinus
Confluence of the sinuses
Tentorium cerebelli
Transverse sinus
Superior petrosal sinus

Dural folds or partitions

In certain places, the meningeal layer separates from the periosteal layer and forms inwardly projecting folds. These folds form partial septa which divide the cranial cavity into compartments. Four septa are present:

(1) The falx cerebri

(2) The falx cerebelli

(3) The tentorium cerebelli

(4) Diaphragma sellae

Falx cerebri

- **It's a large sickle shaped fold of the dura mater lie in the median longitudinal fissure between the 2 cerebral hemispheres.**
- **Its narrow anterior end is connected to the crista galli and the broad posterior end on to the upper surface of the tentorium cerebelli along the median plane.**
- **Its convex upper margin is connected to the lips of the sagittal sulcus of the skull vault and**

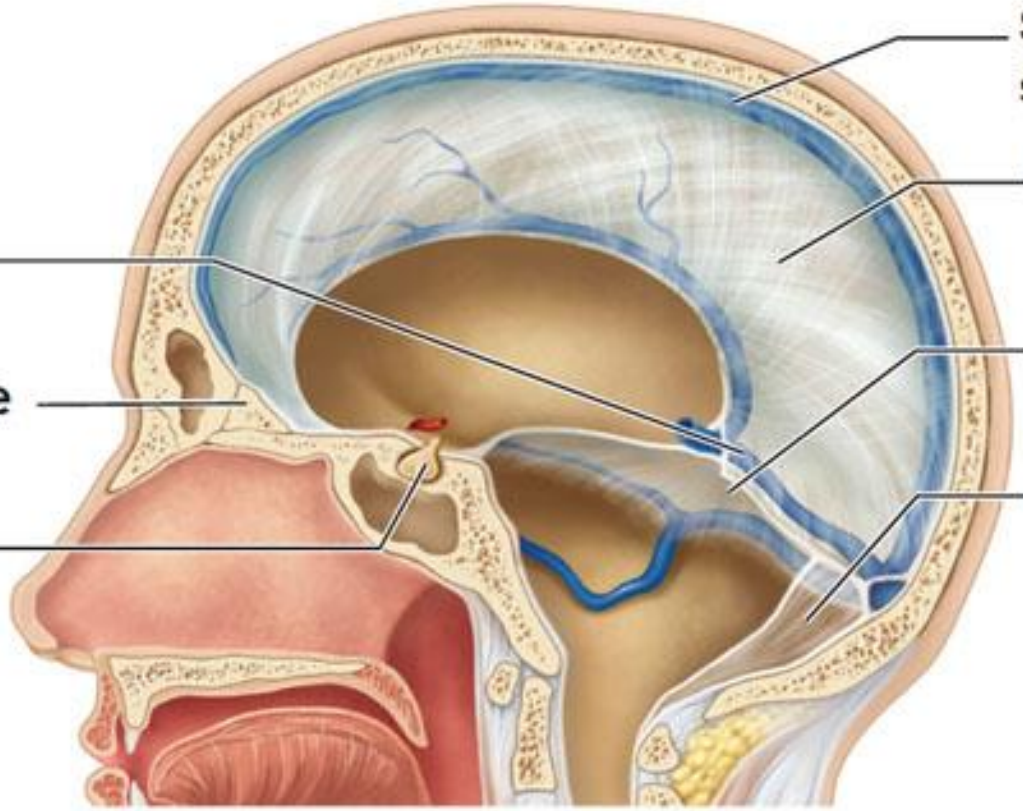
its lower concave margin is free and is located just above the corpus callosum.

Venous sinuses related with falx cerebri-

1. Superior sagittal sinus- is enclosed inside the convex upper border.
2. Inferior sagittal sinus- is enclosed inside the lower concave margin.

3. **Straight sinus- is located along the line of connection of the falx cerebri with the tentorium cerebelli.**

The Dura Mater and Dural Sinuses



(a) Midsagittal view

Tentorium cerebelli

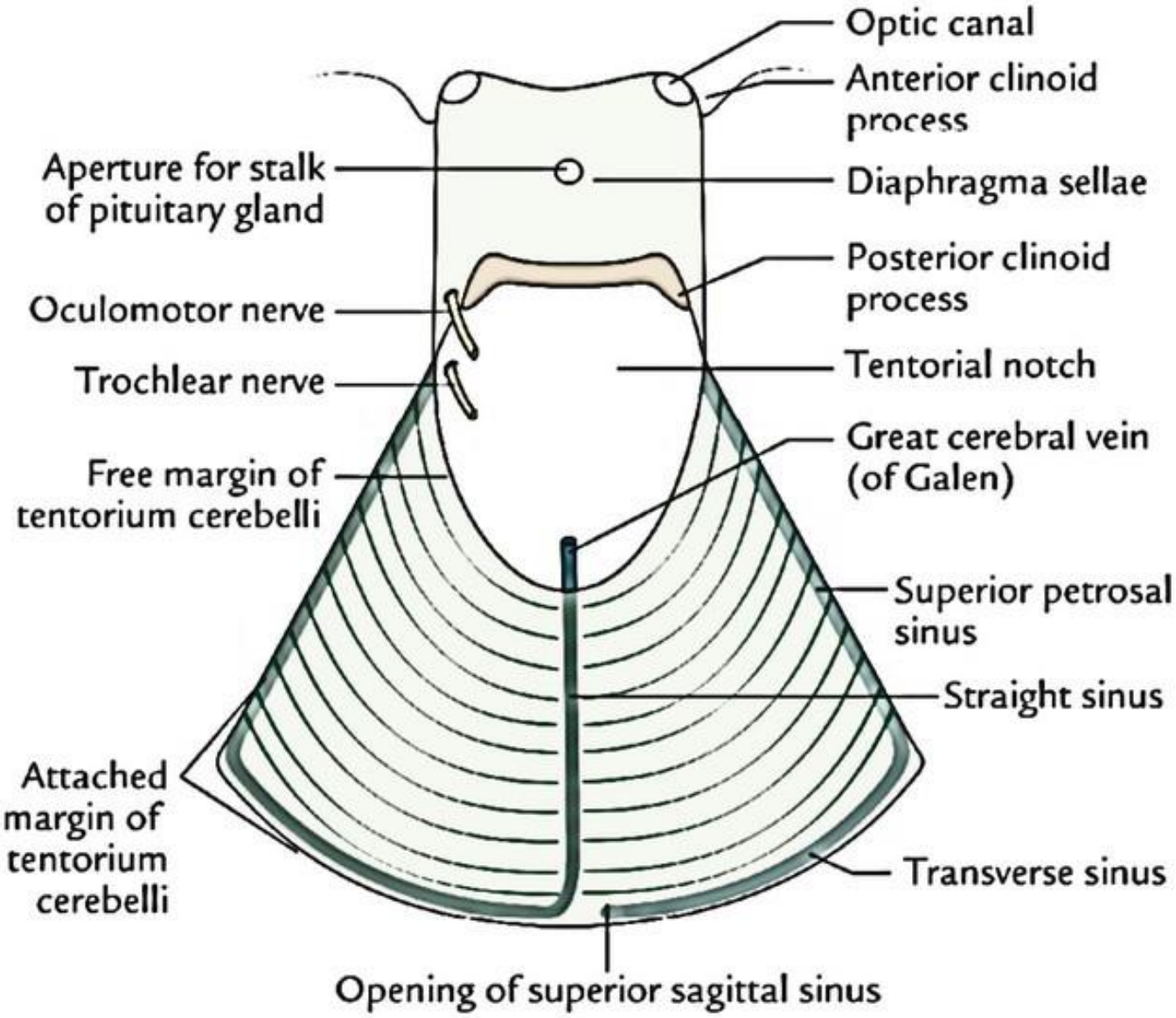
- **It’s a tent-shaped fold of the dura mater creating the roof of the posterior cranial fossa.**
- **It divides the cerebellum from the occipital lobes of the cerebrum.**
- **It is 2 margins-**

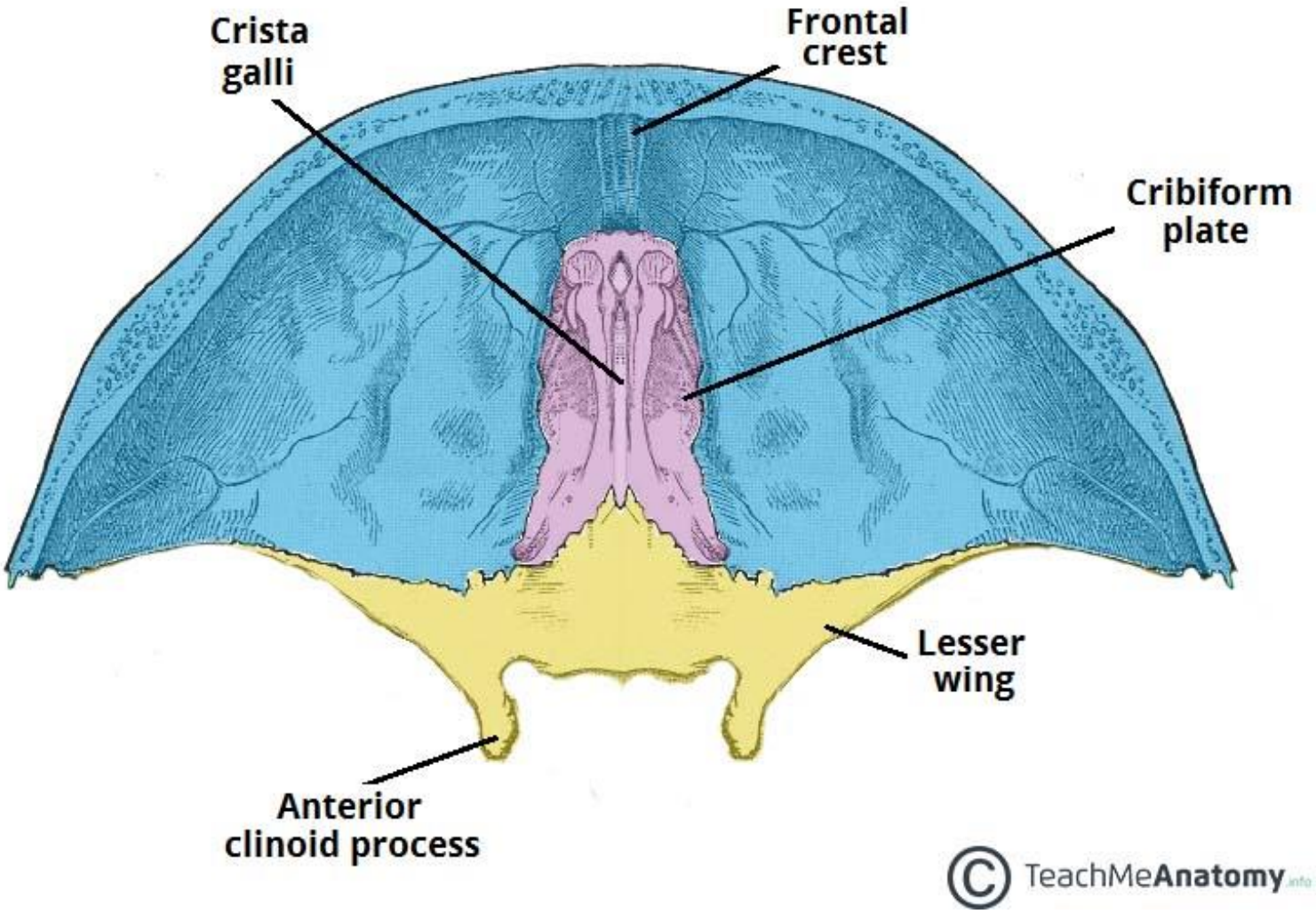
- **The inner free margin is U shaped and encloses the tentorial notch (incisure) for the passage of the midbrain. The anterior ends of the concave free margin are connected to the anterior clinoid processes.**
- **The outer connected margin is convex and connected on every side (from before backward) to the posterior clinoid process, the posteroinferior angle of the parietal bone**

and the lips of transverse sulci on the occipital bone.

Venous sinuses related with tentorium cerebelli-

1. **Transverse sinus- inside the posterior part of the connected margin.**
2. **Superior petrosal sinus- inside the anterolateral part of the connected margin**


Optic canal
Anterior clinoid process
Aperture for stalk of pituitary gland
Diaphragma sellae
Posterior clinoid process
Oculomotor nerve
Trochlear nerve
Tentorial notch
Great cerebral vein (of Galen)
Free margin of tentorium cerebelli
Superior petrosal sinus
Straight sinus
Attached margin of tentorium cerebelli
Transverse sinus
Opening of superior sagittal sinus


Crista galli
Frontal crest
Cribiform plate
Lesser wing
Anterior clinoid process
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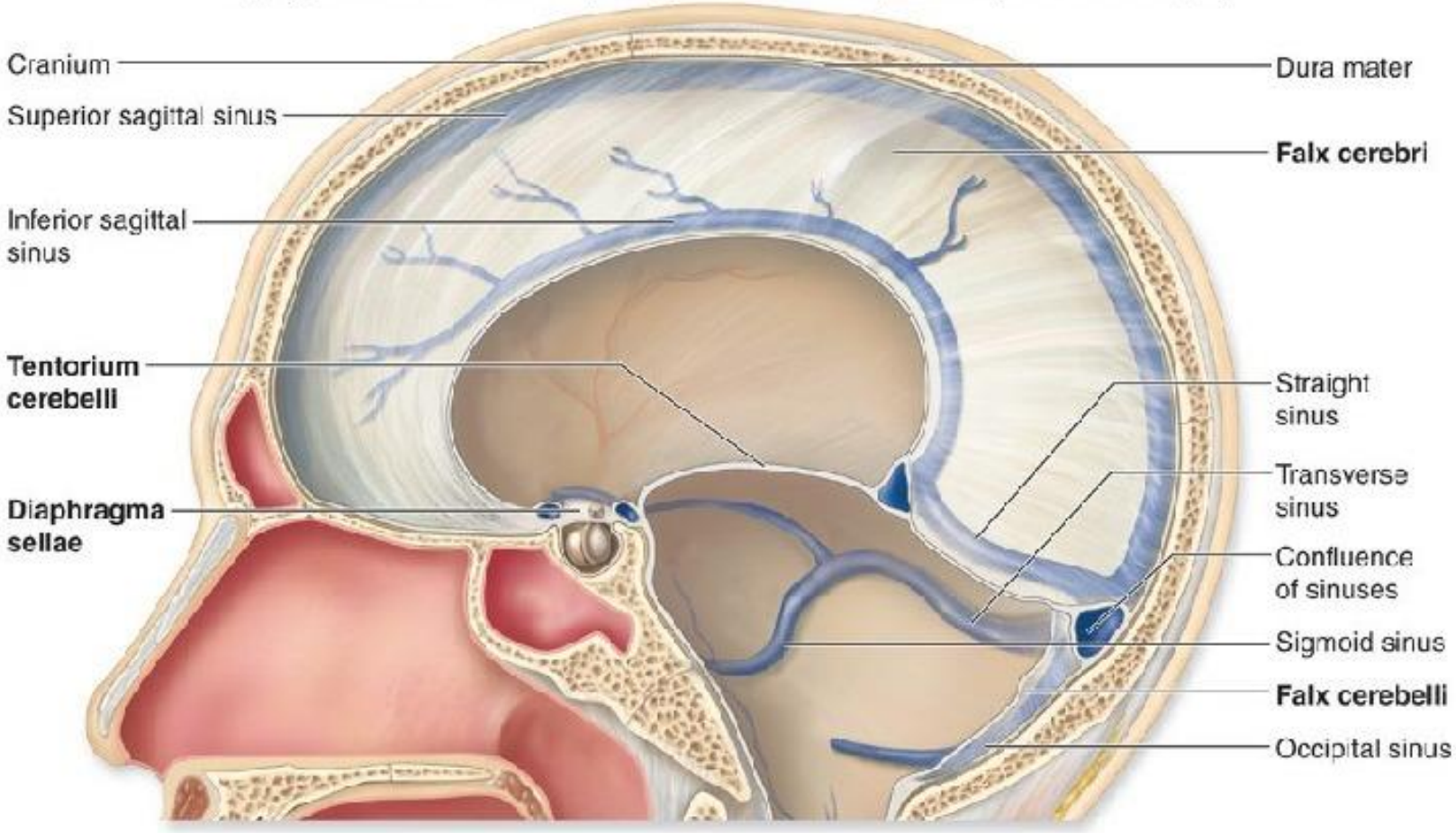
FALX CEREBELLI

- **It's a small sickle shaped fold of the dura mater in the sagittal plane. It occupies the median groove (vallecula cerebelli) that separates the lower part of the right and left cerebellar hemisphere.**
- **It's a free concave anterior margin and a convex connected posterior border.**

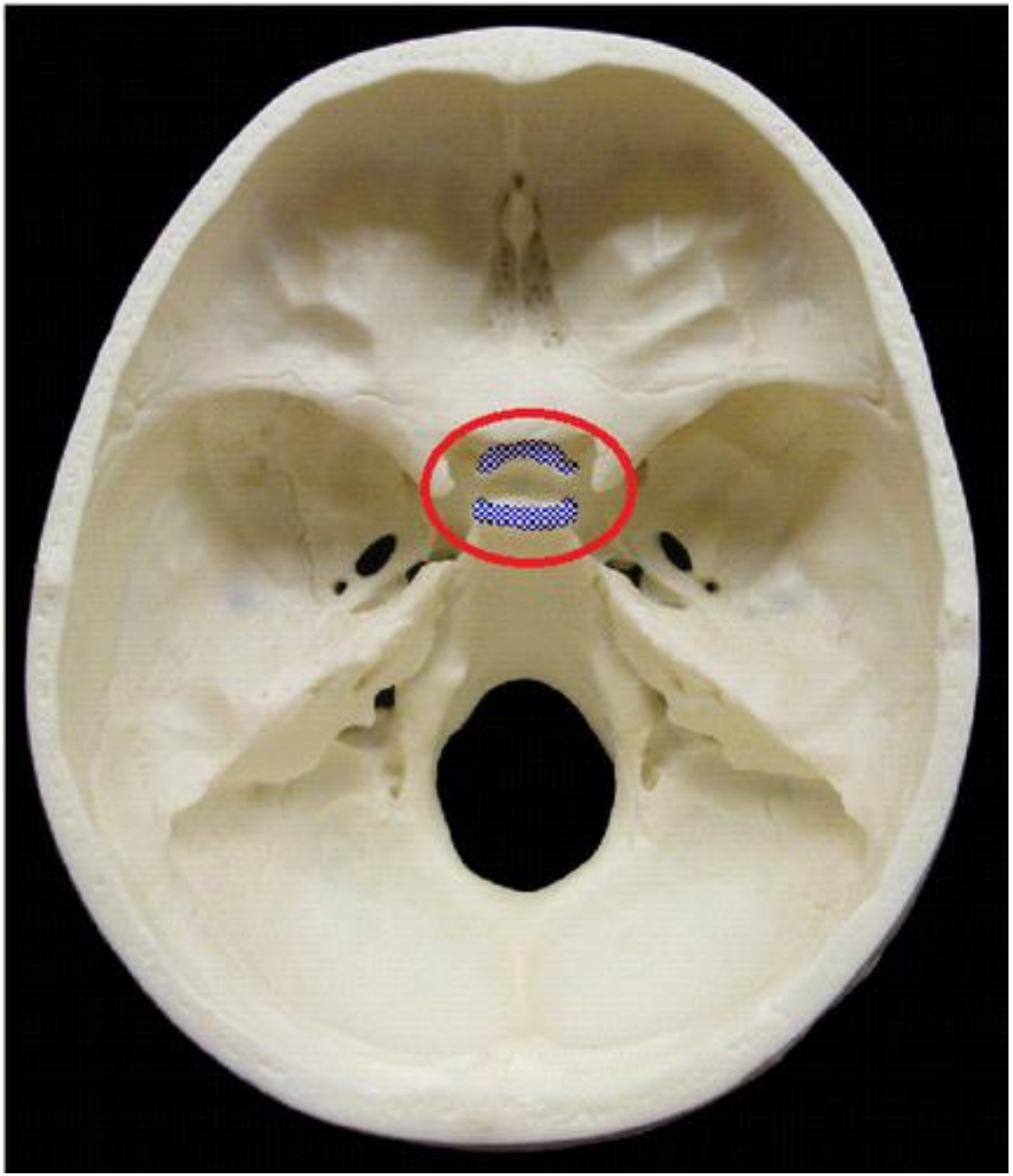
Venous sinus enclosed in the falx cerebelli-

1. **Occipital sinus- together with its posterior connected part.**



DIAPHRAGMA SELLAE

- **It's a small circular horizontal fold of the inner layer of the dura mater creating the roof of the hypophyseal fossa.**
- **It's connected anteriorly to the tuberculum sellae and posteriorly to the dorsum sellae and becomes constant on every side together with the dura mater of the middle cranial fossa.**
- **It's a central aperture which gives passage to the stalk of the pituitary gland.**



BLOOD SUPPLY OF THE DURA MATER

In the anterior cranial fossa:

1. **Meningeal branches of the ophthalmic artery**
2. **Meningeal branches of the anterior and posterior ethmoidal arteries**
3. **Middle meningeal artery**

In the middle cranial fossa:

1. **Middle and accessory meningeal arteries**
2. **Meningeal branches of the internal carotid and ascending pharyngeal arteries.**

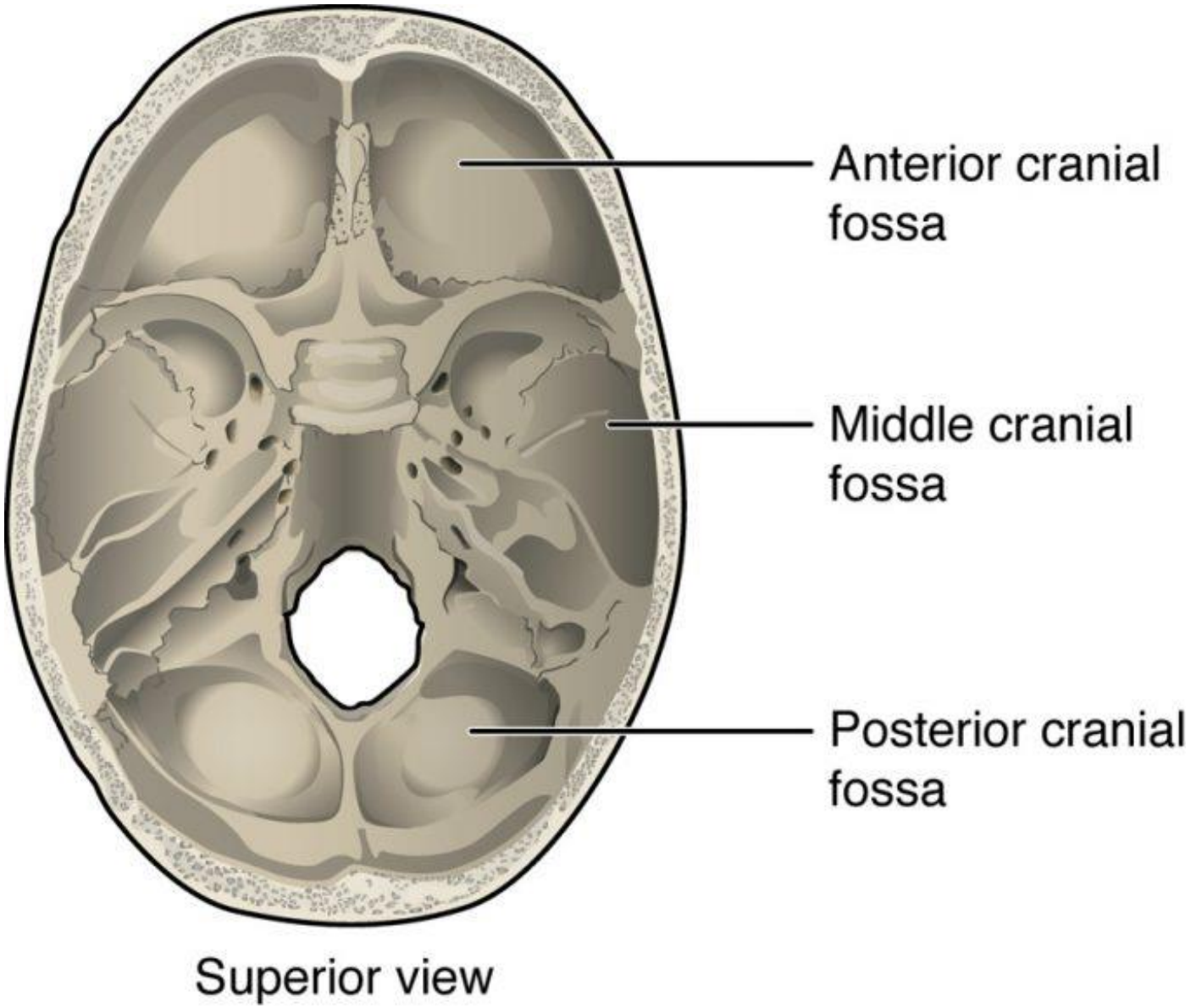
- **In the posterior cranial fossa:**

1. **Meningeal branches of the vertebral and occipital arteries.**

NERVE SUPPLY OF THE DURA MATER

- **In the anterior cranial fossa: by the anterior and posterior ethmoidal nerves.**
- **In the middle cranial fossa: by the meningeal branch of the maxillary nerve (in the anterior part) and the meningeal branch of the mandibular nerve in the posterior part.**
- **In the posterior cranial fossa: by the meningeal branches of the vagus and hypoglossal nerves.**

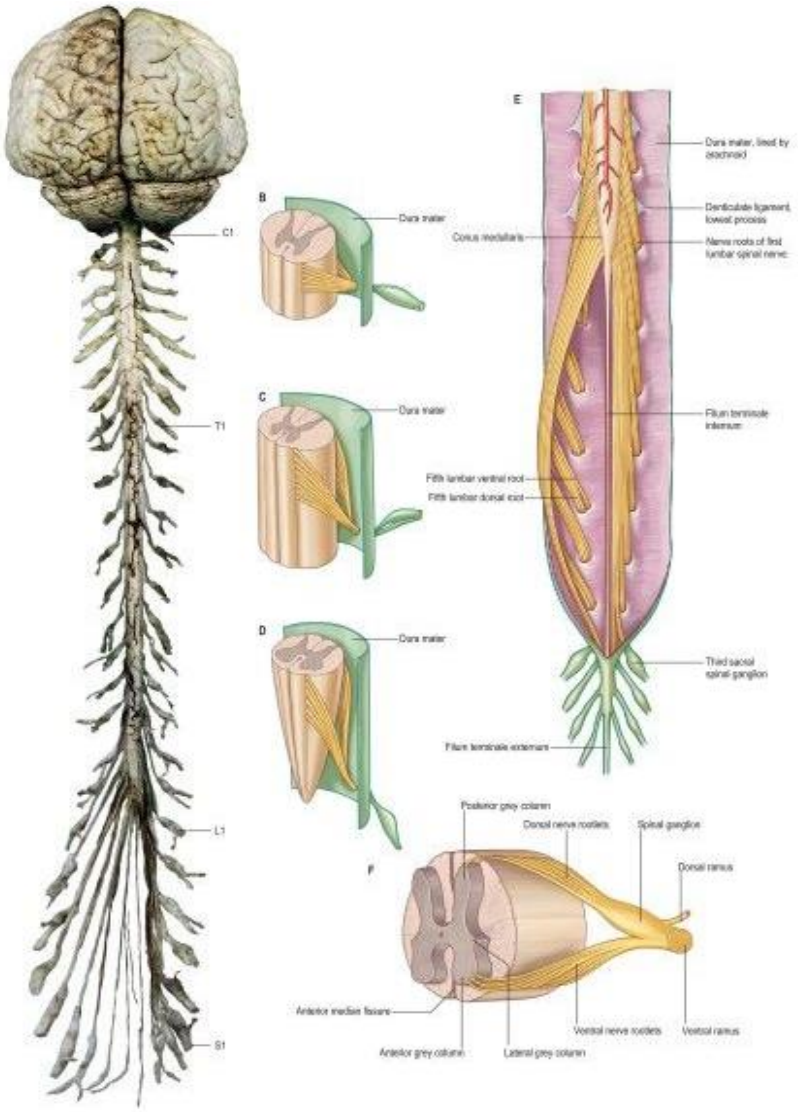
- **The dura mater around the foramen magnum is directly supplied by the C2 and C3 cervical nerve**



Superior view

SPINAL CORD

External anatomy of spinal cord



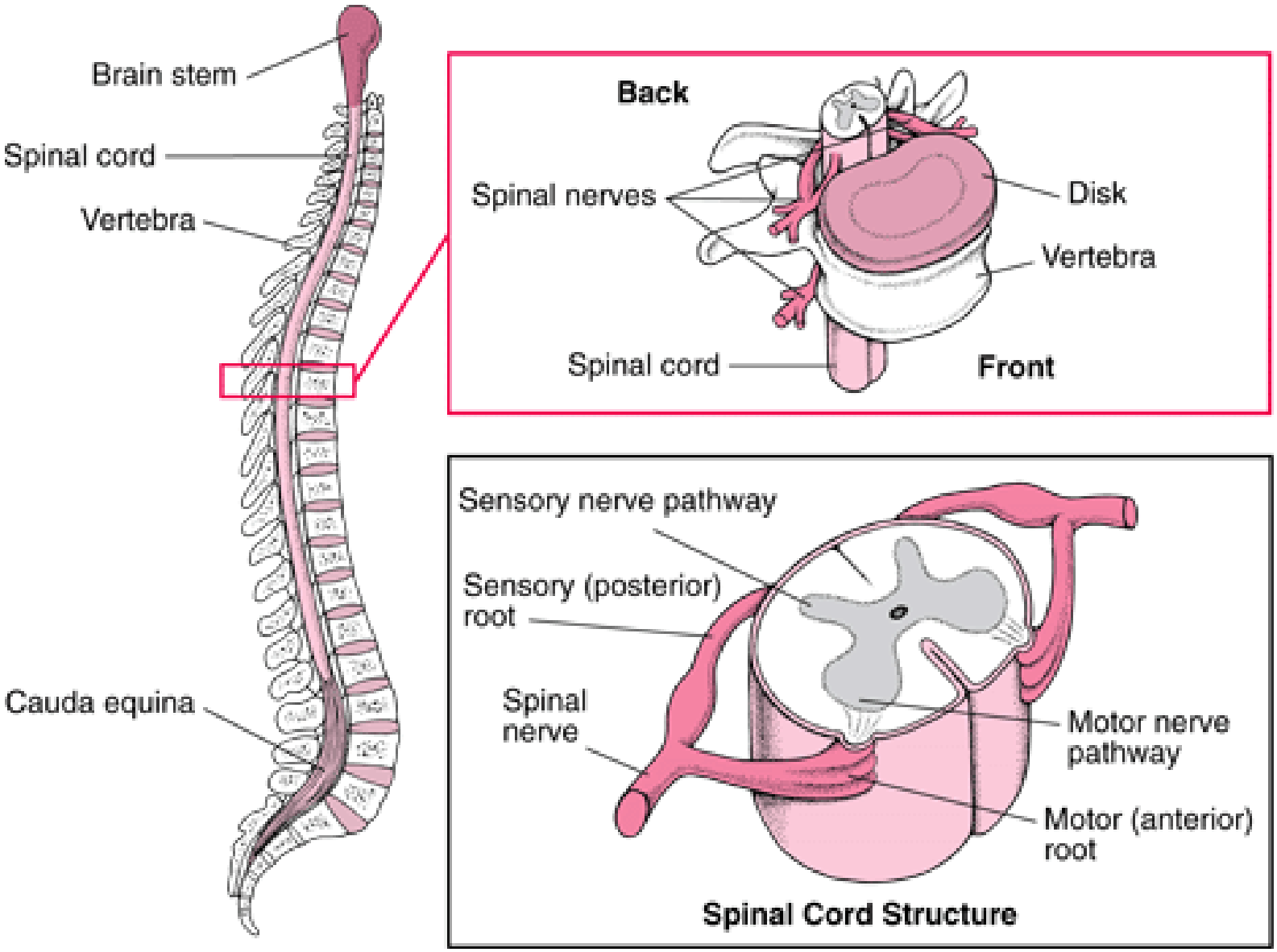
- **Elongated, cylindrical, suspended in the vertebral canal**
- **Surrounded by the meninges and cerebrospinal fluid.**
- **The spinal cord occupies the superior two-thirds of the vertebral canal.**
- **Extend (adult C1-L1), Infants (C1-L3)**
- **its weight approximately 30 g.**
- **The length of the adult spinal cord ranges from 42 to 45 cm.**

During early childhood, both the spinal cord and the vertebral column grow longer as part of overall body growth. Elongation of the spinal cord stops around age 4 or 5, but growth of the vertebral column continues. Thus, the spinal cord does not extend the entire length of the adult vertebral column.

Its diameter is about 2 cm in the midthoracic region, somewhat larger in the lower cervical and midlumbar regions, and smallest at the inferior tip.

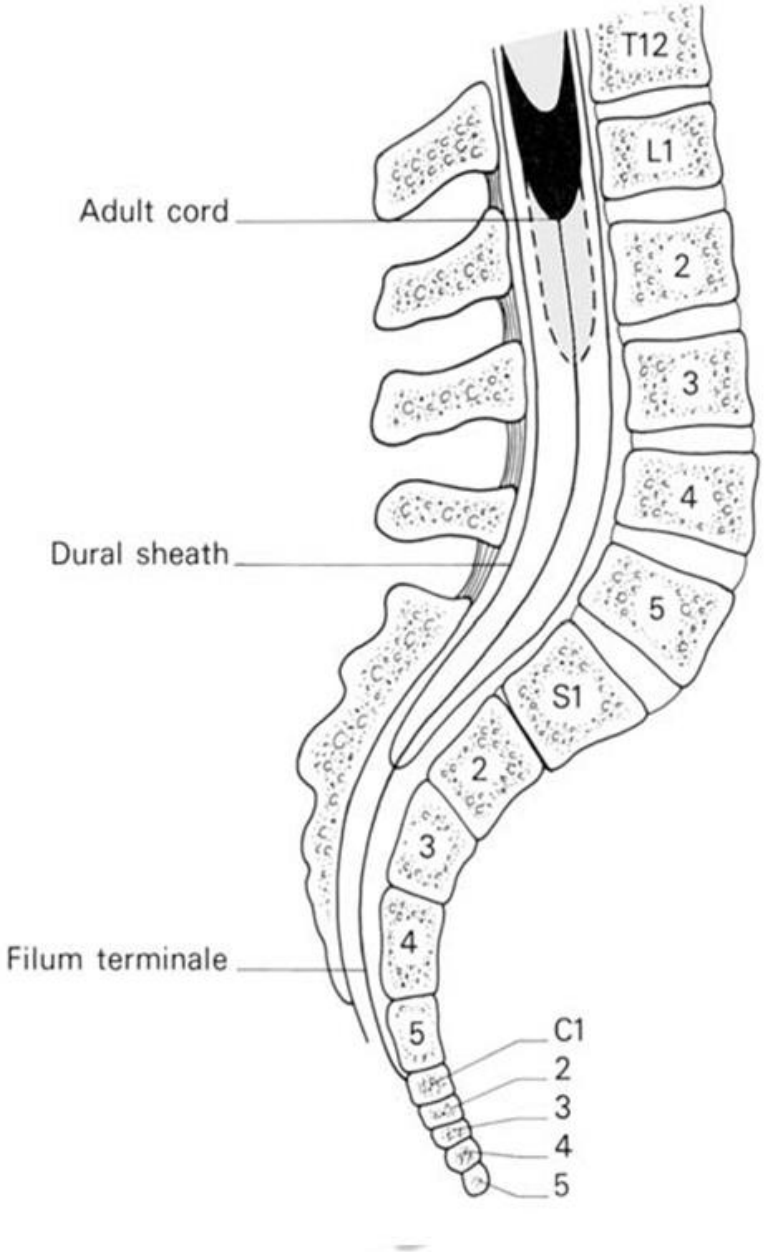
Externally-

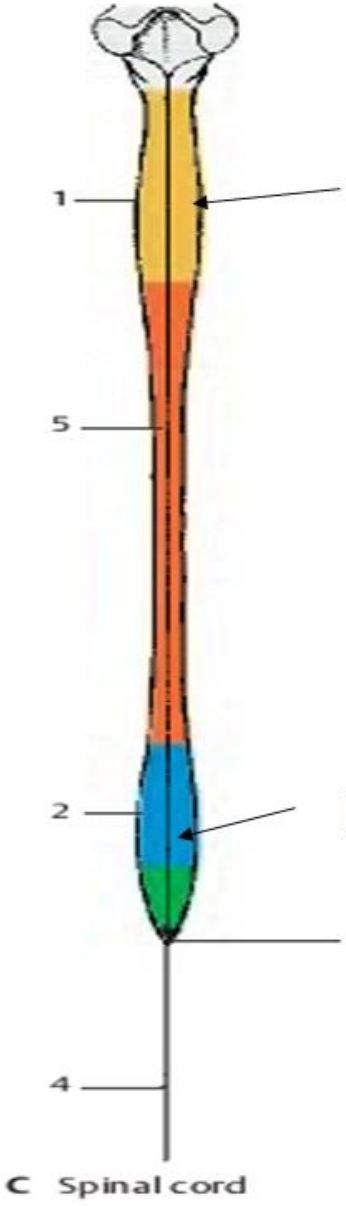
- **Anterior- anterior median fissure**
- **Posterior- posterior median sulcus**
- **Laterally- Anterolateral sulcus and posterolateral sulcus**
- **3 regions- anterior, posterior and lateral region.**
- **Anterolateral sulcus- motor root of spinal nerve.**
- **Posterolateral sulcus- sensory root of spinal nerve.**


Brain stem
Spinal cord
Vertebra
Cauda equina
Back
Spinal nerves
Disk
Vertebra
Spinal cord
Front
Sensory nerve pathway
Sensory (posterior) root
Spinal nerve
Motor nerve pathway
Motor (anterior) root
Spinal Cord Structure

Enlargement-2

1. **Cervical enlargement- extends from the C4 to the T1. Nerves to and from the upper limbs arise from the cervical enlargement.**
2. **Lumbar enlargement- extends from the T11 to S2. Nerves to and from the lower limbs arise from the lumbar enlargement.**





cervical enlargement

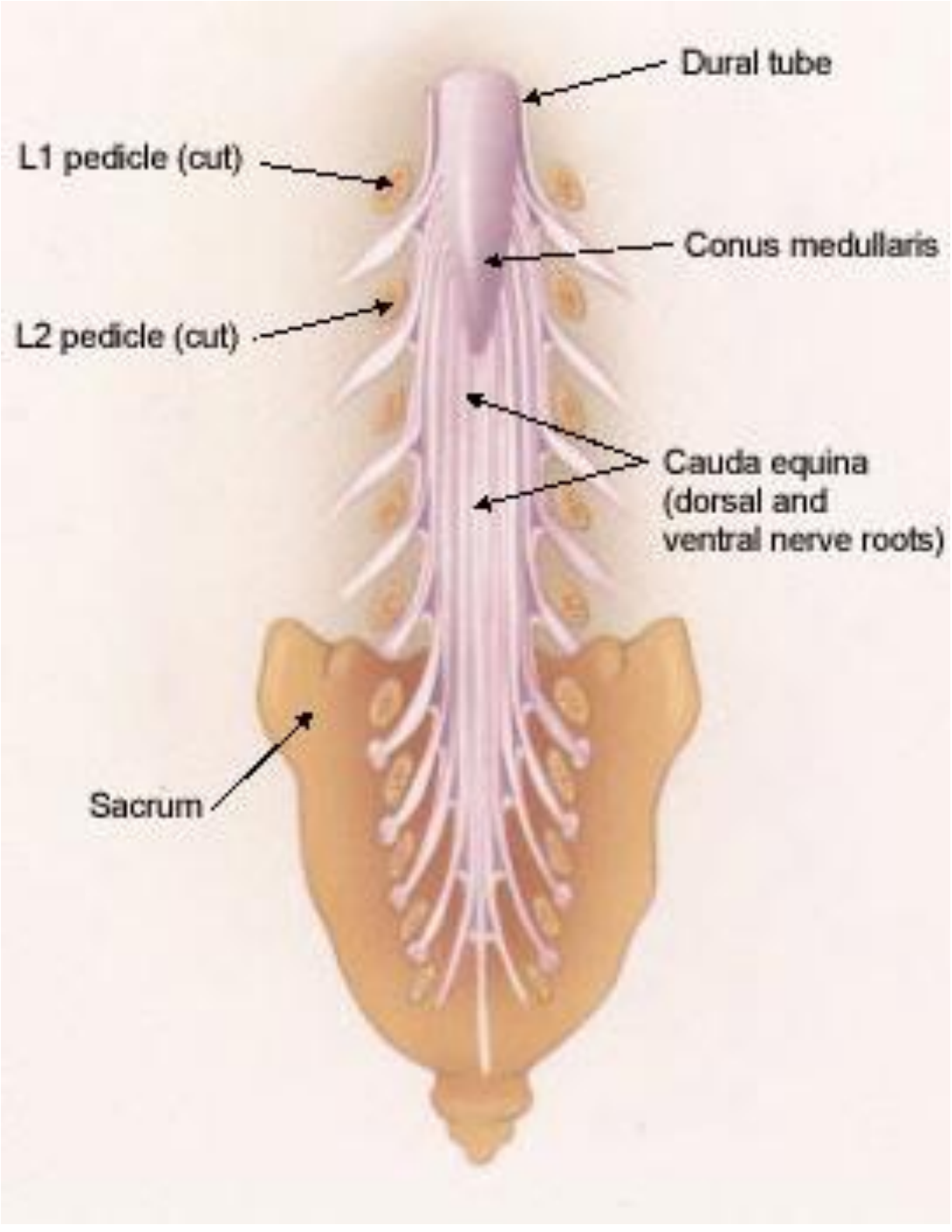
lumbosacral enlargement

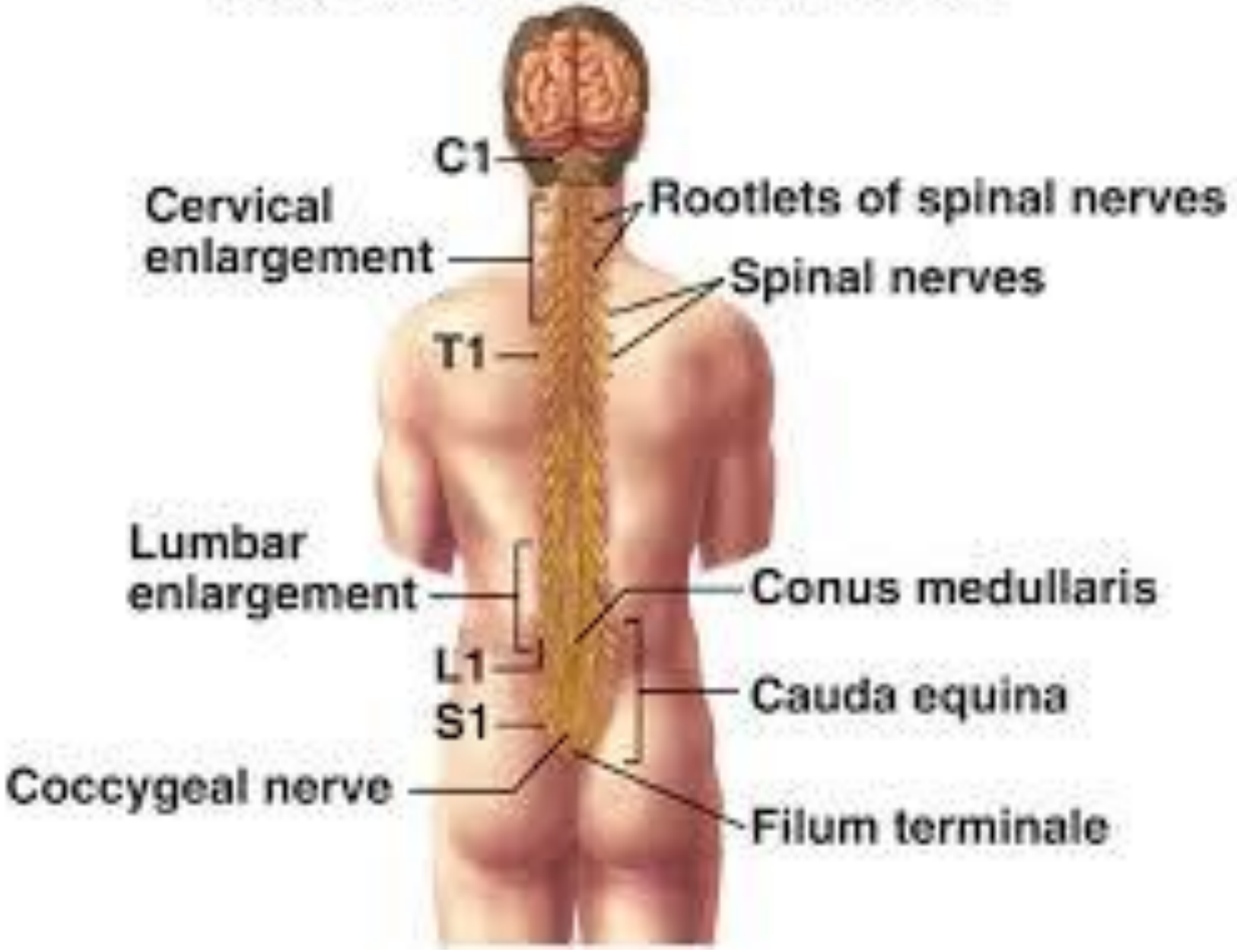
C Spinal cord

Inferior to the lumbar enlargement, the spinal cord terminates as a tapering, conical structure called the conus medullaris, which ends at the level of the intervertebral disc between the first and second lumbar vertebrae in adults.

Filum terminale

Arising from the conus medullaris is the filum terminale, an extension of the pia mater that extends inferiorly and blends with the arachnoid mater and dura mater and anchors the spinal cord to the coccyx.


Dural tube
L1 pedicle (cut)
Conus medullaris
L2 pedicle (cut)
Cauda equina
(dorsal and
ventral nerve roots)
Sacrum


C1
Cervical enlargement
Rootlets of spinal nerves
Spinal nerves
T1
Lumbar enlargement
Conus medullaris
L1
Cauda equina
S1
Coccygeal nerve
Filum terminale

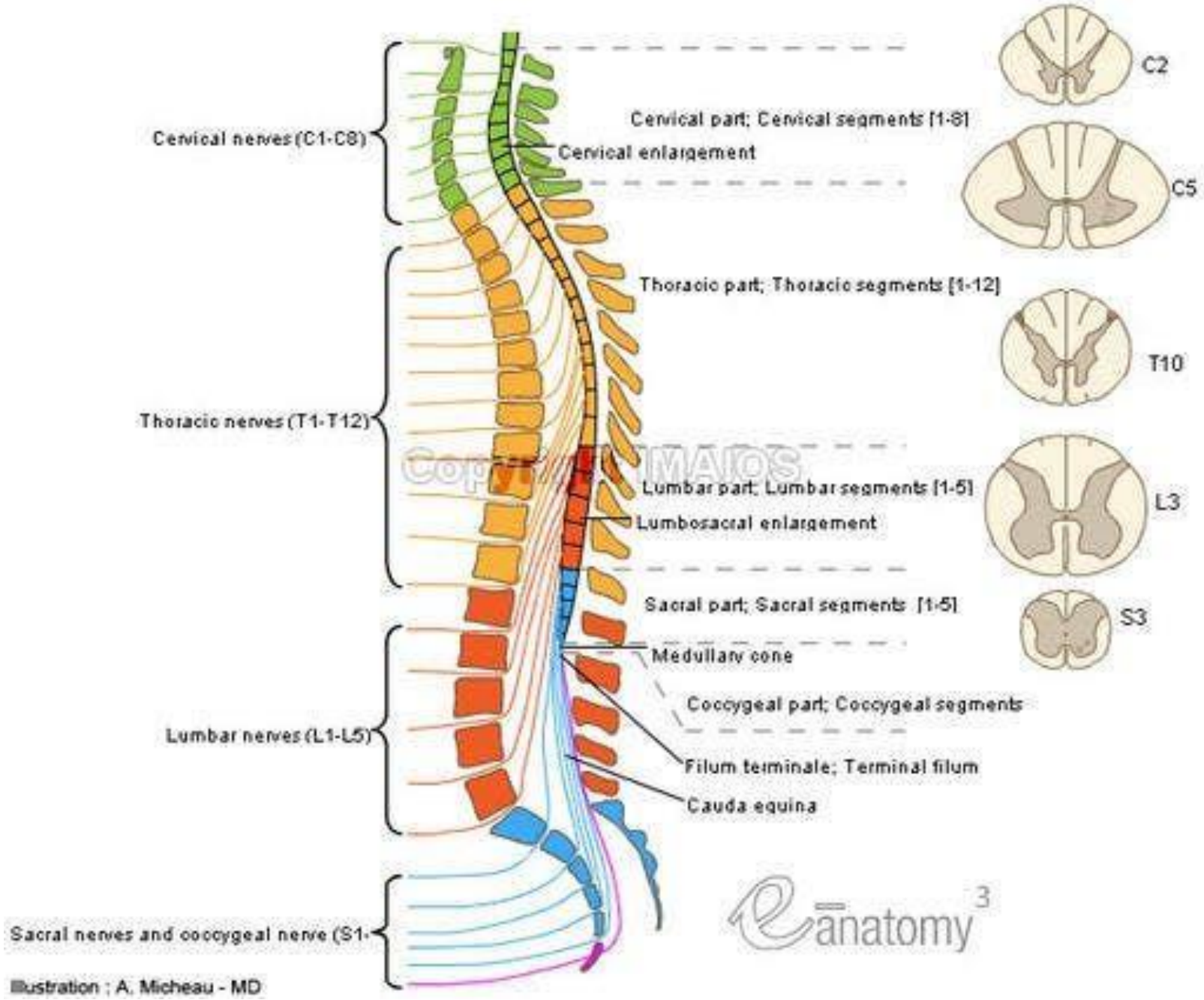
Spinal Nerve

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.

The naming of spinal nerves is based on the segment in which they are located.

1. **8 pairs of Cervical nerves- C1–C8**
2. **12 pairs of thoracic nerves (T1–T12)**
3. **5 pairs of lumbar nerves (L1–L5)**
4. **5 pairs of sacral nerves (S1–S5)**
5. **1 pair of coccygeal nerves (Co1).**

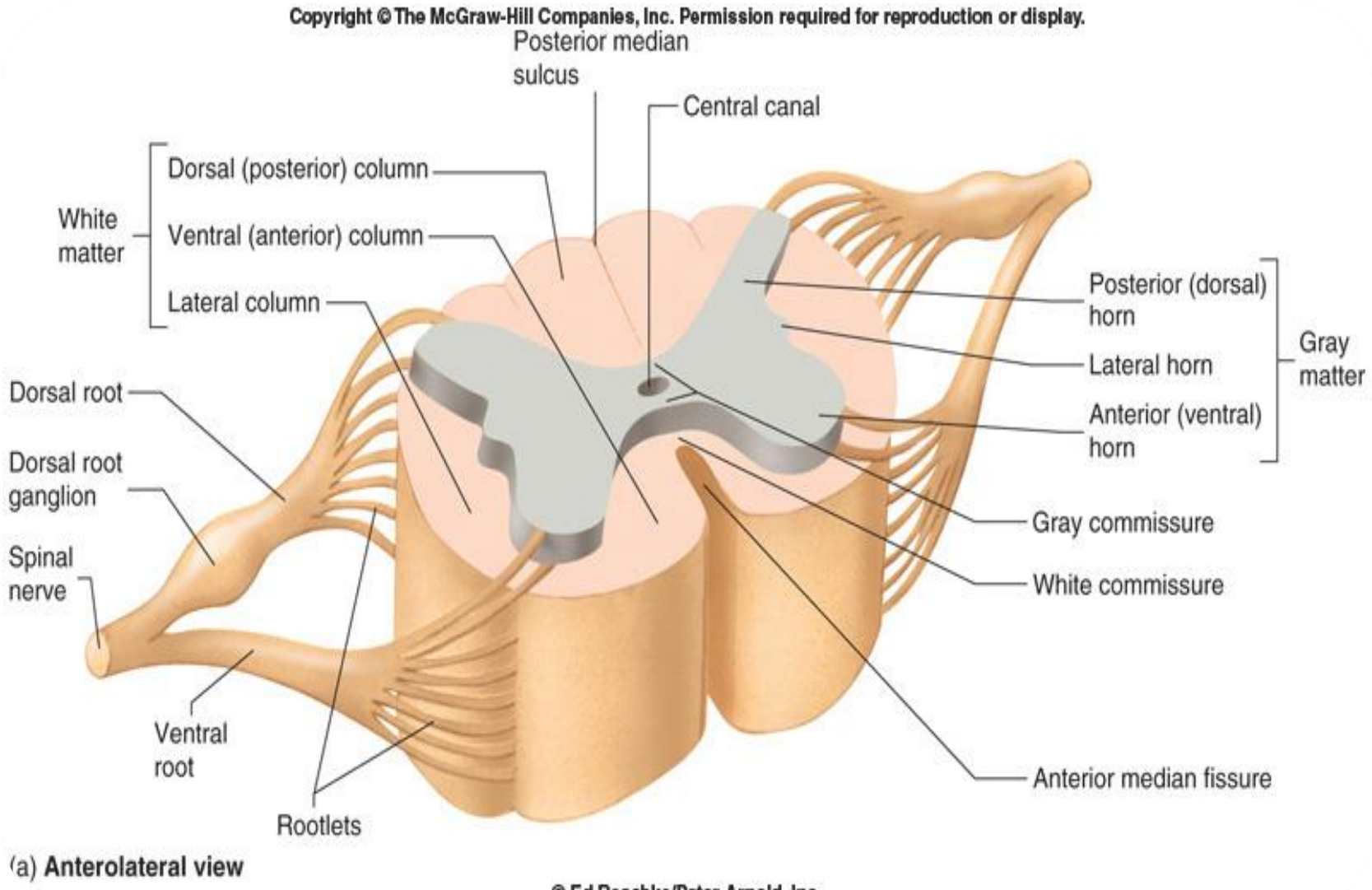

Cervical nerves (C1-C8)
Thoracic nerves (T1-T12)
Lumbar nerves (L1-L5)
Sacral nerves and coccygeal nerve (S1-
Cervical part; Cervical segments [1-8]
Cervical enlargement
Thoracic part; Thoracic segments [1-12]
Lumbar part; Lumbar segments [1-5]
Lumbosacral enlargement
Sacral part; Sacral segments [1-5]
Medullary cone
Coccygeal part; Coccygeal segments
Filum terminale; Terminal filum
Cauda equina
C2
C5
T10
L3
S3
anatomy 3
Illustration : A. Micheau - MD

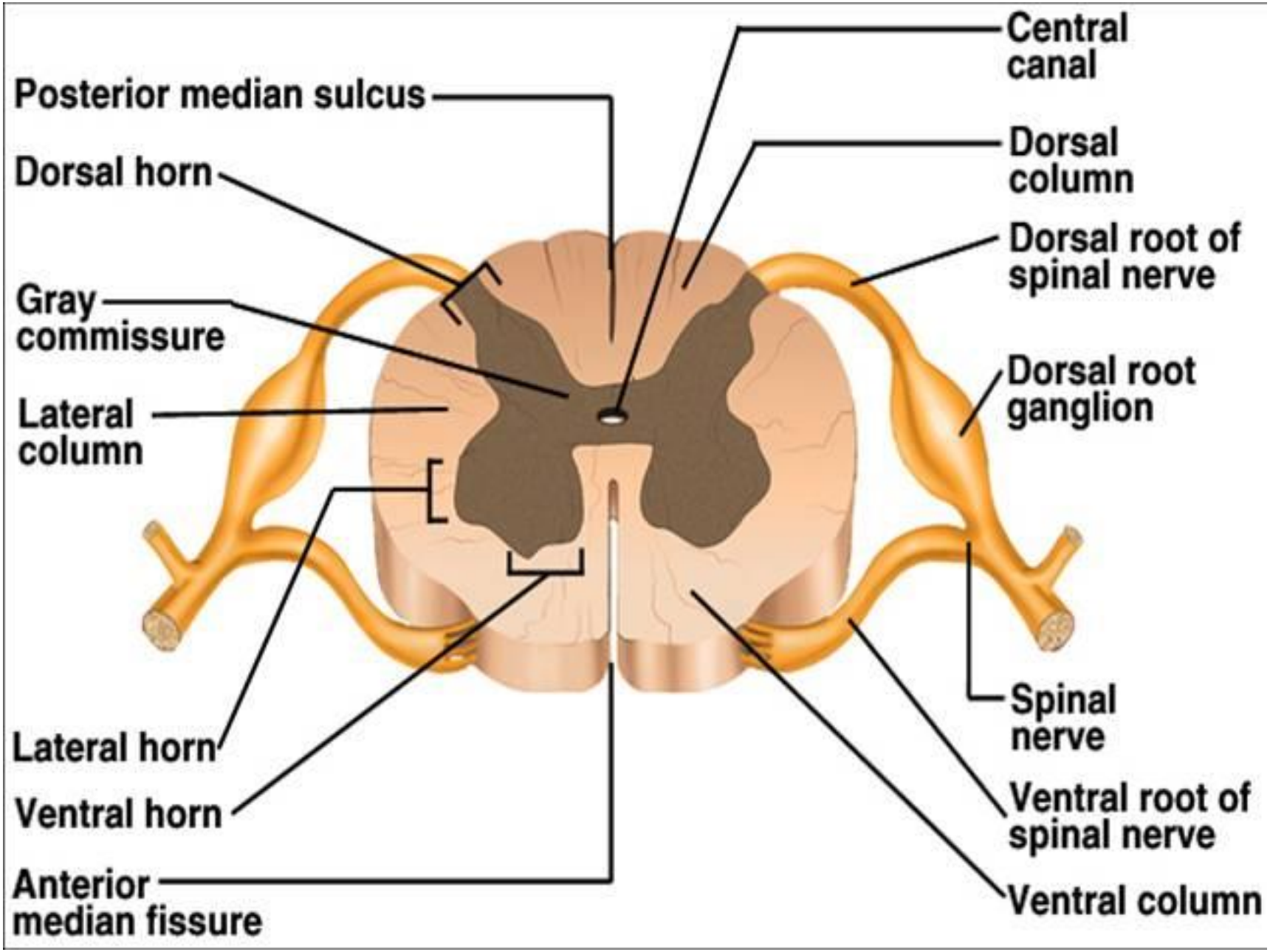
Because the spinal cord is shorter than the vertebral column, nerves that arise from the lumbar, sacral, and coccygeal regions of the spinal cord do not leave the vertebral column at the same level they exit the cord.

The roots of these spinal nerves angle inferiorly in the vertebral canal from the end of the spinal cord like wisps of hair. Appropriately, the roots of these nerves are collectively named the cauda equina, meaning “horse’s tail” .

Internal anatomy of spinal cord

Cross Section of Spinal Cord




Central canal
Posterior median sulcus
Dorsal column
Dorsal horn
Dorsal root of spinal nerve
Gray commissure
Dorsal root ganglion
Lateral column
Spinal nerve
Lateral horn
Ventral root of spinal nerve
Ventral horn
Anterior median fissure
Ventral column

Two grooves penetrate the white matter of the spinal cord and divide it into right and left sides.

- **The anterior median fissure- on the anterior (ventral) side.**
- **The posterior median sulcus- on the posterior (dorsal) side.**

- **The gray matter of the spinal cord is shaped like the letter H or a butterfly.**
- **The gray commissure forms the crossbar of the H.**
- **In the center of the gray commissure is a small space called the central canal; it extends the entire length of the spinal cord and is filled with cerebrospinal fluid.**

- **Anterior to the gray commissure is the anterior (ventral) white commissure, which connects the white matter of the right and left sides of the spinal cord.**
- **The gray matter on each side of the spinal cord is subdivided into regions called horns.**

❑**The posterior (dorsal) gray horns contain cell bodies and axons of interneurons as well as axons of incoming sensory neurons.**

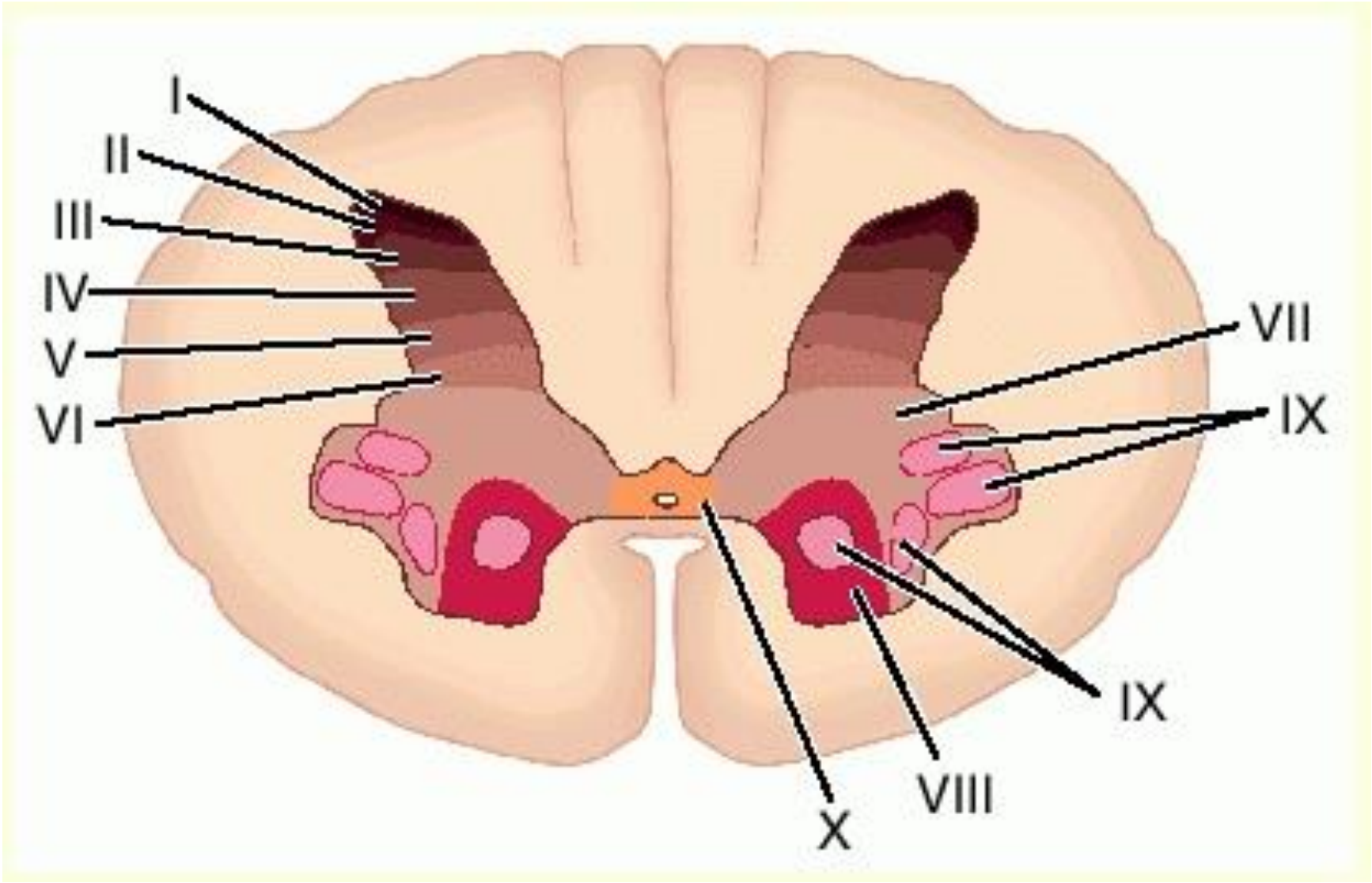
- **The anterior (ventral) gray horns contain cell bodies of somatic motor neurons that provide nerve impulses for contraction of skeletal muscles.**
- **lateral gray horns -Between the posterior and anterior gray horns, which are present only in thoracic and upper lumbar segments of the spinal cord.**

- **The lateral gray horns contain autonomic motor nuclei, which are clusters of cell bodies of autonomic motor neurons that regulate the activity of cardiac muscle, smooth muscle, and glands.**

- **The white matter of the spinal cord, like the gray matter, is organized into regions. The anterior and posterior gray horns divide the white matter on each side into three broad areas called columns:**
- **(1) anterior (ventral) white columns,**
- **(2) posterior (dorsal) white columns, and**
- **(3) lateral white columns .**

Neuronal Architecture of Spinal Grey Matter

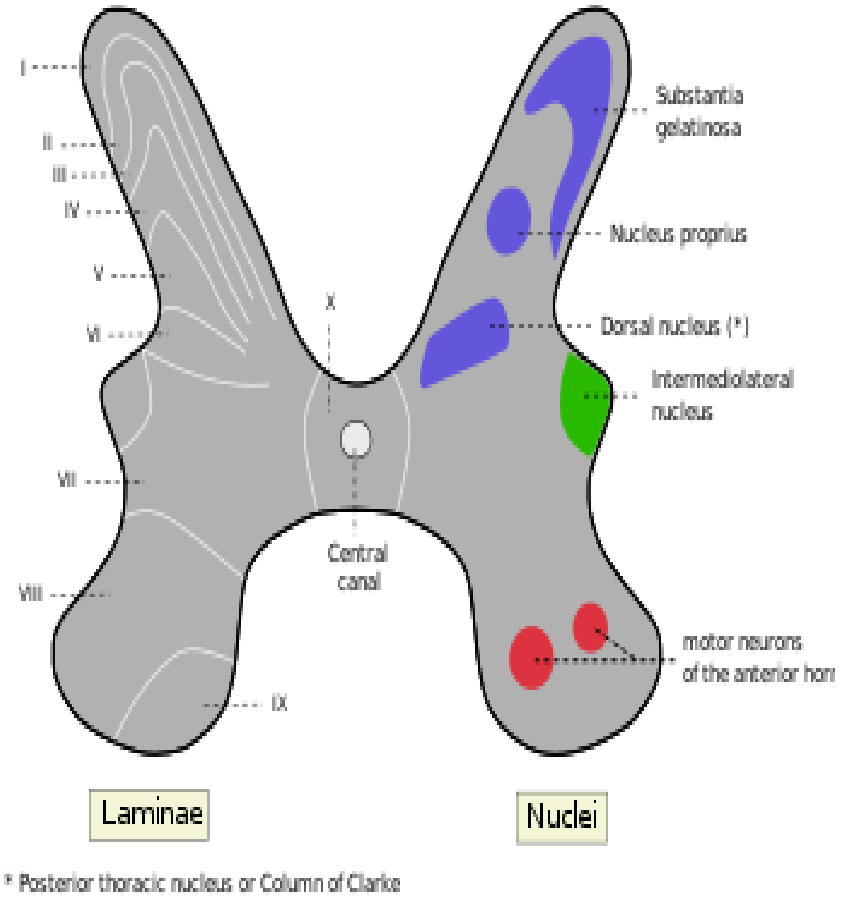
- **Cells of the same type are clustered into groups, which occur in long columns**
- **In transverse section, these columns appear as layers, especially within the dorsal horn**
- **These layers are called the laminae of Rexed (a Swedish neuroscientist), that are numbered consecutively by Roman numerals, starting from the tip of the dorsal horn and moving ventrally into the ventral horn**


I
II
III
IV
V
VI
VII
IX
IX
VIII
X

Nerve Cell Groups in Dorsal Horn

4 main groups

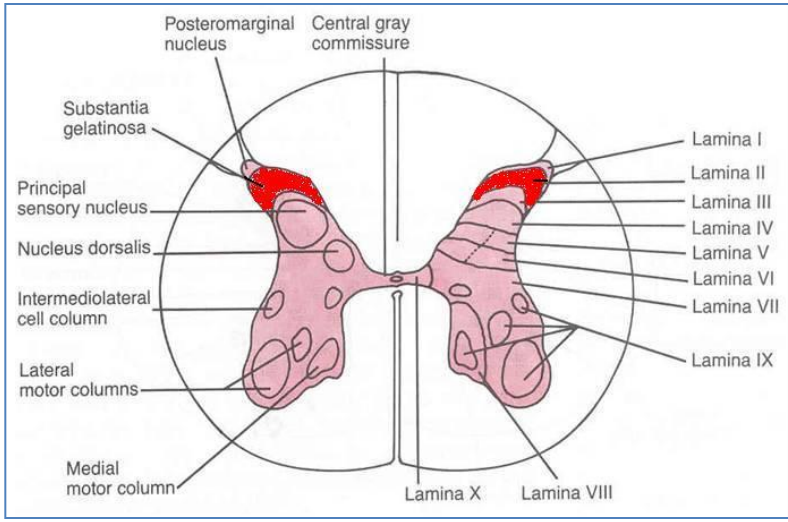
1. Substantia gelatinosa
2. Nucleus proprius
3. Nucleus dorsalis (Clark's column, nucleus thoracis)
4. Visceral afferent nucleus



* Posterior thoracic nucleus or Column of Clarke

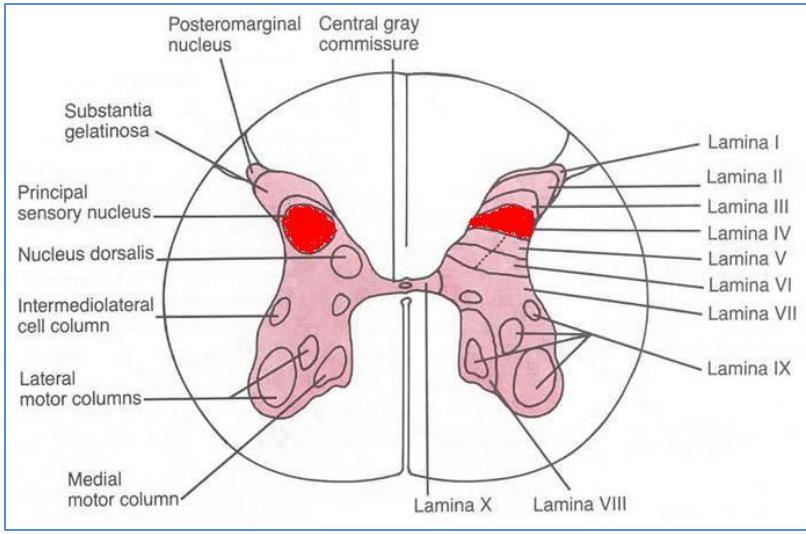
Substantia Gelatinosa

- Rexed Laminae II
- Located at the apex of the horn
- Composed of large neurons
- Extends throughout the length of spinal cord
- Afferents: dorsal root fibers concerned with pain, temperature and touch



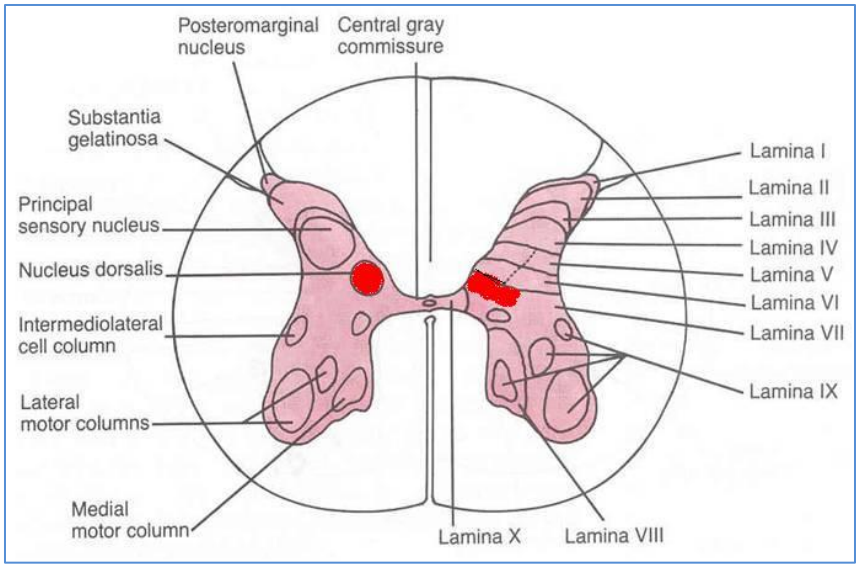
Nucleus Proprius

- **Rexed Lamina IV**
- **Located anterior to substantia gelatinosa**
- **Composed of large neurons**
- **Extends throughout the length of spinal cord**
- **Afferents: dorsal root fibers concerned with senses of position & movement**



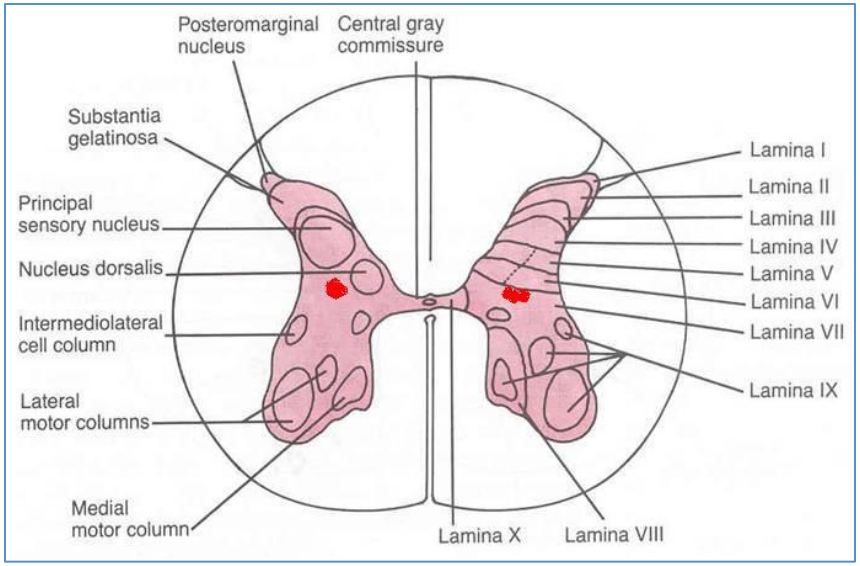
Nucleus Dorsalis (Clark's column, Nucleus thoracis)

- Rexed Lamina VII
- Located at the base of dorsal horn
- Composed mostly of large neurons
- Extends from C8 to L3-4 segments
- Afferents: dorsal root fibers concerned with information from muscle spindles.



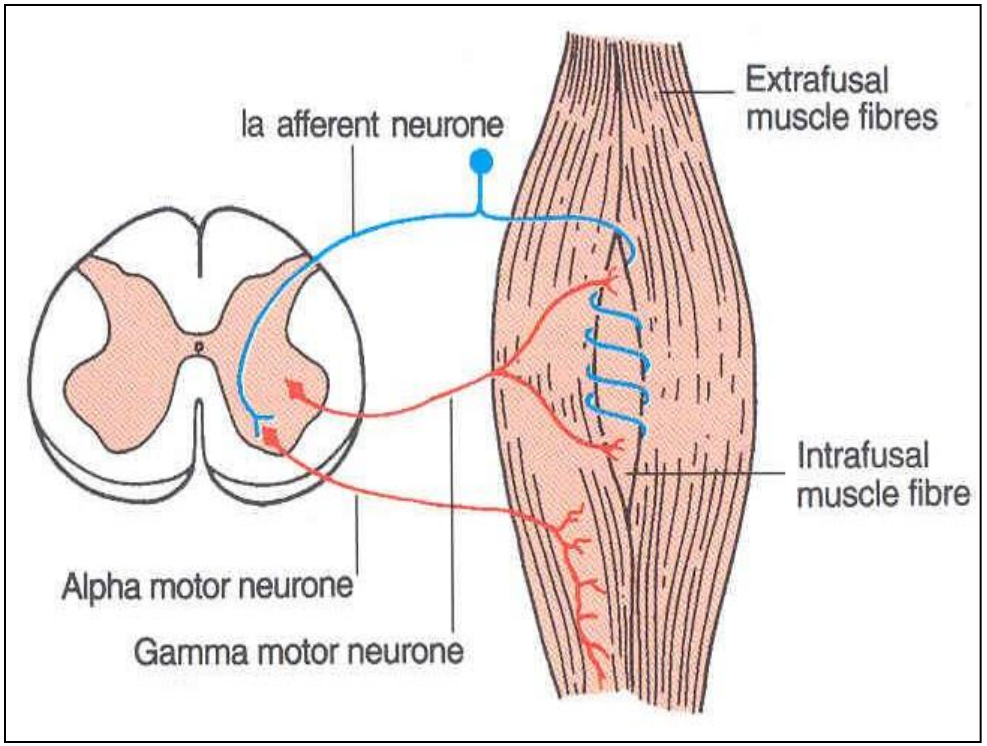
Visceral Afferent Nucleus

- Rexed Lamina VII
- Located lateral to nucleus dorsalis
- Composed mostly of medium size neurons
- Extends from T1 to L3 segments
- Afferents: Visceral afferents



Motor Neurons in Ventral Horn

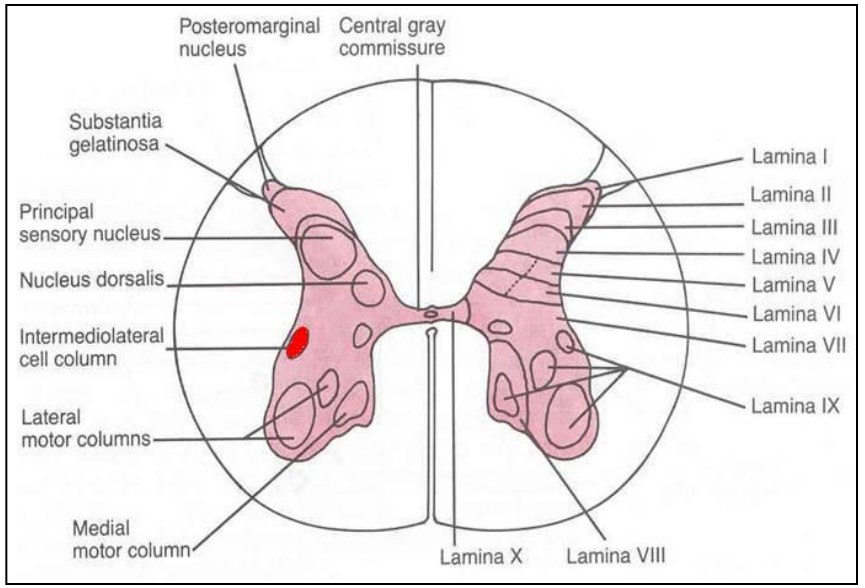
- Are of **Two types**
  - alpha neurons
  - Gamma neurons



Nerve Cell Groups in Lateral Horn

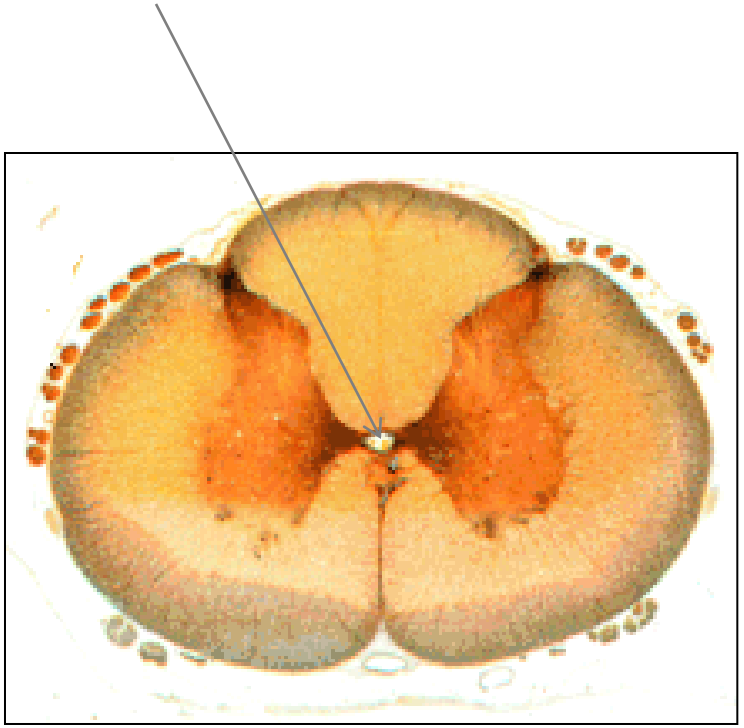
Small Column composed of small neurons

- **Extends from T1 to L2-3 segments:**
  - **Give rise to preganglionic sympathetic fibers**
- **Extends from S2-4 segments:**
  - **Give rise to preganglionic parasympathetic fibers**



Central Canal

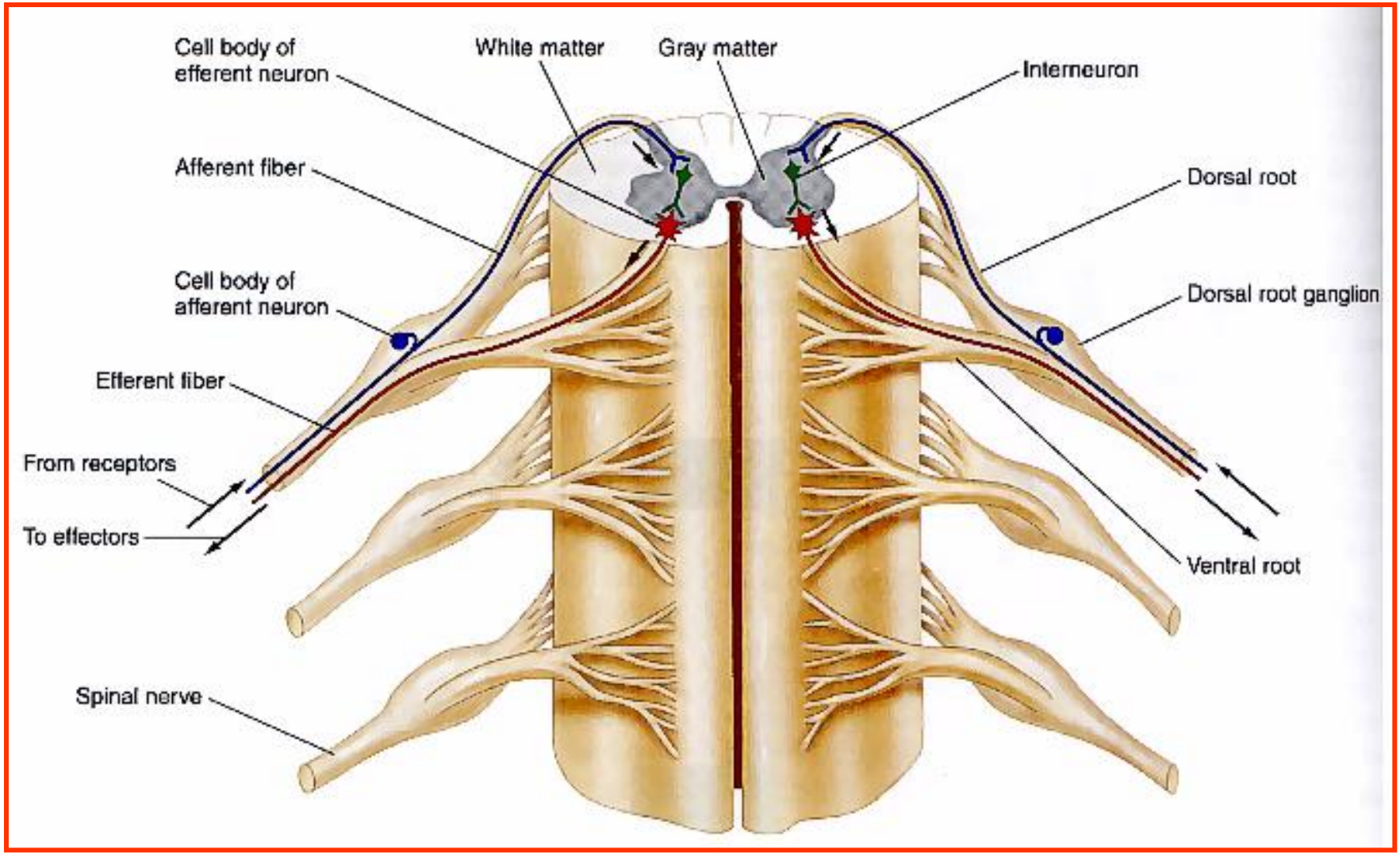
- The cerebrospinal-filled space that runs longitudinally through the entire length of the spinal cord.
- Lined by ependyma (ciliated columnar epithelium)
- Continuous with the ventricular system of the brain
- Superiorly opens into the 4th ventricle
- Inferiorly in the conus medullaris, it expands into the fusiform terminal ventricle and terminates below at the root of filum terminale



Spinal Nerves

- **Thirty-one pairs of spinal nerves**
- **First pair exit vertebral column between skull and atlas, last four pairs exit via the sacral foramina and others exit through intervertebral foramina**
- **Eight pair cervical, twelve pair thoracic, five pair lumbar, five pair sacral, one pair coccygeal**
- **Each spinal nerve arises as rootlets which then combine to form dorsal (posterior) & ventral (anterior) roots.**

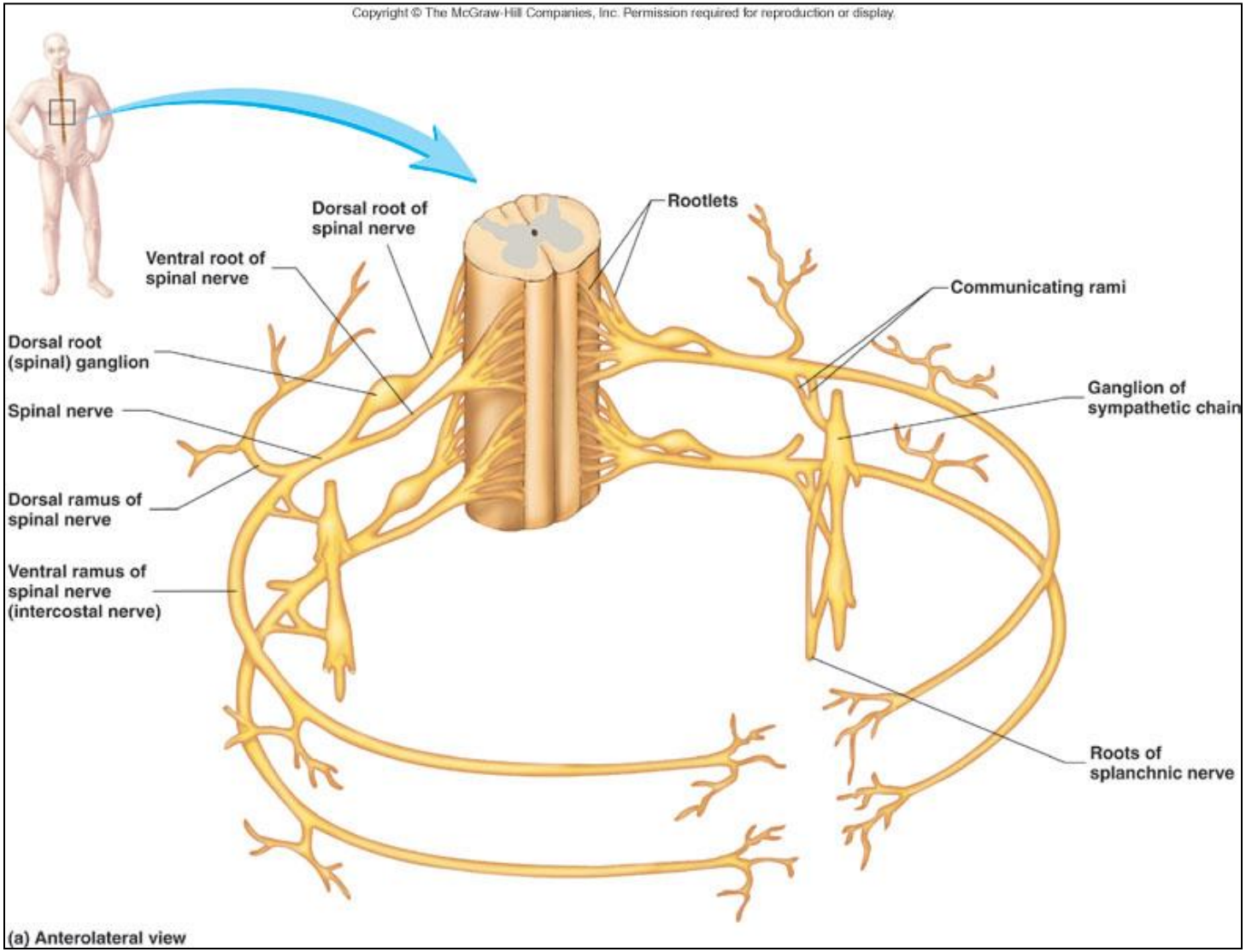
- **Two roots merge laterally and form the spinal nerve.**
- **Dorsal (posterior) root has a ganglion (dorsal root/sensory ganglion) that contains the cell bodies of the sensory neurons**
- **Each spinal nerve then divides into a smaller dorsal and a larger ventral ramus**


Cell body of efferent neuron
White matter
Gray matter
Interneuron
Afferent fiber
Dorsal root
Cell body of afferent neuron
Dorsal root ganglion
Efferent fiber
From receptors
To effectors
Ventral root
Spinal nerve

Branches of Spinal Nerves

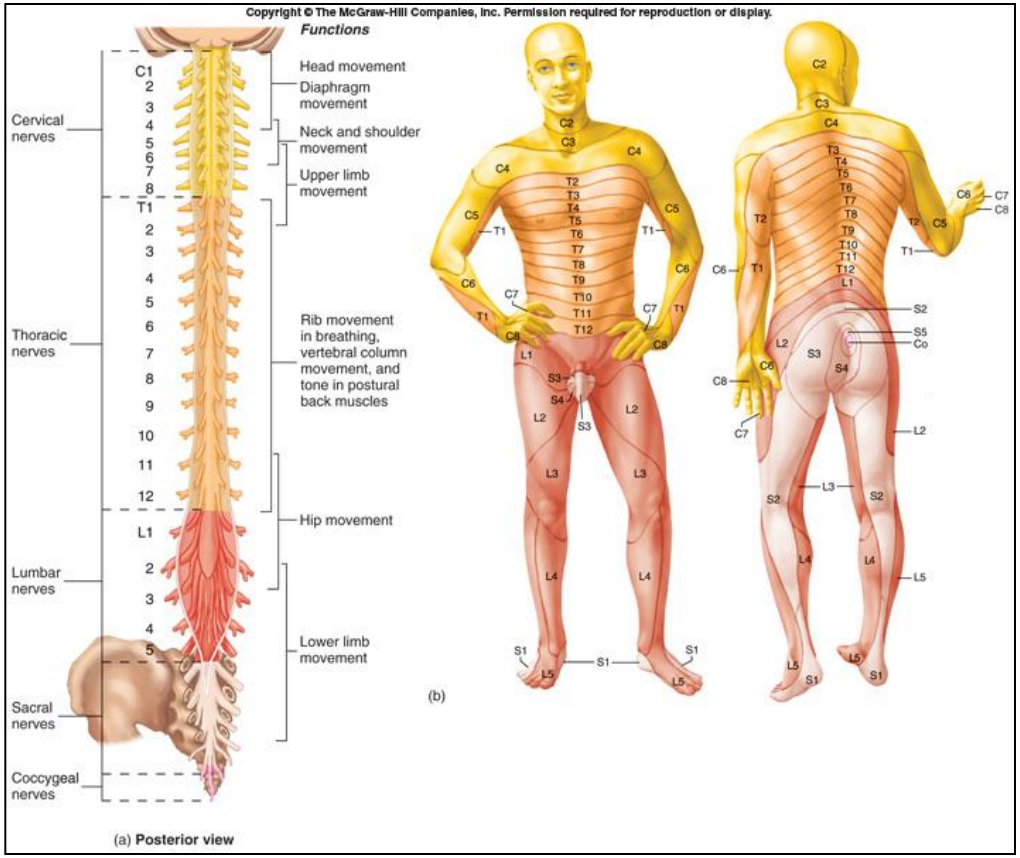
- **Dorsal Ramus:** innervate deep muscles of the trunk responsible for movements of the vertebral column and skin near the midline of the back.
- **Ventral Ramus:**
  - **Thoracic region:** form **intercostal nerves** that innervate the intercostal muscles and the skin over the thorax
  - **Remaining spinal nerve ventral rami (roots of the plexus):** form five plexuses.

- **Ventral rami of C1-C4= cervical plexus**
- **Ventral rami of C5-T1= brachial plexus**
- **Ventral rami of L1-L5= lumbar plexus**
- **Ventral rami of L4-S4= sacral plexus**
- **Ventral rami of S4 , S5 & CO1= coccygeal plexus**



Dermatomes

- **A dermatome is an area of skin in which sensory nerves derive from a single spinal nerve root**
- **Help to diagnose the level of spinal cord injury.**



Thank-you