

Lecture

The Spinal Cord & Its Tracts

Dr. Eyad M. Hussein

Ph.D. of Neurology

**Consultant & Head of Neurology Department,
Nasser Hospital**



الرجاء تحويل الجوال إلى وضع
الصامت مع الشكر



Anatomy of the Spinal Cord (SC)

- **Shape:** compressed cylindrical column.
- **Number of neurons in human SC:** about 13,500,000
- **Length of human SC:** about 45 cm (male); 42 cm (female).
- **Weight of human SC:** about 35g and comprises 2% of the weight of the adult brain.
- **Diameter:** about 1 cm.
- **Location:** It is located in the spinal (vertebral) canal.

Location of the Spinal Cord

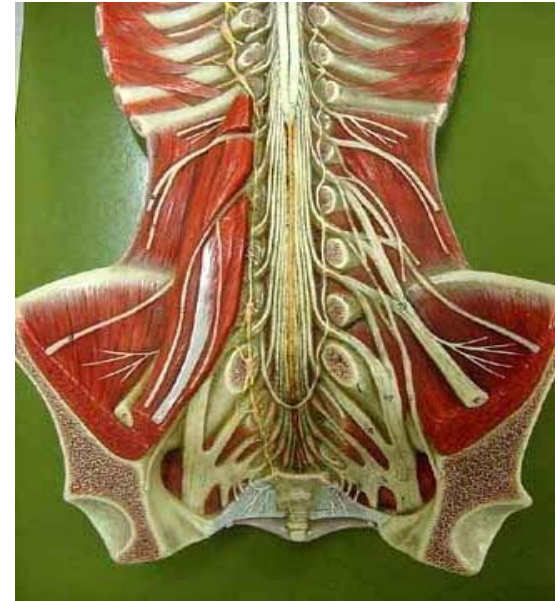
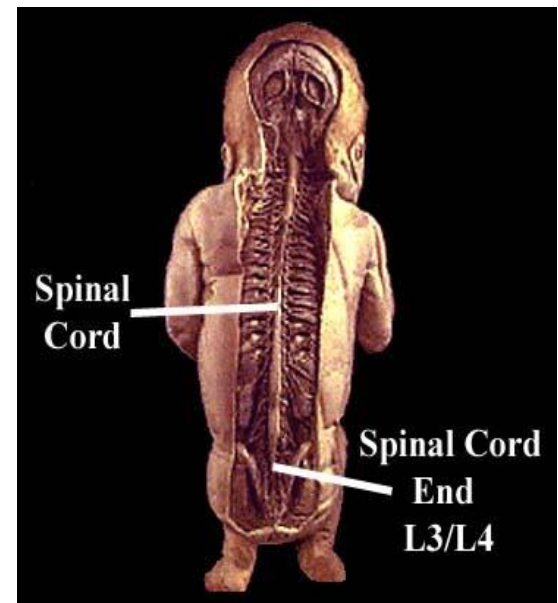


- The spinal cord (SC) is an extracranial part of the central nervous system enclosed inside the vertebral column “Spinal Canal”.
- **Beginning:** the SC is continuous with the medulla oblongata at the spinomedullary junction which begin from the foramen magnum downward.
- **A plane defined by three structures:**
 - ✓ The foramen magnum.
 - ✓ The pyramidal decussation.
 - ✓ The emergence of the first cervical nerve anterior rootlets.
- Lies within the subarachnoid space.
- The subarachnoid space extends caudally to the level of **the second sacral vertebra.**



Termination of the Spinal Cord

- **At the third month of intrauterine life:** the SC fills the whole spinal canal.
- **At birth:** it ends at the level of L3 vertebra.
- **In the adult:** it ends at the level of lower border of the L1 vertebra.



Function of the Spinal Cord

1. Conduction function: from and to the brain:

a. Ascending tracts: conduct sensory impulses from the SC to the brain.

b. Descending tracts: conduct motor impulses from the brain to SC.

2. Reflexes center: the gray matter of the SC is the integrative area for all spinal reflexes.

Meninges of the Spinal Cord

The spinal cord is covered by 3 membranes (meninges),
from inside to outside they are:

- 1. Pia Mater.**
- 2. Arachnoid Mater.**
- 3. Dura mater.**

The Pia Mater

- Closely adherent .
- Ends at the level of SC termination (**lower border of the first lumbar vertebra in adult**).
- Form the **denticulate ligaments**.
- It continues as the **filum terminale** which attached to the back of coccyx .

The Arachnoid Mater

- The inner surface of the dura matter.
- It ends at the level of **the second sacral vertebra.**

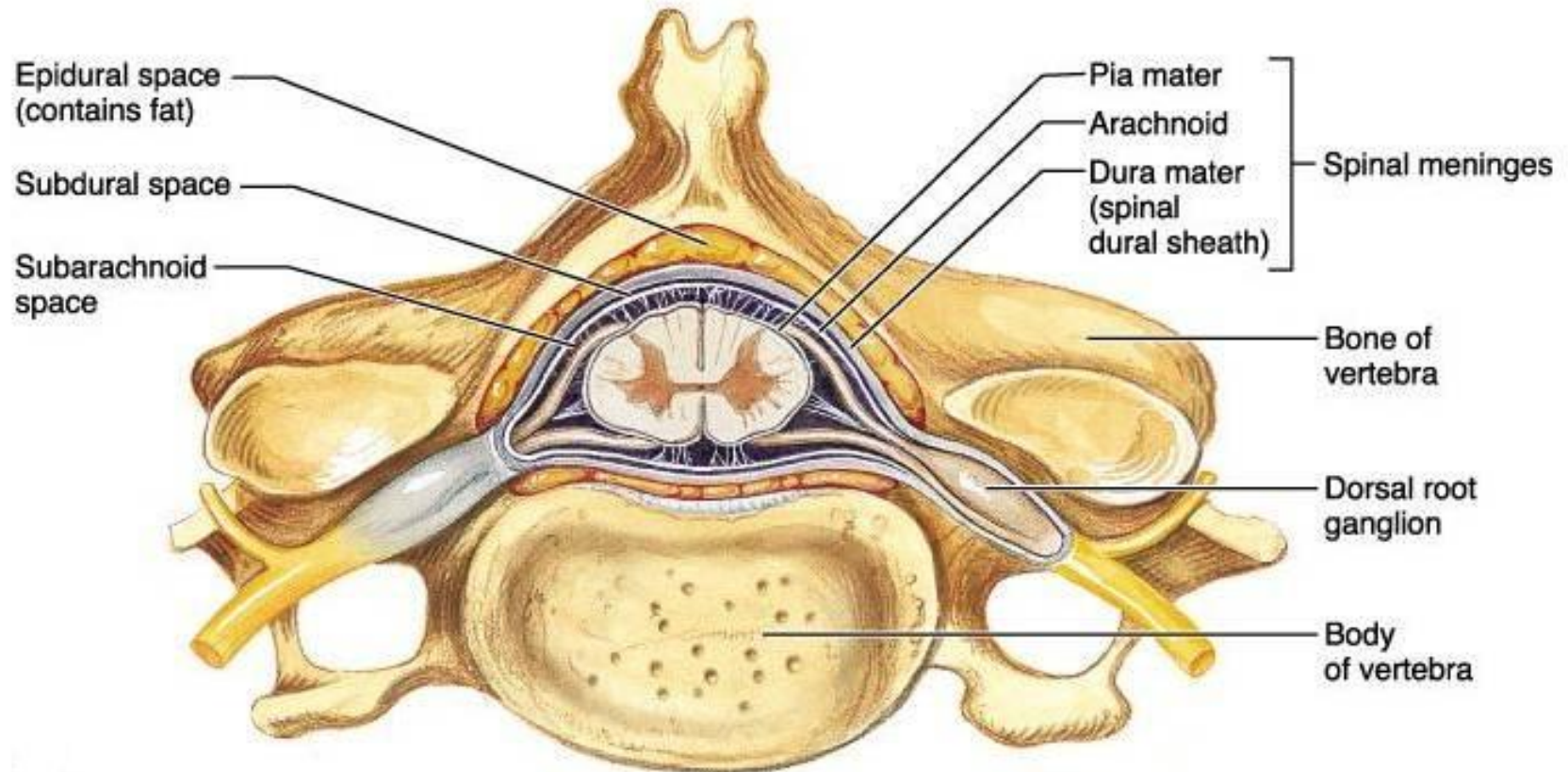
The Dura Mater

- It ends at the level of **the second sacral vertebra.**
- It is attached to:
 - Margins of foramen magnum.
 - Intervertebral foramina.
 - Bodies of the 2nd and 3rd cervical vertebrae.

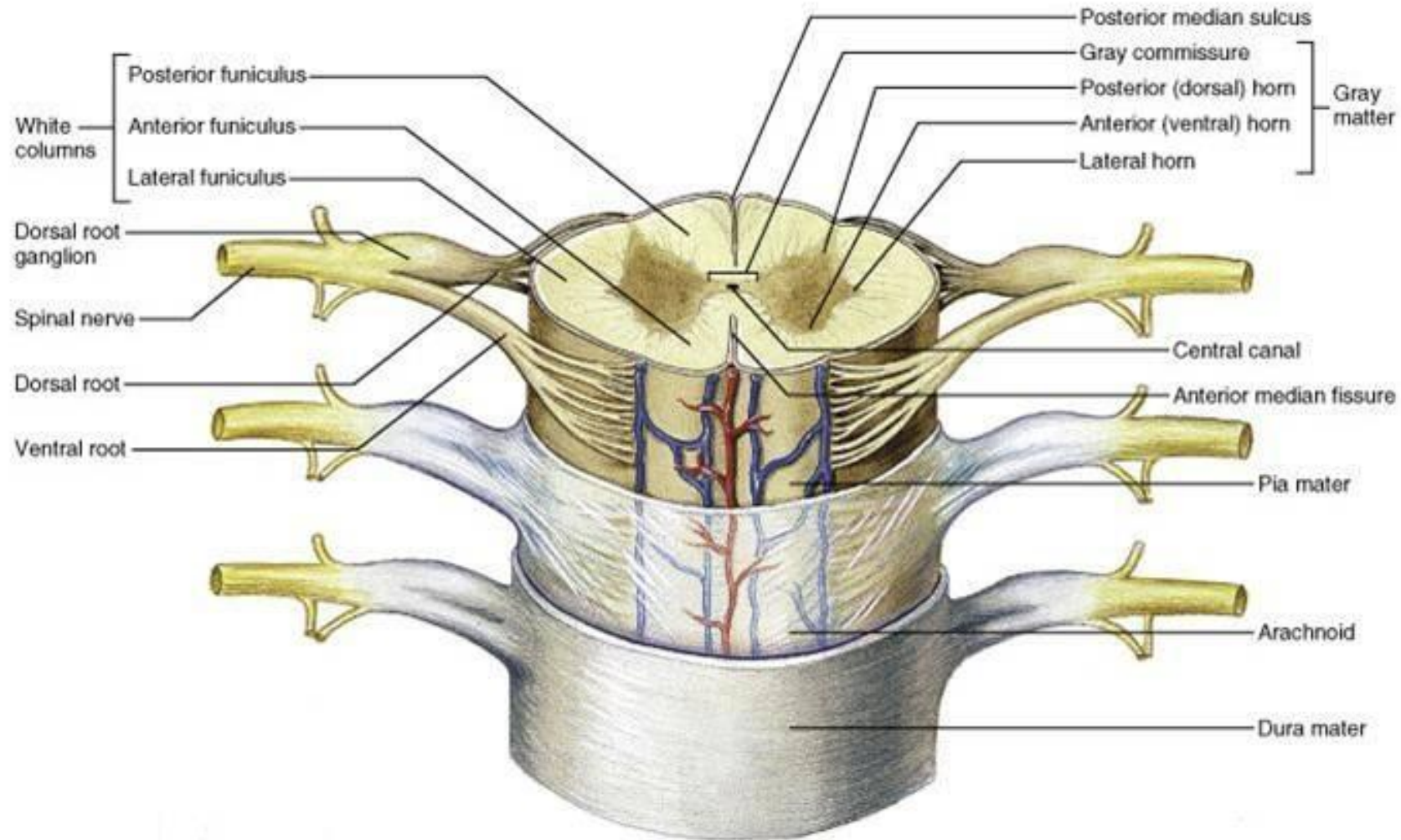
Meningeal Spaces Of Spinal Cord

1. **Epidural Space:** it is a potential space located between the dura matter and vertebral periosteum. It contains semiliquid fat and internal vertebral venous plexus.
2. **Subdural Space:** it is located between the dura matter and arachnoid matter. Contains thin film of serous fluid.
3. **Subarachnoid Space:** it is located between the arachnoid and pia matter. Is a wide space contains:
 - CSF.
 - Spinal blood vessels.
 - Roots of spinal nerves.

Anatomy of the Spinal Cord

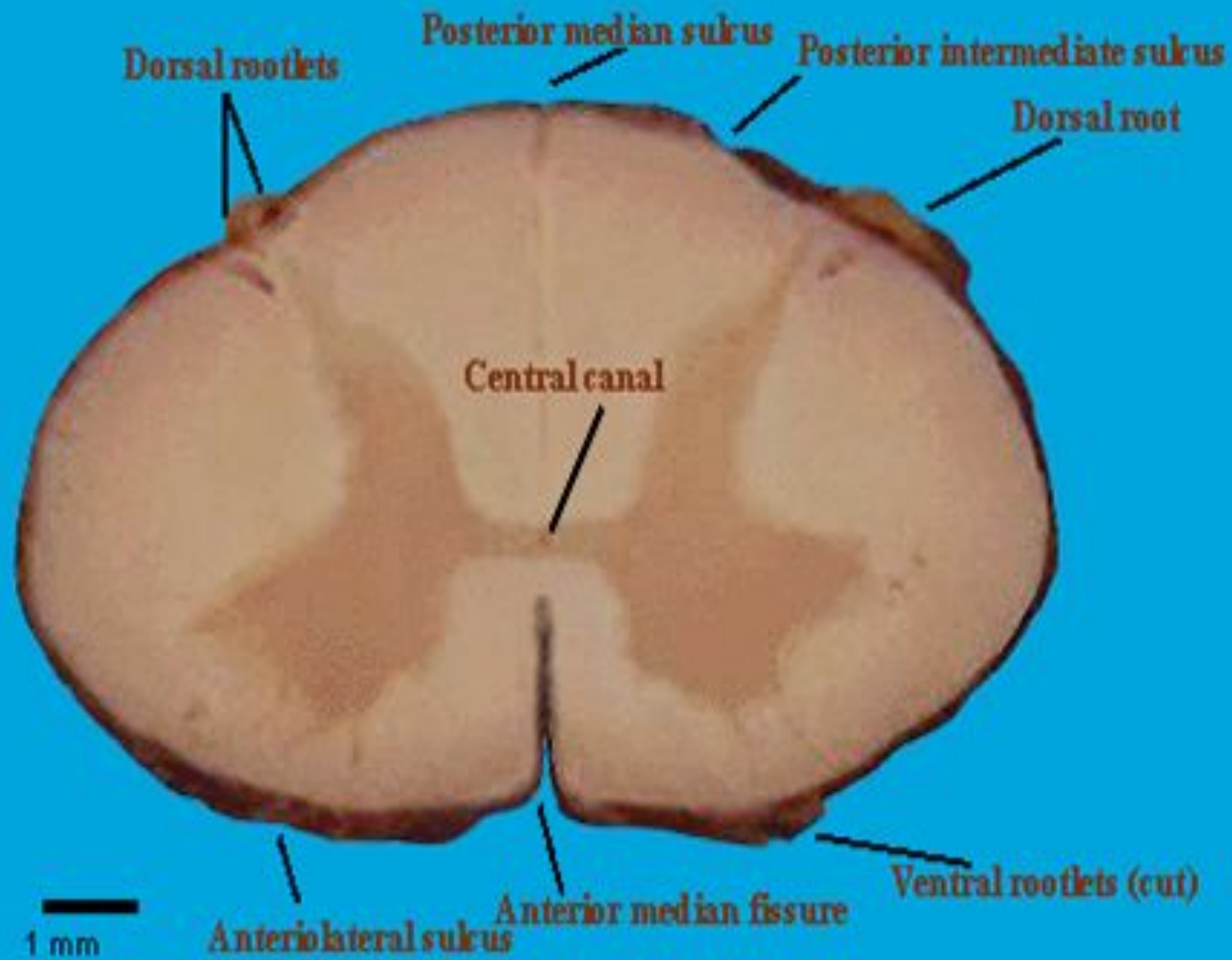


Anatomy of the Spinal Cord



External Structure of the Spinal Cord

- **Anterior median fissure:** the anterior spinal artery is found superficially.
- **Posterior median sulcus.**
- **Anterior lateral sulcus:** from which the anterior rootlets emerge.
- **Posterior lateral sulcus:** into which the posterior rootlets enter.
- **Posterior intermediate sulcus:**
 - ✓ Found between the posterior lateral and posterior median sulci but only above T6 level.
 - ✓ Separates the **Gracile fasciculus** from the **Cuneate fasciculus**.



The Spinal Cord Segments

There are 31 segments:

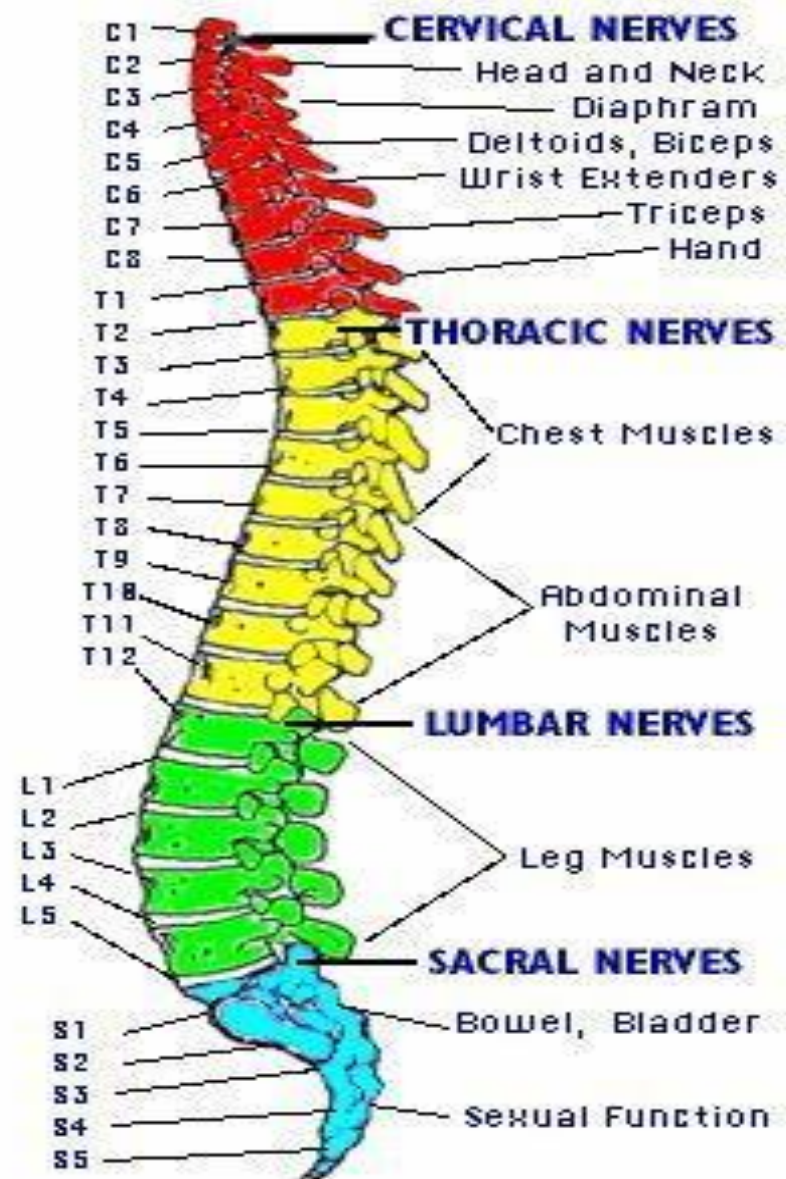
8 – Cervical segments.

12 – Thoracic (dorsal).

5 – Lumbar segments.

5 – Sacral segments.

1 – Coccygeal segments.

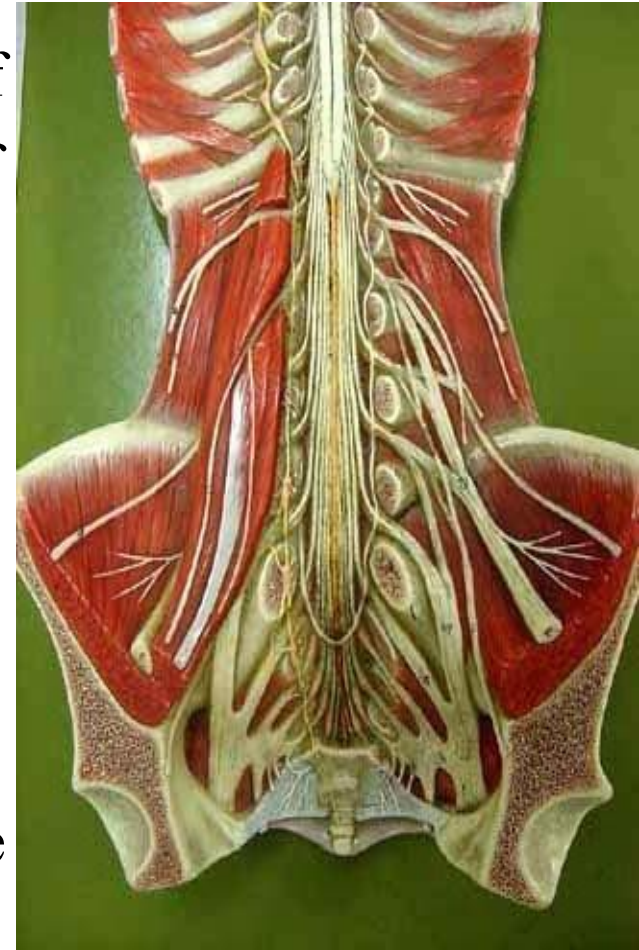


- **Epiconus:** it is the L4, 5 and S1, 2 segments of the SC.

- **Conus medularis:** the lower end of the SC. It is the S3, 4, 5 segments of the SC.

- **Cauda equina:**

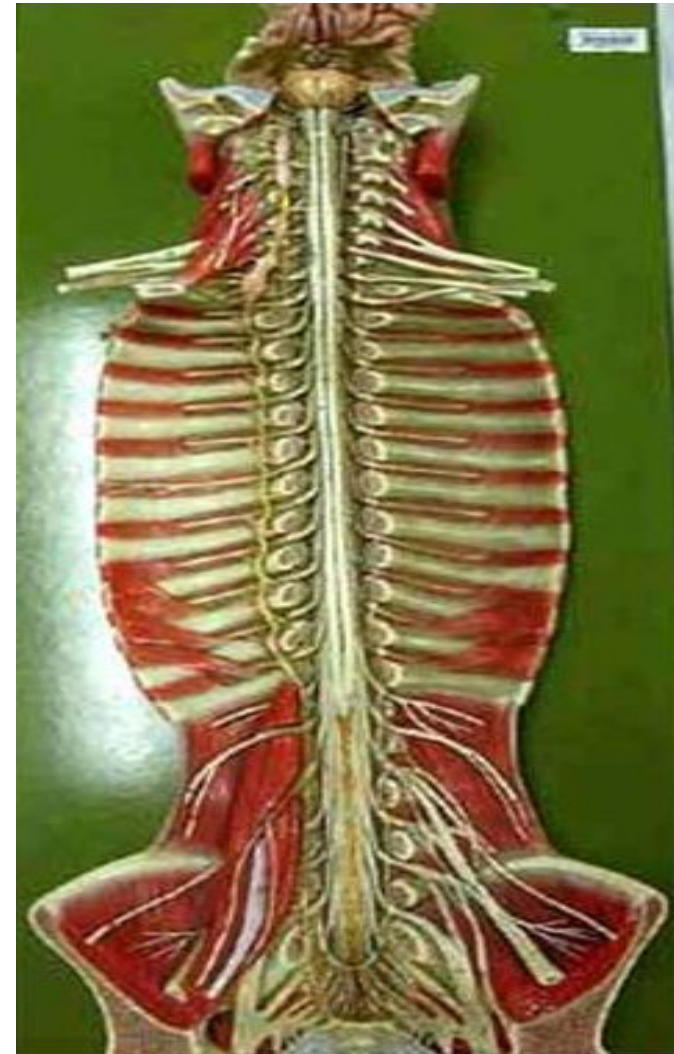
- It is located below the lower border of the first lumbar vertebra, the spinal canal is filled by the collection of lumbo-sacral roots which descends in this space to their corresponding intervertebral canal.



Enlargement of the Spinal Cord

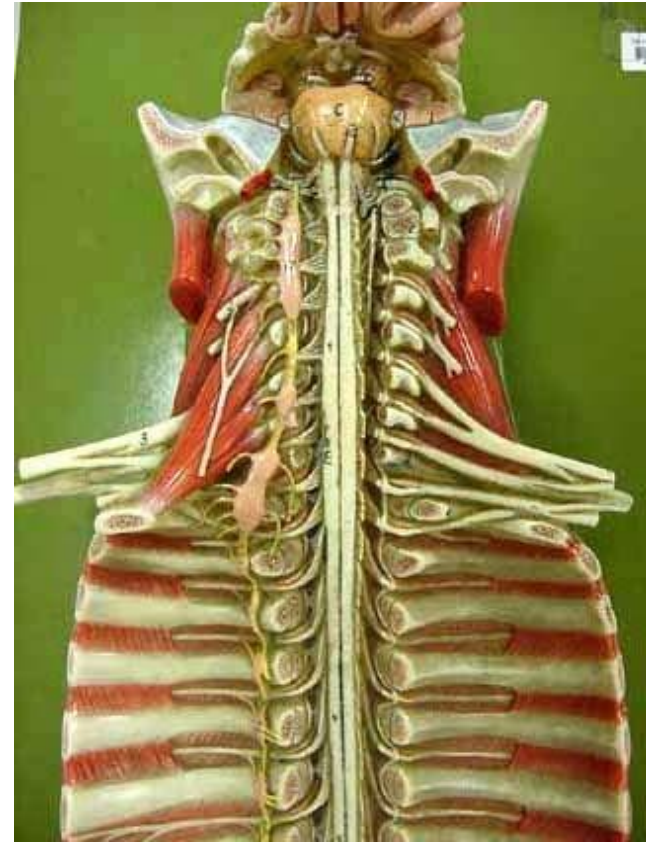
.Cervical enlargement .1

.Lumbar enlargement .2



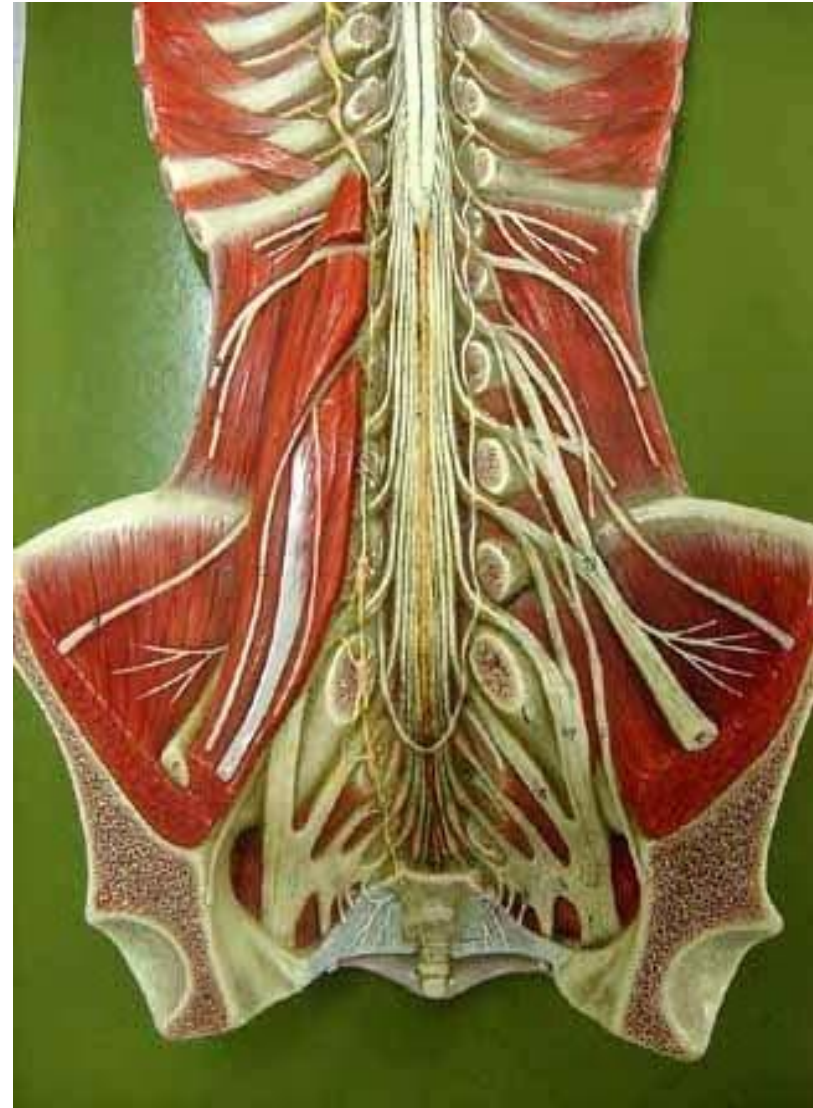
Cervical Enlargement of the Spinal Cord

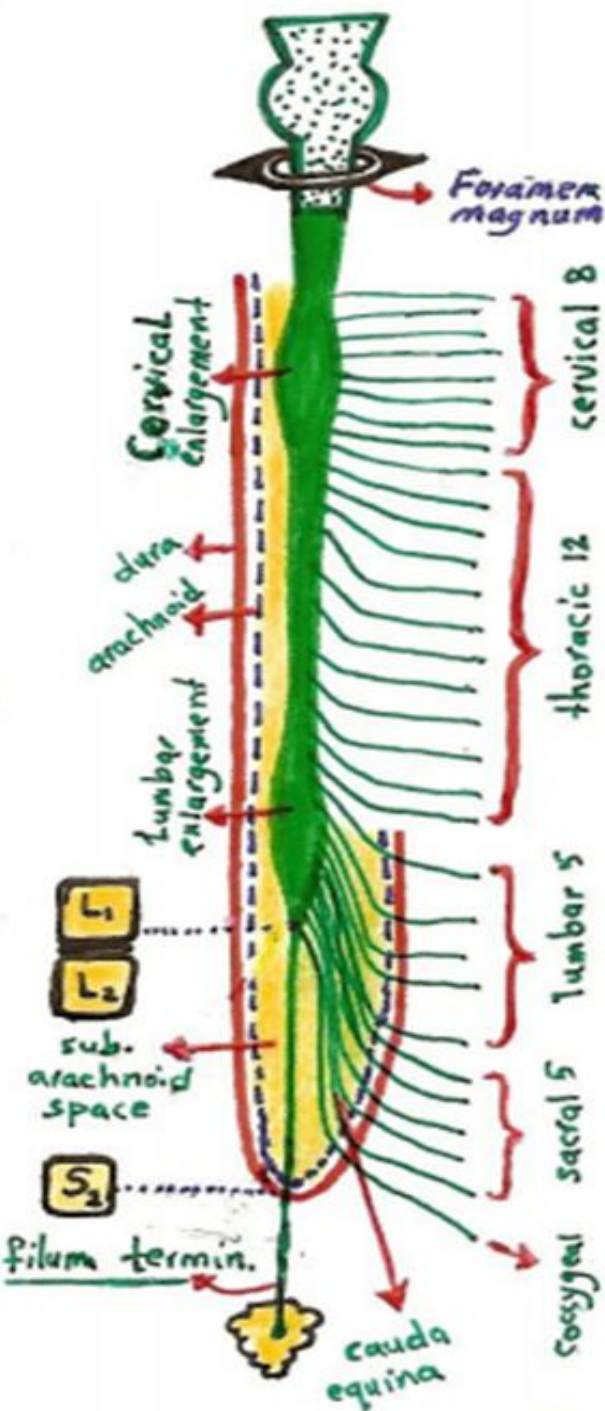
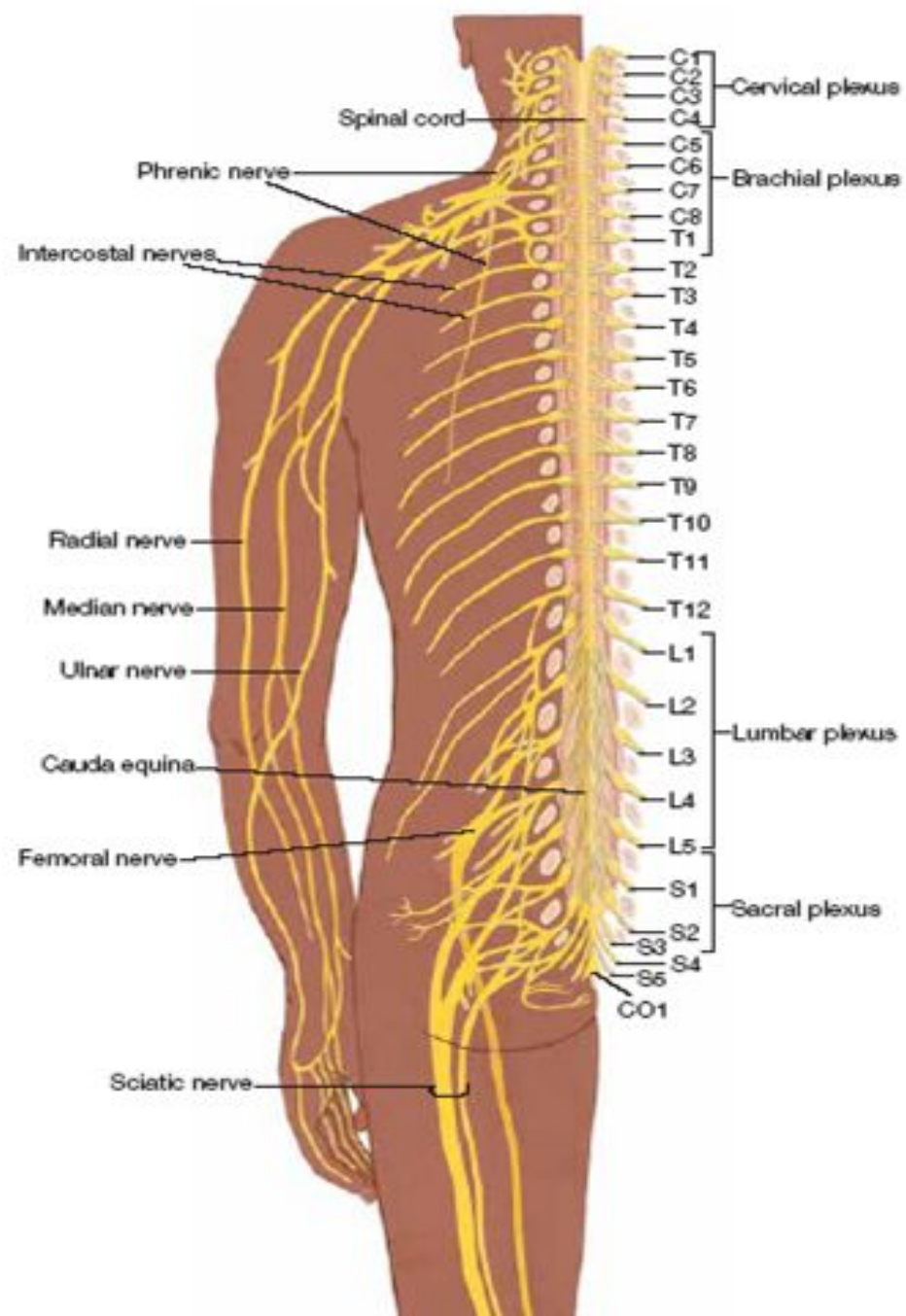
It is the **C5, 6, 7, 8 and D1 segments** of the SC, corresponding to the region from which the brachial plexus arises → give spinal .nerves that supply the upper limbs



Lumbar Enlargement of the Spinal Cord

It is the **L1, 2, 3, 4, 5** and **S1, 2 segments** of the SC, corresponding to the region from which the lumbar and sacral plexuses arise → give spinal nerves that supply the lower limbs.

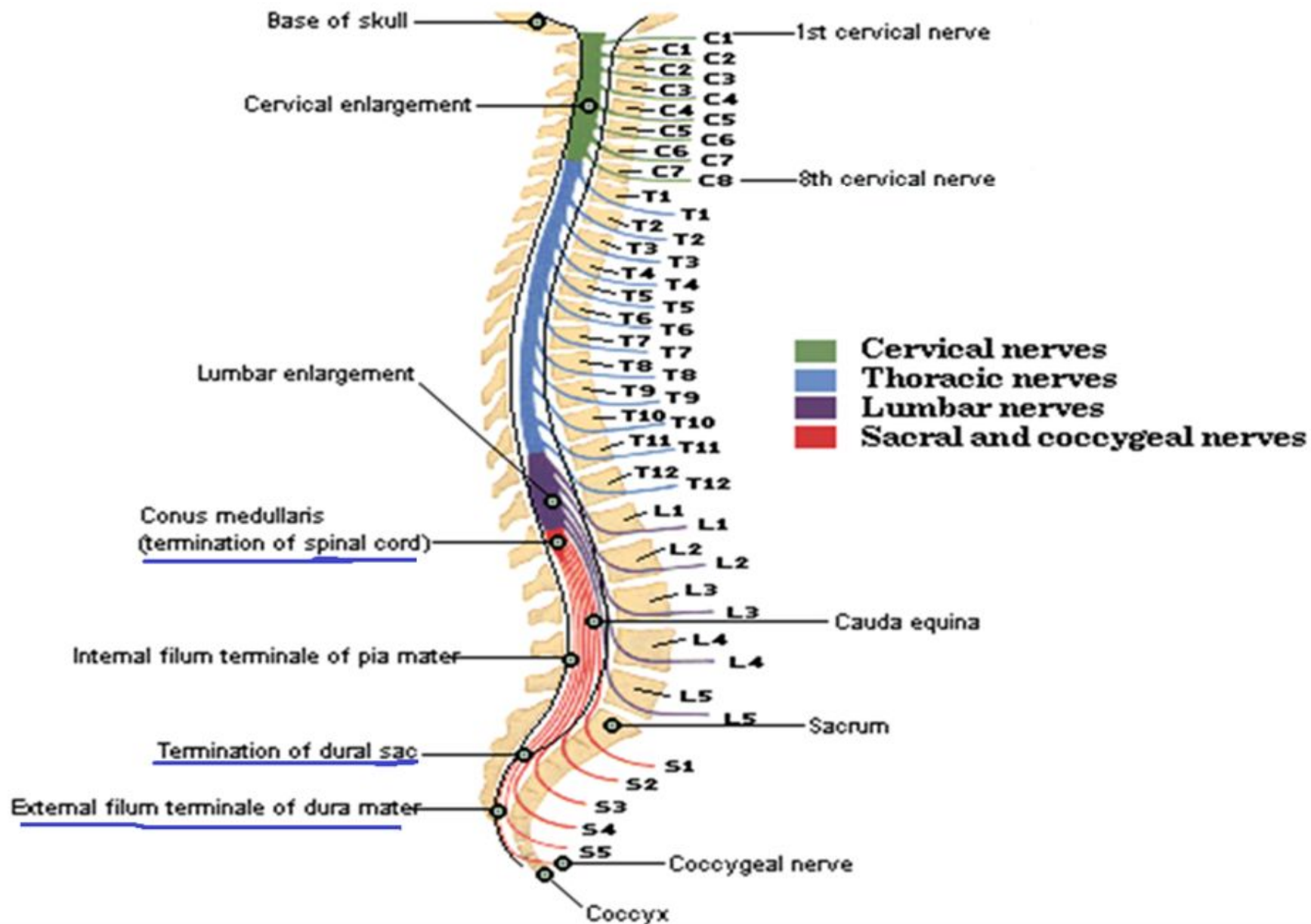




Relationship between the Spinal Cord Segment and the Vertebra

No	Spinal Cord	Vertebra
1	From C ₁ - C ₄ segments	Opposite C ₁ - C ₄
2	From C ₅ - C ₈ segments	Subtract 1
3	From T ₁ - T ₆ segments	Subtract 2
4	From T ₇ - L ₂ segments	Subtract 3
5	L ₃ - L ₄ segments	Opposite T ₁₂
6	L ₅ and all sacral segments	Opposite L ₁

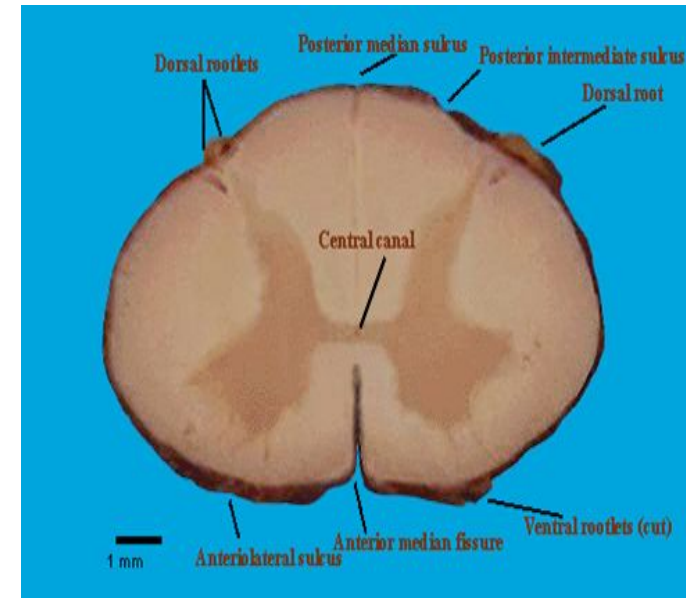
Relation of Spinal Nerve Roots to Vertebrae



Internal Structure of the Spinal Cord

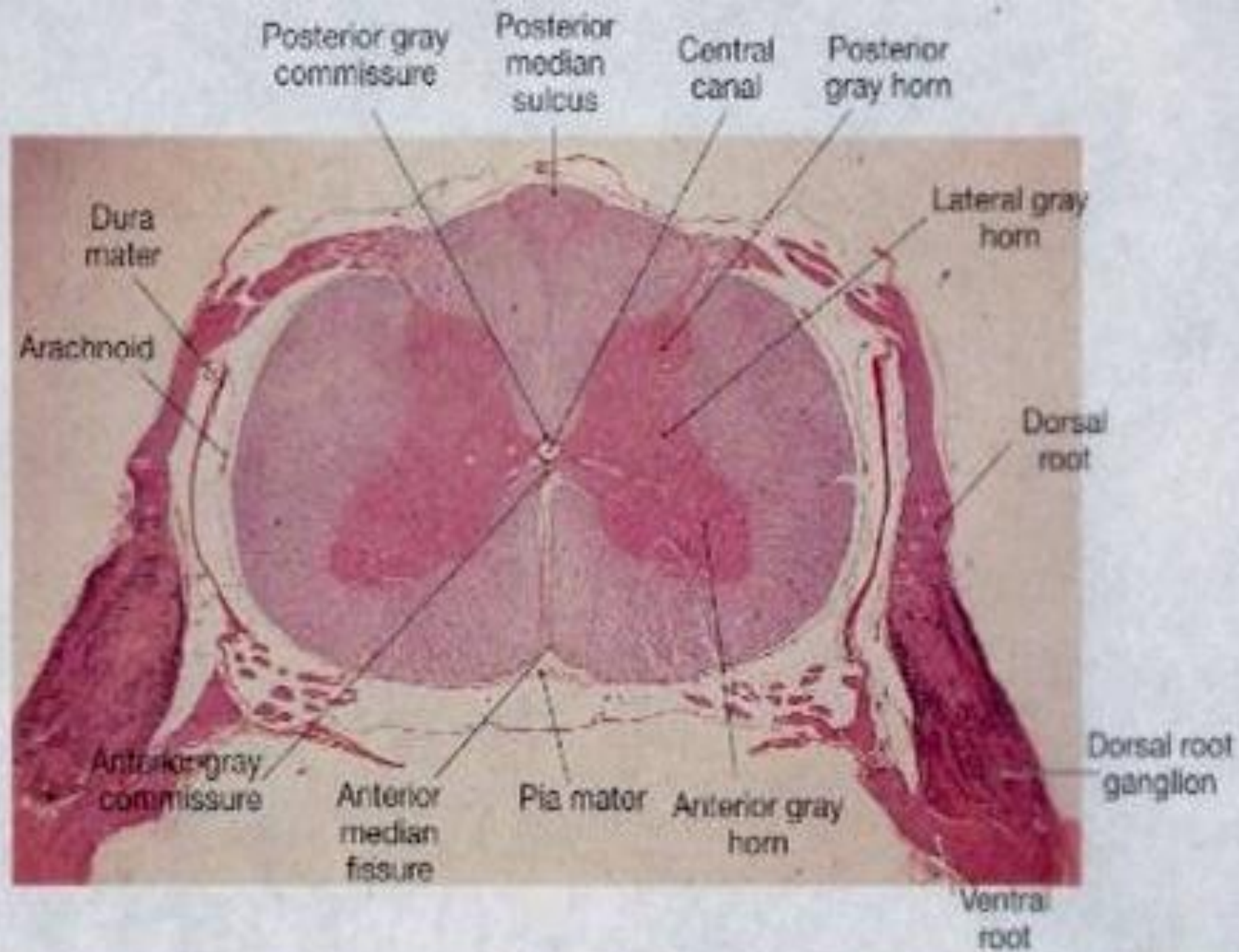
◆ A transverse section of the SC is formed of:

- White matter (outer or peripheral).
- Gray matter (inner or central).
- Central canal (1 mm in diameter): is present in gray matter.



The Gray Matter of the Spinal Cord

- **Structure:** it consist of nerve cells.
- **Shape:** the grey matter resembles the letter “**H**” divided into:
 1. **Anterior horns (right and left):** Consist of motor cells.
 2. **Posterior horns (right and left):** Consist of sensory cells.
 3. **Lateral horns (right and left):** In the thoraco-lumbar segments “T₁-L₂”. They contain sympathetic nerve cells.
 4. **Central canal:** The central canal contains C.S.F.
 5. **Gray commissure:** anterior and posterior gray commissure.



The Posterior (Dorsal) Horn Cells

- Between the dorsal horn & posterolateral sulcus there is the **dorsolateral tract of Lissauer's**.
- The posterior horn cells receives and processes sensory input and **consist of following sensory nuclei:**

The Posterior (Dorsal) Horn Cells

1. Substantia gelatinosa of Rolandi:

- Found at all cord levels.
- For pain & temperature sensations.

2. The main sensory nucleus or nucleus Proprius:

- Found at all cord levels.
- For crude “light” touch sensation.

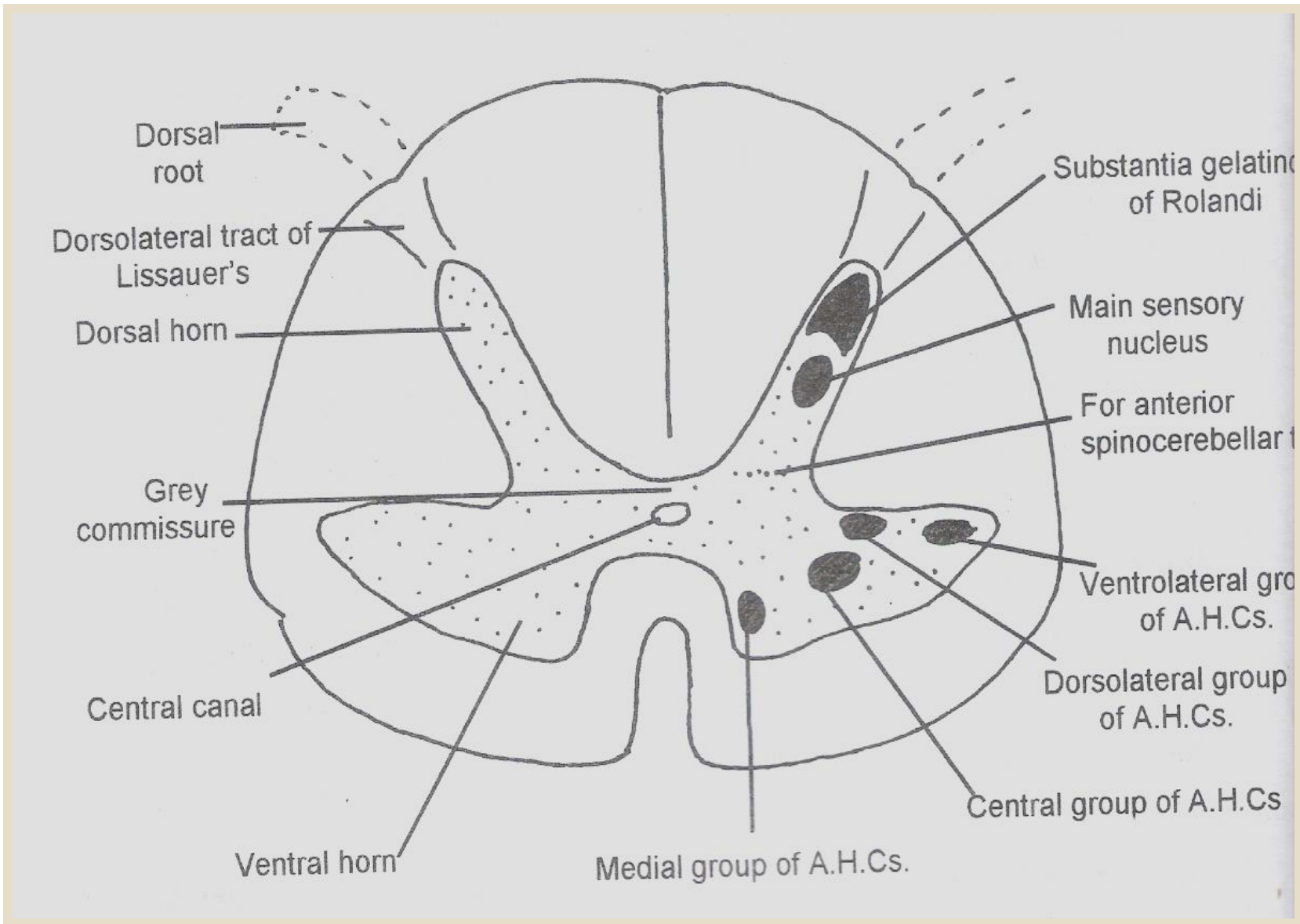
3. Clarck's nucleus or posterior thoracic nucleus:

- Found at the medial side of the **C₈-L₂** segments of the spinal cord.
- Carries unconscious proprioception to **dorsal spinocerebellar tract** → **inferior cerebellar peduncle**.

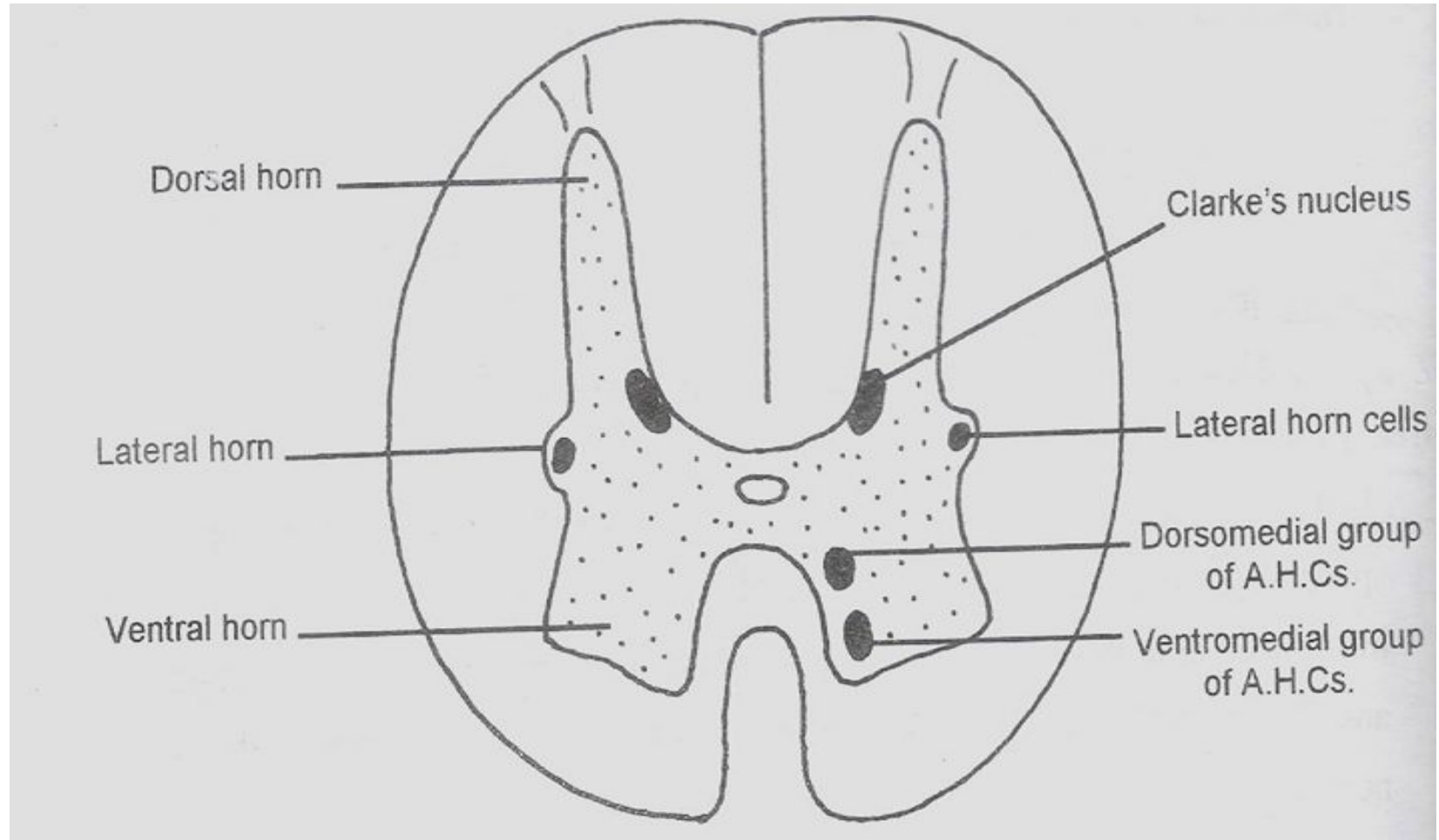
4. Scattered nuclei:

- Found at the **L₃-S₂** segments of the spinal cord.
- Carries unconscious proprioception to **ventral spinocerebellar tract** → **superior cerebellar peduncle**.

The Gray Matter of the Spinal Cord



The Gray Matter of the Thoracic SC



The Anterior (Ventral) Horn Cells

The anterior horn cells contain the following nuclei:

A. Medial group:

- Lies in the whole SC.
- In the thoracic segments, divided into ventromedial and dorsomedial groups.
- **They supply muscles of the trunk.**

B. Lateral group (ventrolateral & dorsolateral):

- Present in lower cervical, lumbar and upper 2 sacral region.
- **They supply upper and lower limb muscles.**

C. Central group:

1. Spinal accessory nucleus:

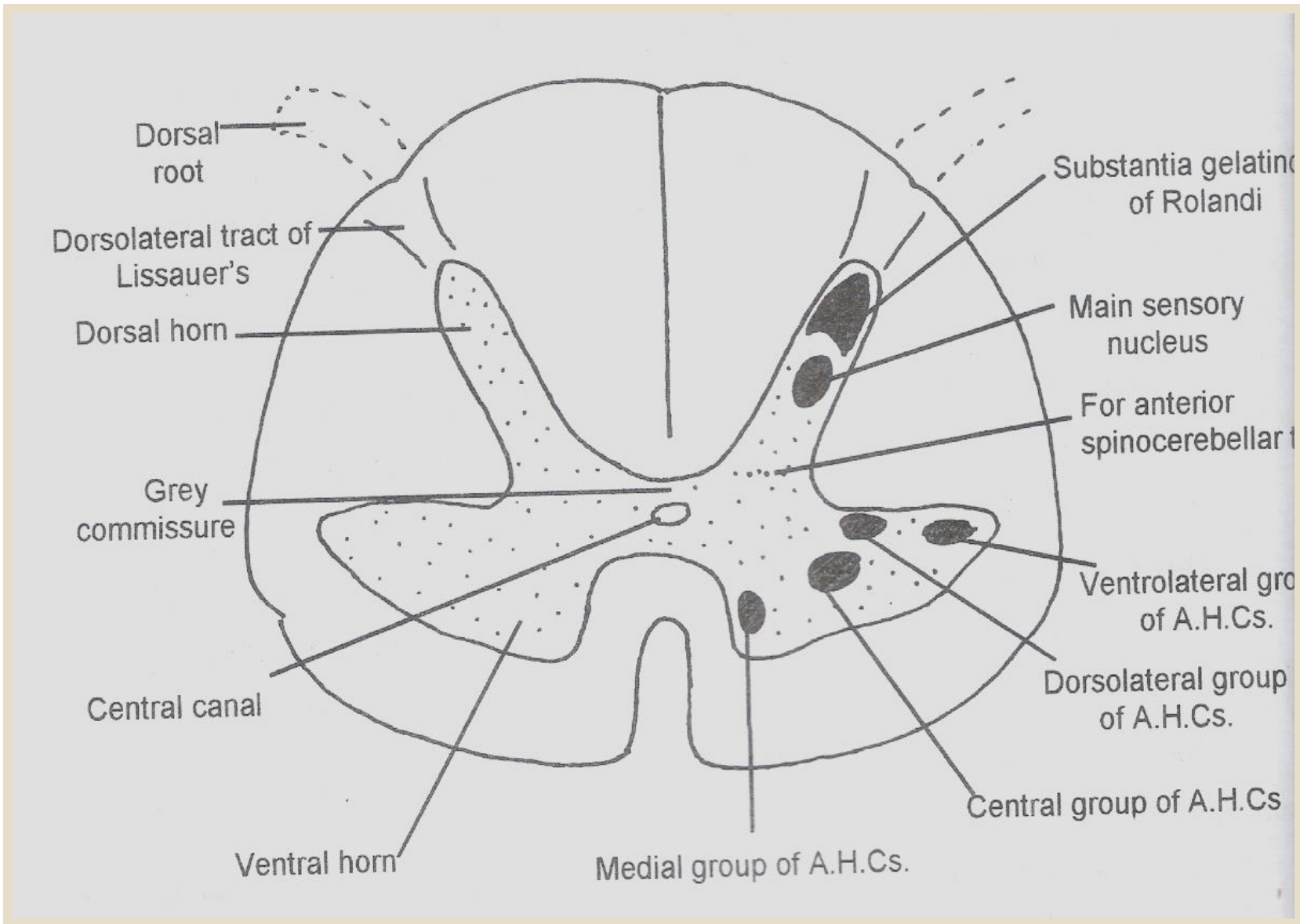
- Lies in the upper cervical region “C₁ - C₆”.
- Their axons form **the spinal accessory nerve**.
- Innervates **the sternocleidomastoid and trapezius**.

2. Phrenic nucleus:

- Extends from C₃ to C₆.
- Their axons form **the phrenic nerve**.
- Innervate **the diaphragm**.

D. Sacral parasympathetic nuclei:

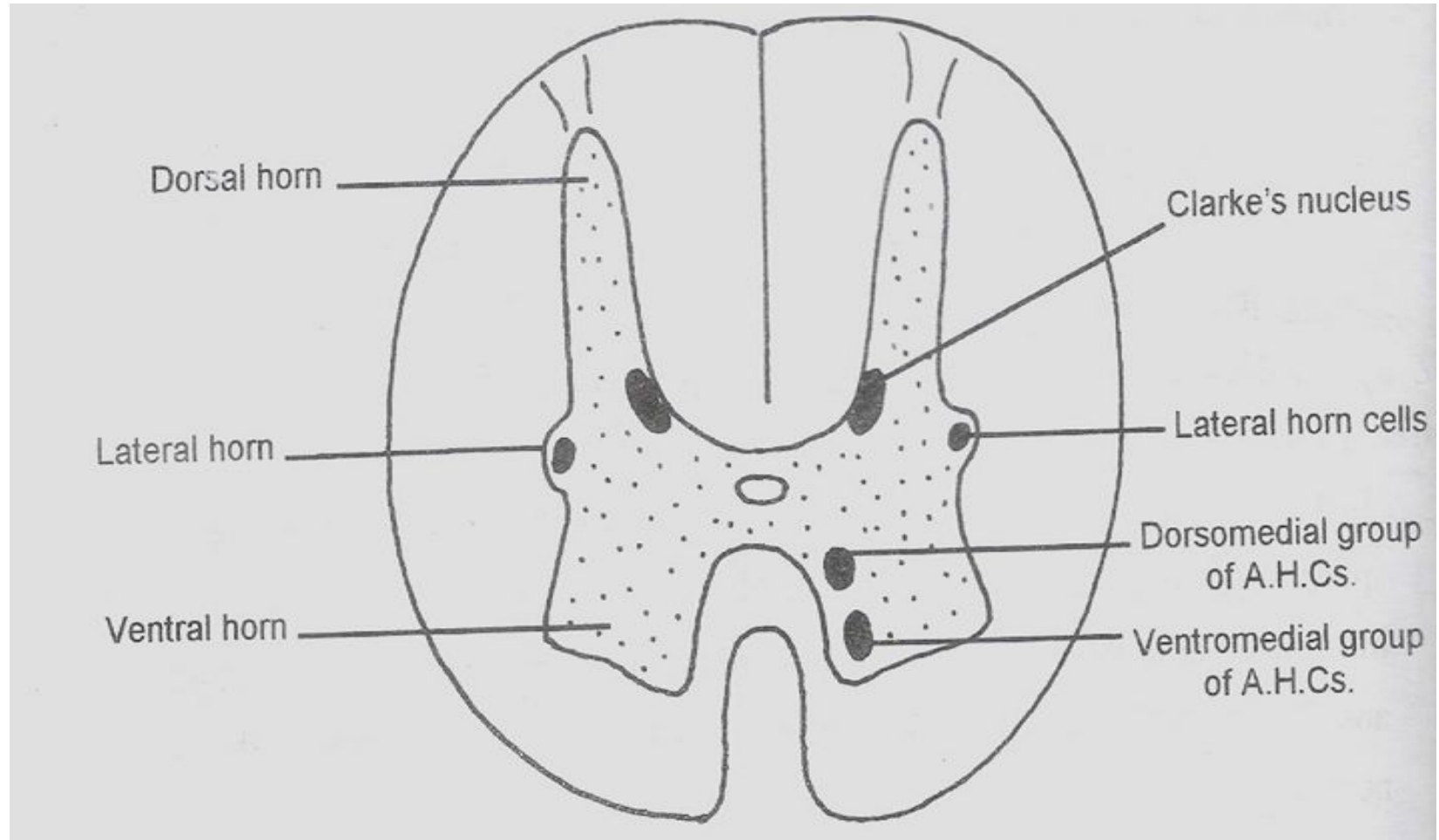
- Extends from S₂ to S₄.
- Gives rise to preganglionic parasympathetic fibers that innervate the pelvic viscera via the pelvic splanchnic nerves



The Lateral Horns

- Receives viscerosensory input.
- Found between the posterior and anterior horns of “T₁-L₂” segments of the spinal cord.
- Contains the **intermediolateral nuclei** “preganglionic sympathetic neurons”.
- At “T₁-T₂ or C₈-T₂” level located the **Cilio-spinal center of Budge** (sympathetic innervation of the eye).

The Gray Matter of the Thoracic SC



Neurons of the Gray Matter

A. Sensory neurons: in the posterior horns.

B. Motor neurons: in the anterior horns.

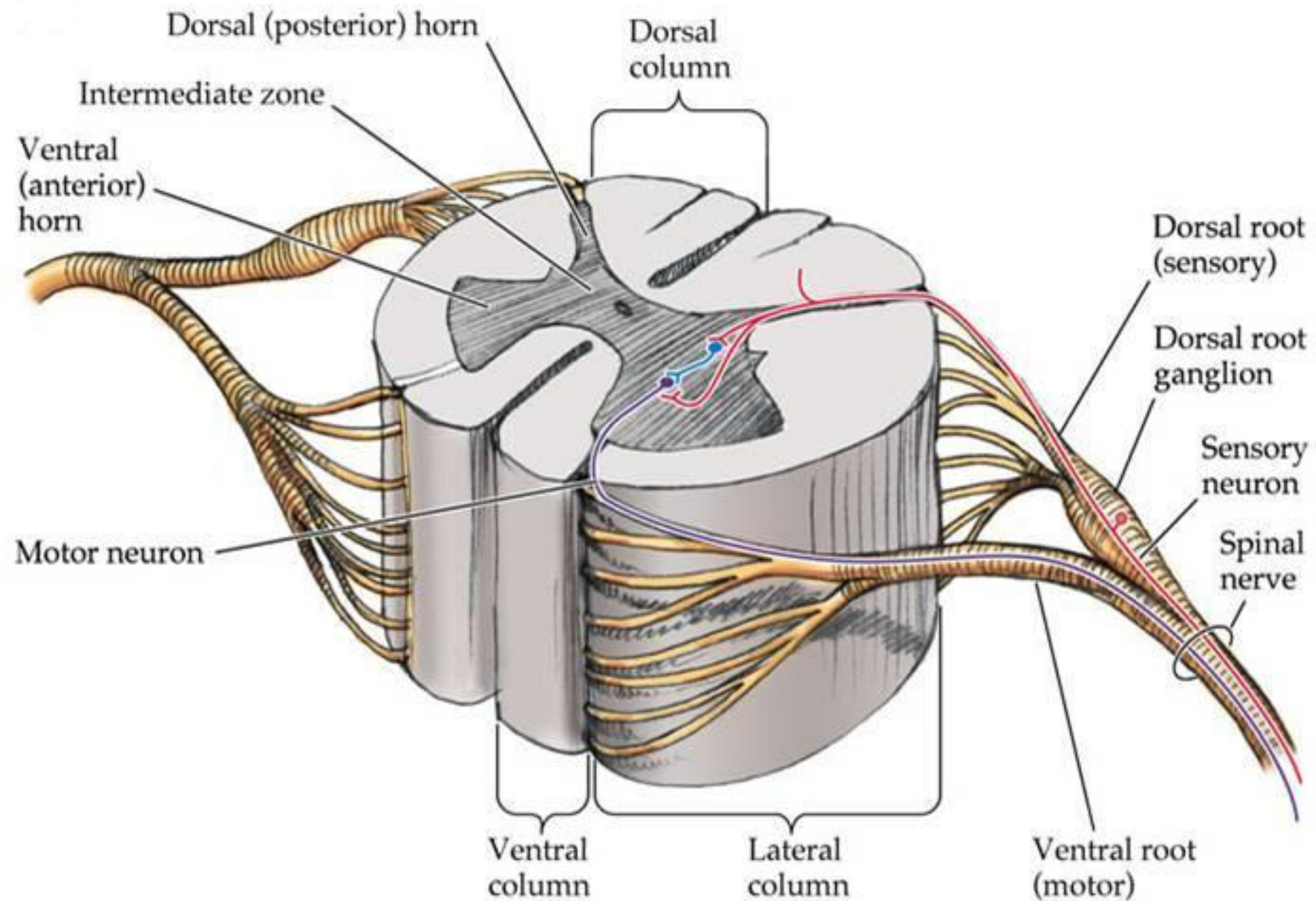
- **Alpha motor neurons:** give rise to large type A alpha ($A\alpha$) motor nerve fibers for **stimulation the muscle fibers.**
- **Gamma motor neuron:** transmit impulses through much smaller type A gamma ($A\gamma$) motor nerve fibers for **control muscle tone.**

C. Interneurons “Intermediate”:

- In the intermediate areas between the ventral and dorsal horns.
- **Function:** integrative functions of the SC (reflexes center).

The White Matter of the Spinal Cord

- The white matter surround the gray matter and contains ascending and descending tracts.
- **It is divided into three column (fasciculus) of SC on each side:**
 1. **Anterior column (AC):** lying between the anterior median fissure & the attachment of anterior spinal root “anterolateral sulcus”.
 2. **Posterior column (PC):** lying between the posterior median fissure & the attachment of dorsal spinal root “posterolateral sulcus”.
 3. **Lateral column (LC):** lying between attachment of anterior and posterior spinal roots.



Structure of White Mater

The white mater contains 3 types of nerve fibers (tract):

1. Ascending tracts of the SC:

Carrying sensory impulses from the SC to the brain:

e.g. Lateral Spinothalamic Tract.

2. Descending tracts of the SC:

Carrying motor impulses from the brain to the SC:

e.g. Corticospinal Tract.

3. Associative tracts:

Containing short ascending & descending fibers which coordinate the function of the different regions of spinal cord.



Also the tracts are divided into:

1. Short Tracts:

- They begins and end in the spinal cord.
- They are found close to the gray matter.
- They are associative in function.

2. Long Tracts:

- Ascending tracts.
- Descending tracts.

Blood Supply of the Spinal Cord

- 1. Anterior (ventral) spinal artery.**
- 2. Posterior spinal arteries (right and left).**
- 3. Radicular arteries.**

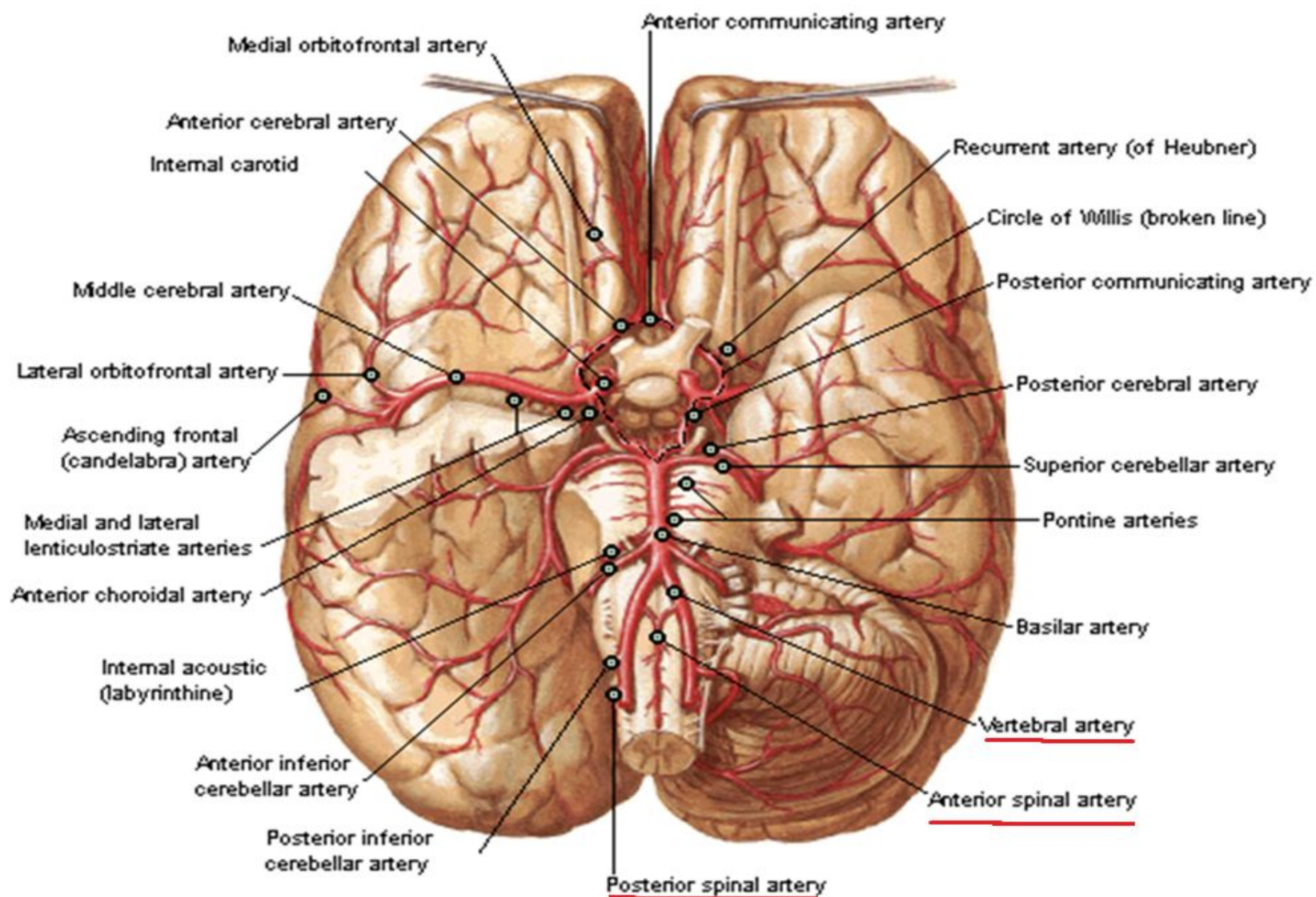
Blood Supply of the Spinal Cord

❑ Arise from the:

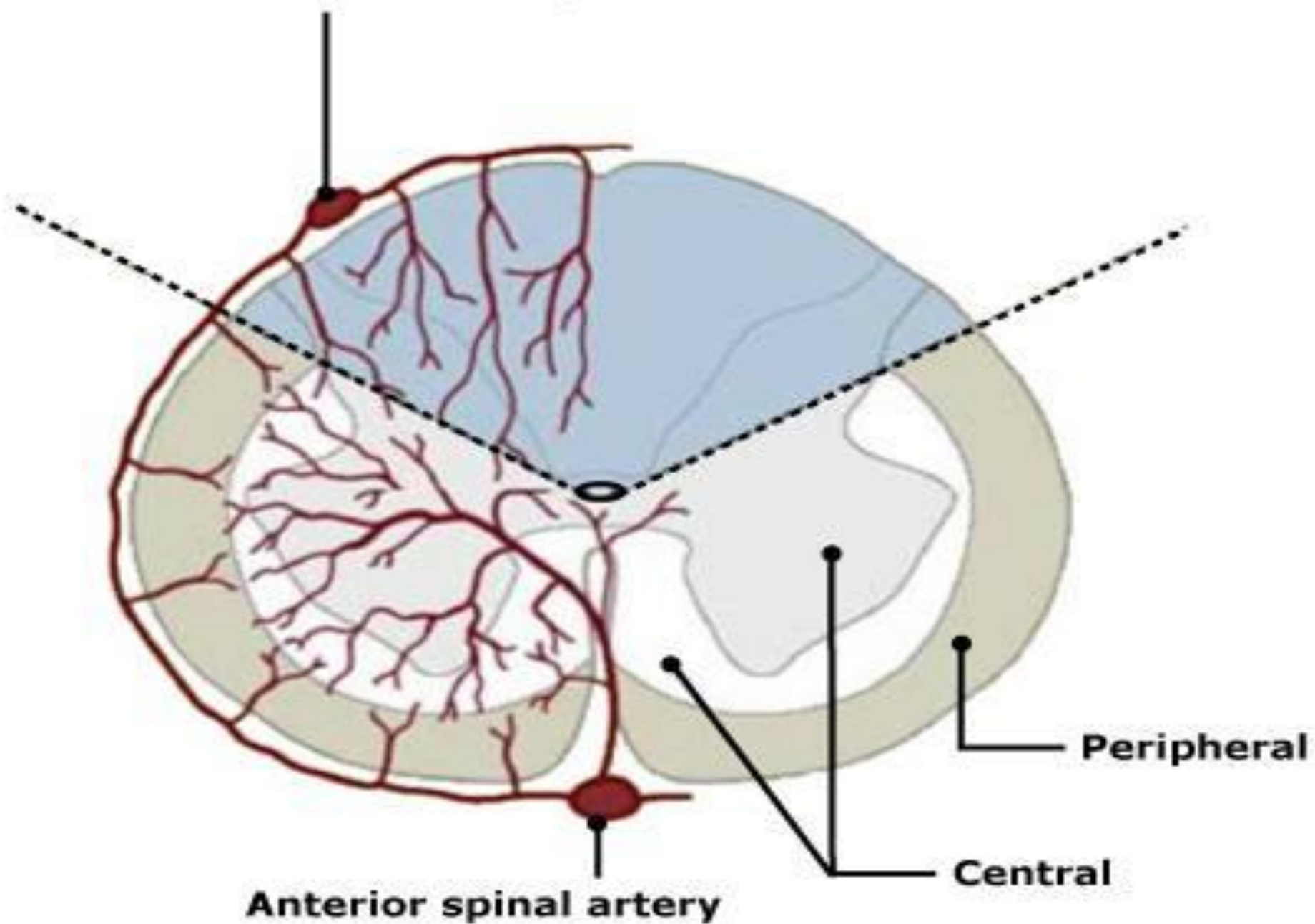
- A. Vertebral Arteries:** a branch of the subclavian artery. Gives rise to **the anterior spinal artery** and may give rise to **the posterior spinal artery**.
- B. Segmental “Radicular or Medullary” Arteries.**

Arteries of Brain

Inferior View



Posterior spinal artery



Anterior spinal artery

Peripheral

Central

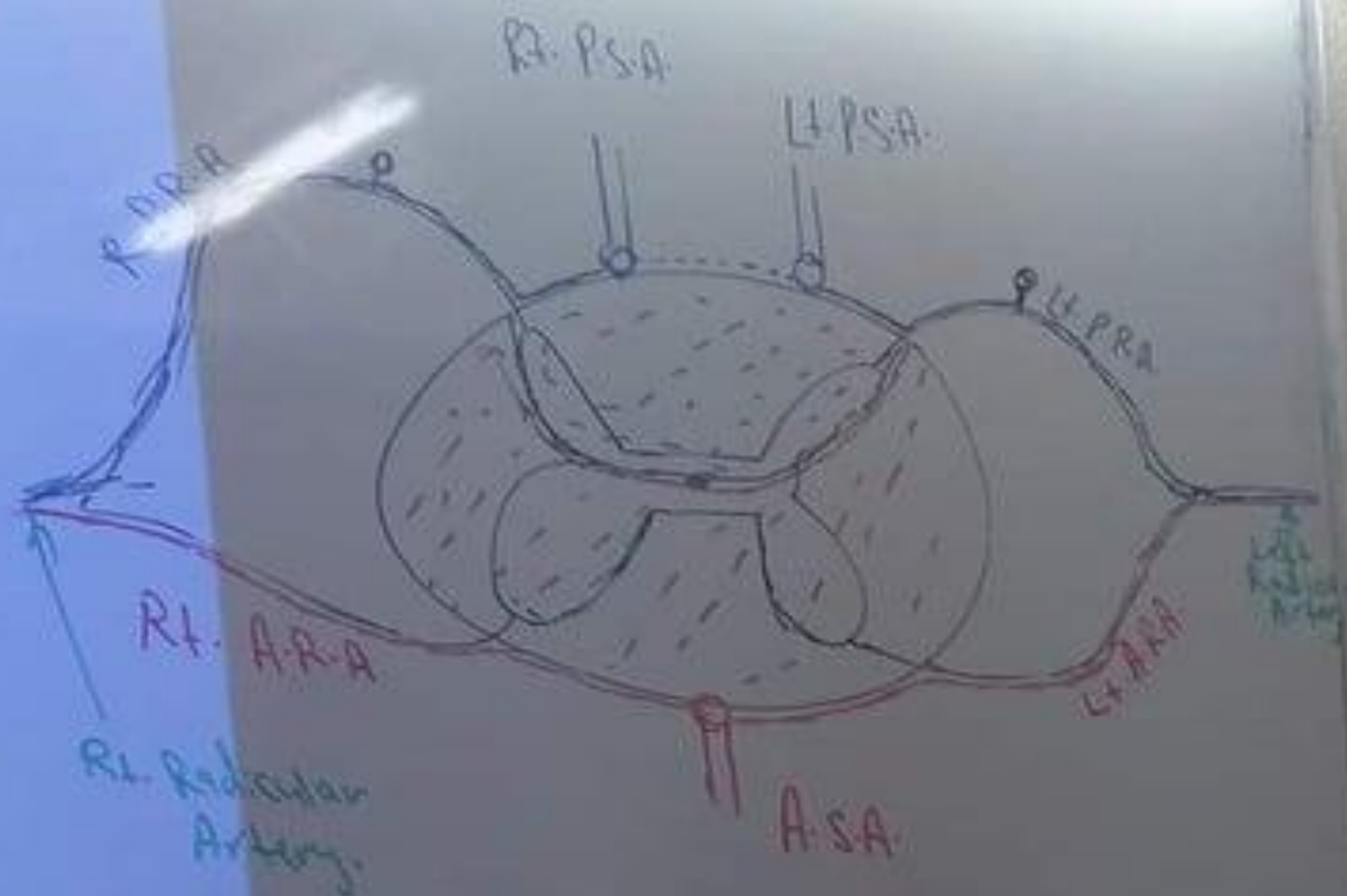
A. Vertebral Arteries

1. Anterior Spinal Artery

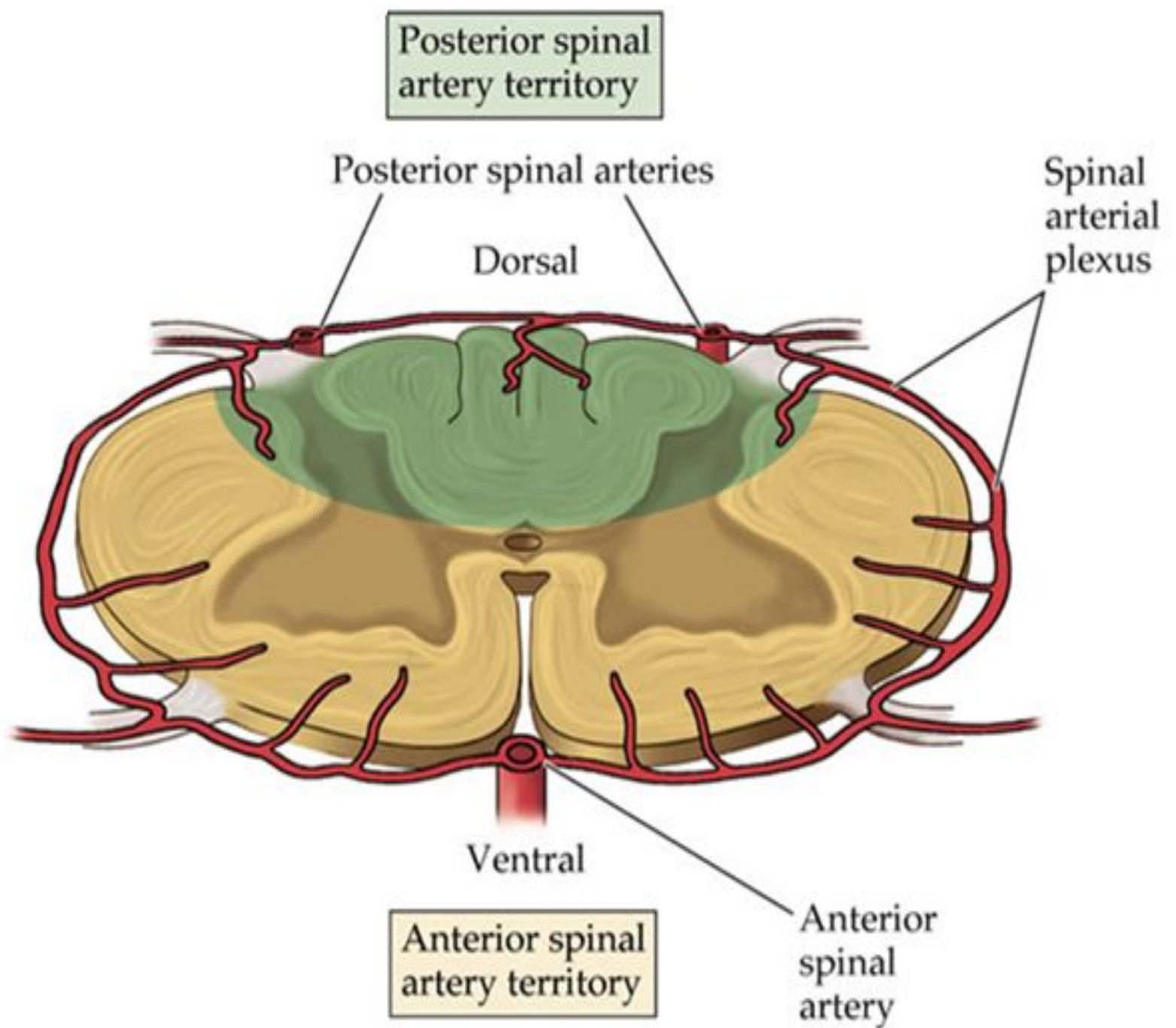
- Formed inside the cranial cavity by the union of right & left anterior spinal arteries arising from the **right and left vertebral arteries**.
- It descends in front of the anterior median fissure of the spinal cord.
- Supplies the anterior two-third of the spinal cord (**anterior and lateral columns, anterior and lateral horn cells**).
- Supplies **the pyramid, medial lemniscus, and hypoglossal nucleus in the medulla**
- The anterior spinal artery is **the longest artery in the body**.

Posterior Spinal Arteries .2

- Two posterior spinal arteries (Right & Left).
- Each artery arises inside the cranial cavity from **vertebral artery** and may be arises from **PICA**.
- Supply posterior one third of the spinal cord (**Posterior horns and posterior columns**).
- Supply the **Gracile and Cuneate nuclei in the medulla**.

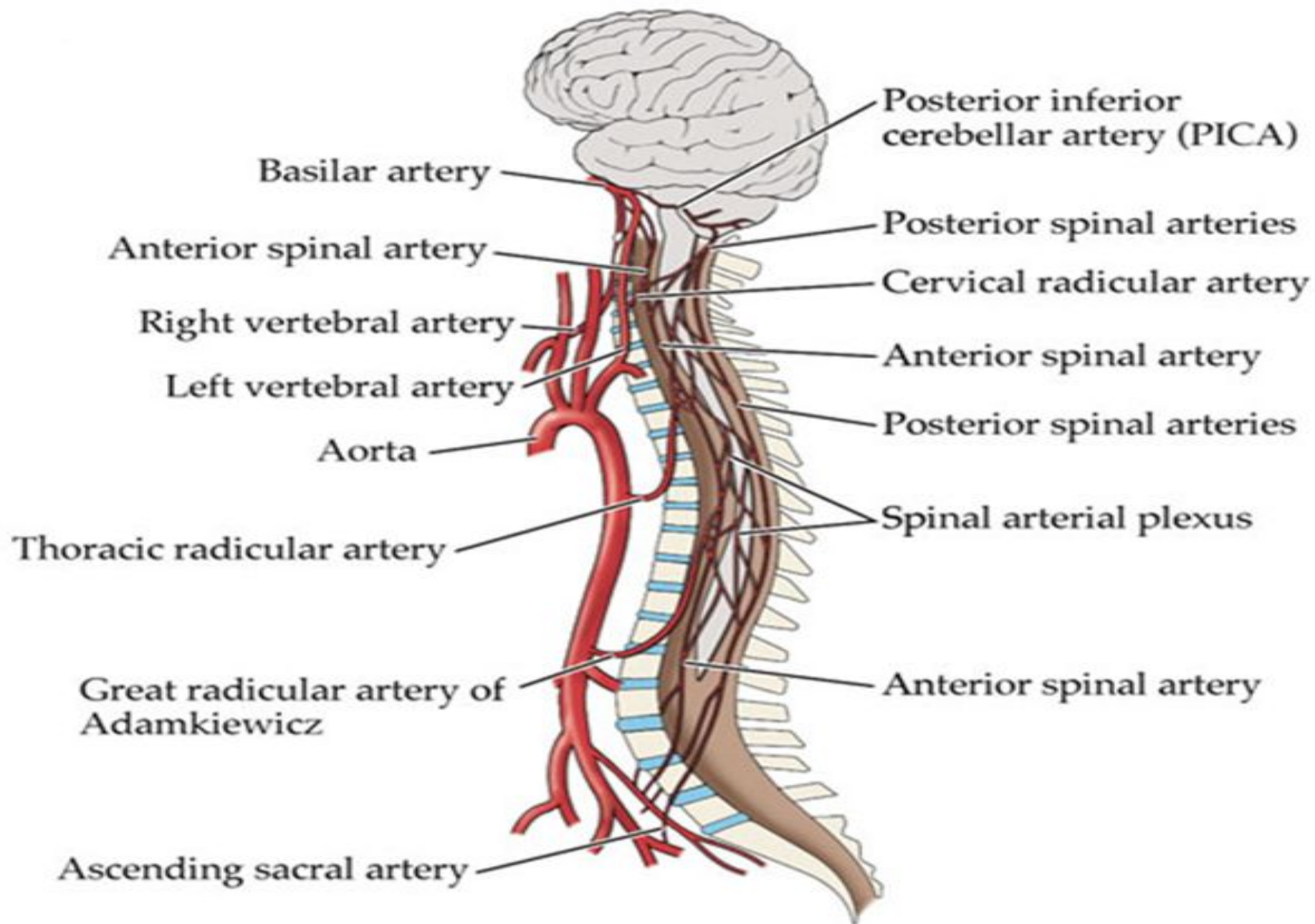


Blood supply of the
Spinal cord

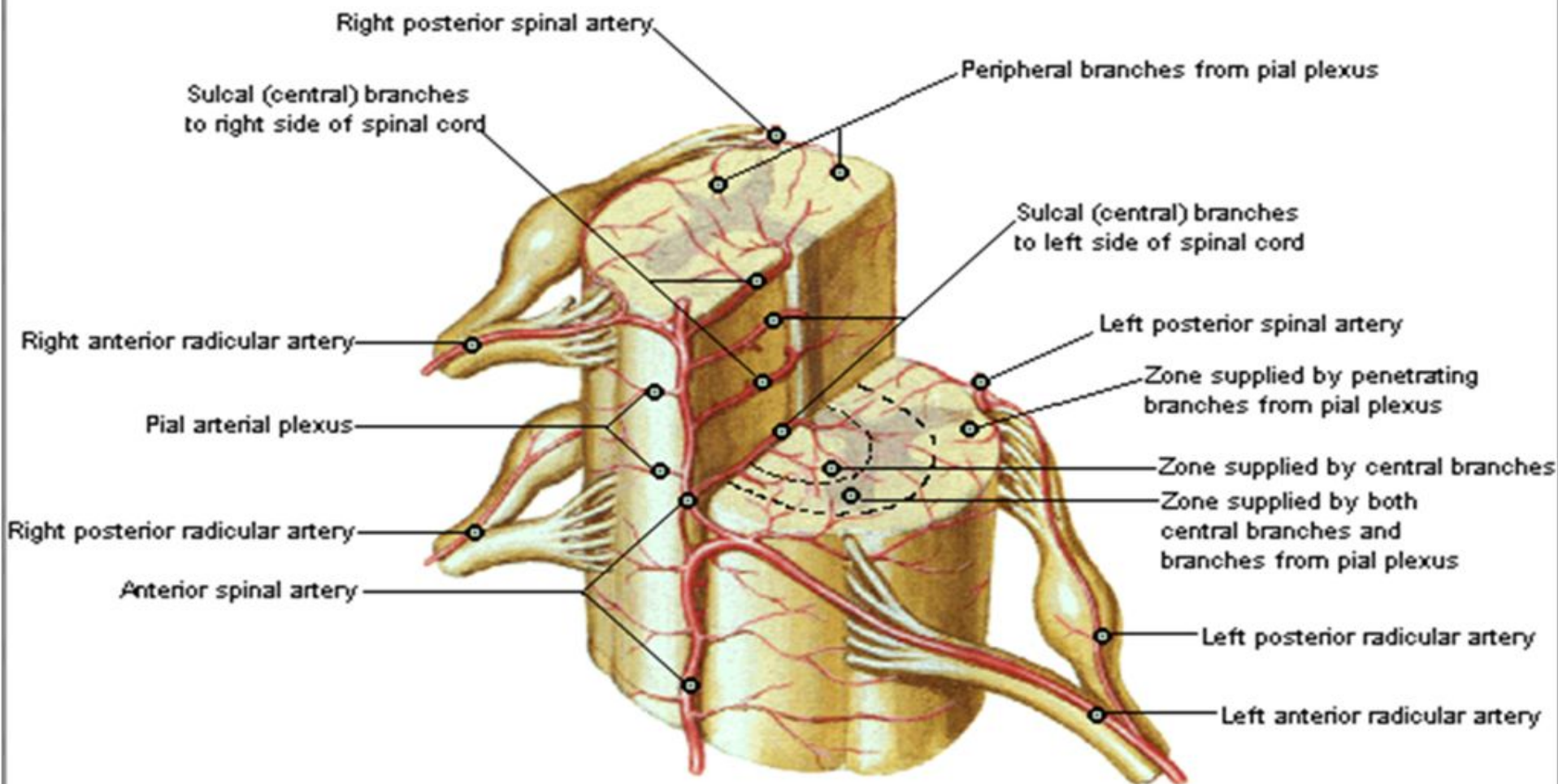


B. Segmental Arteries

- Arise from **the aorta, vertebral arteries, and common iliac arteries** as **medullary arteries** “**Radicular arteries**”, which anastomose with the anterior and posterior spinal arteries.
- One large “great” radicular artery (**artery of Adamkiewicz**). Its origin varies from **T12 to L4**, and it usually arises on **the left side**.



Arteries of Spinal Cord - Intrinsic Distribution



Venous Drainage of the Spinal Cord

- ❖ Venous blood passes from spinal veins within the **subarachnoid space to the epidural internal venous plexus** before draining into:
 - Intracranial veins.
 - Cervical veins.
 - Thoracic veins.
 - Intercostal veins.
 - Abdominal veins.

I. Ascending Tracts

- Represent functional pathways that convey sensory information from the periphery to higher levels.
- Usually consist of a chain of **three order neurons**.
- The first-order neuron is always in **the spinal ganglion**.

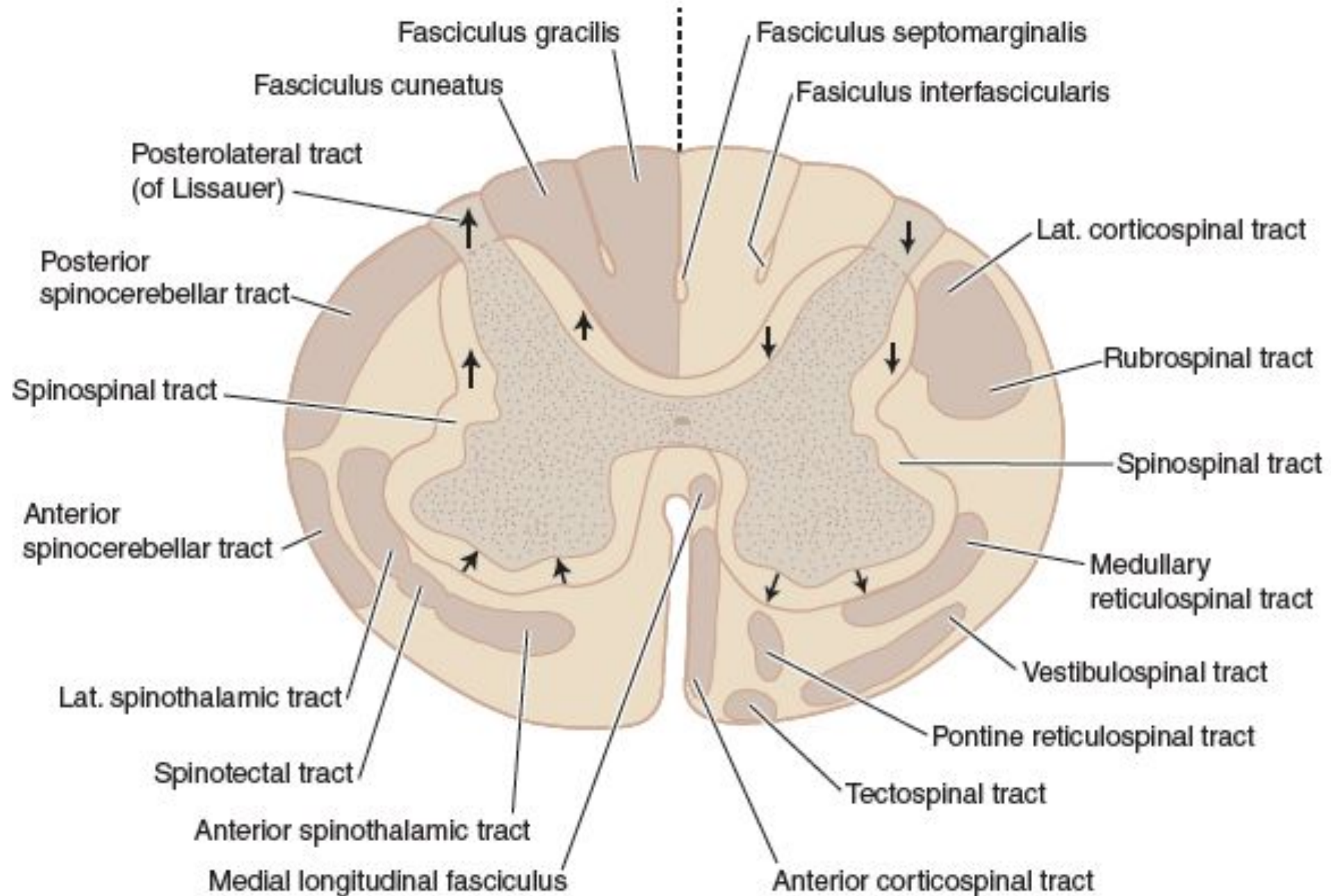
Ascending Tracts of the Spinal Cord

1. **Gracile tract (PC)**: for proprioception & fine touch from lower half of the body.
2. **Cuneate tract (PC)**: for proprioception & fine touch from upper half of the body.
3. **Lissaurer's tract**: for pain and temperature sensation, lies between the tip of the posterior horn & posterior lateral sulcus.
4. **Dorsal spinocerebellar tract (LC)**: carries proprioceptive fibers from **Clarck's nuclei** to the inferior cerebellar peduncle.
5. **Ventral spinocerebellar tract (LC)**: carries proprioceptive fibers from **spinal border cells** to the superior cerebellar peduncle.

- 
6. **Lateral spinothalamic tract (LC):** for pain and temperature pathway.
 7. **Ventral spinothalamic tract (AC):** for crude touch.
 8. **Spinotectal tract (LC):** arises from the posterior horn & ends in the superior colliculus (spinovisual reflexes).
 9. **Spino-olivary tract (LC):** carries proprioceptive impulses to accessory olivary nuclei in the medulla.

Ascending tracts

Descending tracts



Ascending tracts

Fasciculus gracilis

DORSAL COLUMNS

Fasciculus cuneatus

Descending tracts

Medial longitudinal fasciculus

Lissauer's tract

Lateral corticospinal tract

Rubrospinal tract

Pontine reticulospinal tract

Medullary reticulospinal tract

Lateral vestibulospinal tract

Tectospinal tract

Ventral corticospinal tract

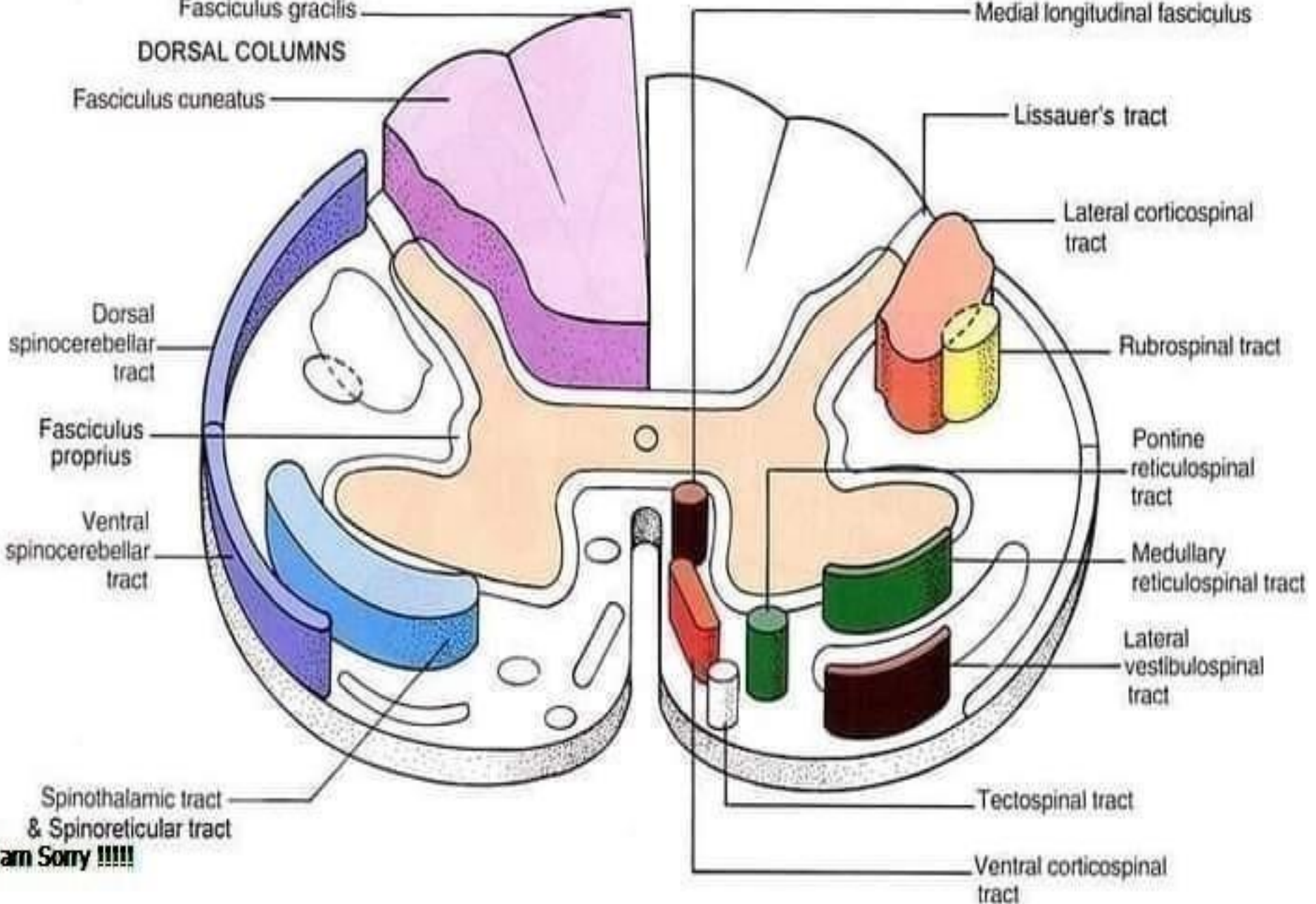
Dorsal spinocerebellar tract

Fasciculus proprius

Ventral spinocerebellar tract

Spinothalamic tract & Spinoreticular tract

I am Sorry !!!!!



A. Anterolateral System

1. Lateral spinothalamic tract:

- Mediates **pain, and temperature sensations.**
- Receives input from free nerve endings and thermal receptors.
- Receives input from A-delta and C fibers.

2. Anterior spinothalamic tract:

- Concerned with **crude touch sensation.**
- Receives input from free nerve endings and from Merkel tactile receptors.

Lateral Spinothalamic Tract

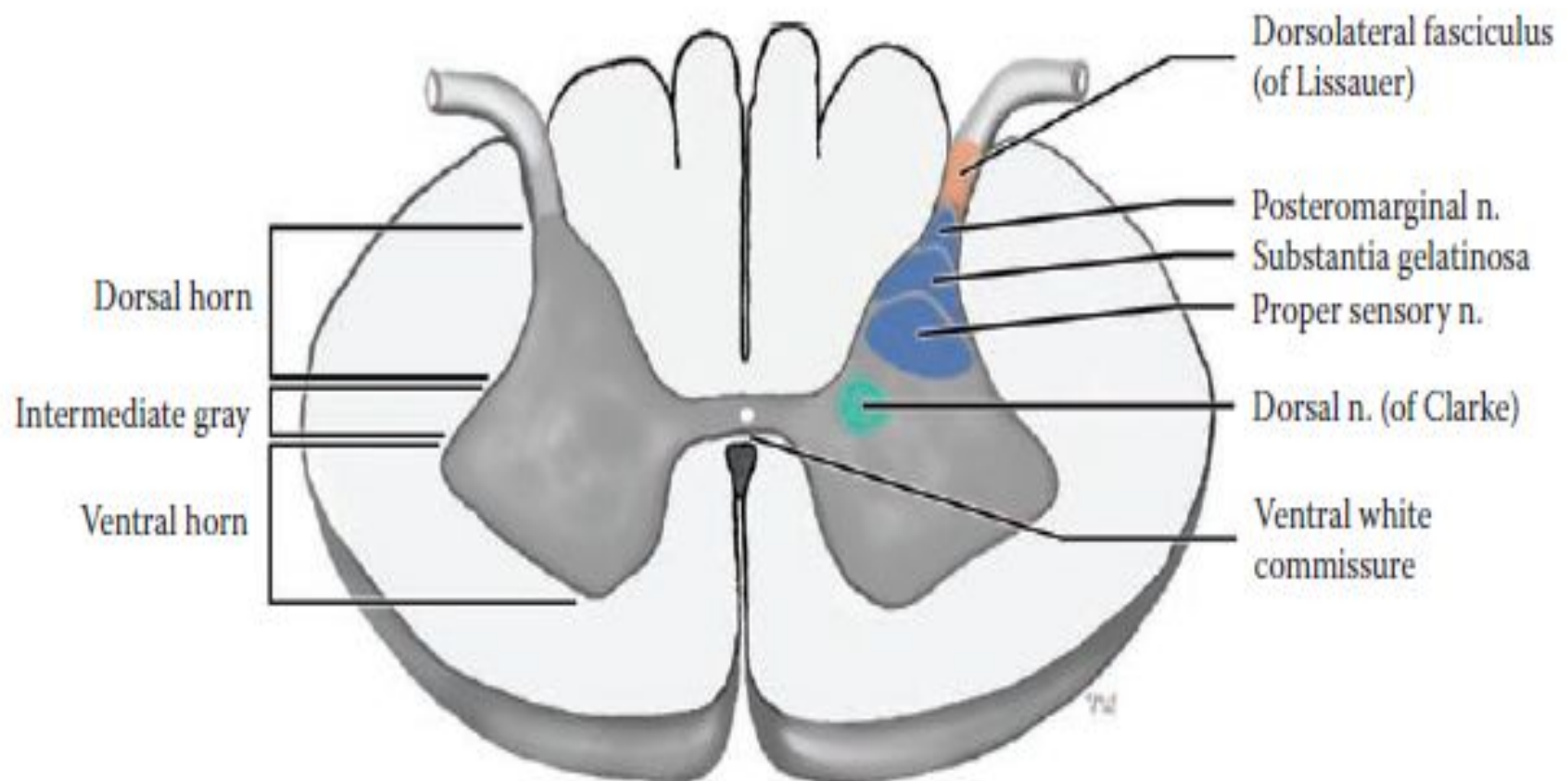
“Pathway of Pain and Temperature Sensations”

1. The first order neuron:

Found in **the posterior root spinal ganglion** at all levels.

The process divided into:

- **The lateral branch (Dendrite):** goes peripherally forming the afferent sensory nerve (the ends of this nerve are receptors of the skin).
- **The medial branch (Axon):** enters the spinal cord, forming **Lissauer's tract** and make synapse with second order neurons in the posterior horn cells “**Substantia Gelatinosa of Rolandi**”.



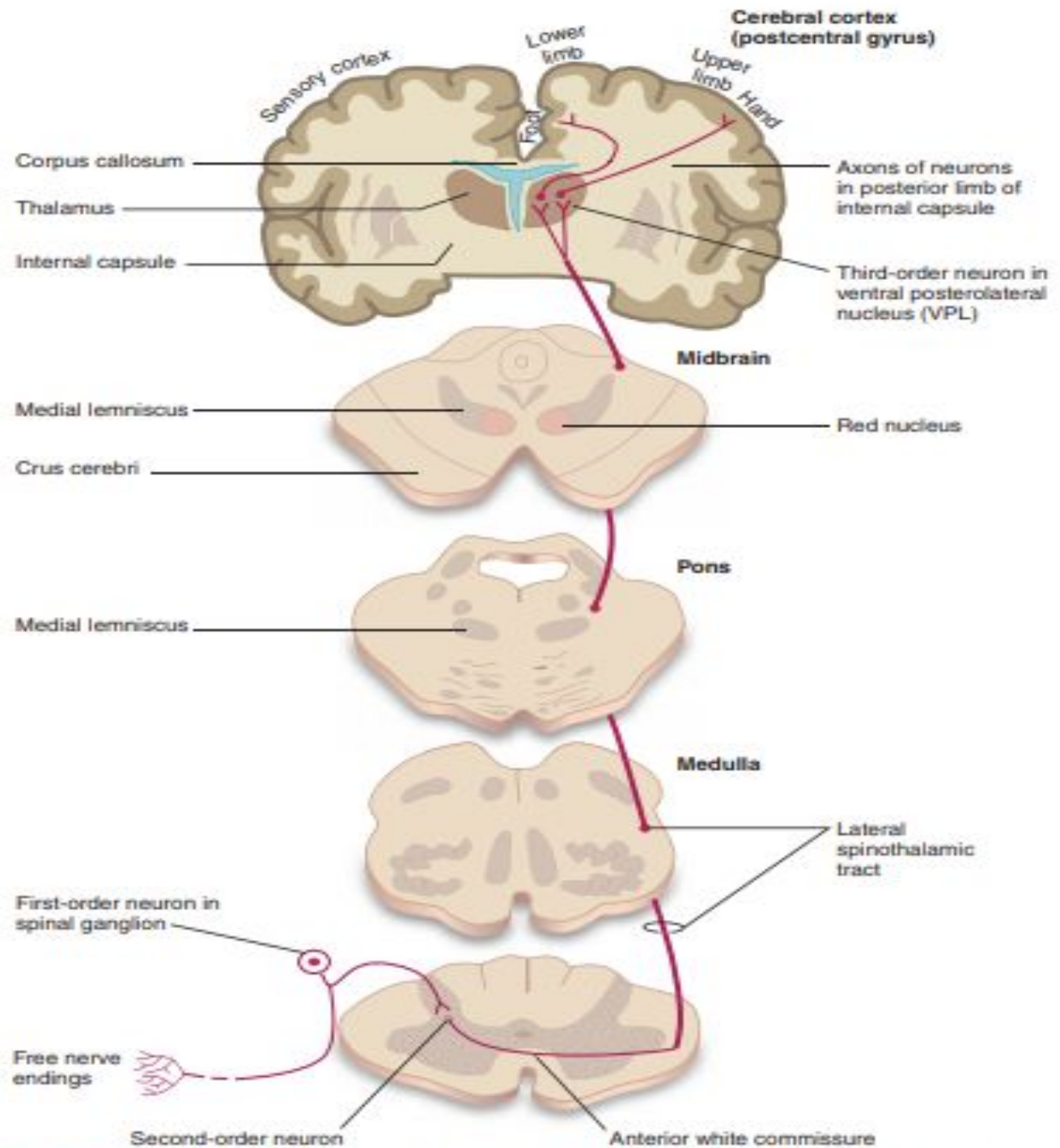
Lateral Spinothalamic Tract

2. The second neuron:

Is the cells of **Substantia Gelatinosa of Rolandi** and its axon. This axon crosses to the opposite side cross the midline in the **ventral white commissure**, usually **within two to three segments** above the level of entry of the peripheral fibers and ascends in the lateral column of the SC as the **lateral spinothalamic tract** → medulla oblongata → the pons → the mid brain → to relay the sensory impulse at the VPL nucleus of thalamus.

3. The third order neuron:

Starts in the cells of **the ventral posterolateral nucleus (VPL) and intralaminar nuclei of the thalamus**, its axon ascends to pass through the posterior limb of the internal capsule conducting the impulse to the cortical somatic sensory area (1, 2, 3) in the upper 2/3rd of the postcentral gyrus of the parietal lobe.



5

The anterolateral tract terminates in the VPL of the thalamus. From the thalamus, fibers project through the internal capsule and corona radiata to terminate in the primary somatosensory cortex (postcentral gyrus).

4

In the pons and midbrain, the anterolateral tract lies lateral to the medial lemniscus.

3

In the rostral medulla, the anterolateral tract lies between the inferior olivary nucleus and the nucleus of the spinal tract of the trigeminal nerve.

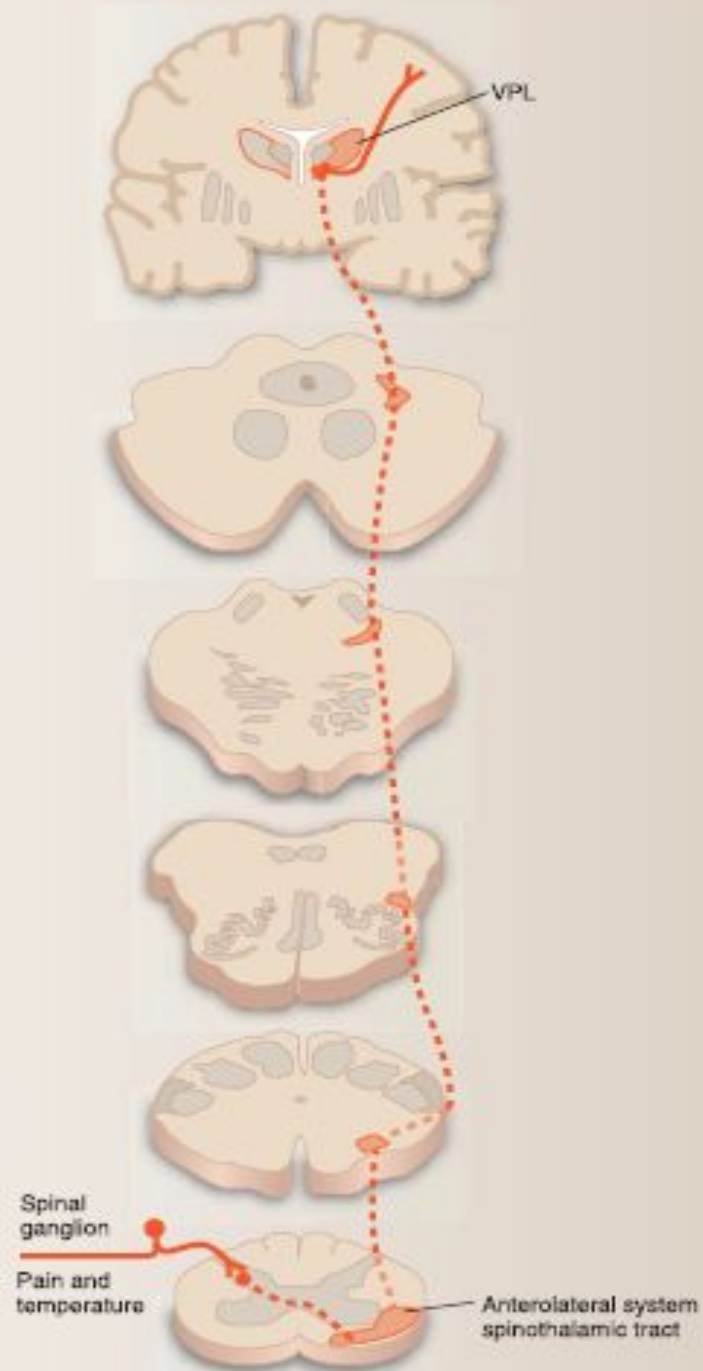
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Anterolateral tract in the caudal medulla.

1

Axons enter the spinal cord from the spinal ganglia, travel up or down 1–2 segments in Lissauer tract, and then synapse in the posterior horn.

Axons of secondary neurons cross the midline in the anterior white commissure and ascend as the anterolateral tract in the spinal cord.



Anterior Spinothalamic Tract

“Pathway of Crude Touch Sensation”

- Has the same pathway as lateral spinothalamic tract but the second order neuron is **main sensory nucleus** in posterior horn cells.
- The axons crosses to the opposite side through the white ventral commissure and ascends in the ventral column of the spinal cord as the **Ventral Spinothalamic Tract**.
- Found in the **VPL nucleus** of the thalamus.

N.B. The spinal lemniscus= lateral spinothalamic tract + ventral spinothalamic tract

Lesions of the Anterolateral System

- **Lesions to the posterior horn cells:** **Ipsilateral at the same level** loss of pain and temperature, and nondiscriminative forms of touch sensations.
- **Lesions to the anterolateral spinothalamic tract:** **Contralateral loss** of pain and temperature, and nondiscriminative forms of touch sensations below the level of lesion.
- **Lesions thalamus and postcentral gyrus:** **Contralateral loss** of pain and temperature, and nondiscriminative forms of touch sensations.

B. Posterior Column Medial Lemniscus System

- The posterior column-medial lemniscus system carries general somatic afferent (general sensory) information about **discriminative “Fine” touch, pressure, vibration and conscious proprioception.**
- Receives input from Pacinian and Meissner’s corpuscles, joint receptors, muscle spindles, and Golgi tendon organs.
- Transmitted through the fast-conducting large-diameter fibers **(A-Beta fibers).**

Pathway of Posterior Column Medial Lemniscus System

1. The first order neuron:

Found in **the posterior root spinal ganglion** at all levels.

The process divided into:

- **The lateral branch (Dendrite):** goes peripherally forming the afferent sensory nerve (the ends of this nerve are receptors of the tendon).
- **The medial branch (Axon):** enters the SC and ascends directly in the Gracile and Cuneate tracts “Fasciculus” within the posterior column **at the same side** to relay in the **Gracile and Cuneate nuclei** of the medulla.

Pathway of Deep Sensation

2. The second neuron:

- Is the cells of **the Gracile and Cuneate nuclei** in the medulla → give rise to axons, **internal arcuate fibers** that decussate to the opposite side of the medulla oblongata ascends as **Medial Lemniscus through** → the pons → the mid brain → to relay in the “PLV” nucleus of thalamus.

3. The third order neuron:

Starts in the cells of **the posterolateral ventral nucleus (PLV) nucleus of the thalamus**, its axon ascends to pass through the posterior limb of the internal capsule conducting the impulse to the cortical somatic sensory area (1, 2, 3) in the upper 2/3rd of the postcentral gyrus of the parietal lobe.

6

The medial lemniscus terminates in the VPL of the thalamus. From the thalamus, fibers project through the internal capsule and corona radiata to terminate in the primary somatosensory cortex (postcentral gyrus).

5

As the medial lemniscus continues to ascend through the rostral pons and midbrain, it moves laterally and becomes more vertical.

4

In the caudal pons, the medial lemniscus flattens horizontally.

3

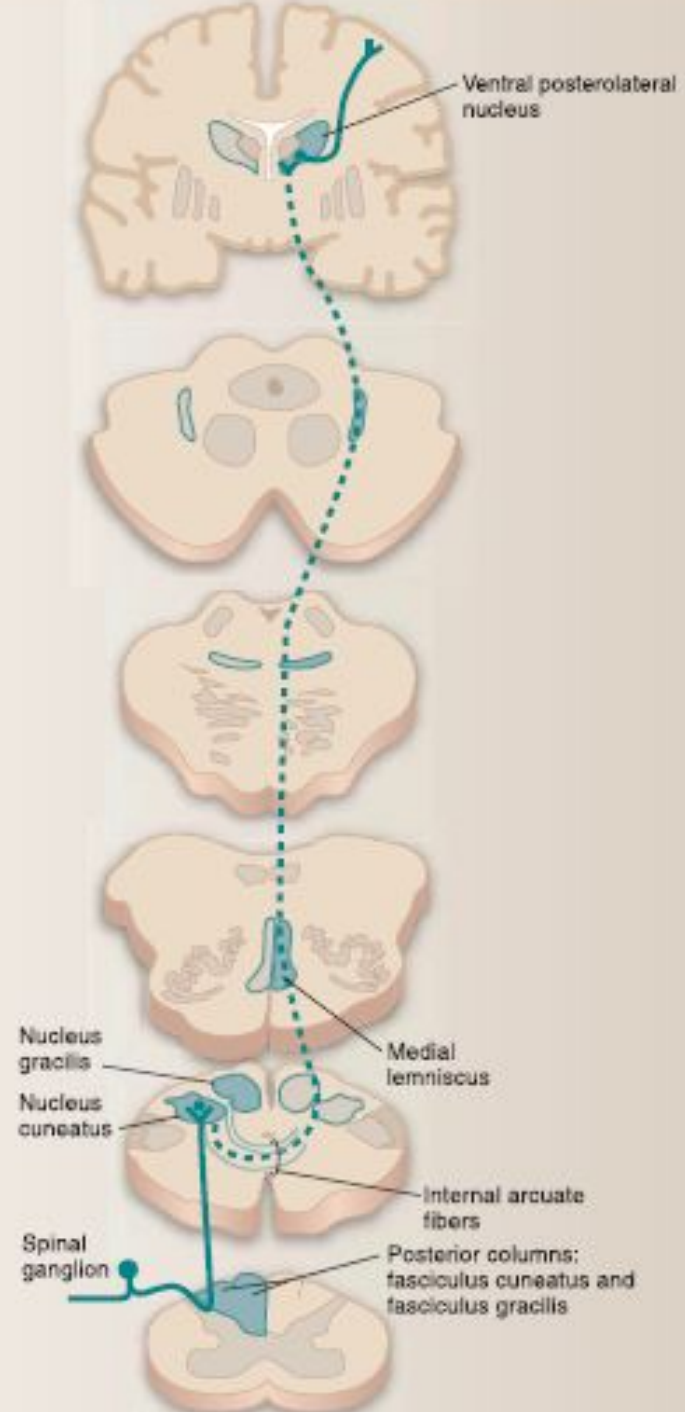
In the rostral medulla, the fibers travel as the medial lemniscus adjacent to the midline.

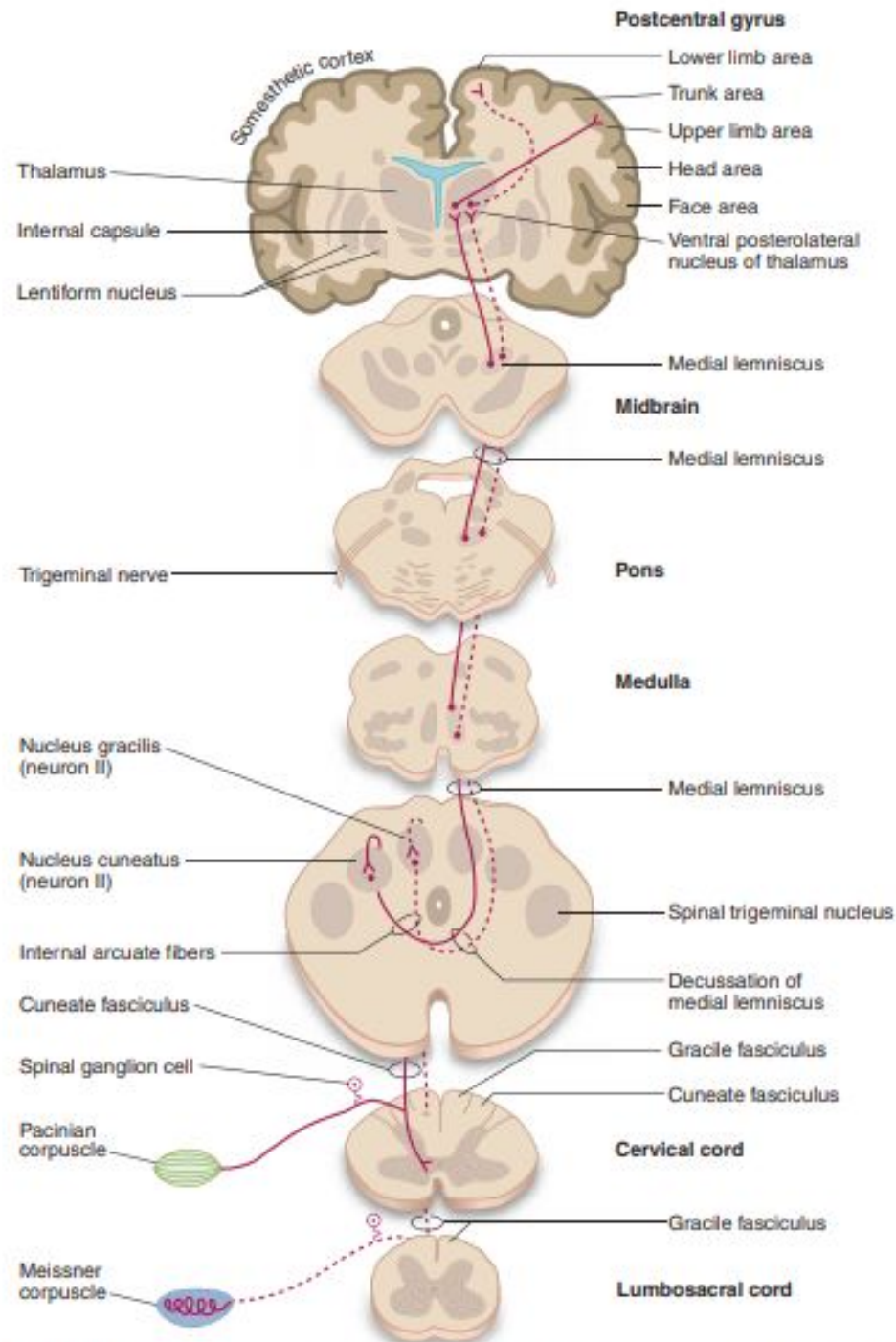
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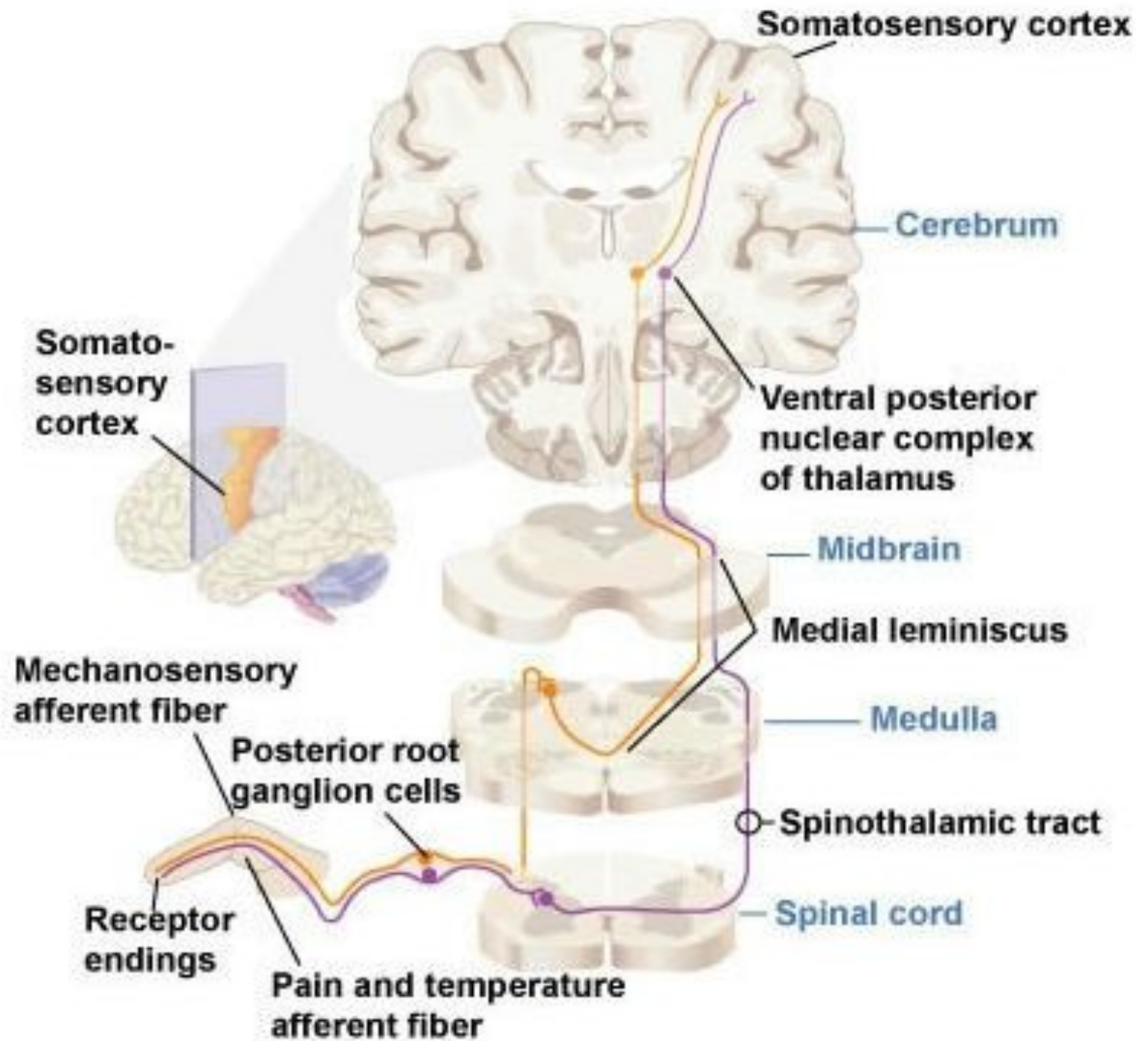
They terminate in nucleus gracilis and nucleus cuneatus. From these nuclei, axons of secondary neurons cross the midline as internal arcuate fibers and form the medial lemniscus.

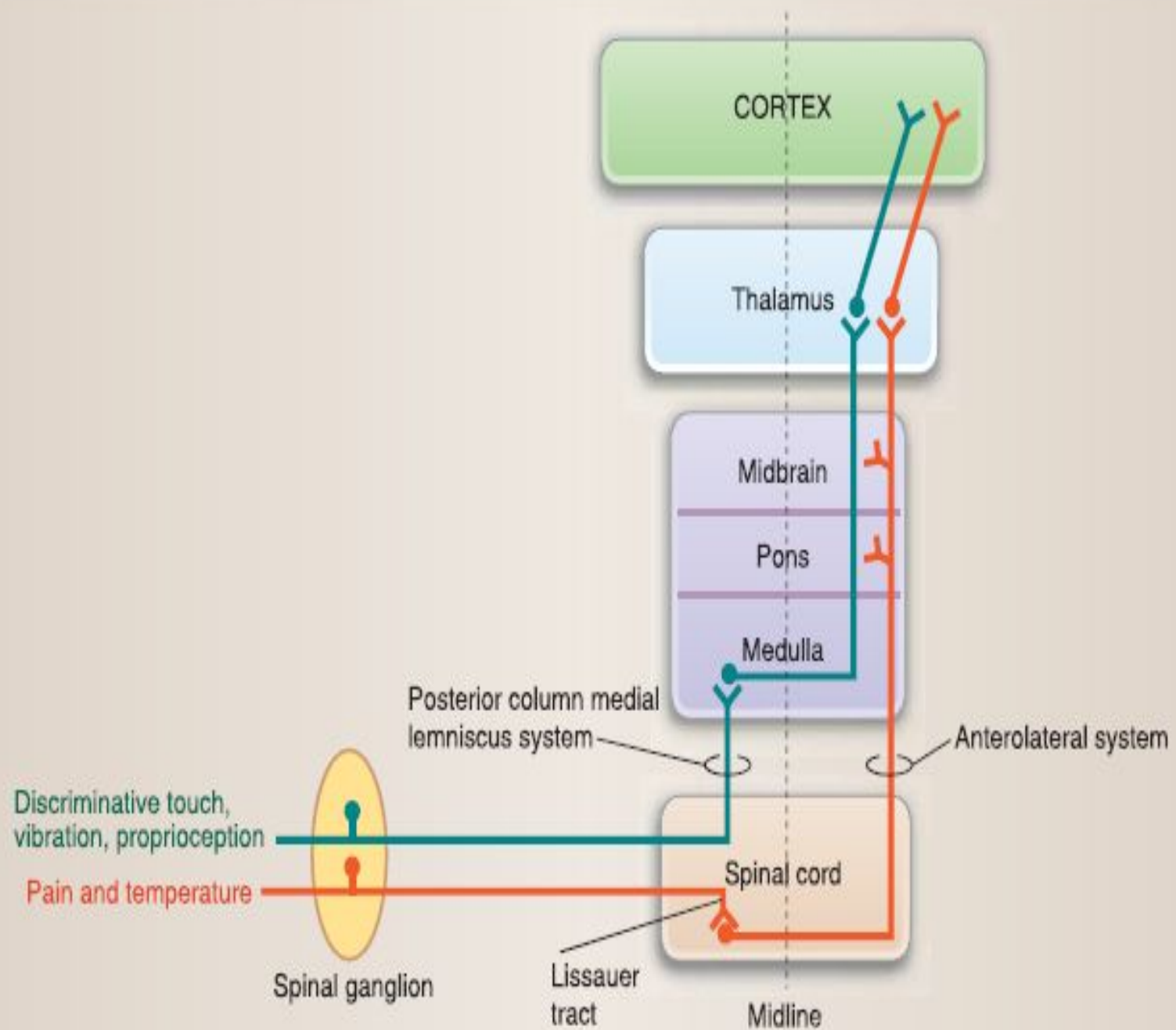
1

Axons enter the spinal cord from the spinal ganglia and pass directly to ipsilateral posterior column. Caudal fibers (up to and including T6) enter fasciculus gracilis (medial) and rostral fibers (above T6) enter fasciculus cuneatus to ascend.









Lamination of the Gracile and Cuneate Tracts

- ❖ **The Gracile Tract:** lies more medially and received impulses from the lower part of the body (the lower limbs and lower half of the trunk).
- ❖ **Cuneate Tract:** lies more laterally and received impulses from the upper part of the body (the upper limbs and upper half of the trunk).
- ❖ **From medial to lateral side:** sacral nerve fibers → lumbar nerve fibers → thoracic nerve fibers → cervical nerve fibers.

Lesions of the Posterior Column Medial Lemniscus System

- **Lesions to the posterior columns:** **Ipsilateral loss** of discriminative touch, pressure, vibration and conscious proprioception “Sensitive Ataxia”.
- **Lesions to the medial lemniscus, thalamus and postcentral gyrus:** **Contralateral loss** of discriminative touch, pressure, vibration and conscious proprioception “Sensitive Ataxia”.

C. Spinocerebellar Tracts

1. Posterior spinocerebellar tract:

- Transmits unconscious proprioceptive information to the cerebellum.
- Receives input from muscle spindles, Golgi tendon organs, and pressure receptors.
- Carries unconscious proprioceptive information from ipsilateral lower extremity and trunk.
- An uncrossed tract.

2. Anterior spinocerebellar tract:

- Transmits unconscious proprioceptive information to the cerebellum.
- Carries proprioception from the lower limb to the cerebellum .
- Receives input from muscle spindles, Golgi tendon organs, and pressure receptors.
- A crossed tract.

3. Cuneocerebellar tract:

- The upper-extremity equivalent of the posterior spinocerebellar tract.

1. Posterior Spinocerebellar Tract

“Flechsigs Tract”

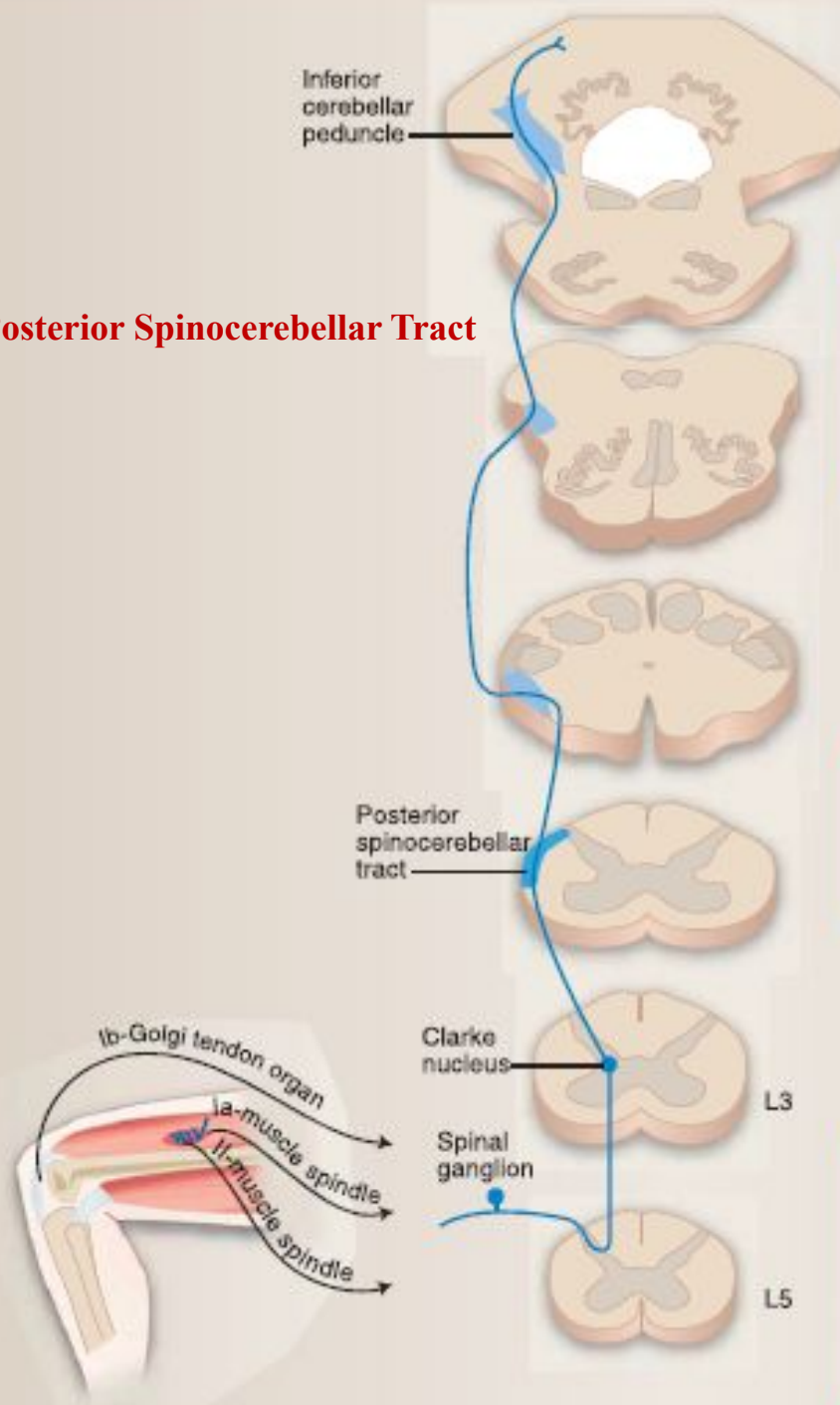
a. First-order neurons:

- Found in the **posterior spinal root ganglia**.
- Project in the posterior thoracic nucleus “Clarck’s nucleus”.

b. Second-order neurons:

- Found in **the posterior thoracic nucleus “Clarck’s nucleus”** of (C8–L3).
- Give rise to axons that ascend in the lateral funiculus and reach the cerebellum via **the inferior cerebellar peduncle ipsilateral**.

Posterior Spinocerebellar Tract



3

In the rostral medulla **posterior spino-cerebellar fibers** travel through the inferior cerebellar peduncle to the ipsilateral cerebellum, mainly to the anterior lobe and the vermis.

2

Fibers then travel in the **posterior spino- cerebellar tract** through the spinal cord and brainstem.

1

Proprioceptive information from muscle spindles and Golgi tendon organs (Ia, Ib, and II fibers) and from skin enters the spinal cord. Fibers travel in the fasciculus gracilis until they reach L3 where they synapse in the Clarke nucleus. The Clarke nucleus extends from L3 to C8.

2. Anterior Spinocerebellar Tract

a. First-order neurons:

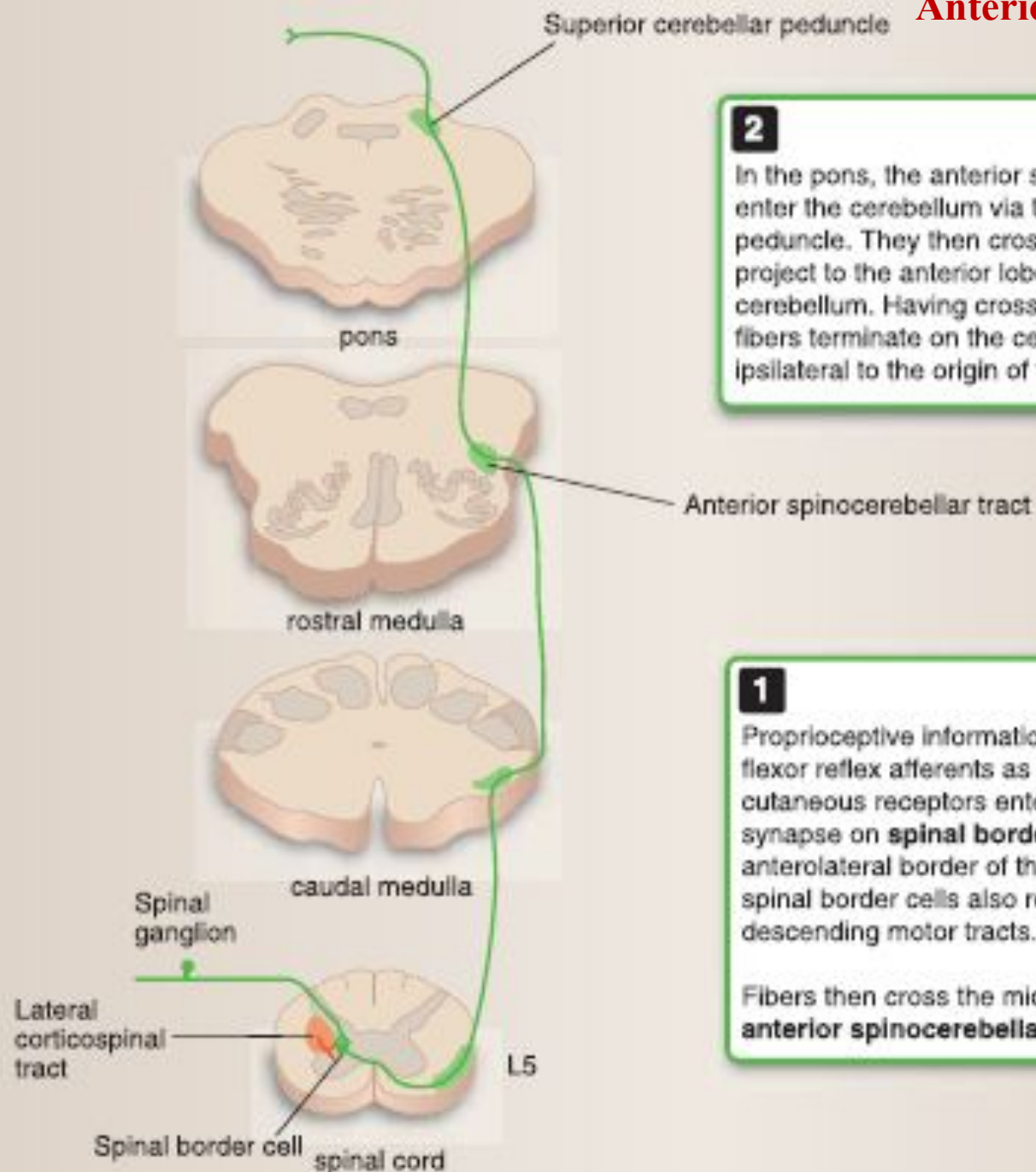
- Found in the **posterior spinal root ganglia**.
- Project in the posterior horn cells and make synapse with **the spinal border cells**.

b. Second-order neurons:

- Found in **the spinal border cells** of anterior horns (L1–S2).
- Give rise to axons that decussate in the anterior white commissure and ascend lateral to the lateral spinothalamic tract in the lateral column.
- Give rise to axons that enter the cerebellum via **the superior cerebellar peduncle contralateral**. **They then cross the midline again and project the anterior lobe and vermis.**

Lesion: Contralateral lower limb discoordination “Ataxia”. The patient has difficulty performing the heel-to-shin test.

Anterior Spinocerebellar Tract



2

In the pons, the anterior spinocerebellar fibers enter the cerebellum via the superior cerebellar peduncle. They then cross the midline again and project to the anterior lobe and vermis of the cerebellum. Having crossed the midline twice, the fibers terminate on the cerebellar hemisphere ipsilateral to the origin of the stimulus.

1

Proprioceptive information from Ia and Ib fibers and flexor reflex afferents as well as information from cutaneous receptors enter the spinal cord and synapse on **spinal border cells** located in the anterolateral border of the anterior horn. These spinal border cells also receive information from descending motor tracts.

Fibers then cross the midline and travel as the **anterior spinocerebellar tract**.

3. Cuneocerebellar Tract

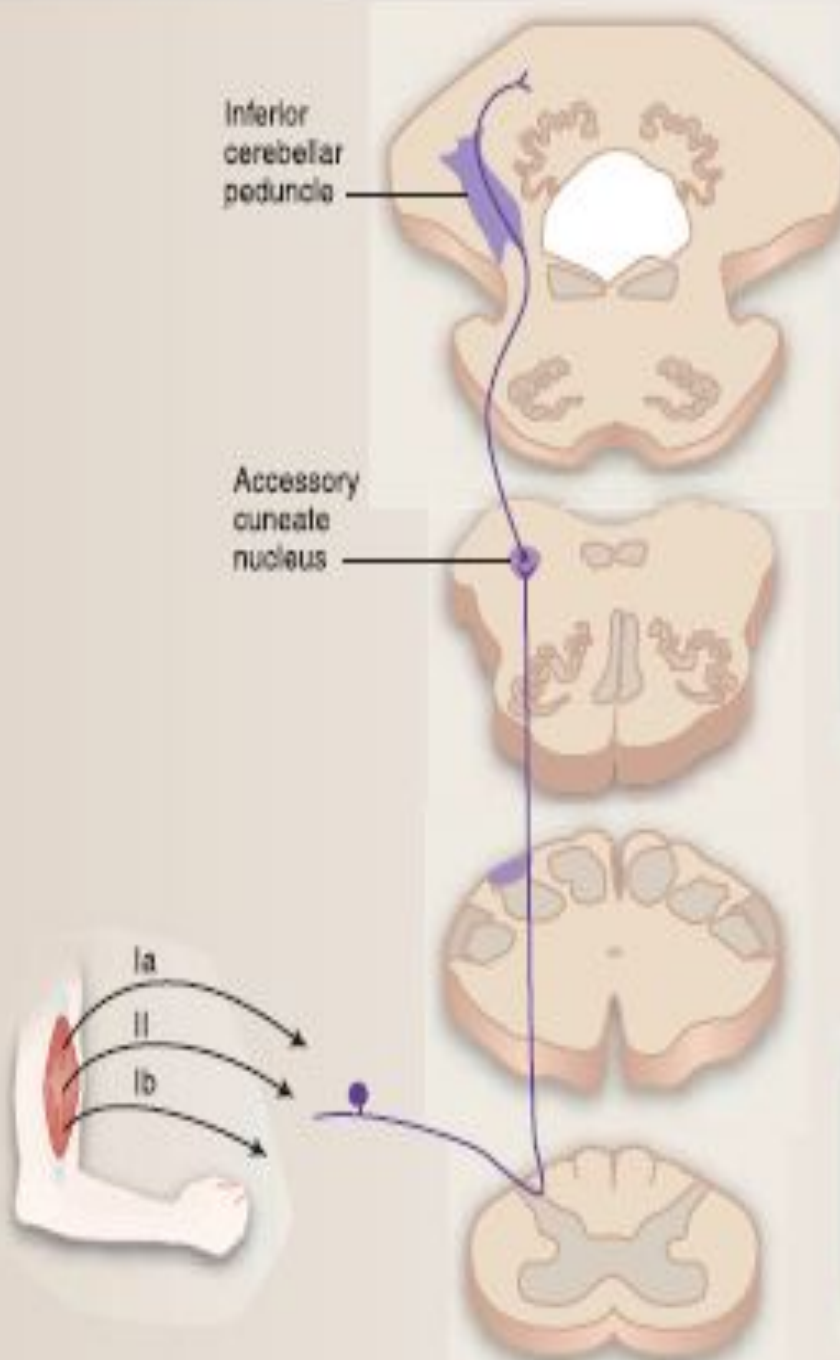
a. First-order neurons:

- Found in **the posterior spinal root ganglia** “C2 to T7”.
- Project their axons via the Cuneate tract to the medulla, where they synapse in the **accessory cuneate nucleus** (similar to Posterior thoracic nucleus “Clarck’s nucleus”).

b. Second-order neurons:

- Located in **the accessory cuneate nucleus** of the medulla.
- Give rise to axons that project **ipsilaterally** to the cerebellum via **the inferior cerebellar peduncle**.

Cuneocerebellar Tract



2

Cuneocerebellar fibers originate in the accessory cuneate nucleus in the rostral medulla and then travel through the ICP to the ipsilateral cerebellum, mainly to the anterior lobe, vermis and intermediate zone.

1

Ia, Ib, and II fibers as well as fibers from skin receptors enter the spinal cord above C8 and travel with the fasciculus cuneatus to the rostral medulla.

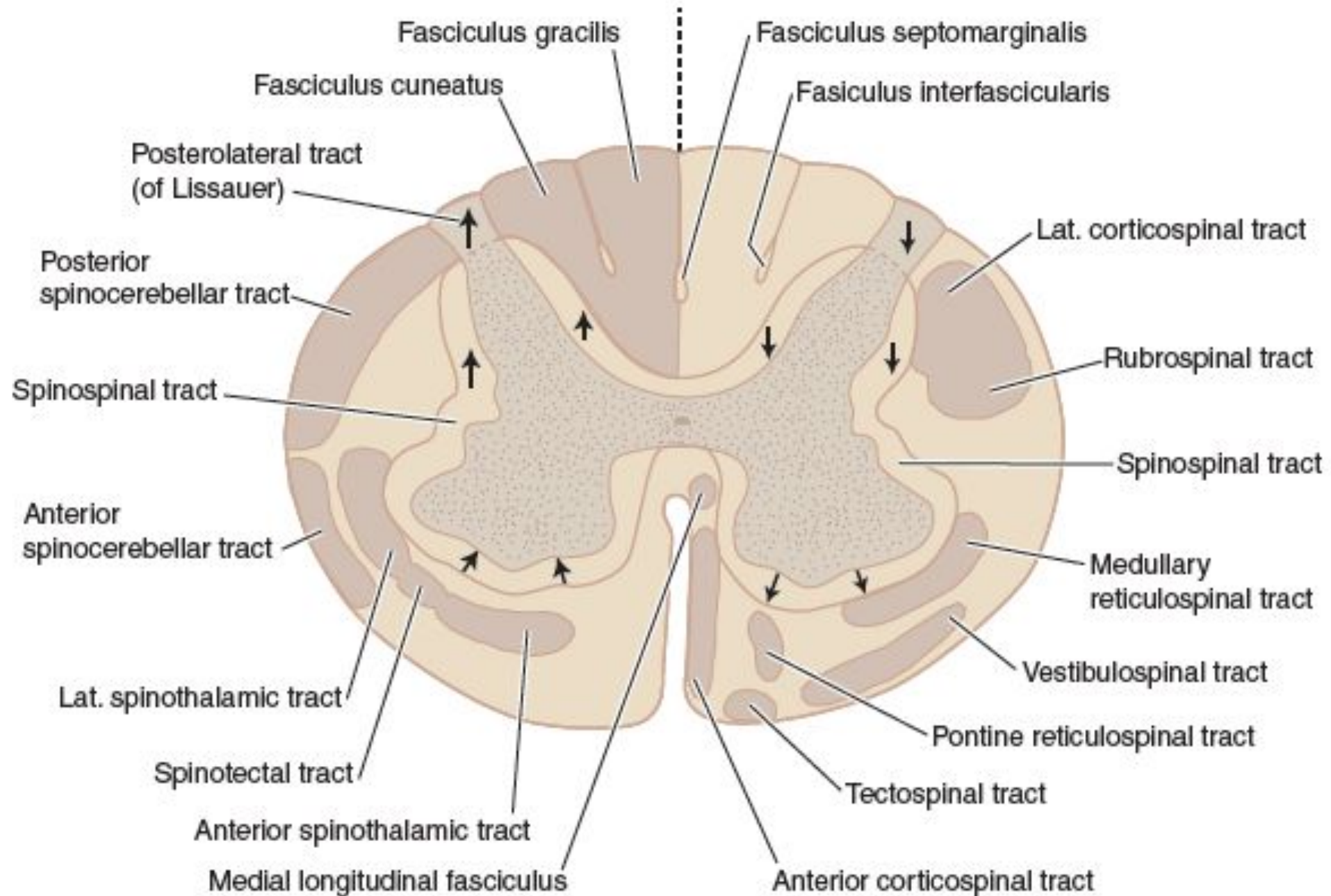
Descending Tracts of the Spinal Cord

- A. **Lateral corticospinal (LC):** crossed pyramidal tract.
- B. **Rubrospinal tract (LC):** an extrapyramidal tract.
- C. **Lateral reticulospinal tract (LC):** an extrapyramidal tract.
- D. **Hypothalamospinal tract (LC):** the fibers arise from the hypothalamus & end in autonomic cells in the lateral horns.
- E. **Olivospinal tract (LC):** an extrapyramidal tract.

- 
- F. **Sulcomarginal tract (AC):** is very close to anterior median fissure.
 - G. **Anterior corticospinal tract (AC):** contains uncrossed corticospinal fibers.
 - H. **Medial reticulospinal tract (AC):** an extrapyramidal tract.
 - I. **Tectospinal tract (AC):** arises from the superior colliculus of midbrain & the fibers end in the A.H.Cs. (spinovisual reflexes).
 - J. **Vestibulospinal tract (LC):** for equilibrium arises from vestibular nuclei & ends in the A.H.Cs.

Ascending tracts

Descending tracts



The Pyramidal Tract

- The pyramidal tract is a bundle of motor nerve fibers.
- It begins in the cerebral cortex and ends in:
 - a. **Anterior horn cells of the spinal cord**
(corticospinal tract).
 - b. **Motor nuclei of the cranial nerves** in the brain stem (corticonuclear or corticobulbar tract).
- The pyramidal tract consists of:
 1. Corticospinal tracts (lateral & ventral).
 2. Corticonuclear or corticobulbar tracts (Lateral & Medial).

The Upper Motor Neuron System (Corticospinal Tract)

:Function

1. Initiation and control of voluntary motor activity.
2. Inhibition of muscles tone.
3. Inhibition of deep reflexes.

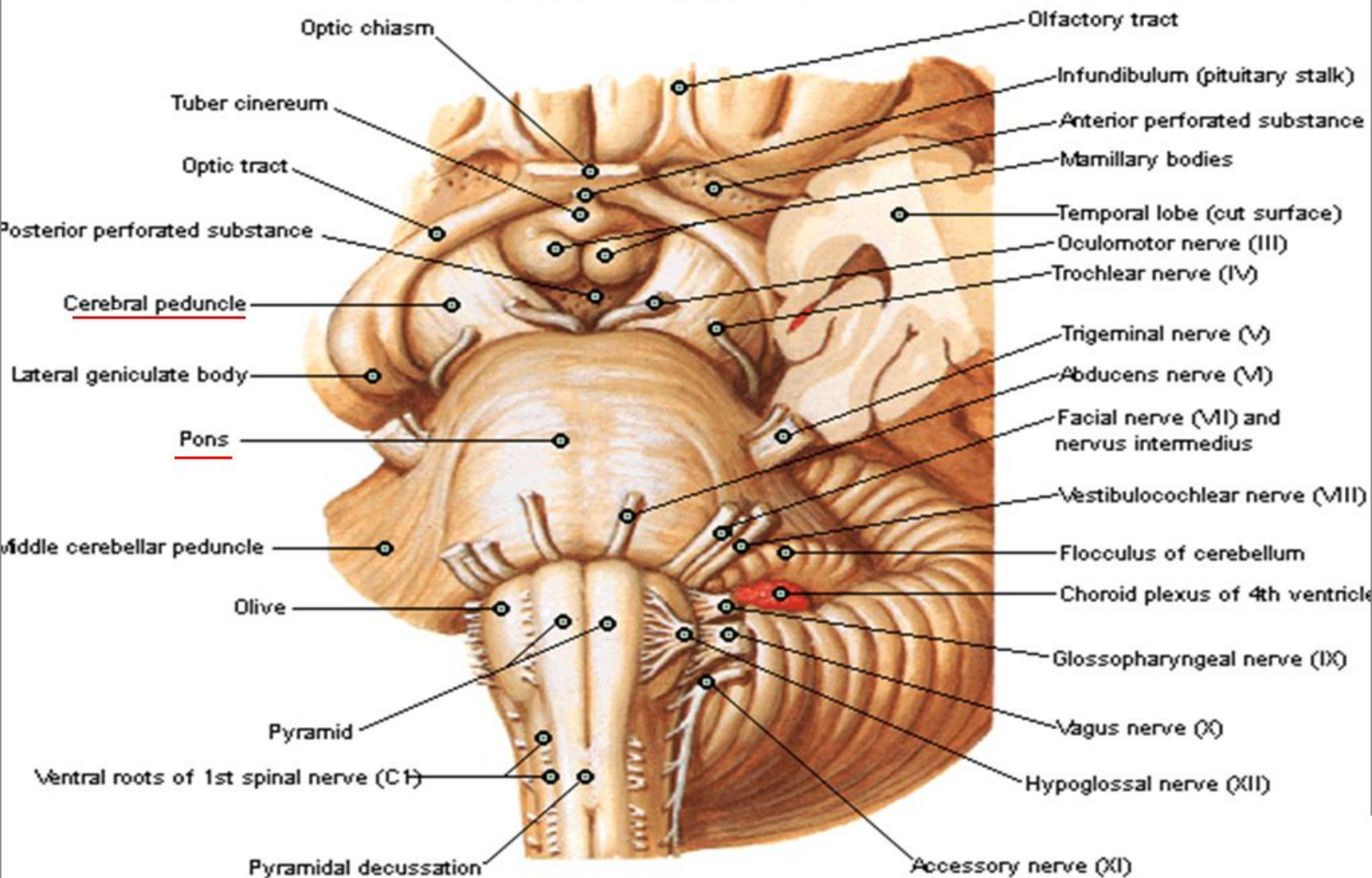
A. The Lateral Corticospinal Tract

B. The Anterior Corticospinal Tract

- ❖ From Betz cells in motor area 4 (in the upper 2/3 precentral gyrus of frontal lobe) → descends in the corona radiata → pass in the posterior limb of the internal capsule → descends in midbrain, pons and medulla oblongata.
- ❖ In the medulla the pyramidal fibers collect to form the pyramid → **pyramidal decussation.**

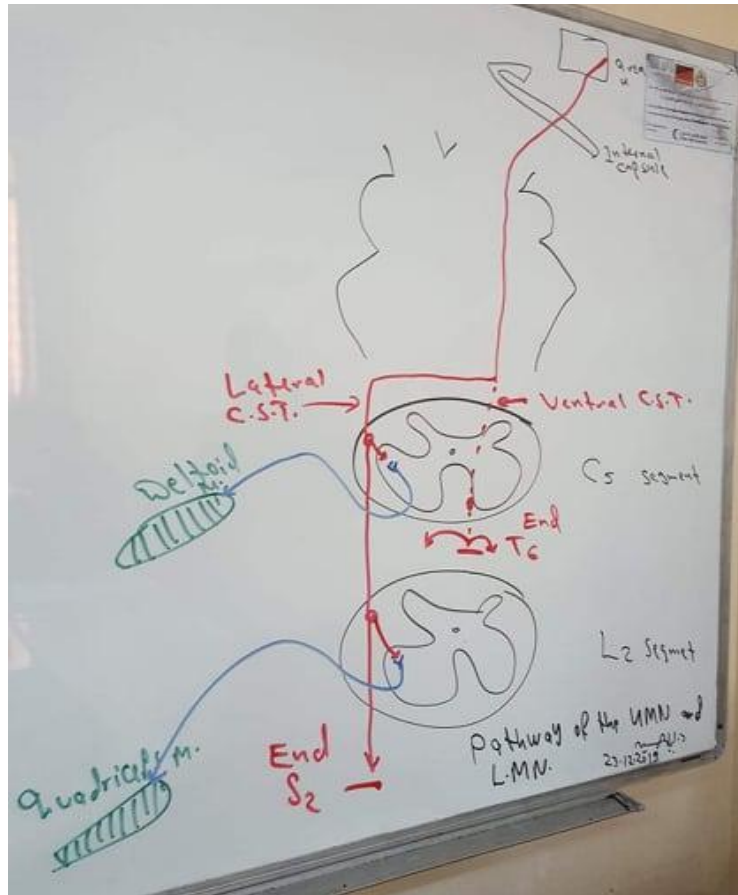
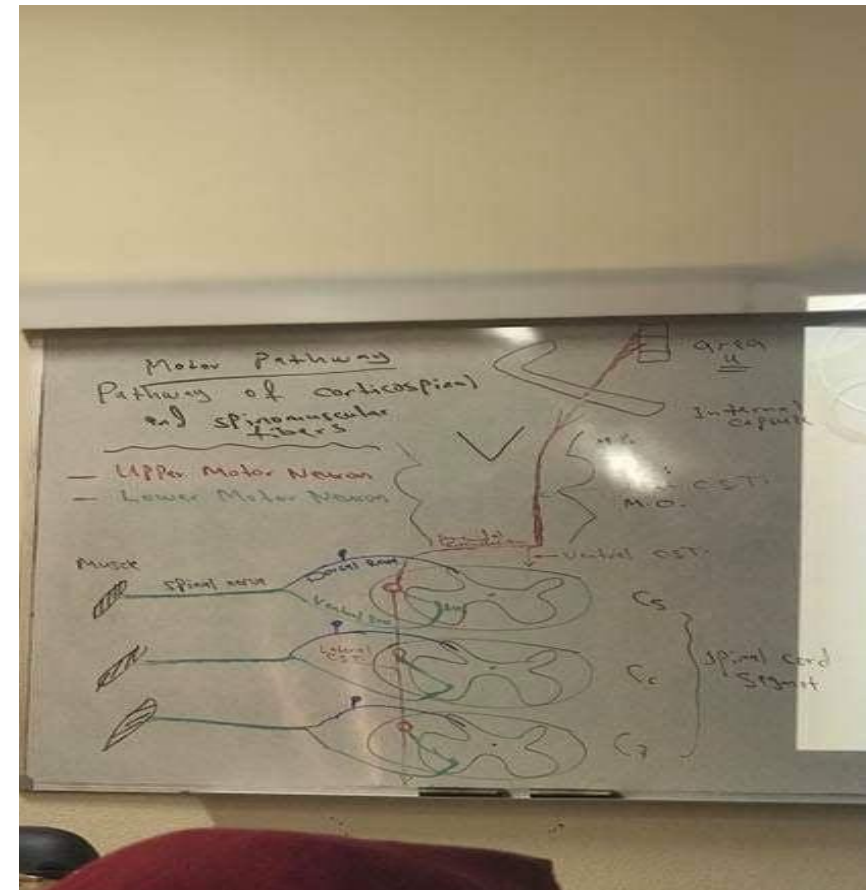
Brainstem

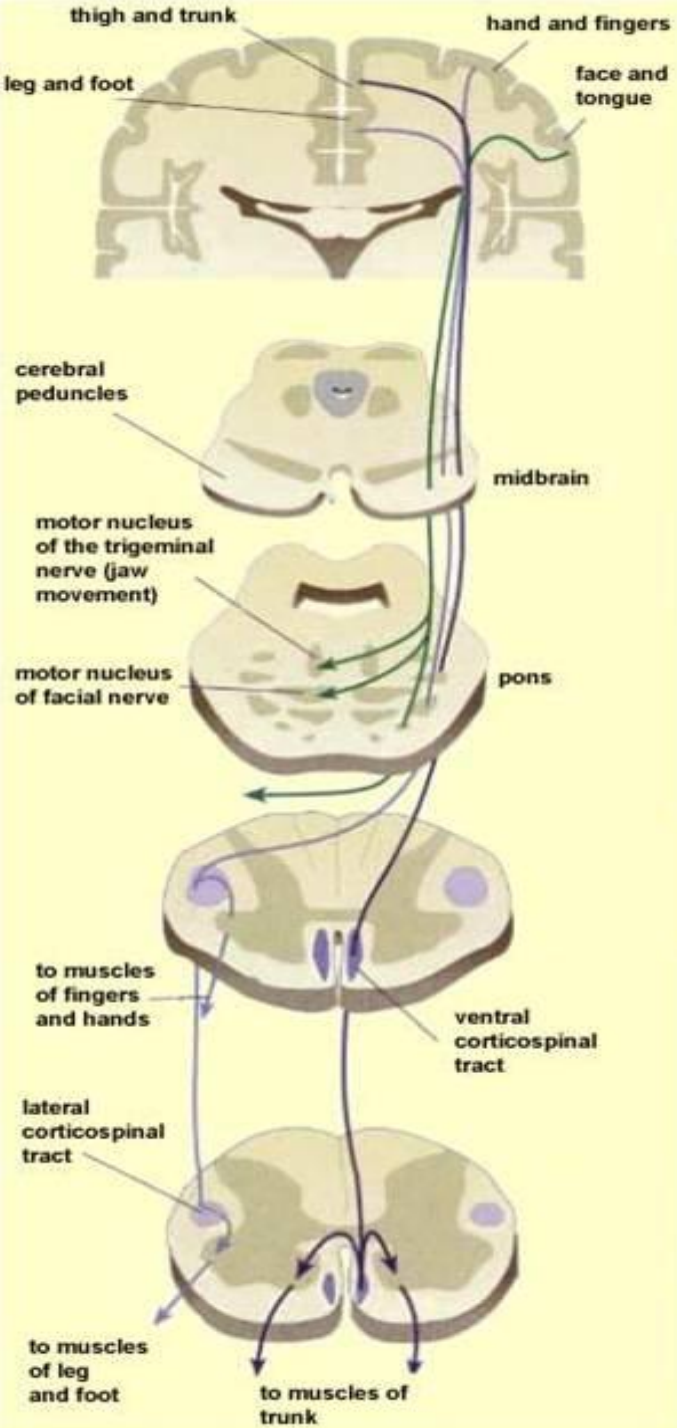
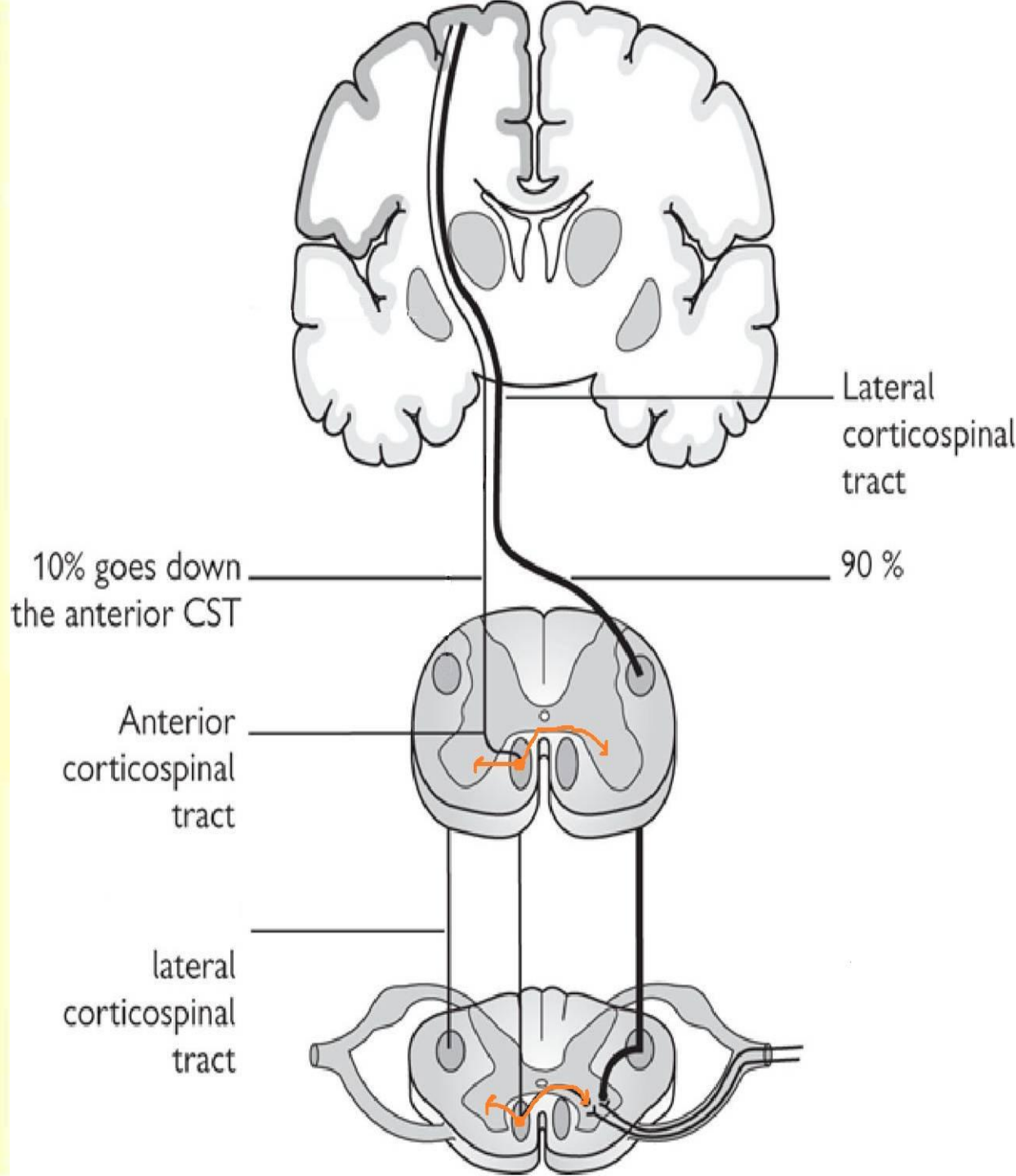
Anterioinferior View

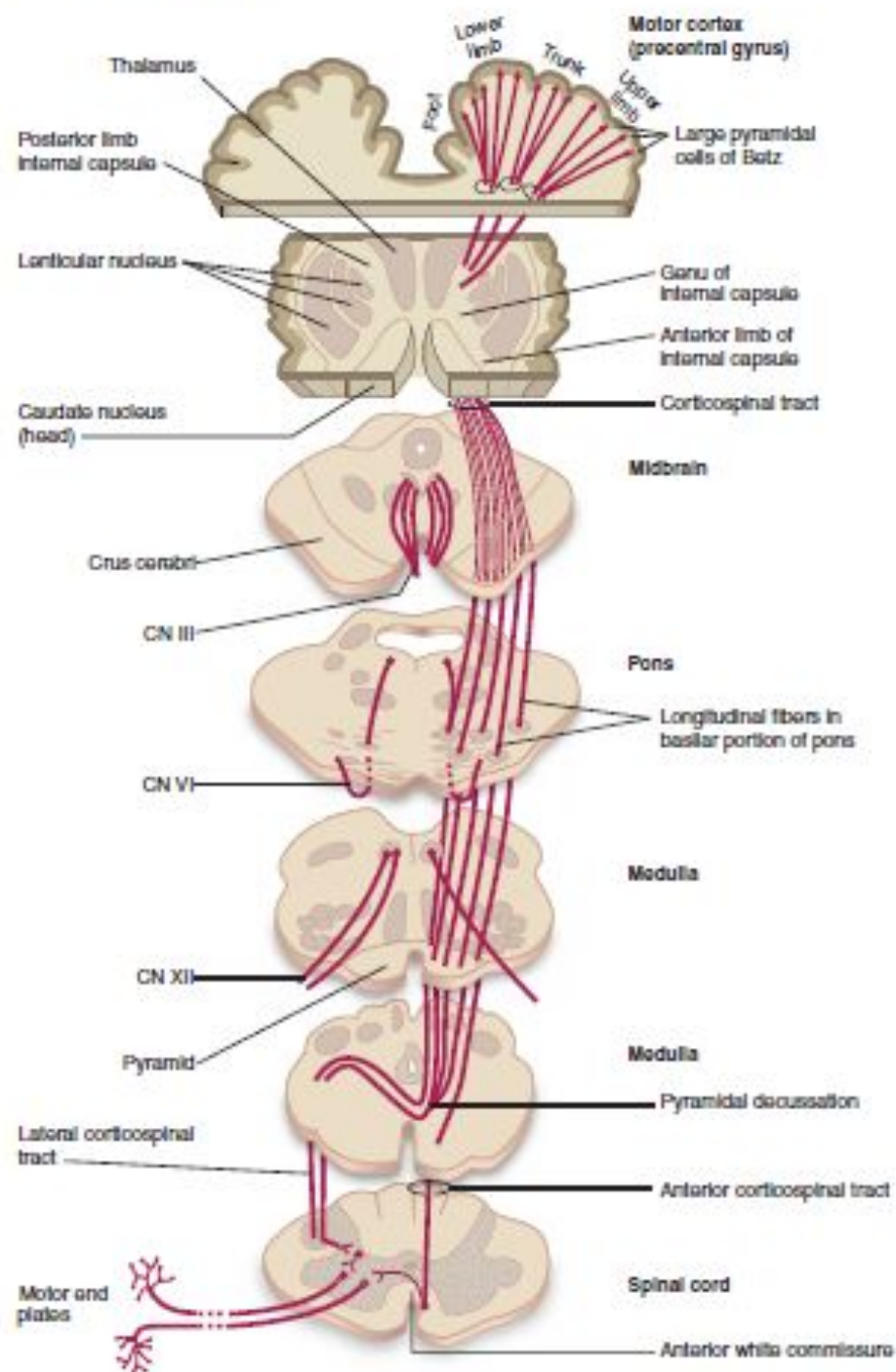


□ In the lower medulla:

- a. 85 - 90% of fibers decussate to descends → in the lateral column of the opposite side of the spinal cord (**indirect or lateral crossed corticospinal tract**). The tract gradually diminishes in size and ends about the level of S3 or S4 segment of the SC. **For regulation of voluntary movement.**
- b. 10 - 15% of fibers descend directly → in the anterior column of the same side (**direct or anterior corticospinal tract**) then gives fibers for AHCs at the segmental level in **both side**. They descend in the spinal cord until they disappear in **the midthoracic region**.







The Corticospinal Tract

- The motor area of one side of cerebral hemisphere is responsible for movement of the muscles of the opposite $\frac{1}{2}$ of the body (mainly the limbs).
- Anterior or direct corticospinal tract end in both AHCs to supply the trunk and respiratory muscles.
- The muscles of respiration are received fibers from both cerebral hemispheres. This explain the absence of respiratory paralysis in hemiplegic person.

The Lower Motor Neuron System

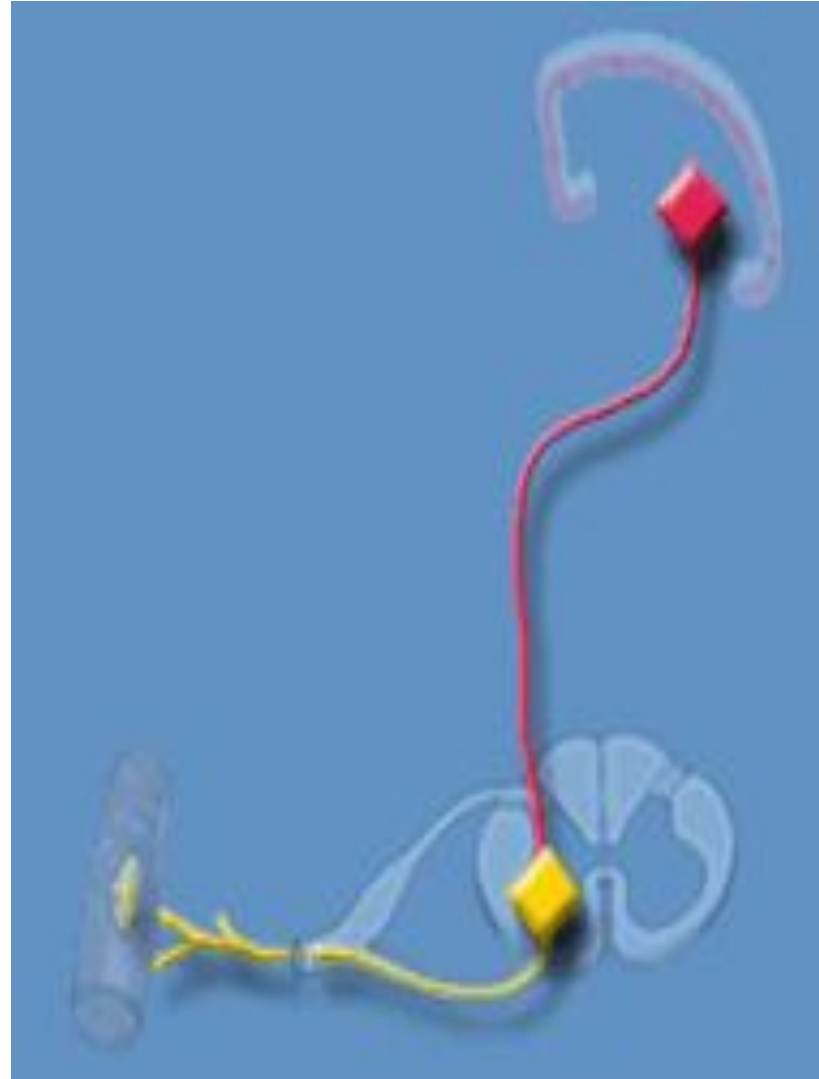
(Spinomuscular Fibers)

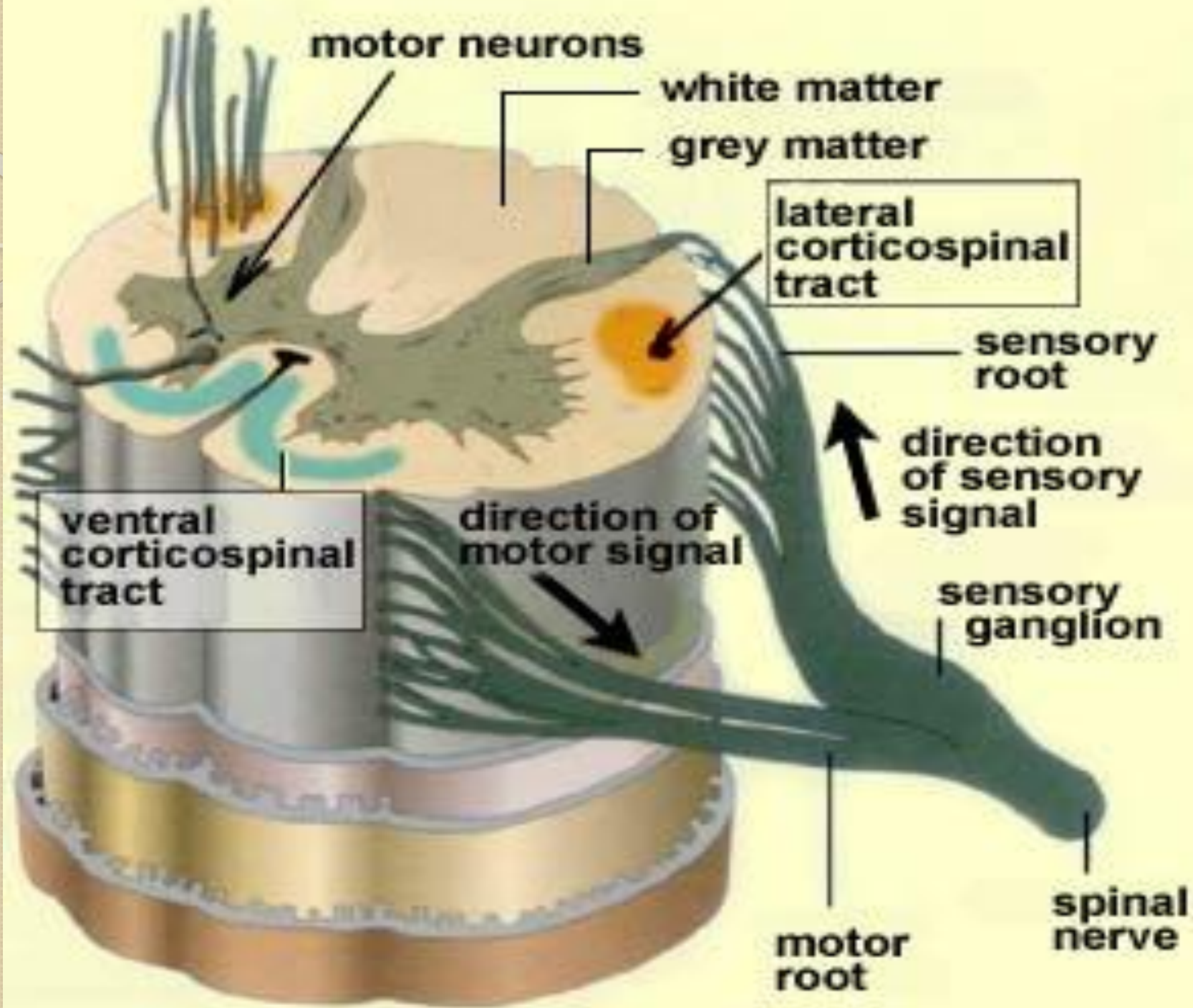
Function:

1. Stimulation of voluntary motor at the level of the same side.
2. Stimulation of muscles tone at the level of the same side.
3. Stimulation of deep reflexes at the level of the same side.

Pathway of the Lower Motor Neuron System (Spinomuscular fibers)

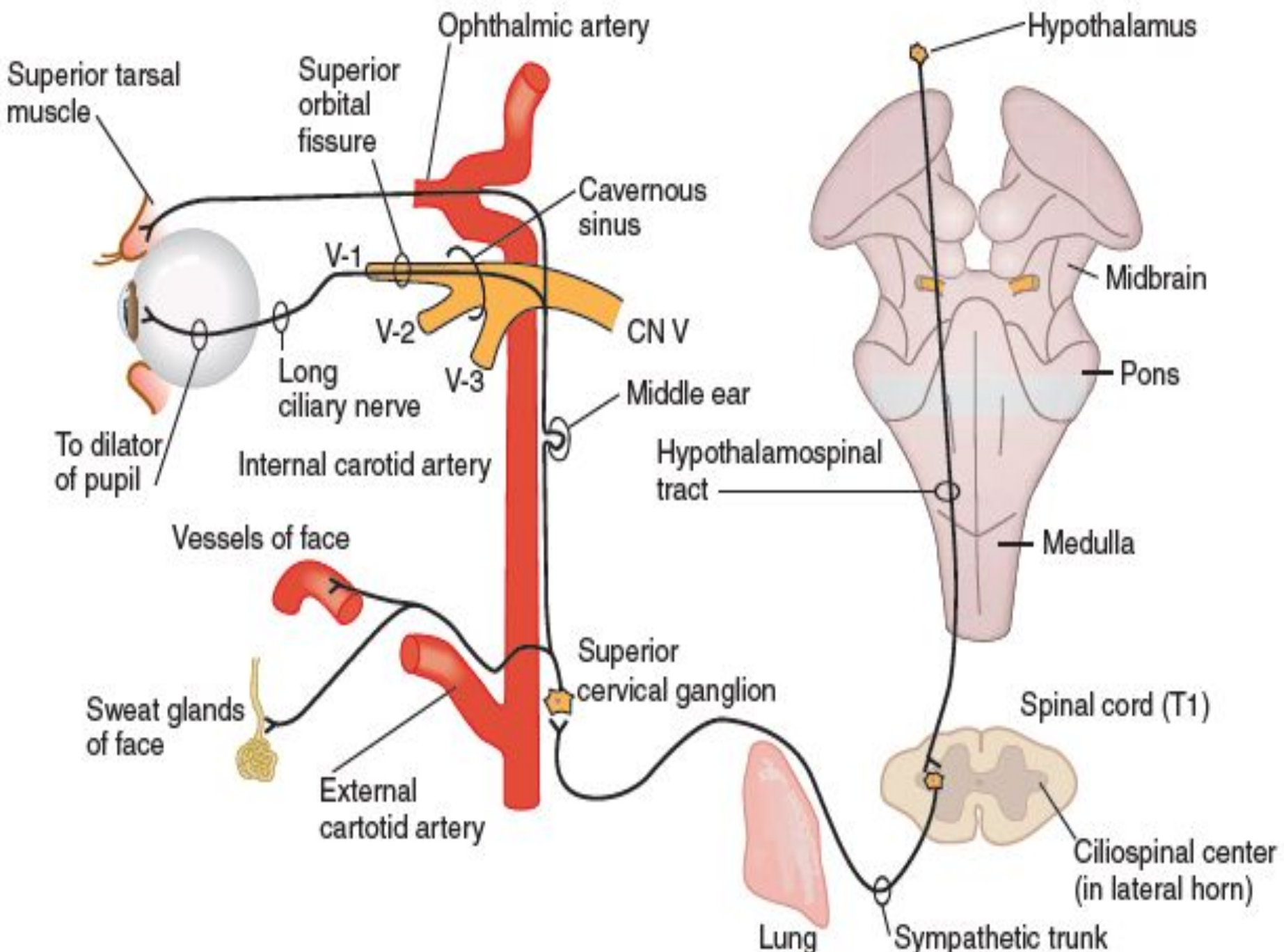
From AHCs of the spinal cord
→ fibers exit from the spinal
cord as the anterior roots of
the same side → peripheral
nerves → motor end plate →
.voluntary muscles





C. Descending Autonomic Tract “Hypothalamospinal Tract”

- Project to sympathetic (T1–L2) and parasympathetic (S2–S4) centers in the spinal cord.
- Innervate the ciliospinal center (T1–T2), a pupillary center.
- Found in the posterior quadrant of the lateral column.
- **Interruption of this hypothalamospinal tract:**
results in **Horner syndrome**.



Horner's Syndrome

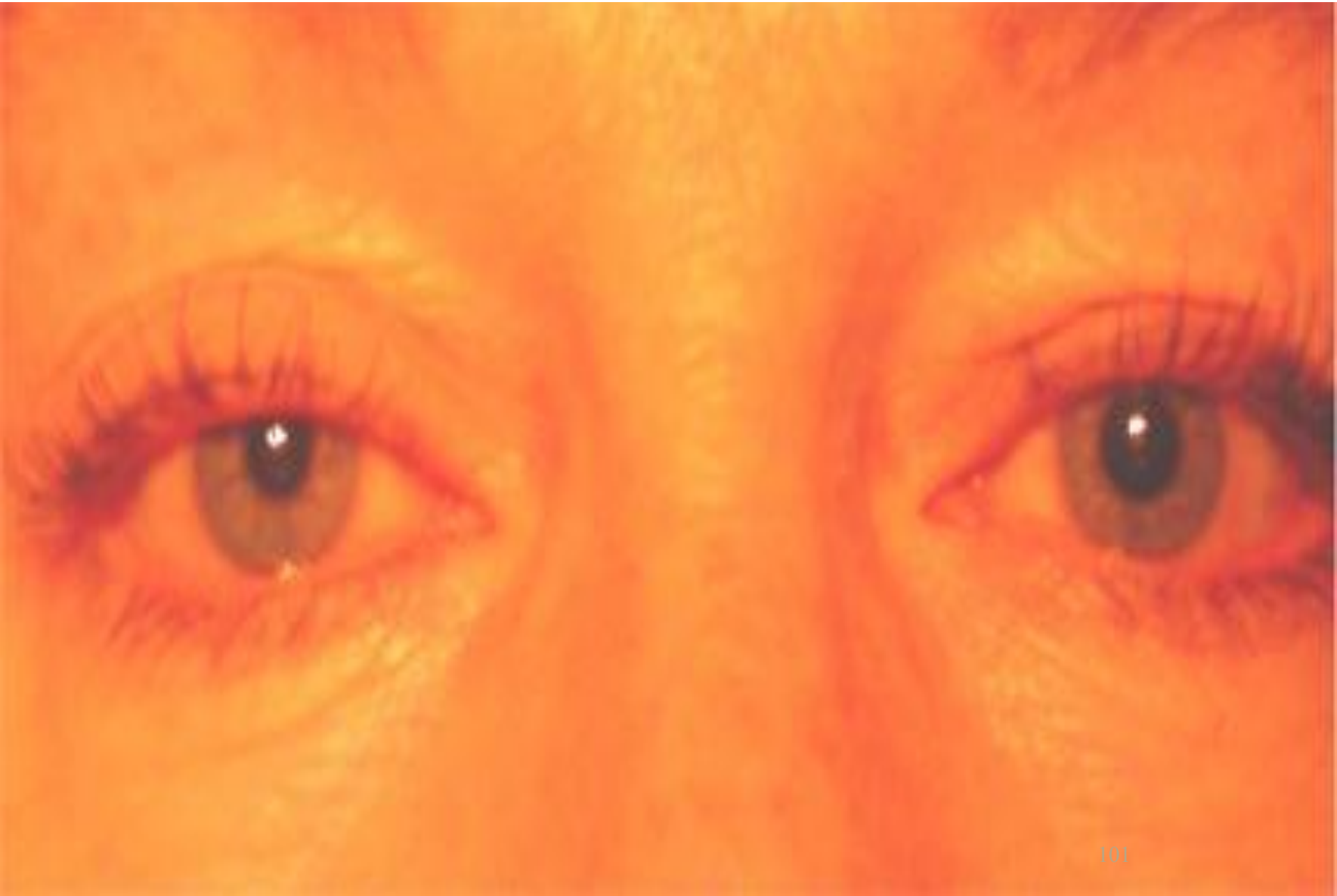
□ Horner's Syndrome:

- Partial ptosis “paralysis of the Müller's muscle”.
- Miosis.
- Enophthalmus.
- Anhidrosis.

□ Causes:

- **Brain lesion:** (massive ischemic stroke, brain stem lesion).
- **Cervical cord lesion:** (syringomyelia and cervical spinal cord tumor),
- **Neck pathology:** (Pancoast tumor, cervical rib, neck surgery)

Horner's Syndrome



Classification of the Motor Neuron Lesion

I. According to the location of the lesion:

1. Upper motor neuron lesion (spastic or central paralysis).
2. Lower motor neuron lesion (flaccid or peripheral paralysis).

II. According to the affected limbs:

1. Monoplegia (Rt. UL or LL, Lt. UL or LL): paralysis of one limb.
2. Hemiplegia (Rt. or Lt. sided): paralysis of one side of the body.
3. Paraplegia: paralysis of both limbs.
4. Triplegia: paralysis of three limbs (one upper and two lower limbs).
5. Quadriplegia (tetraplegia): paralysis of four limbs.
6. Bilateral hemiplegia.

Lower Motor Neuron lesions (LMNL)

- Result from damage to motor neurons of the anterior horns or motor neurons of the cranial nerve nuclei.
- Result from interruption of the final common pathway connecting the neuron via its axon with the muscle fibers it innervates (the motor unit).

Signs of the Lower Motor Neuron lesions (LMNL)

1. Flaccid paralysis.
2. Muscle atrophy (hypotrophy).
3. Muscle hypotonia.
4. Areflexia of deep tendon and superficial reflexes.
5. Muscle fasciculations (visible muscle twitches).
6. Muscle fibrillations (on electromyography).

Diseases of Lower Motor Neuron lesions

- 1. Anterior horn cells lesion:** spinal muscular atrophy, poliomyelitis, and syringomyelia.
- 2. Peripheral nerve lesion:** mononeuropathy, polyneuropathy.
- 3. Motor end plate lesion:** myasthenia.
- 4. Muscle disease:** myopathy.

Upper Motor Neuron lesions (UMNL)

- Lesions of the corticospinal and corticobulbar tracts
“Pyramidal tract lesions”.
- May occur at all levels of the neuroaxis from the cerebral cortex to the spinal cord.
- When the lesion above the pyramidal decussation, the motor deficit present below the lesion, on the contralateral side.
- When the lesion below the pyramidal decussation, the motor deficit present below the lesion, on the ipsilateral side.

Signs of the Upper Motor Neuron lesions (UMNL)

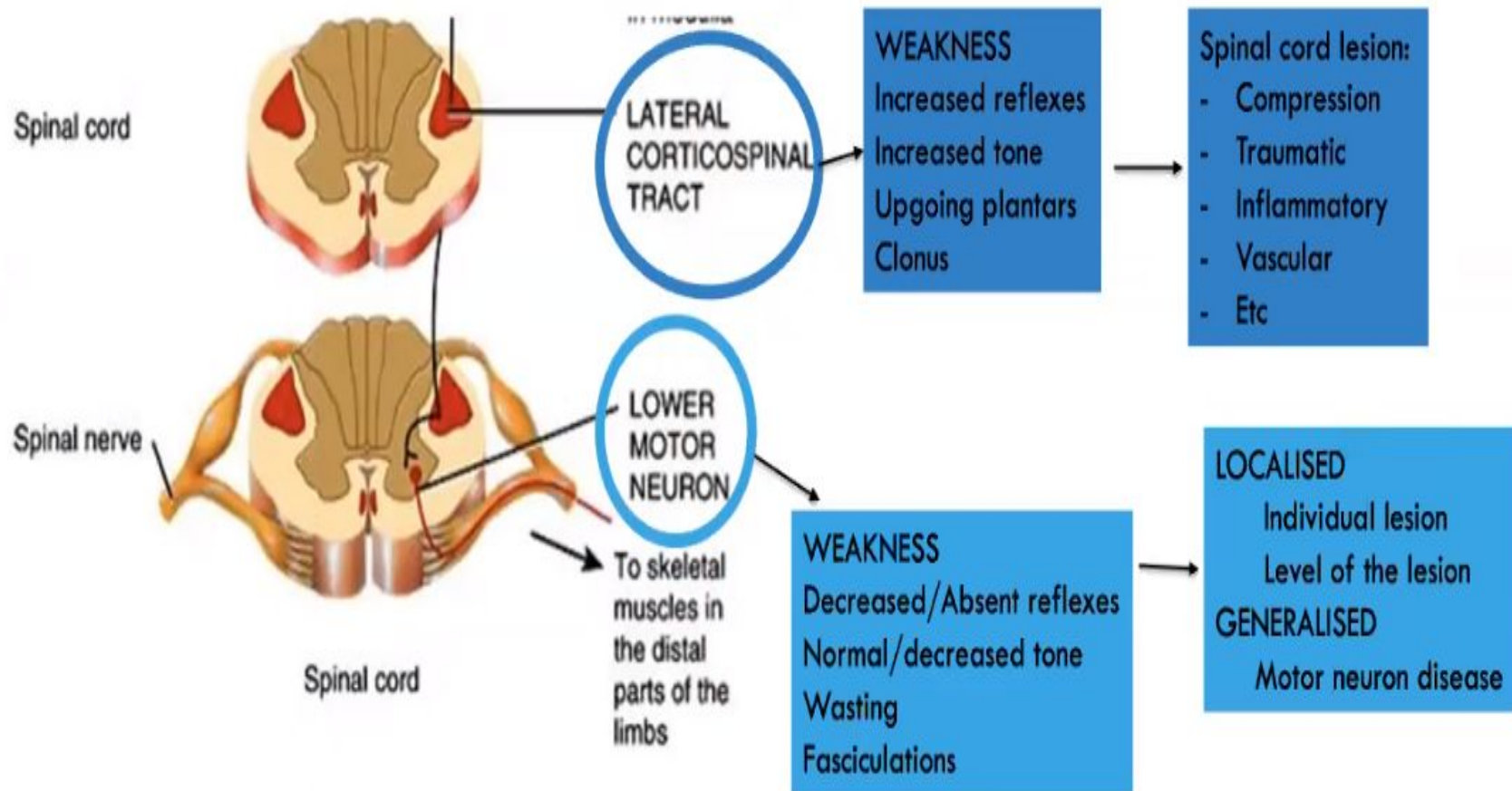
1. Spastic paralysis.
2. Hyperreflexia of deep tendon reflexes.
3. Clonus: rhythmic contractions of muscles in response to sudden, passive movements (patellar, or ankle clonus).
4. Loss of superficial (abdominal and cremasteric) reflexes.
5. Muscle hypertonia “Clasp-knife spasticity”: when a joint is moved briskly, resistance occurs initially and then fades.
6. Babinski sign: plantar reflex response that is extensor (dorsiflexion of big toe).

Diseases of Upper Motor Neuron lesions

1. CVA.
2. Multiple sclerosis.
3. Brain and spinal cord tumors.
4. **Inflammatory:** encephalitis, transverse myelitis.
5. **Traumatic:** head trauma, subdural hematoma, spinal cord trauma.
6. Congenital: cerebral palsy, hereditary spastic paraplegia.
7. **Degenerative:** vertebral spondylosis and myelopathy.
8. **Motor neuron disease.**

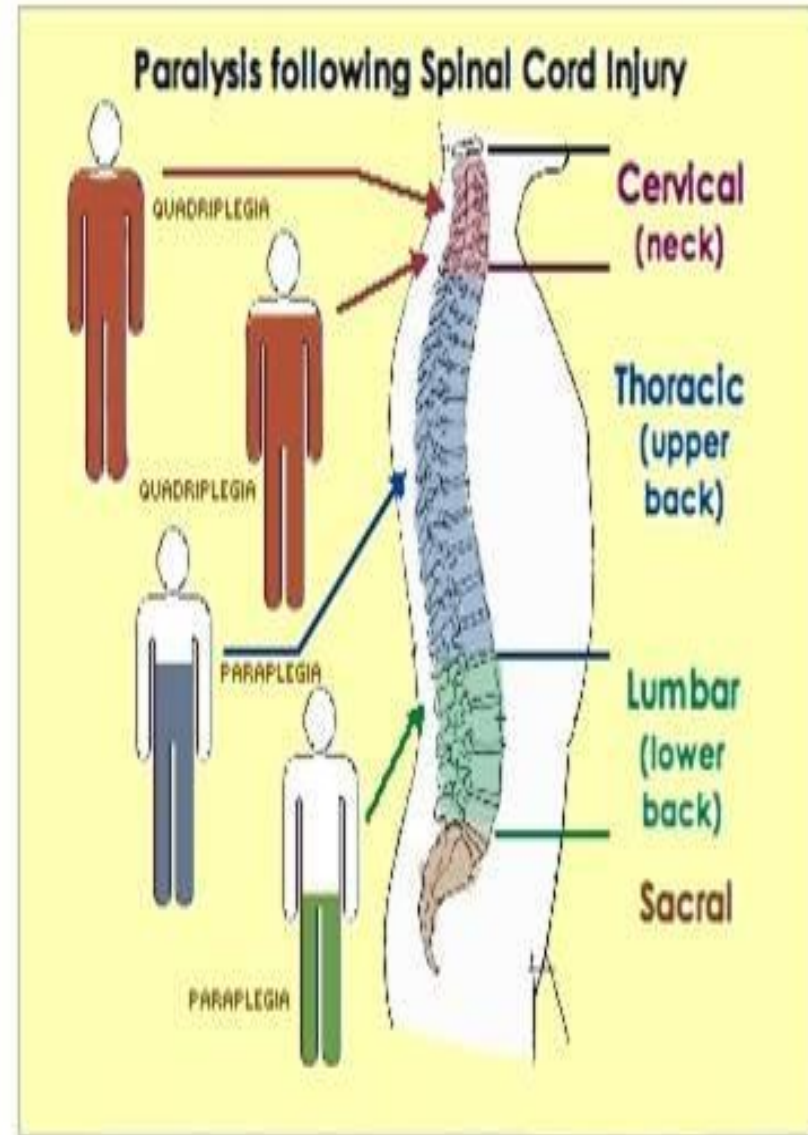
Differential between the UMNL & LMNL

	U.M.N. LESION	L.M.N. LESION
1. Location of lesion	From area 4 until AHCs	From AHCs until muscles
2. Location of paralysis	Below the level of lesion: Contralateral (above decussation) and ipsilateral (below decussation)	Ipsilateral at the level of lesion
3. Paralysis	Spastic or central	Flaccid or peripheral
I. MUSCLES		
1. State of the muscles	Wasting occurs very late due to disuse	Wasting occurs early (hypotrophy)
2. Muscle tone	Hypertonia (spasticity)	Hypotonia (flaccidity)
Muscle fasciculation .3 (spontaneous contraction of muscles group).	Absent	May be present in the irritative lesions of AHCs
II. REFLEXES		
1. Deep reflexes	Hyperreflexia	Hyporeflexia or areflexia
2. Clonus (Rhythmical series of contraction in response to sudden stretch of muscle tendon).	May be present	Absent
3. Pathological reflexes (Babinski reflex)	+ve (dorsiflexion of big toe + fanning of other toes)	Absent
4. Superficial reflexes	Lost if the lesion is above segmental supply of the reflex	Lost if lesion involve the segmental supply of the reflex



Complete Spinal Cord Lesion

- ❑ Complete loss of motor power below the level of lesion.
- ❑ Complete loss of sensation (superficial and deep) below the level of lesion.
- ❑ Atonia and flaccidity with areflexia (in shock stage)
- ❑ Sphincter dysfunction.



Spinal Shock

- **Definition:** Immediately loss of all SC functions, including the spinal reflexes after sudden transection of the SC.
- **Duration:** From two weeks to several months.
- **Mechanism:** Due to sudden withdrawal of supraspinal facilitation on the alpha motor neurons.

Manifestation of the Spinal Shock

1. Quadriplegia or paraplegia (depending on the level of the lesion)
2. Loss of spinal reflex activity below the level of lesion:
 - Loss of deep and superficial reflexes.
 - Loss of muscle tone with flaccidity of the paralyzed muscles
 - Loss of erection, urination and defecation reflexes
3. Loss of all sensation below the level of lesion.
4. Vasodilatation and hypotension below the level of lesion.

Complication of the Spinal Shock

- DVT and pulmonary embolism.
- Hypotension (specially in cases of high-level spinal cord lesion).
- Muscle wasting.
- Bed sores due to ischemia of the areas are compressed against bed.
- Urine tract infection due to urine retention and stasis.
- Sepsis.
- Decrease of the body temperature due to reduction of the metabolic rate after loss of the muscle tone.

Incomplete Spinal Cord Lesion (Partial Transection)

If any form of sensation, motor power is preserved below the level of the lesion, spinal cord lesion is :considered incomplete

- Brown Sequard syndrome (hemicord lesion).
- Anterior cord lesion.
- Central cord lesion.
- Posterior cord lesion.

Brown-Sequard Syndrome

Hemisecion Lesion of the Spinal Cord

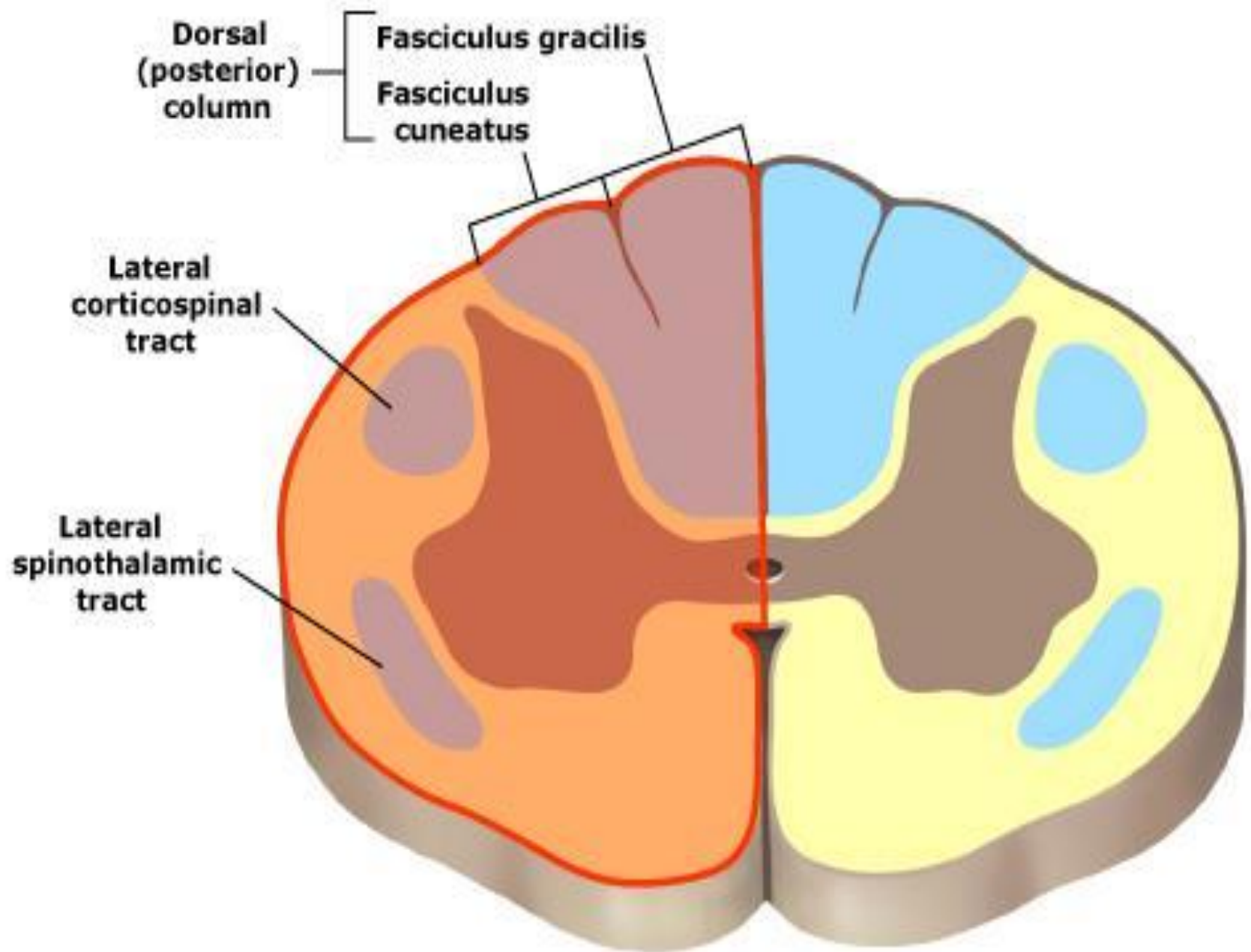
A. At the level of :

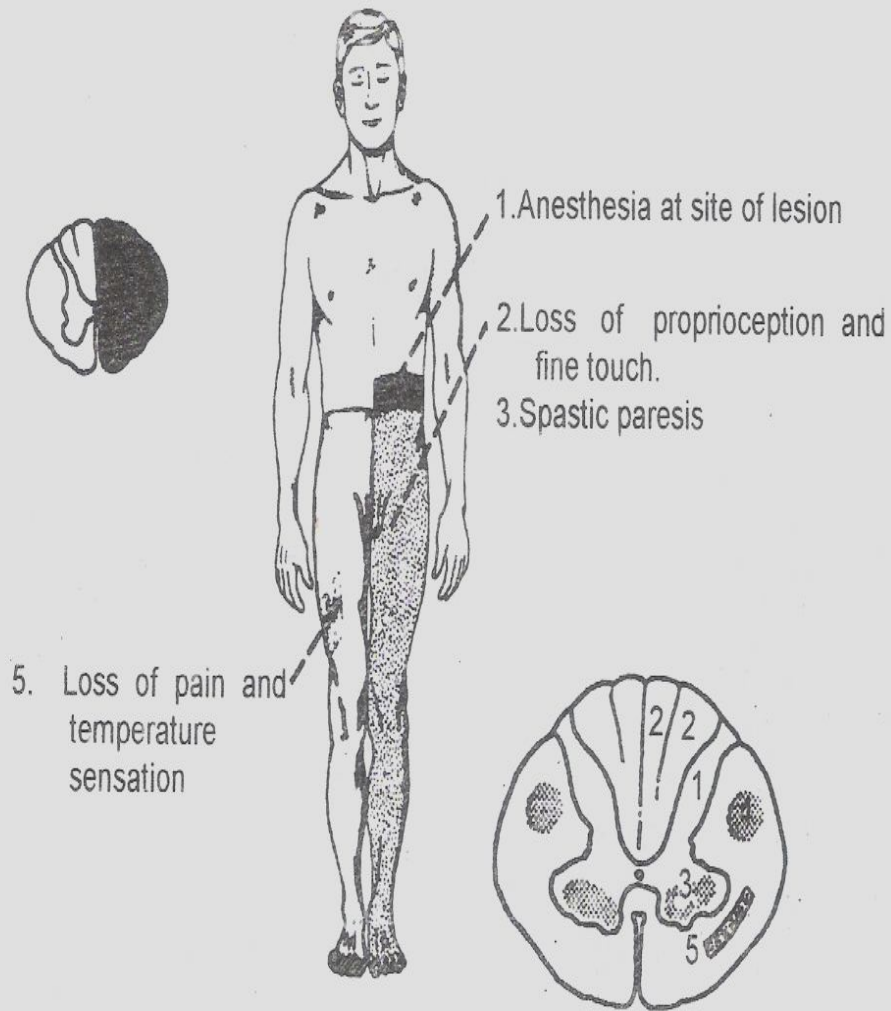
1. Ipsilateral zone of cutaneous anesthesia in the segment of the lesion (due to damage of afferent fibers that entered the cord (PHCs) & have not yet crossed).
2. Ipsilateral lower motor neuron paralysis in the segment of the lesion(due to damage of the lower motor neuron in the AHCs).

Brown-Sequard Syndrome

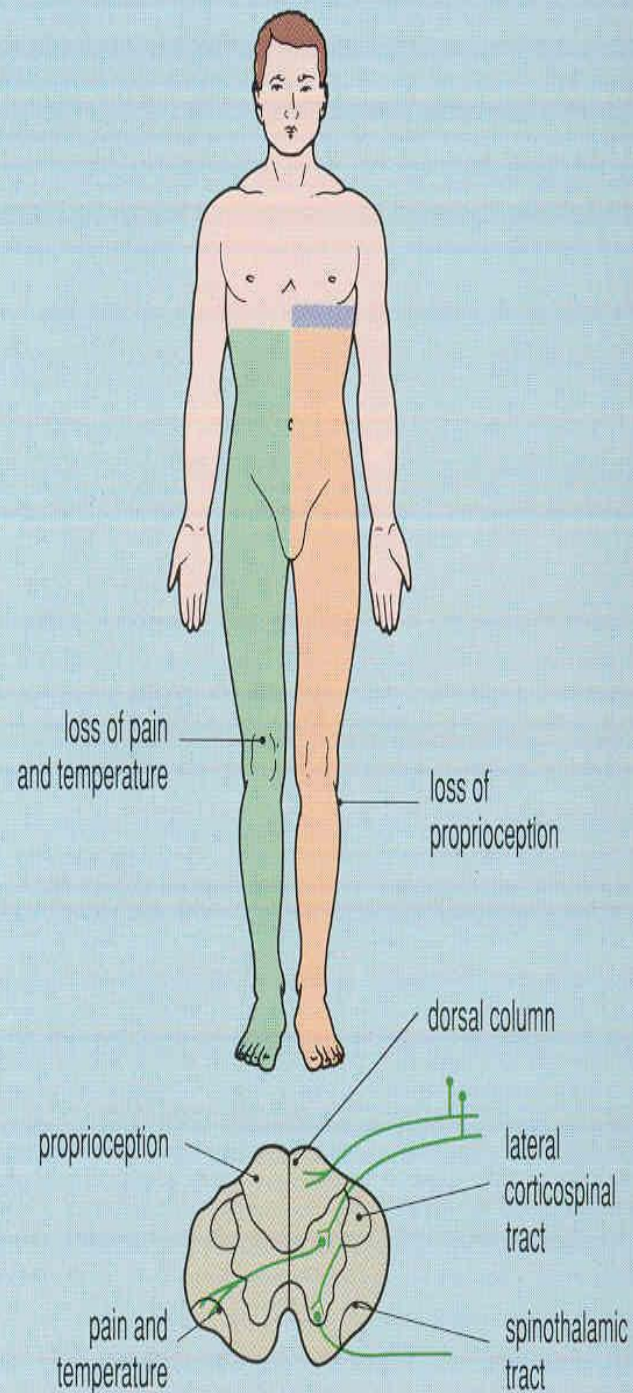
B. Below the level of lesion:

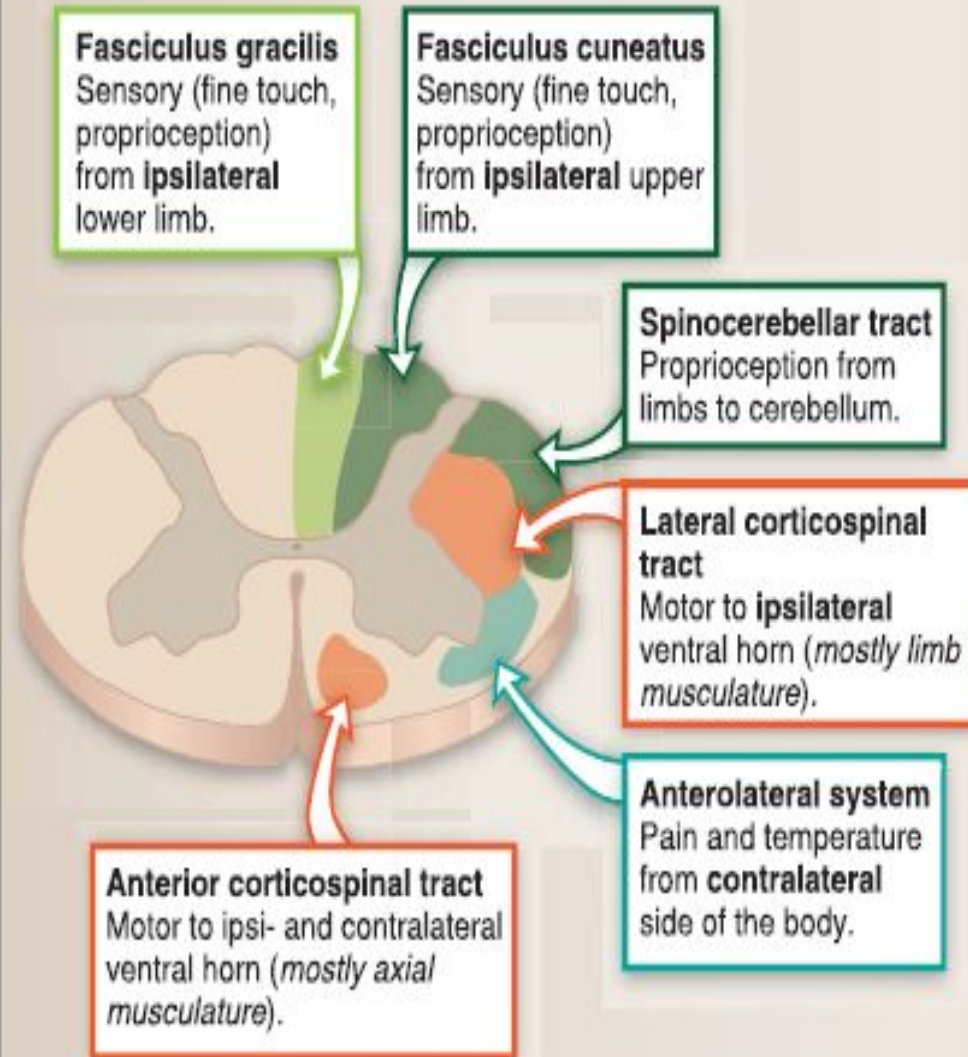
- ❑ Ipsilateral loss of proprioception & fine touch below the level of the lesion (due to damage of the dorsal column → cuneate and Gracile Tract).
- ❑ Ipsilateral upper motor neuron paralysis below the level of the lesion(due to damage of the lateral column → corticospinal tract).
- ❑ Contralateral loss of pain, temperature and crude touch sensations below the level of lesion (due to damage of lateral and ventral spinothalamic tract, which has decussated).



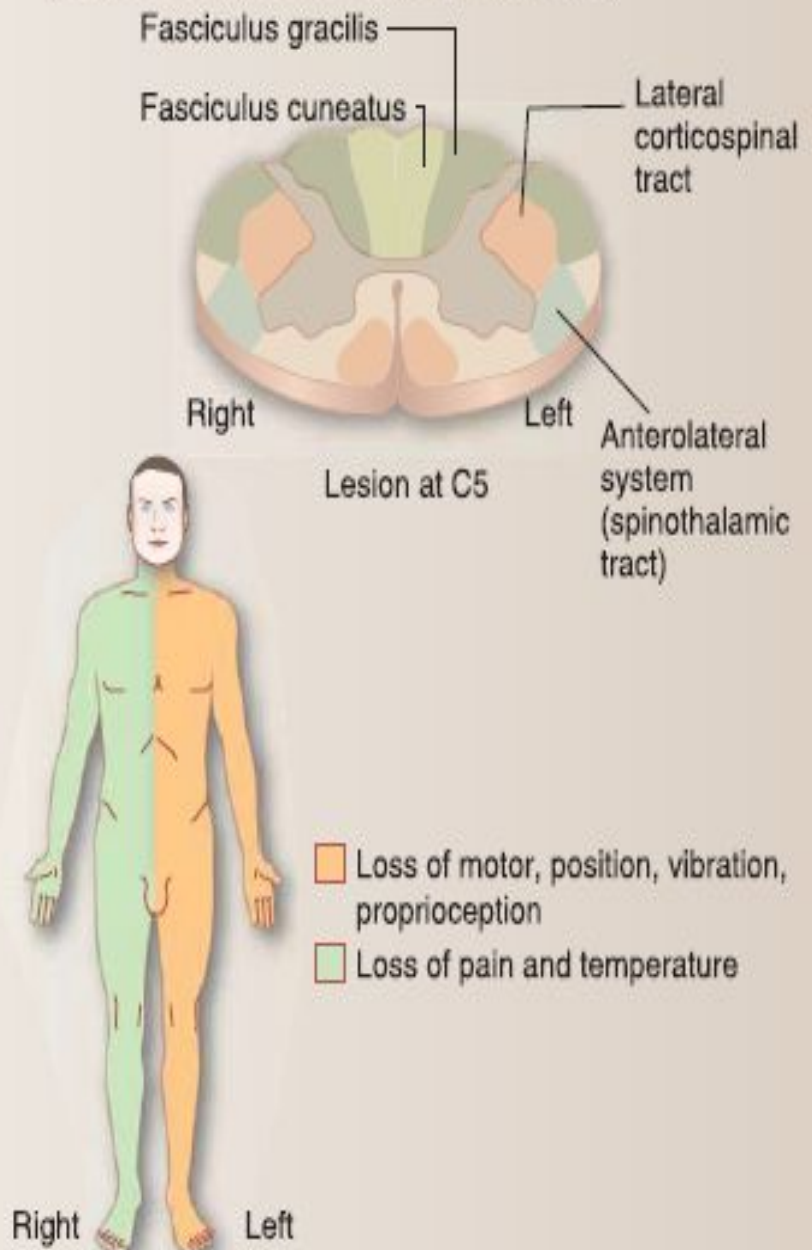


- | | |
|--------------------------------|---|
| 1. Sensory horn | : Ipsilateral anesthesia in the segment of lesion. |
| 2. Gracile, cuneate | : Ipsilateral loss of proprioception below lesion. |
| 3. A.H.Cs | : Ipsilateral LMN Lesion in the segment of the lesion. |
| 4. Crossed pyramid | : Ipsilateral UMN Lesion below the lesion. |
| 5. Lateral spinothalamic tract | : Contralateral loss of pain & temperature below the lesion |



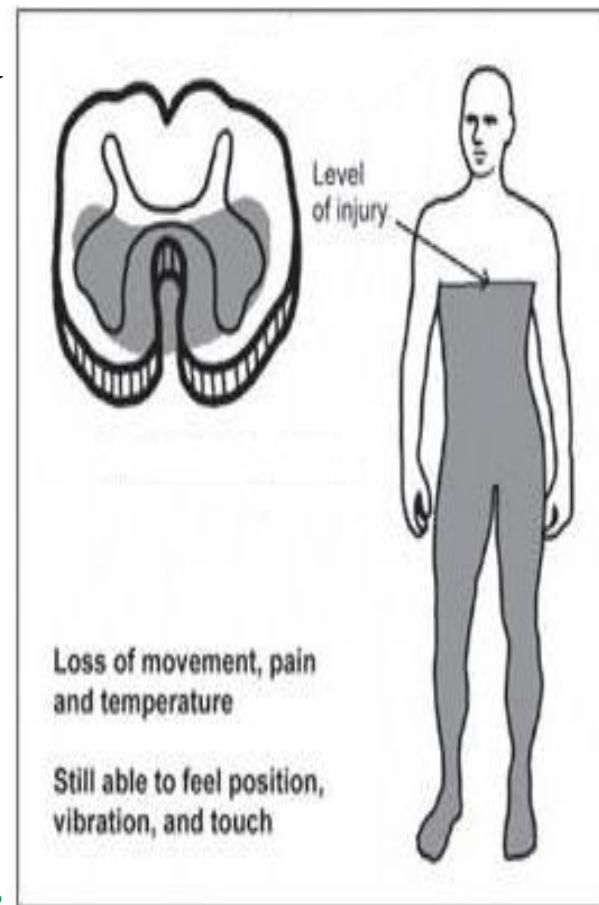


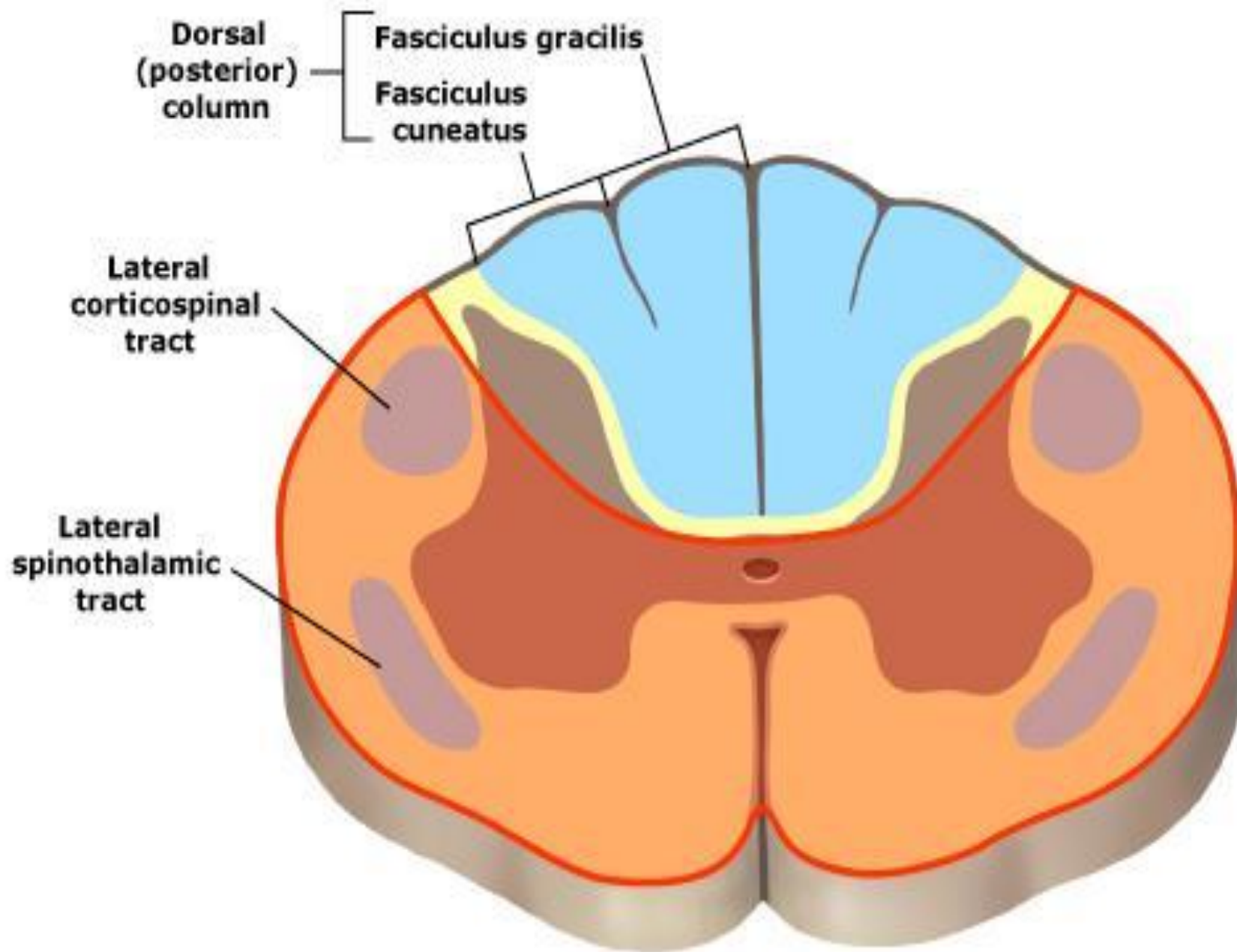
Hemisection (Brown-Séquard syndrome)



Anterior Spinal Cord Syndrome

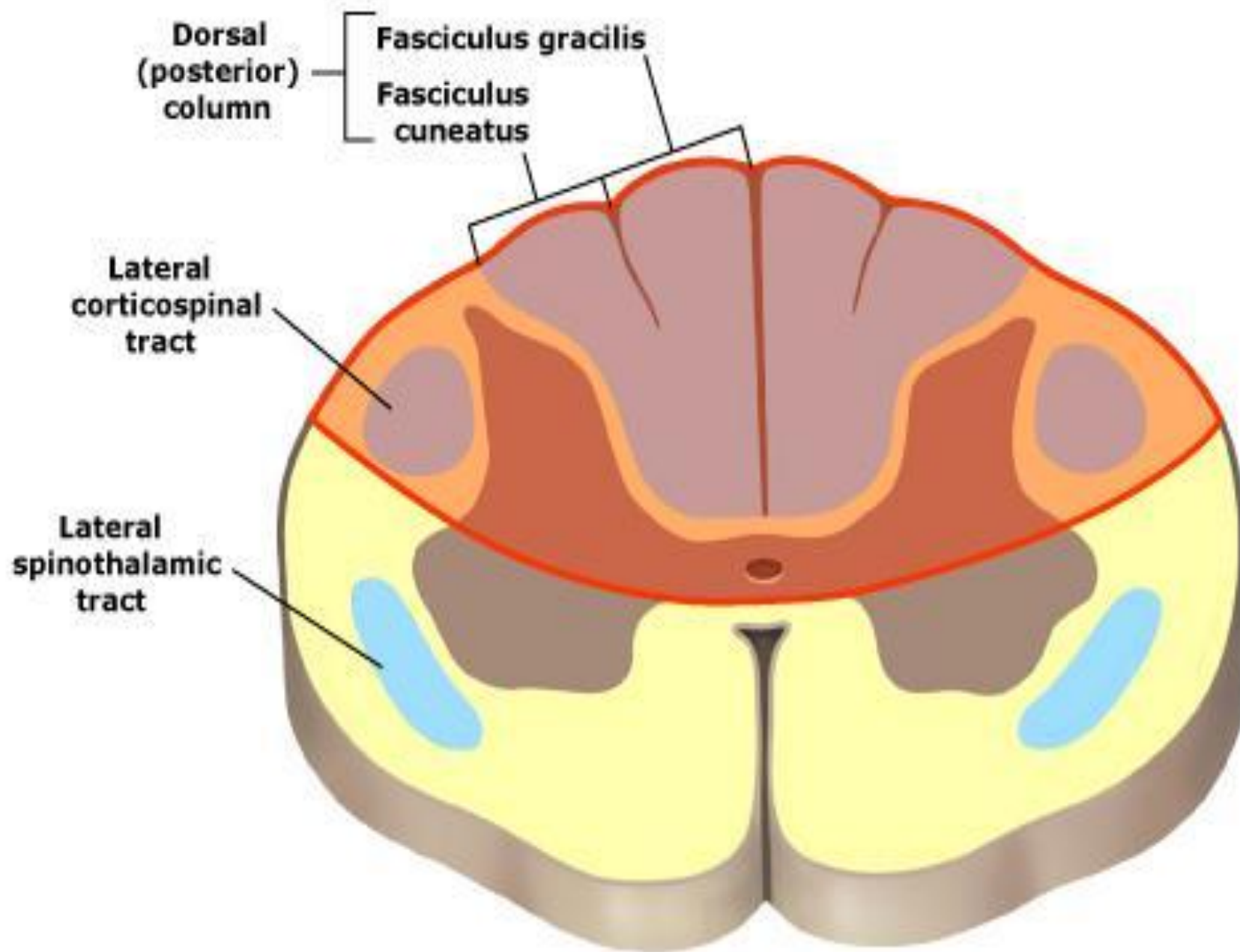
- ❑ Lesion of the anterior part of the SC, usually associated with a flexion injury and occlusion in the anterior spinal artery territory.
- ❑ Loss of motor function at lesion and below, decreased superficial sensation, including pain and loss of temperature sensation below the level of lesion.
- ❑ Dysfunction of sphincter tone.
- ❑ **Deep and fine sensation is preserved.**





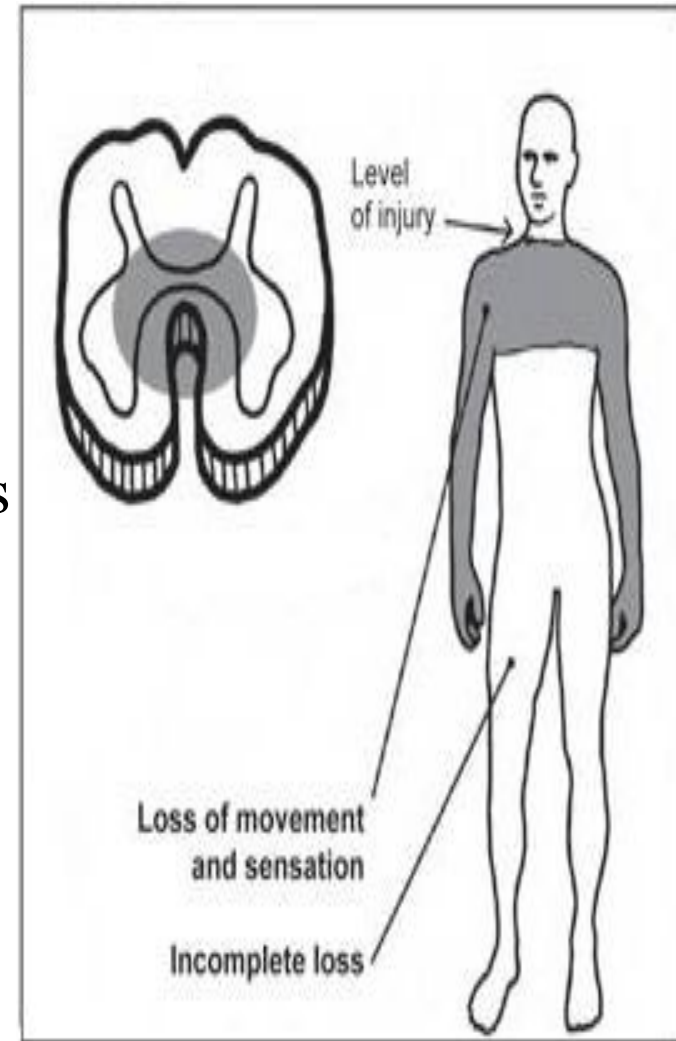
Posterior Spinal Cord Syndrome

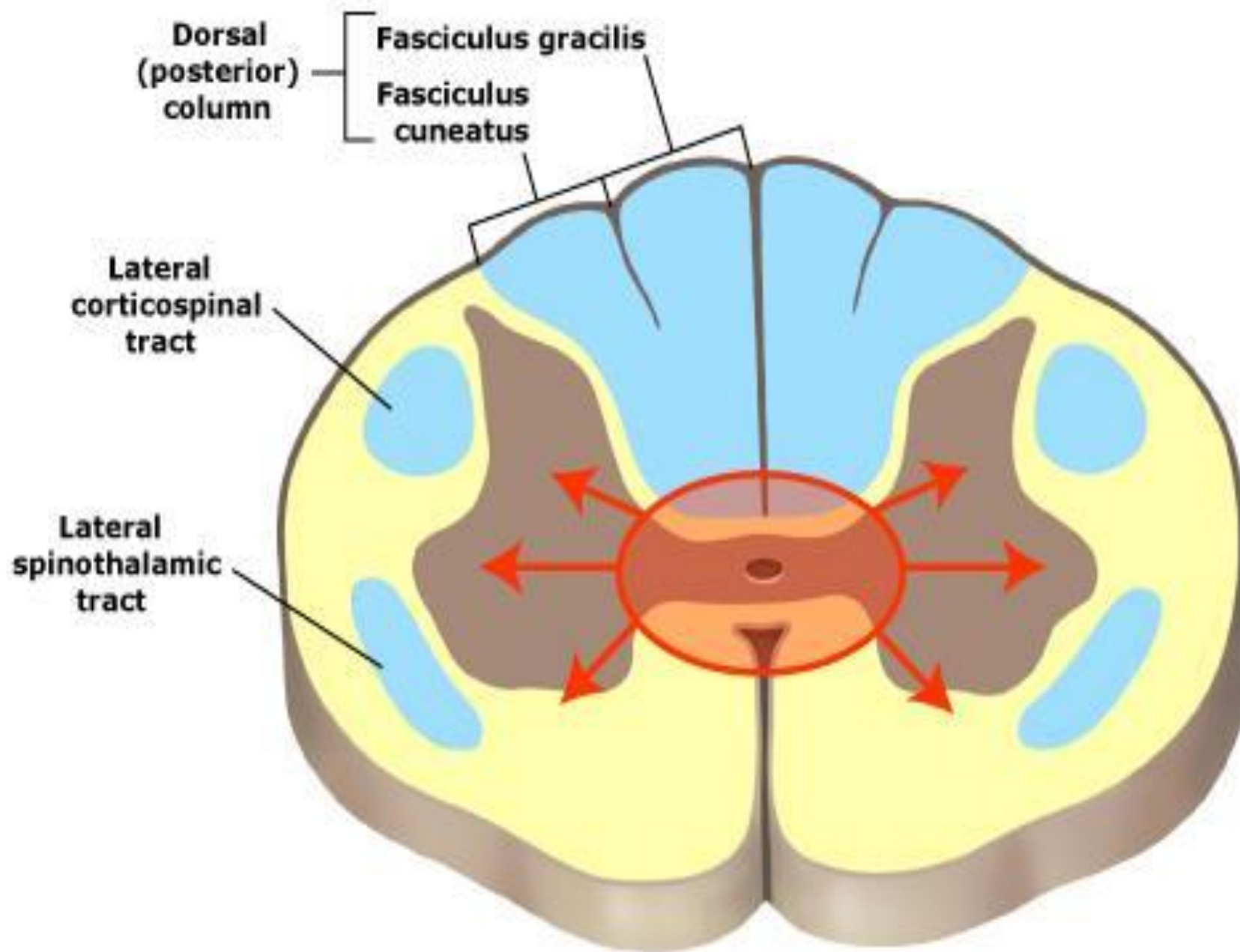
- Lesion of the posterior part of the SC, usually associated with cervical hyperextension injuries, tabes dorsalis (syphilis- tertiary stage), ischemia in the posterior spinal artery territory.
- Loss of deep sensation, fine touch, and difficulty in coordinating movement.
- Variable weakness and bladder dysfunction
- Pain, temperature sensation intact.



The Central Spinal Cord Syndrome

- Often is associated with a cervical region injury in the grey matter of the SC and syringomyelia.
- Leading to greater weakness in the upper limbs than in the lower limbs and jacket or half jacket loss of Superficial sensation (at the level of lesion).
- Sparing of deep sensation.







Level
of injury



Loss of movement
and sensation

Incomplete loss

Conus Medullaris Syndrome

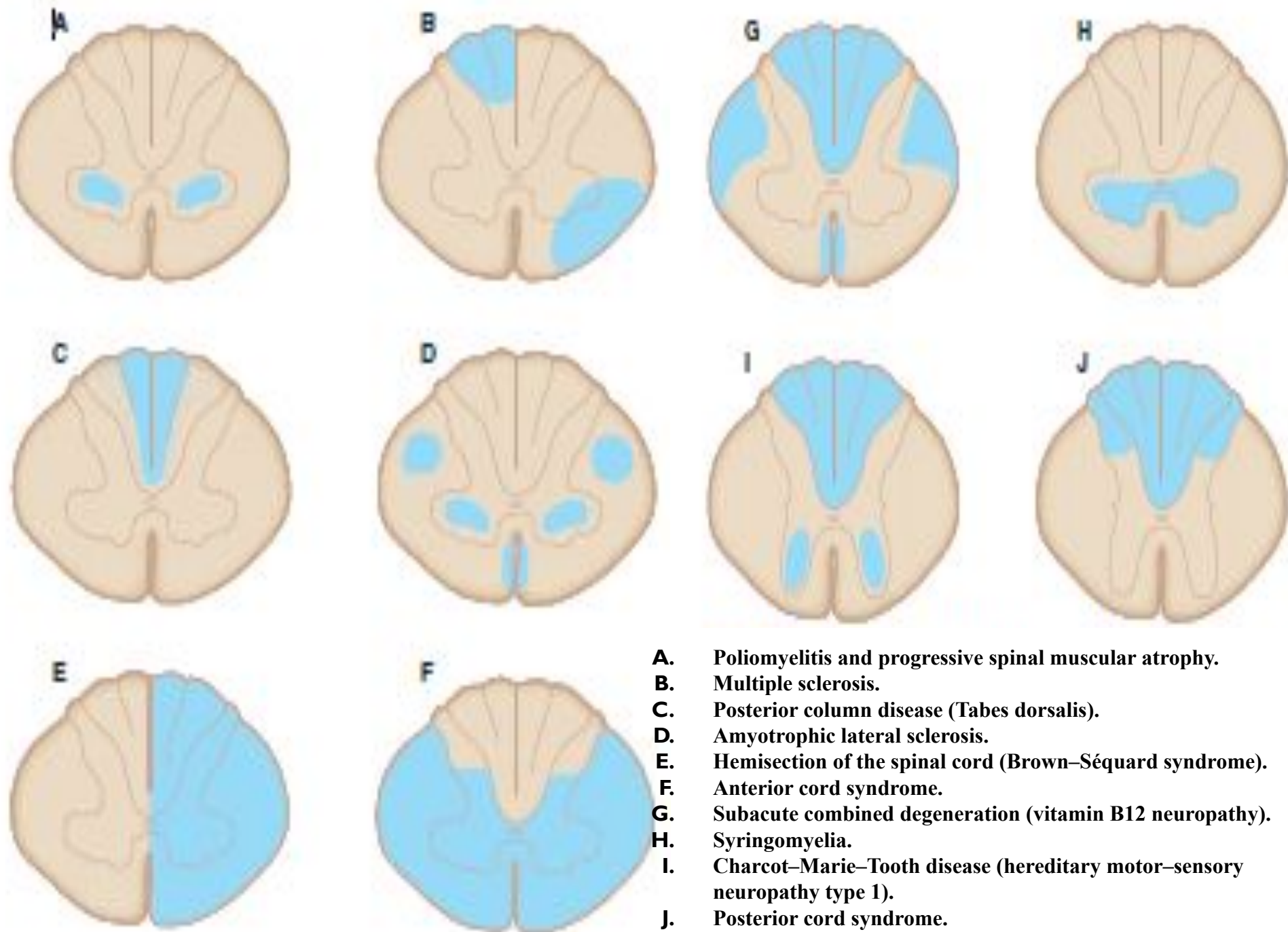
- The lesion involves segments S3–S5.
- Results in destruction of the sacral parasympathetic nuclei: bladder, fecal incontinence, and impotence.
- Perianogenital sensory loss in dermatomes S3–S5 (saddle anesthesia).
- Absence of motor deficits in the lower limbs.

Epiconus Syndrome

- Involves the segments L4–S2.
- Results in sphincter dysfunction.
- Loss motor and sensation below the level of lesion.
- Associated with absent achilles tendon reflex.

Cauda Equina Syndrome

- Classically involves spinal roots L2 - S5 below the lower end of the spinal cord.
- May result from lumbo-sacral intervertebral disk herniation.
- Produces neurologic deficits similar to those seen in conus or epiconus lesions but presented radicular type loss of sensation.
- Results in signs that frequently predominate on one side or asymmetrical presentation.
- Commonly results in severe spontaneous radicular pain (pain that radiates along a dermatome).





Complete transection
of the spinal cord



Brown-Séquard
syndrome



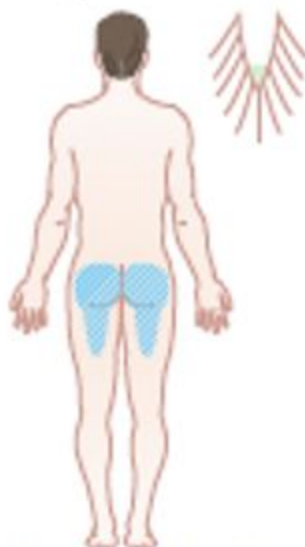
Syringomyelic
syndrome



Anterior cord syndrome
(anterior spinal artery syndrome)



Posterior column
syndrome



Conus medullaris
lesion



Cauda equina
lesion



Medulla oblongata
lesion



Loss of pain sensation



Loss of tactile or position sensation

Thank You

