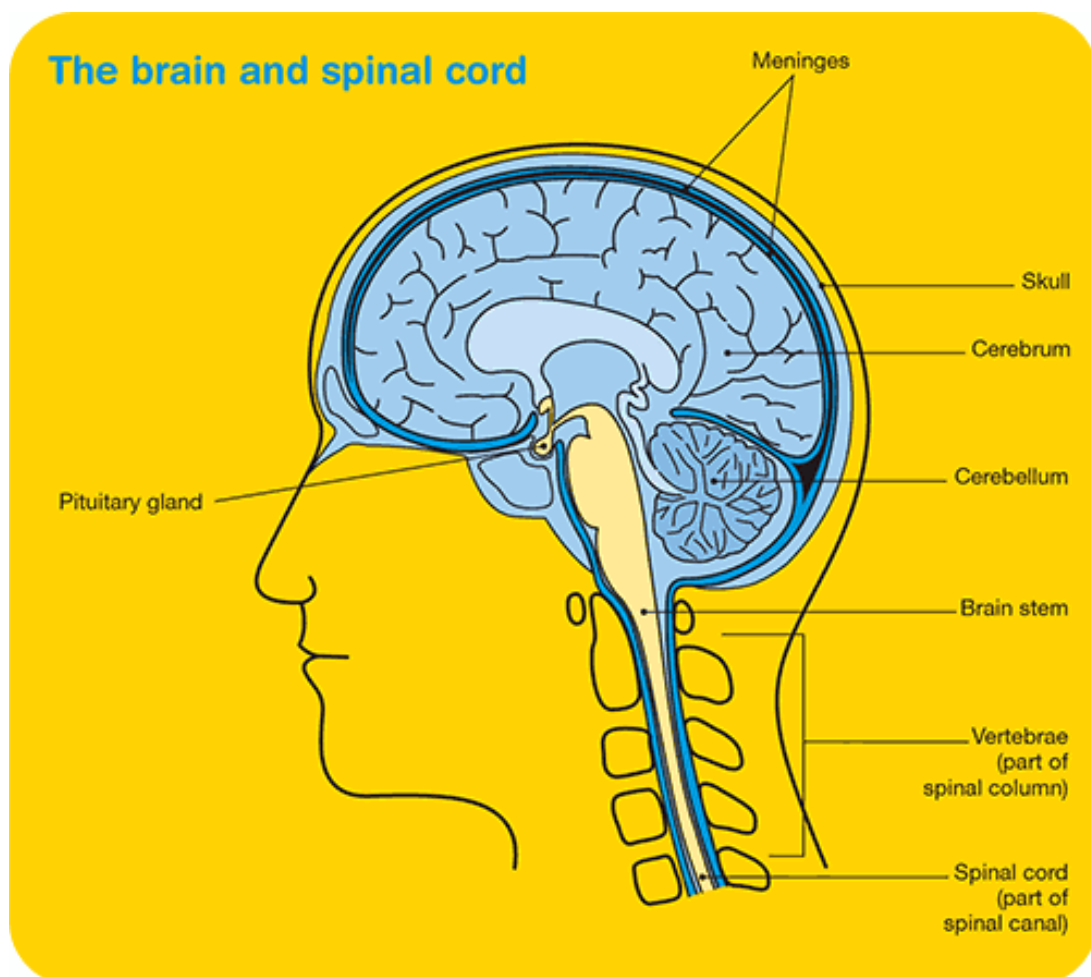


Spinal Cord

I. External Features

- ★ **Site:** It occupies the upper 2/3 of the **vertebral canal in adults**.
- ★ It **begins**, above, at the level of the lower border of **foramen magnum** as a continuation of the **medulla oblongata**.
- ★ The lower end of the spinal cord is conical shaped and called **conus medullaris ends** at the level of the disc between **L1/L2** vertebrae.
- ★ **Length:** It is average **45 cm** in length (about **25 cm shorter** than the length of the vertebral column).



Spinal pia mater

▪ Filum terminale

An extension of pia beyond conus medullaris, descends through the cauda equina to be attached to the coccyx.

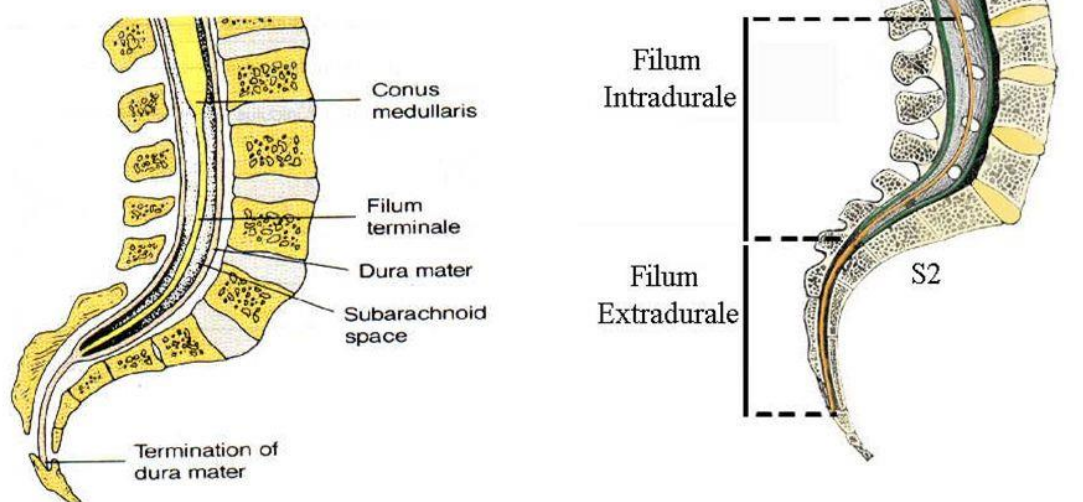
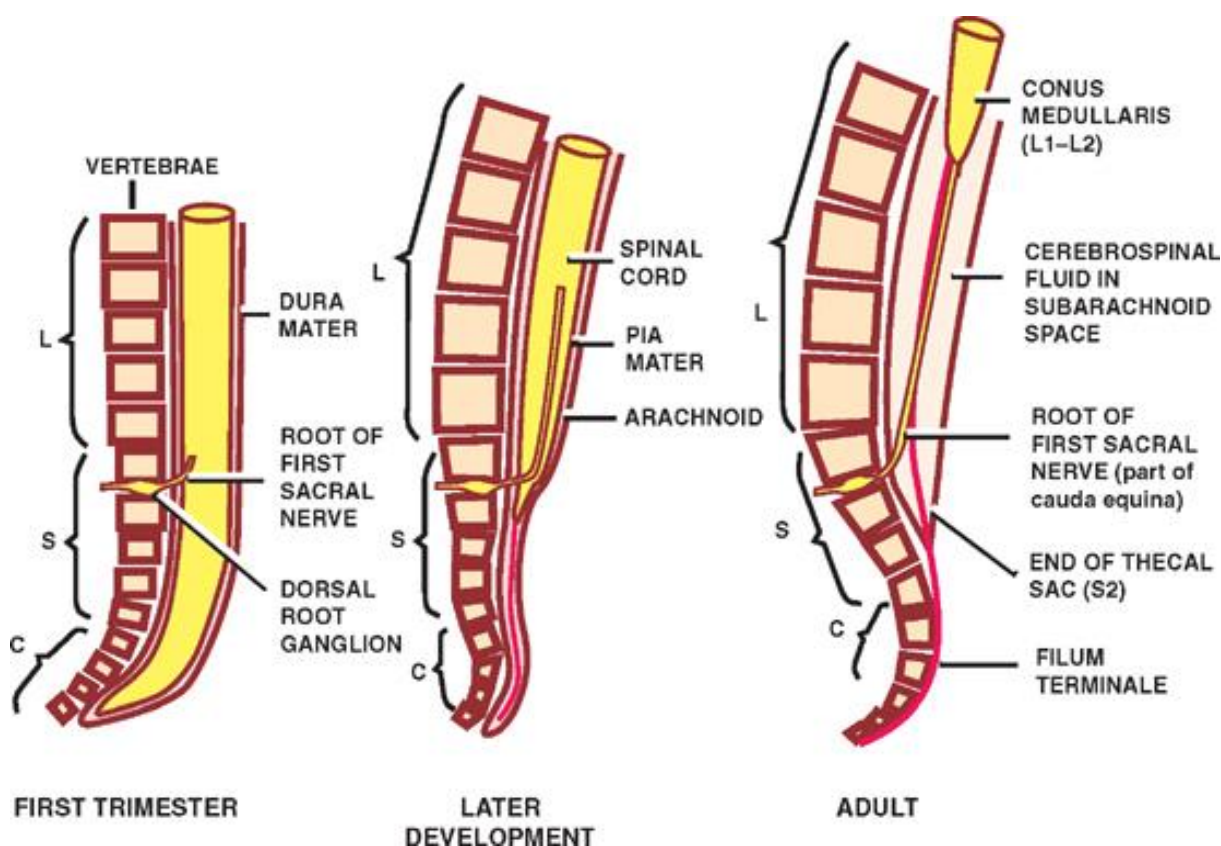


FIGURE 2.1 Longitudinal Spine

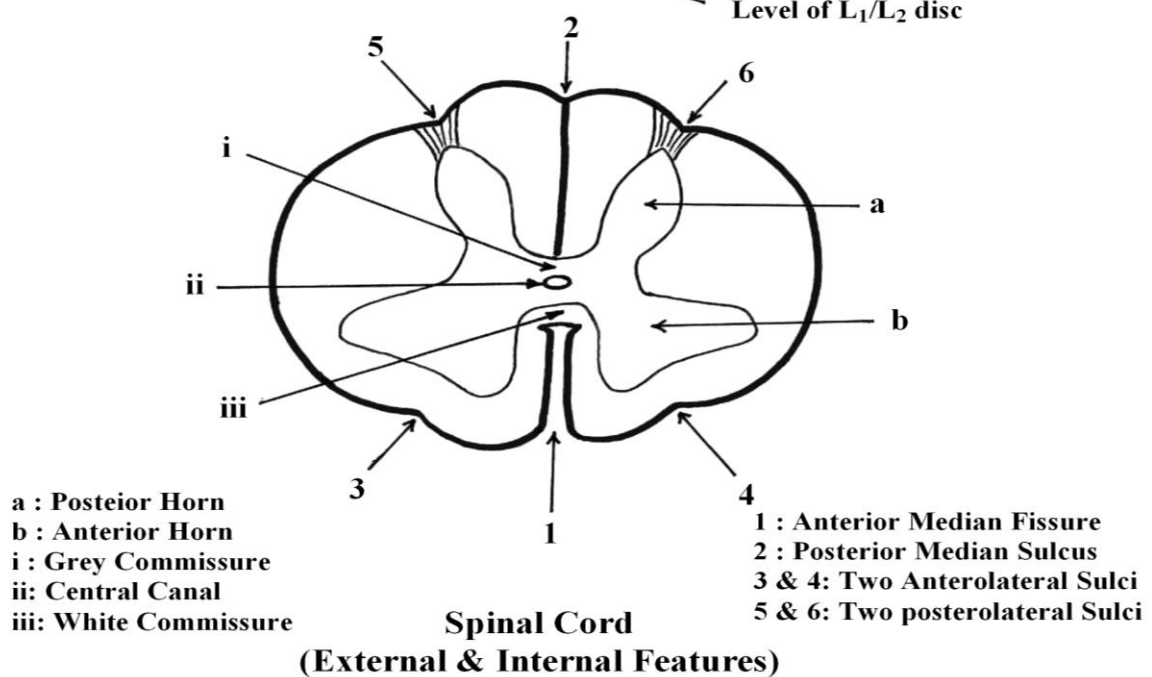
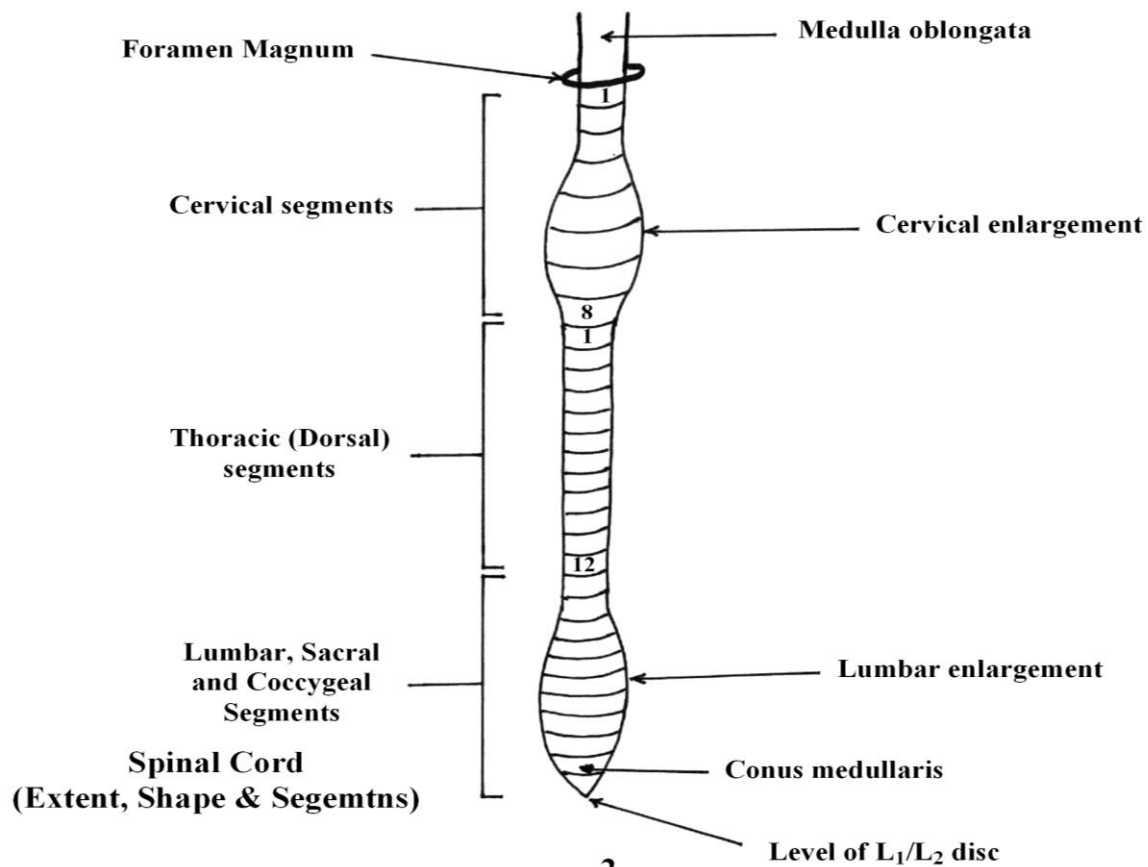
★ Changes in the length of the spinal cord according to age:

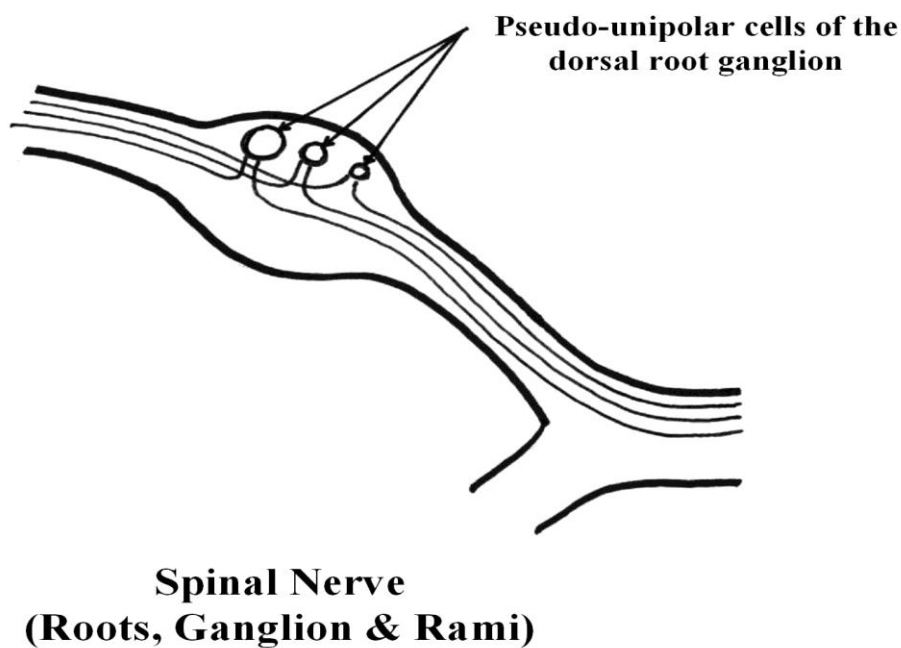
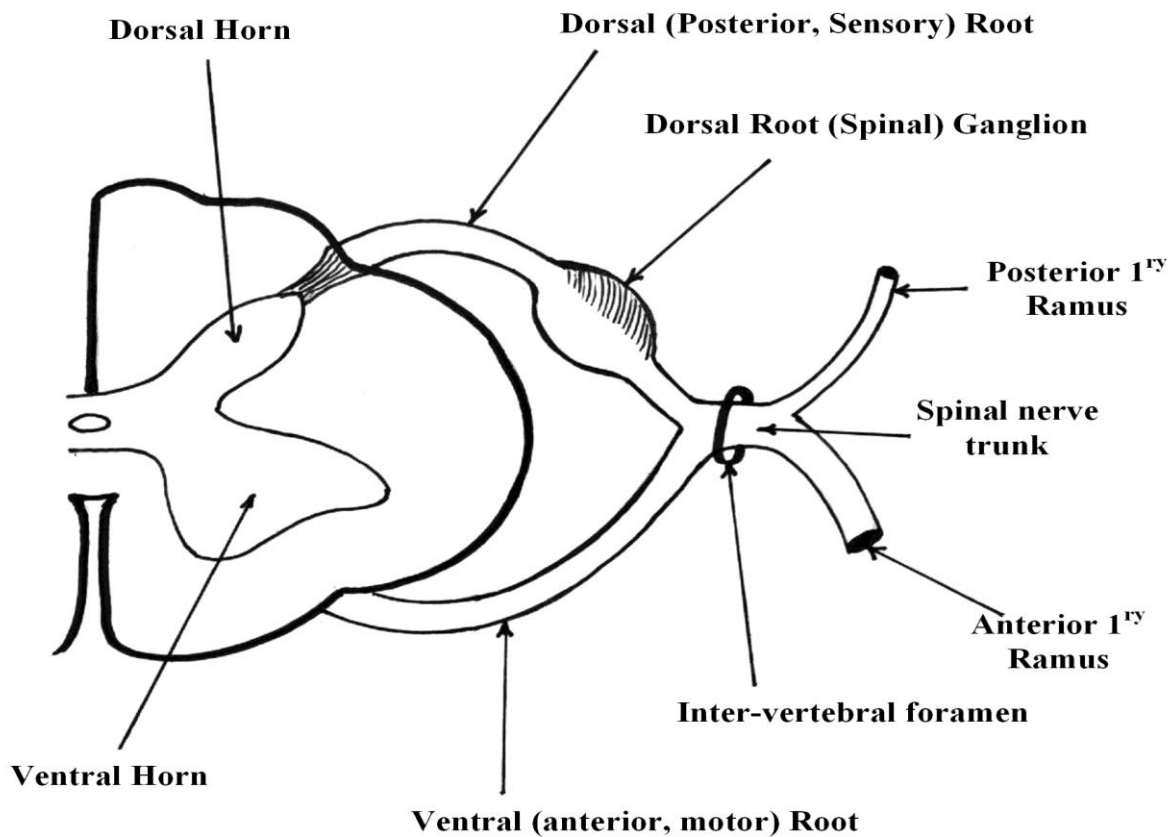
- 1- By the **3rd month of intra-uterine** life (in the fetus), the spinal cord **fills the whole** vertebral canal.
- 2- **At birth**, the spinal cord ends at the level of **L3** vertebra.
- 3- **In adult**, the spinal cord ends at the level of the disc between **L1/2** vertebrae.
 - These changes occur as a result of the difference in the **rate of growth of** the spinal cord (slower) compared with that of the vertebral column (more rapid).



- ★ **Shape:** The spinal cord is **cylindrical** and it shows 2 **enlargements**:
- Cervical enlargement:** opposite **C5-T1 spinal segments**, where the spinal cord give origin to the **brachial plexus** of the upper limb.
 - Lumbar enlargement:** maximum diameter of spinal cord opposite **L1-S3 spinal segments**, where the spinal cord gives origin of **lumbosacral plexuses** of the lower limb.
- ★ **External features:** The spinal cord shows **5 sulci & 1 fissure**:
- **Anterior median fissure:** is the deepest.
 - **Posterior median sulcus.**
 - **Two anterolateral sulci:** one on each side, along which emerge the **ventral (motor) roots** of the spinal nerves.

- **Two posterolateral sulci:** one on each side, along which enter the **dorsal (sensory) roots** of the spinal nerve.





★ Segments of spinal cords:

- The spinal cord is divided into **31** segments, arranged as follows:
 - 8 cervical segments.
 - 12 thoracic segments.
 - 5 lumbar segments.
 - 5 sacral segments.
 - 1 (one) coccygeal segment.

★ Vertebral levels of the spinal cord segments:

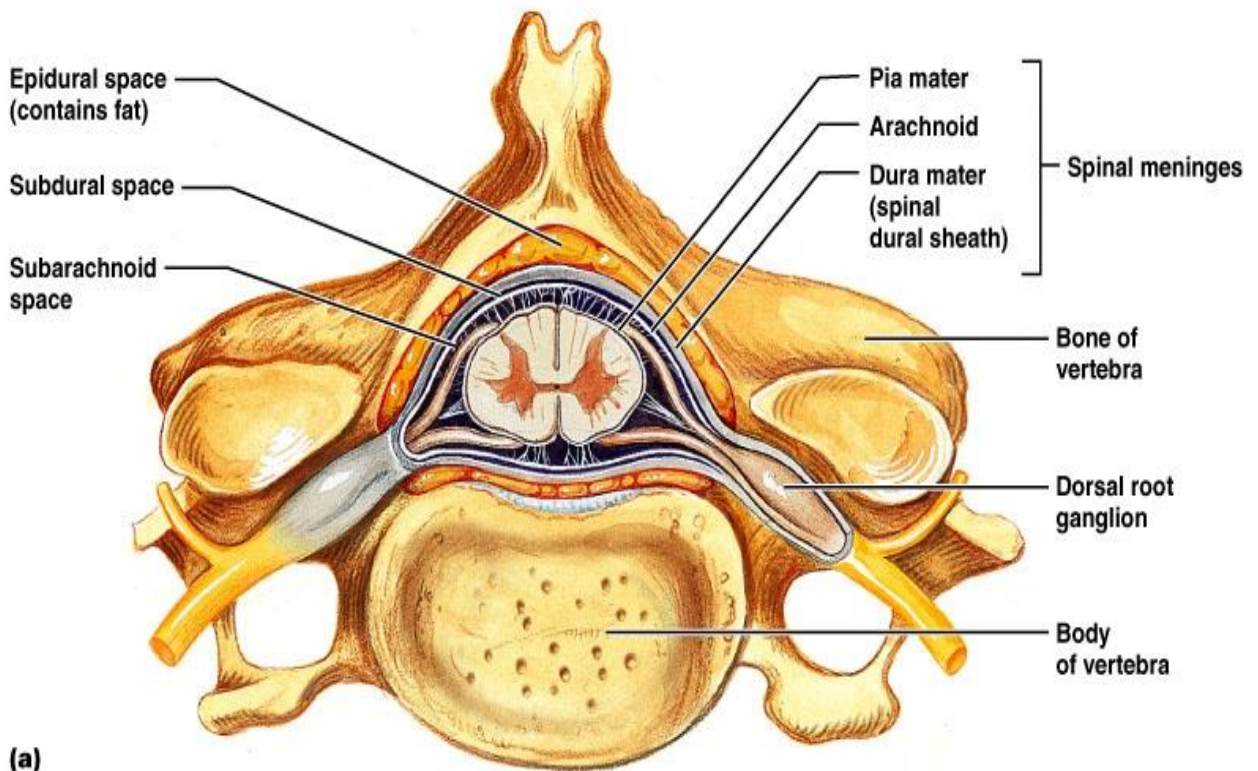
- Since the spinal **cord is shorter** than the vertebral column, therefore, **spinal cord segments** are present **higher** than their corresponding vertebrae.
- **The rule 1,2,3 is applied:**
 - a) **Cervical region: Add 1** to the vertebra e.g. C5 vertebra is opposite to C6 spinal cord segment.
 - b) **Upper thoracic region: Add 2** to the vertebra e.g. T3 vertebra is opposite to T5 spinal cord segment.
 - c) **Lower thoracic region: Add 3** to the vertebra e.g. T10 vertebra is opposite to L1 spinal cord segment.
 - d) **T11** vertebra is **opposite to L2 to L5** spinal cord segments.
 - e) **T12 & L1** vertebrae **are opposite to** all **sacral** segments

★ Spinal nerves:

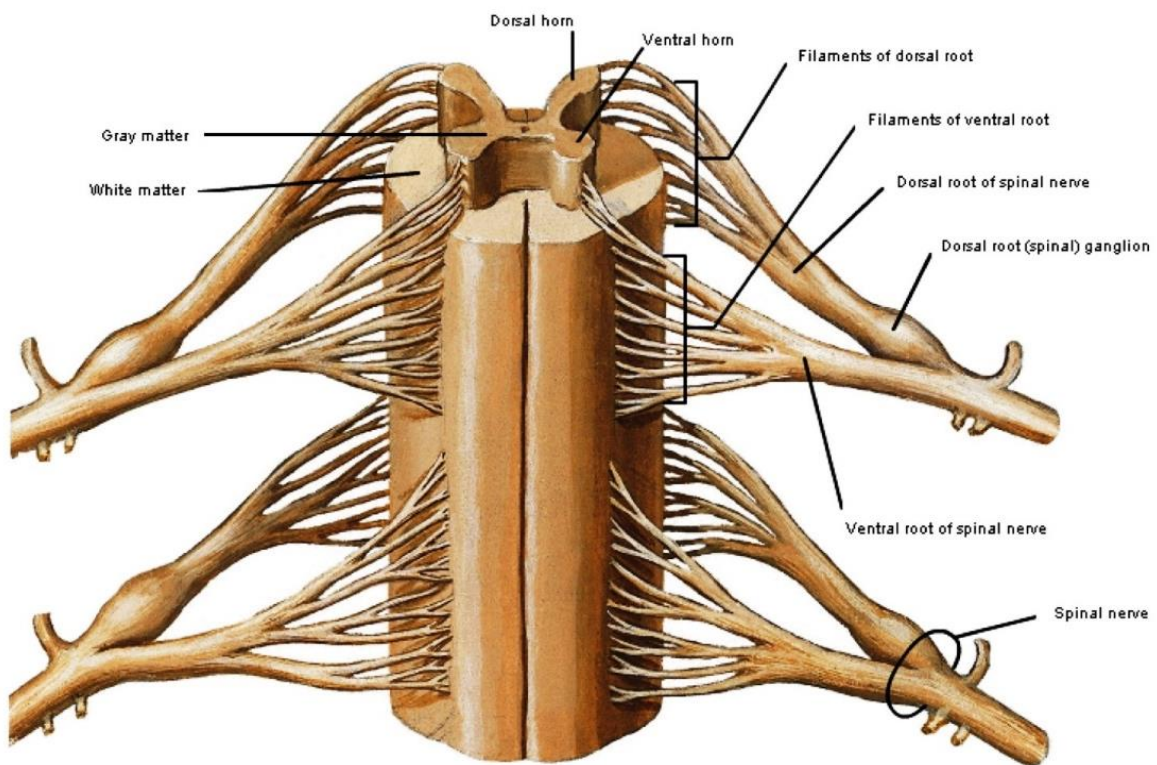
- **Each segment** of the spinal cord **gives origin** to a **pair of spinal nerves**, one on each side (right and left). Accordingly, there are **31 pairs** of spinal nerves (8 cervical, 12 thoracic, 5 lumbar, 5 sacral and one pair coccygeal nerves).
- Each spinal nerve is **attached** to the spinal cord by two roots:

Ventral root (motor)	Dorsal root (sensory)
<ul style="list-style-type: none"> ○ It emerges from the antero-lateral sulcus. 	<ul style="list-style-type: none"> ○ It enters through the postero-lateral sulcus .
<ul style="list-style-type: none"> ○ It contains somatic efferent (motor) fibers. ○ It also contains sympathetic preganglionic fibers in all thoracic & upper 2 lumbar ventral roots. ○ It also contains para-sympathetic pre-ganglionic fibers in 2nd - 4th sacral ventral roots 	<ul style="list-style-type: none"> ○ It consists of general somatic afferent (sensory) fibers carrying (pain, temperature, touch, pressure and proprioception) from the body below the head to enter the spinal cord. ○ It also contains general visceral afferent fibers (visceral sensation) from the body below the head to enter the spinal cord.
	<ul style="list-style-type: none"> ○ Each carries the dorsal root or spinal ganglion whose cells are the 1st order neurons in the pathways of the general somatic sensations from the body below head .

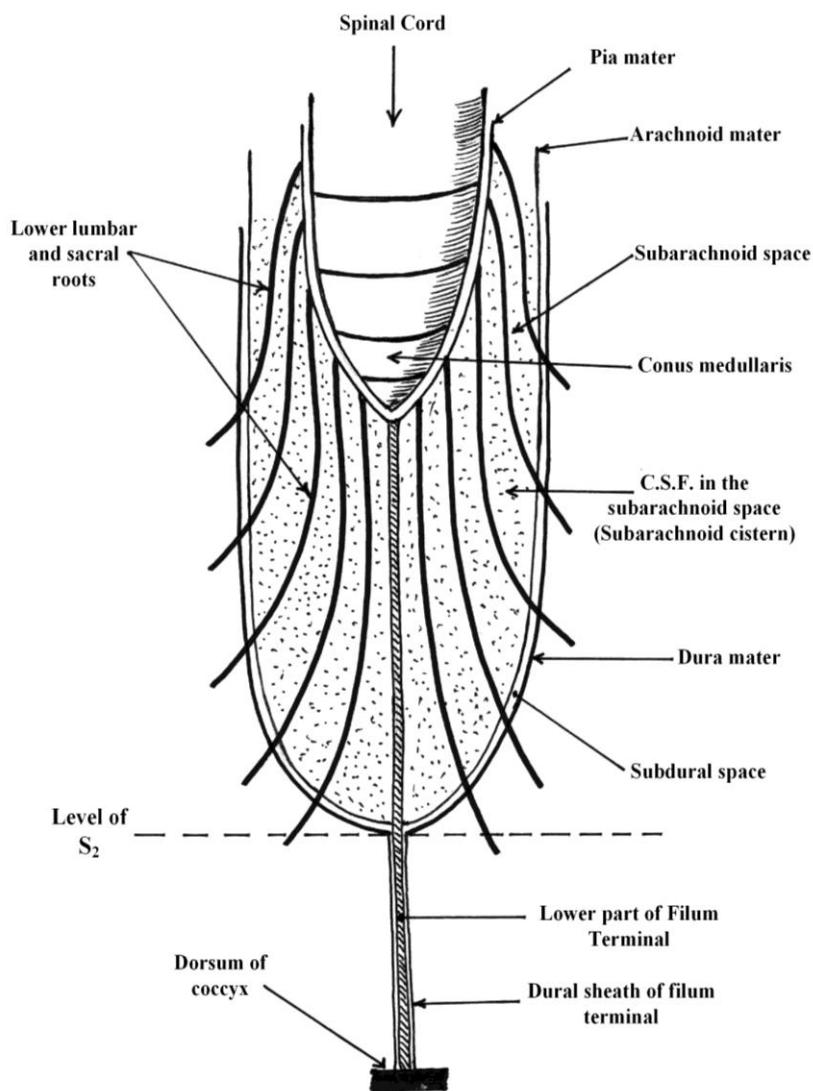
- At the **corresponding intervertebral foramen**, the two **roots** (ventral and dorsal) **unite** together forming the **spinal nerve trunk** which is **mixed** containing both motor and sensory fibers. It leaves the vertebral canal through the **intervertebral foramen.**



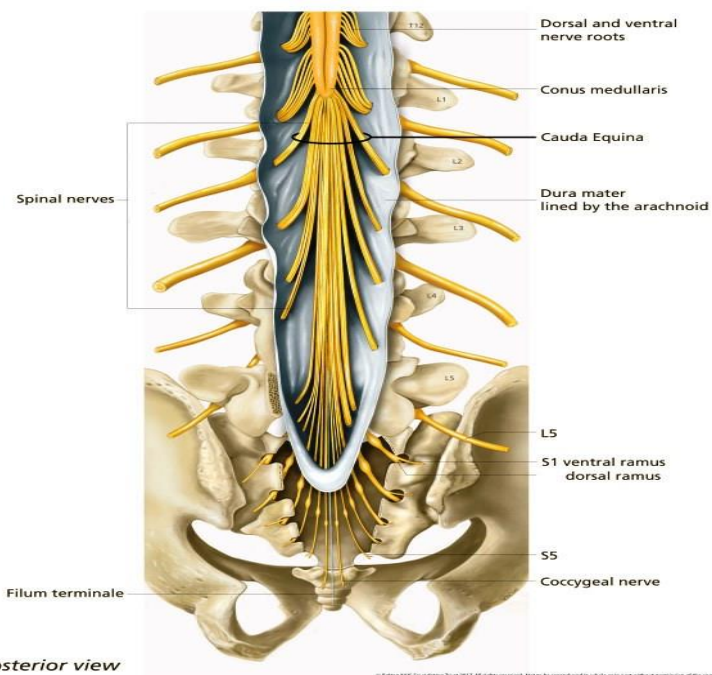
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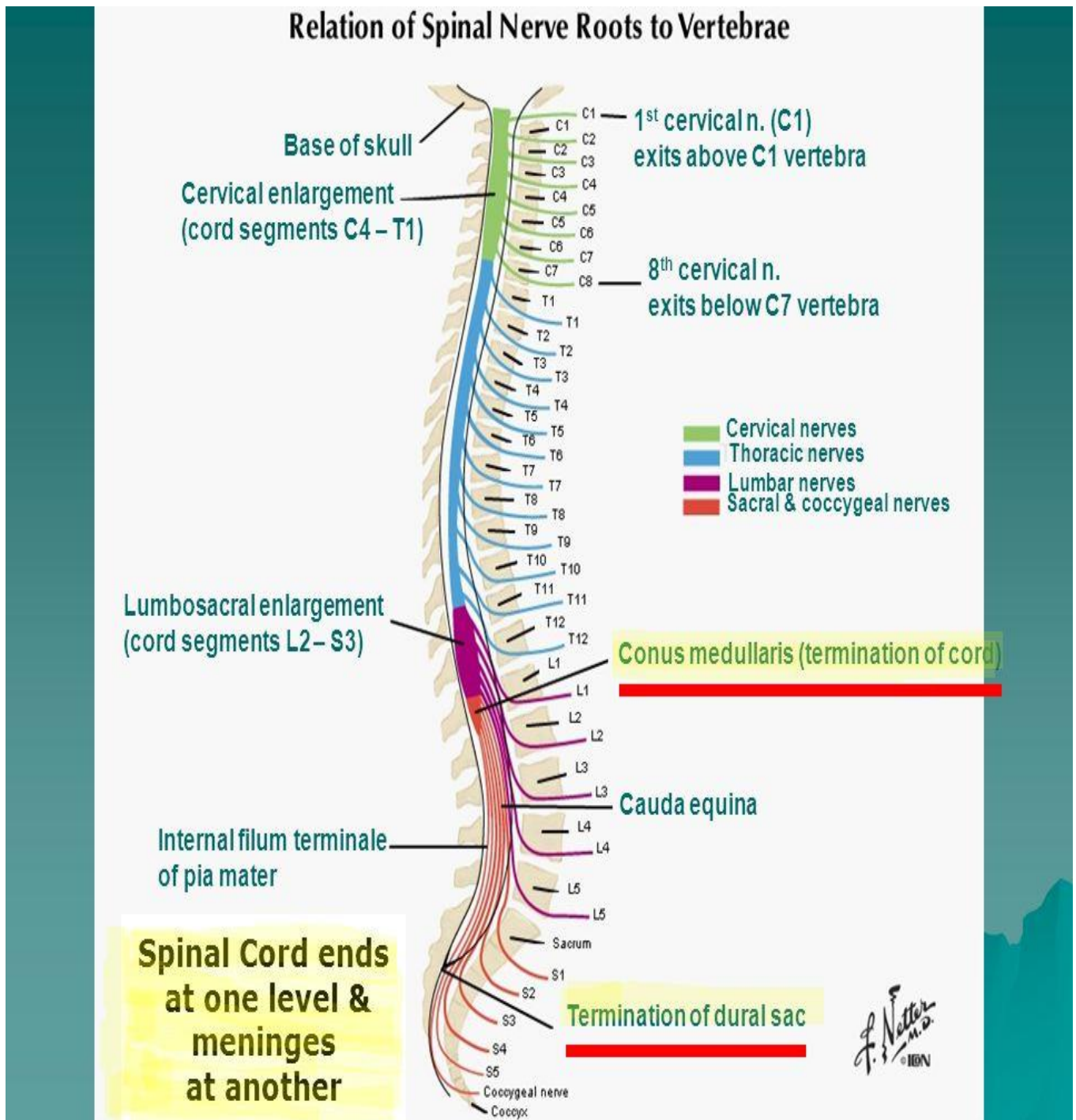


-
- **Each cervical nerve emerges above** its corresponding vertebra. i.e. C1 nerve emerges above atlas and C8 emerges above T1.
 - Each of **the remaining spinal nerves** from T1 **emerges below** the corresponding vertebra.
 - The spinal nerve trunk is **very short**. once it **emerges** from the intervertebral foramen, it **divides** into **two primary rami** (anterior and posterior). Both rami are **mixed** and **supply** the anterior and posterior aspects of the body respectively.
 - **Each root**, during its course, acquires **3 covering** (sheathes) from the pia, arachnoid and dura maters. At the **intervertebral foramen**, only the **dural sheath continues outwards** to blend with the **epineurium** of the nerve outside the intervertebral foramen.
 - **Length of the roots and the cauda equina:**
 - Since the spinal cord is **shorter** than the vertebral column; accordingly, the **roots** of the spinal nerves have to **descend** for some distances in the subarachnoid space to **reach their intervertebral foramina**.
 - Accordingly, the roots of the spinal nerves become **progressively longer and more oblique as we go downwards**.
 - Below the end of the spinal cord (**below L1 vertebra**), the vertebral canal is occupied only by the long **lumbar and sacral** nerve roots, which descend around the **filum terminale** forming the **cauda equine** which float in the **CSF** filling the widened part of subarachnoid space **called lumbar cistern**.



The Cauda Equina

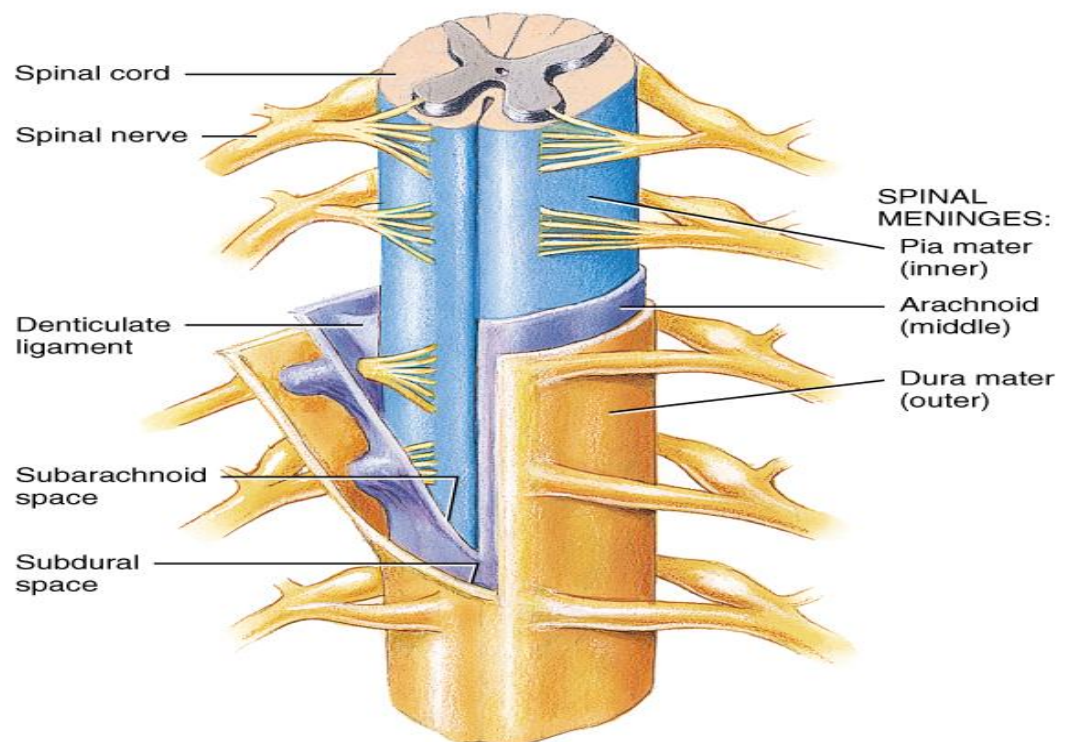




★ **Coverings of the spinal cord: (Spinal Meninges)**

- The CNS is surrounded by **three meninges**; from inside outwards they are: the **pia**, the **arachnoid** and the **dura** maters.
- The spinal meninges are **continuous above** through foramen magnum with cerebral meninges.

- **Below**, both arachnoid & dura matters end at the level of the **S₂** vertebra where they are **pierced** by the filum terminale.
- The pia & arachnoid matters are **separated** by **subarachnoid space** which cerebro-spinal fluid (**CSF**), spinal vessels and roots of spinal nerves.
- **Arachnoid** mater is separated from the dura mater by a **narrow subdural space** containing a **thin film** of fluid.
- **Unlike the cranial dura** mater, the spinal dura mater is separated from the periosteal lining of the vertebral canal by a space outside the spinal dura called the **extradural or epidural space**. This space **contains** loose areolar tissue, semiliquid fat & internal vertebral venous plexus.

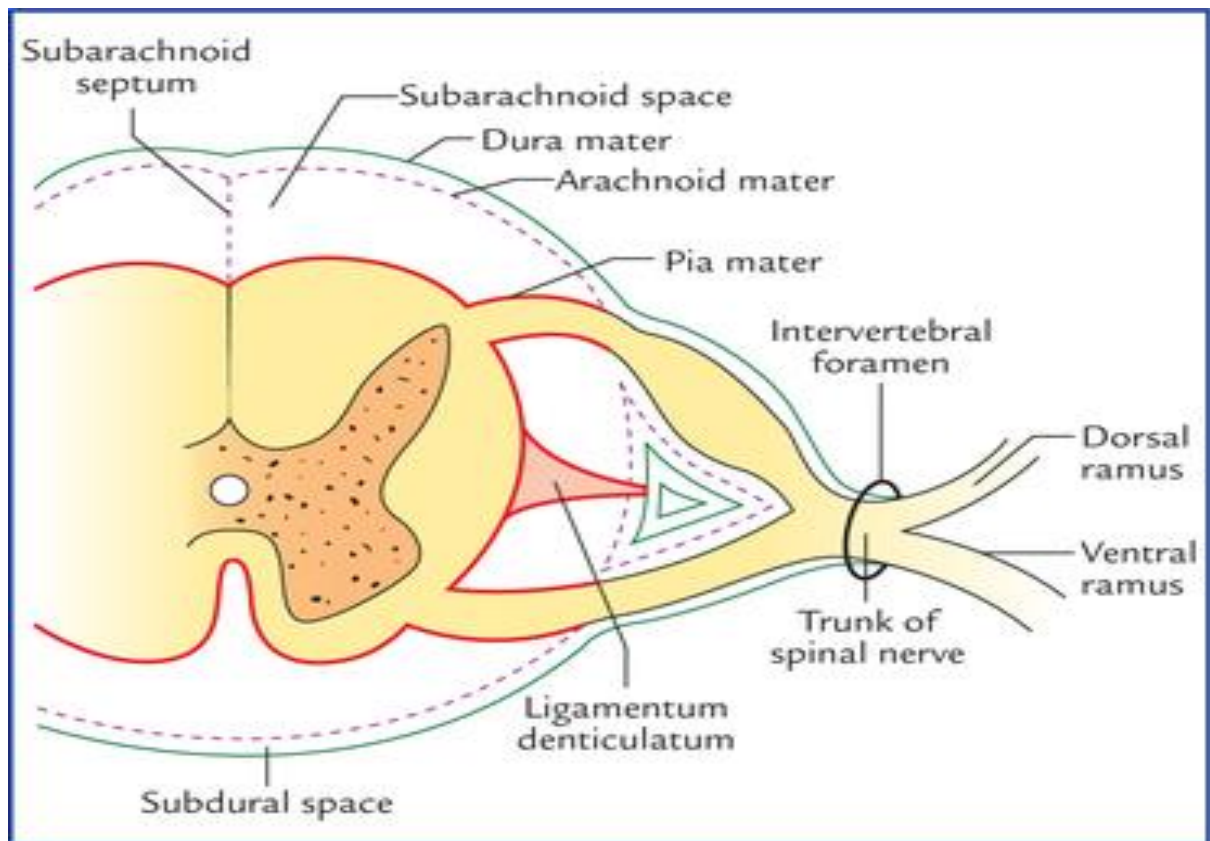
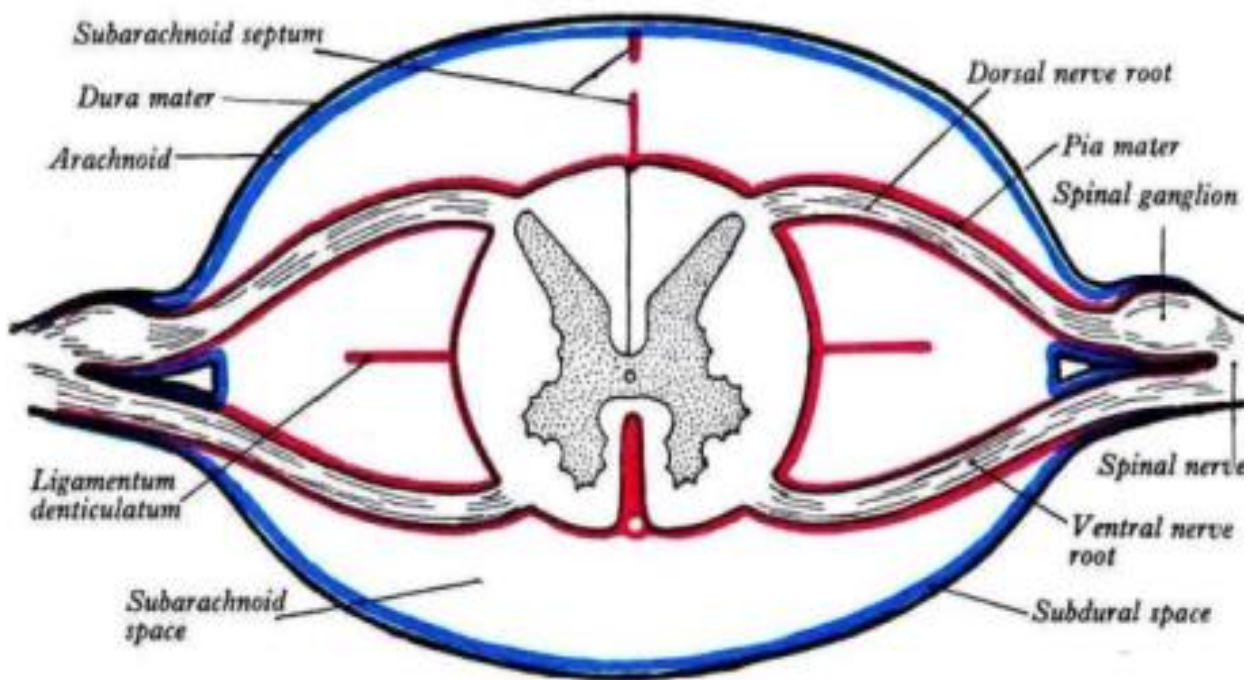


(a) Anterior view and transverse section through spinal cord

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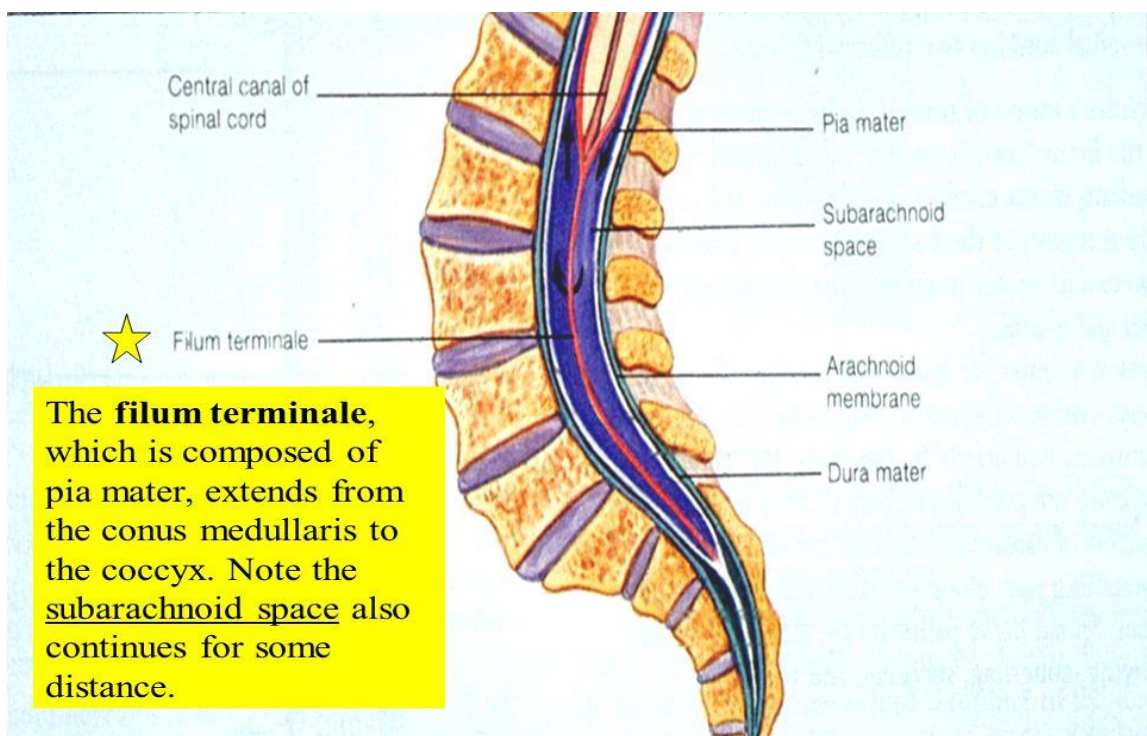
I)The spinal pia mater:

- It is delicate inner most coverings, closely **adherent** to the surface of the spinal cord.
- It sends **prolongations**:
 - **Outwrds** forming sheaths around the **roots & trunks** of spinal nerve until the intervertebral.
 - **Inwards** forming sheaths around the **blood vessels** which **pierce** the substance of the spinal cord.
- It is **thickened at 4 sites** to form strong fibrous bands:
 - a- Denticulate ligaments:**
 - Each ligament **extends** from the **foramen magnum** (above) down to the level of **L₁** vertebra (below).
 - Each ligament extends **laterally** one on each side, **midway** between the ventral and dorsal spinal nerve roots, to attach laterally to the **arachnoid & dura mater**.
 - Each ligament has a **serrated** lateral border with 21 processes (hence the name).
 - b- Subarachnoid septum:** Is a backward extension arising from the pia mater at the **posterior median sulcus** to get attached to the arachnoid mater.
 - c- Linea splendens:** Is median longitudinal band of pia mater extend **along the surface** of the anterior median **fissure** forming a sheath around the anterior spinal artery.



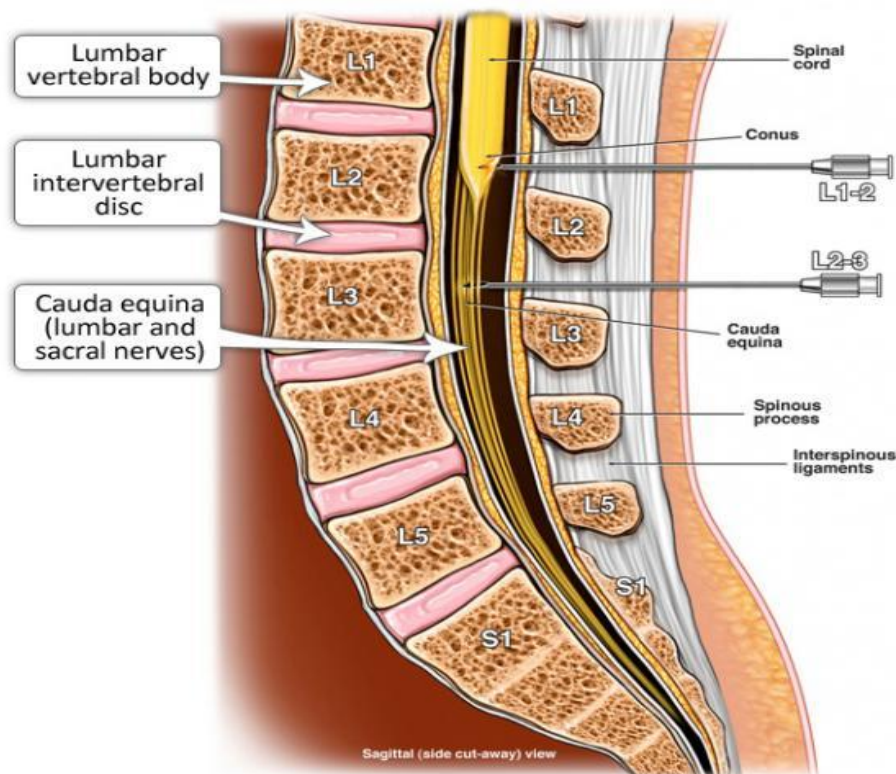
d- Filum terminale:

- At the tip of the **conus medullaris**, the pia mater is transformed into a **fibrous filament** called the filum terminale.
- From the **tip** of the conus medullaris, it **descends** in the center of the **cauda equina** floating in the **CSF** in the **lumbar cistern**.
- At the level of the **S₂** vertebra, it **pierces** the arachnoid and the dural tubes, acquires a **sheath of dura mater** and descends to leave the **sacral canal** through the **sacral hiatus**.
- It is finally attached to the **back of the coccyx**.
- It is distinguished from the nerve roots of the cauda equina by having a **glistening silvery appearance** and by being **attached** to the tip of the conus medullaris.



II) Spinal Arachnoid Mater:

- It is a **delicate intermediate** covering of the spinal cord which lies **outside** the pia mater and **deep** to the dura mater.
- **The subarachnoid space** is traversed by fine connective tissue **trabeculae** connecting the arachnoid and the pia maters together.
- **Below** the end of the spinal cord (below L1 vertebra), these **trabeculae disappear** and the subarachnoid space becomes widened forming **lumbar cistern** which extends from L2 to S2 vertebrae contains CSF, cauda equine & filum terminale.
- **Applied anatomy: Lumbar puncture:** is done by introducing a needle into the lumbar cistern either to obtain a sample of CSF or to inject a drug. It is safe to be done **below the level of L2** vertebra (usually between L3 & L4 vertebrae) to avoid injury of the spinal cord. The nerve roots of the cauda equine, being floating in the CSF, they escape away from the lumbar puncture needle & not injured.



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III) Spinal Dura Mater:

- It is **thick tough fibrous membrane** , the outermost of the three meninges.
- It **extends from** the **foramen magnum** (above) down to the level of **S₂** vertebra, where it **continues downwards** as a narrow sheath **around** the lower part of the **filum terminale**.
- **Attachment:** The spinal dura mater is attached to:
 - **Above** : to the margins of the **foramen magnum**.
 - **Lateral** : to the margins of the **intervertebral foramina**.
 - **Anterior** : to **posterior longitudinal ligament** along the posterior surfaces of the bodies of the vertebrae.
 - **Below:** to the back of the **coccyx** (by filum terminale).

-
- It sends tubular sheaths around the **spinal nerve roots and trunks**. These dural sheaths blend with the **epineurium** of the nerve **outside the intervertebral foramina**.
 - The spinal dura mater receives **nerve supply** from the meningeal branches of the spinal nerves. It receives **blood supply** from branches from the **vertebral** artery (in the neck), the **posterior intercostal** arteries (in the thorax), **lumbar** arteries (in the abdomen) and **lateral sacral arteries** (in the pelvis).
 - **Fixation of the Spinal Cord** in position by:
 1. The **filum terminal** which attaches the spinal cord to the back of the coccyx.
 2. **Denticulate ligaments**: which attach the spinal cord to the dura mater on either side.
 3. The **subarachnoid septum**: which attaches the spinal cord to the arachnoid mater posteriorly.
 4. The **dura mater** itself which is attached above to the margin of the **foramen magnum** and on either side to the margins of the **intervertebral foramina**.

II) Internal features

- ★ Transverse section of the spinal cord shows **central gray matter** surrounded by **peripheral white matter**.
- ★ The spinal cord is divided into **two symmetrical halves** (right and left) by the **posterior median sulcus, posterior median septum** and the **anterior median fissure**. The 2 halves are **connected** together by:

1- Gray commissure connecting the 2 sides, contains the central canal of spinal cord.

2- White commissure connecting the 2 sides, lies in front of the gray commissure.

Spinal Gray Matter

★ It is **formed** mainly of **cell bodies** of neurons & unmyelinated nerve fibers (**grey color**).

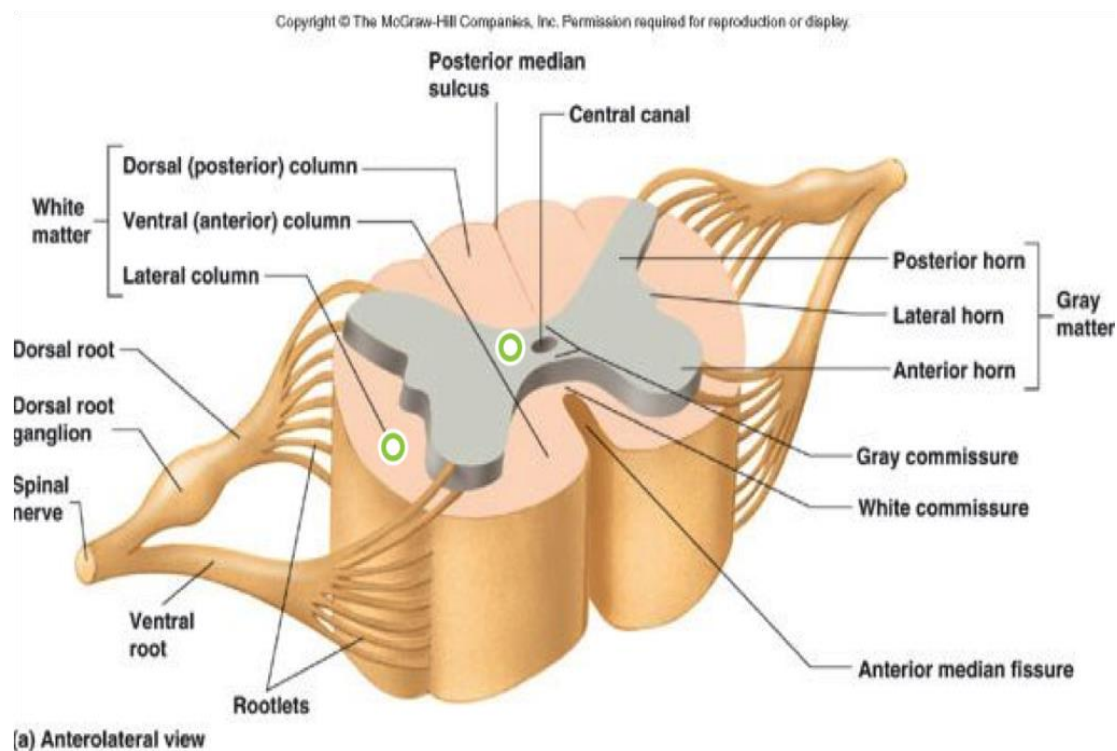
★ In cross section, the gray matter appears as an **H-shaped mass** **formed of :**

- **Ventral (anterior, motor) horns.**

- **Dorsal (posterior, sensory) horns.**

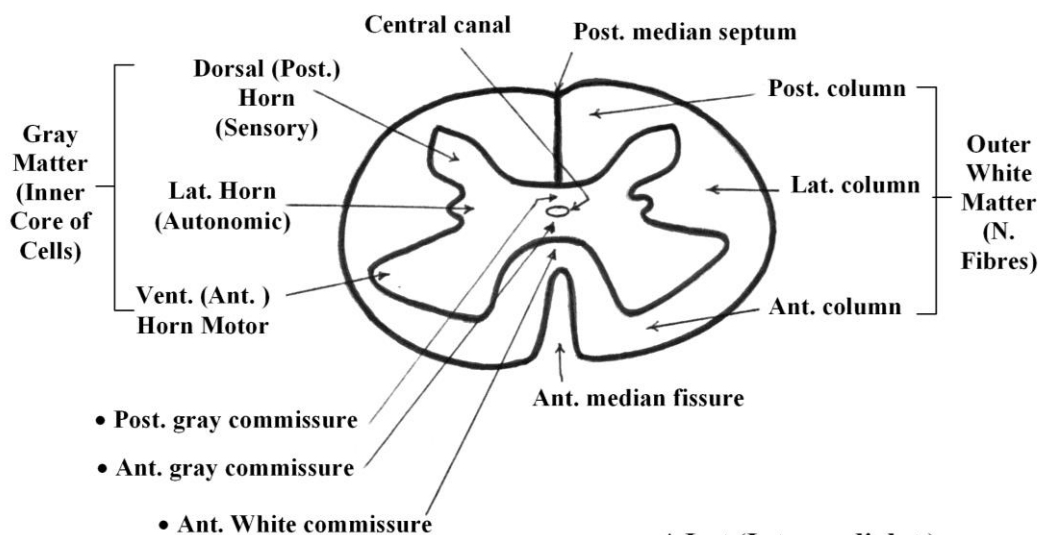
- These horns form the **anterior & posterior grey columns** which extend longitudinally along the whole length of the cord .

★ **Gray commissure** is a transverse band connecting the 2 sides which is traversed longitudinally by the **central canal** of the spinal cord.

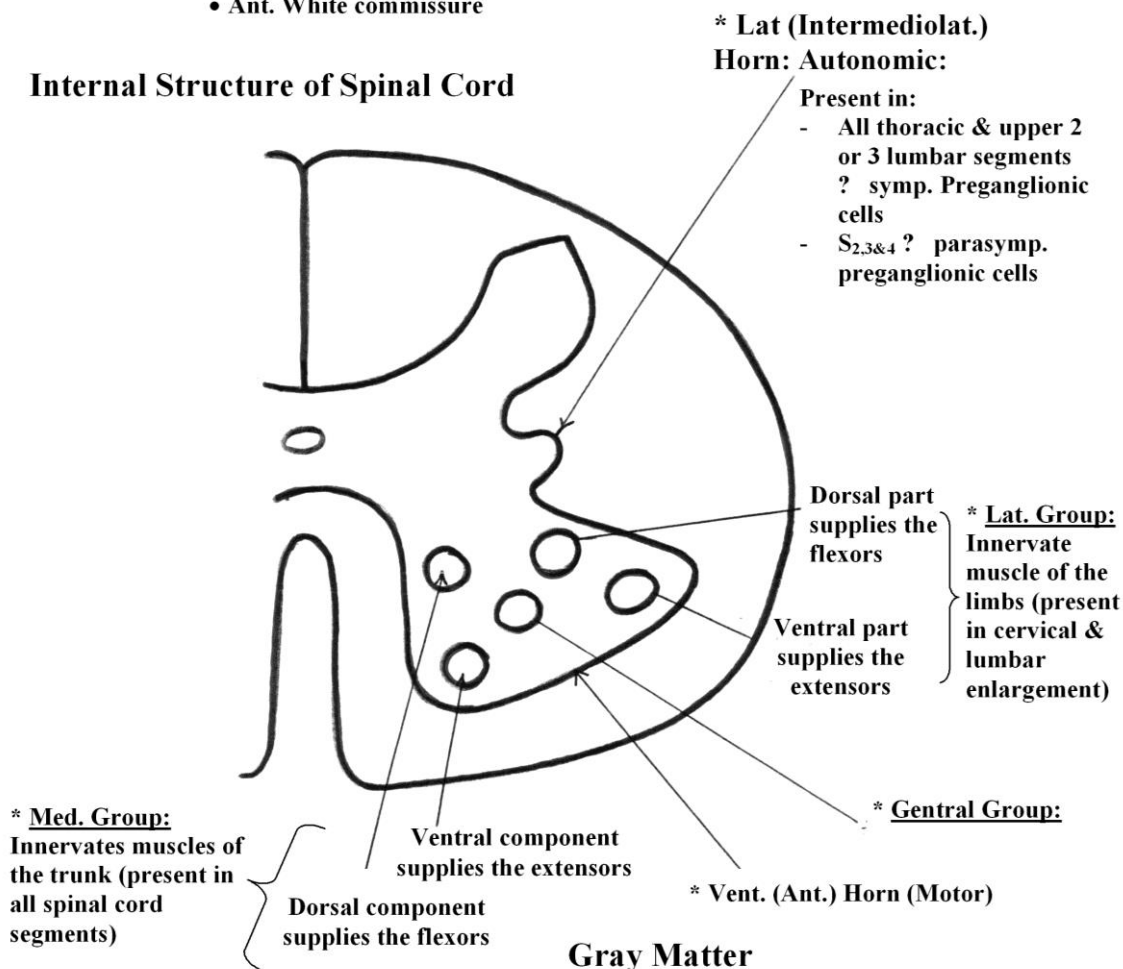


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- ★ The gray commissure is related **posteriorly** directly to the posterior median septum while **anteriorly** it is related to the white commissure.
 - ★ The **central canal** of the spinal cord is **continuous above** with the central canal of the closed medulla oblongata and it ends **below** in a small dilatation called the **terminal ventricle**, in the conus medullaris.
 - ★ The gray matter has **3 horns**:
 - I) The ventral (anterior) horn or column: (motor or efferent)**
 - The anterior horn cells (**AHCs**) and their axons represent the **lower motor neurons (LMNs)**.
 - It is short, wide & contains **general motor (efferent) somatic nuclei** arranged in **3 groups**:
 - 1- Medial group**: their axons supply the muscles of the **trunk** both flexors and extensors, therefore it is present in **all segments** of the spinal cord.
 - 2- Lateral group**: their axons supply the muscles of the **limbs** both flexors and extensors. This group is present **only in the cervical and lumbar enlargements** where their axons of its cells form the roots of the **brachial and lumbosacral plexuses**. The anterior horn is **expanded** in these two regions.
 - 3- Central group**: is present **only** in the **cervical** region and include:
 - a- **Phrenic nucleus**: lies opposite C_{3rd}, 4th & 5th spinal cord segments. The axons of its cells form the **phrenic nerve**.

b- **Spinal accessory nucleus:** lies in the upper 6 cervical segments. The axons of its cells form the **spinal root of accessory nerve.**



Internal Structure of Spinal Cord



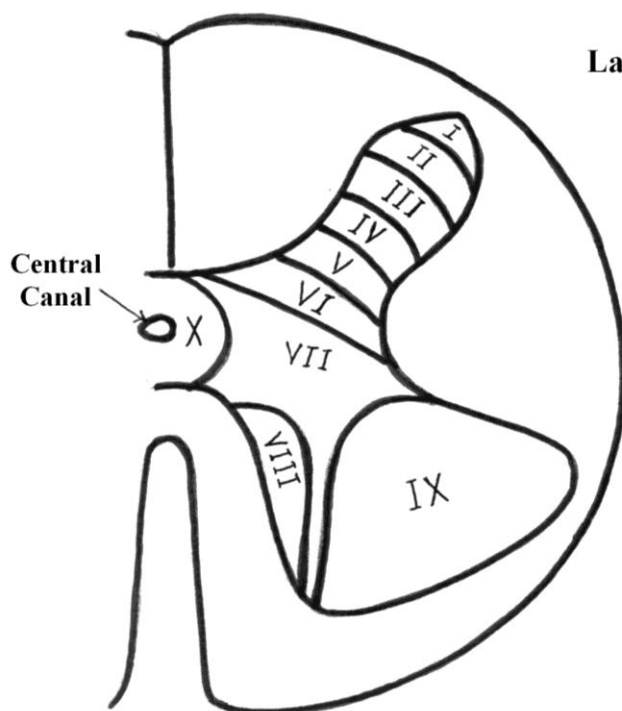
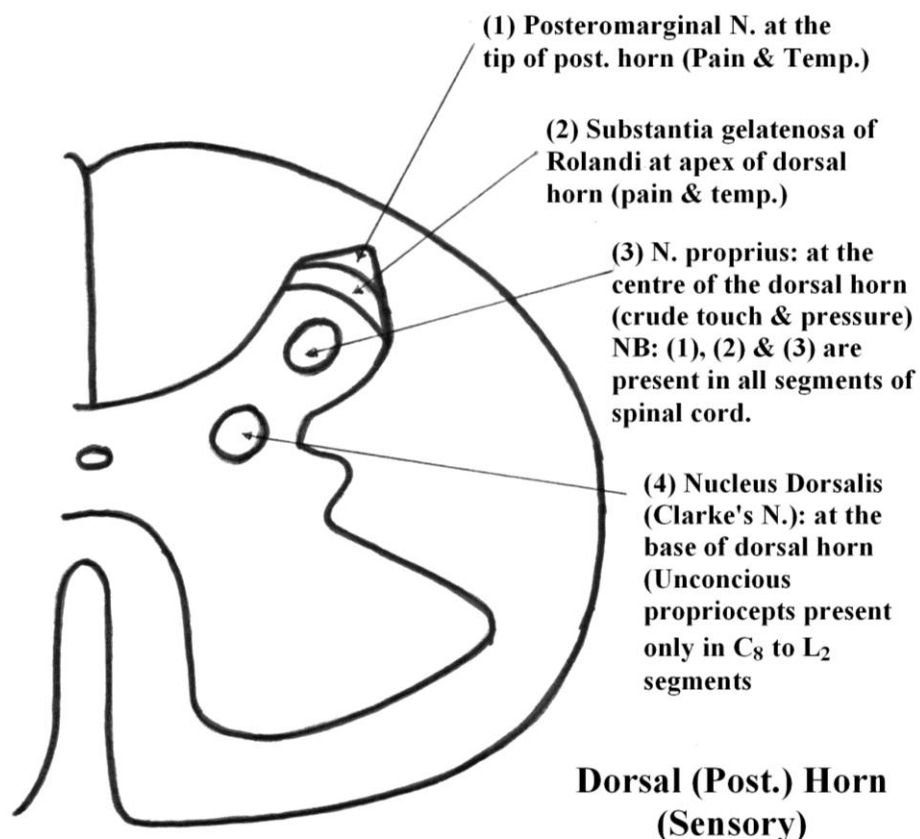
II) The dorsal (posterior) horn or column: (sensory or afferents)

- It is longer, narrower & contains general **somatic afferent (sensory) nuclei** which represent the cell bodies of the **2nd order neurons of these sensory pathways**.
- They **receive central processes** of the sensory nerve cells in the **dorsal root spinal ganglia** (the **1st order neurons** of the general **somatic sensory pathways** below the head).
- The nuclei of the dorsal horn are:
 - 1- Postero-marginal nucleus: (pain and temperature)**
 - It lies at **the tip** of dorsal horn (**at all levels of the cord**).
 - 2- Substantia gelatinosa of Rolandi: (pain and temperature)**
 - It lies at the **apex** of the dorsal horn (**at all levels of the cord**).
 - 3- Nucleus proprius: (crude touch and light pressure)**
 - It lies at the **center** of the dorsal horn (**at all levels of the cord**).
 - 4- Clarke's nucleus: (unconscious proprioception to cerebellum)**
 - It lies at the **center** of the dorsal horn (**from C8 - L3**).

III) Lateral horn: (Autonomic i.e. general visceral motor neurons)

- It **projects** laterally at the level of central canal.
- The neurons of the lateral horn are:
 - 1- Preganglionic sympathetic** neurons found only from **T₁ to L₂** segments.
 - 2- Preganglionic parasympathetic** neurons found only in the **S_{2,3&4}** segments, but it does not form a visible lateral projection.

★ **Laminae of Rexed:** Rexed divided the spinal gray matter into 10 laminae (see the drawing).



Laminae of Rexed

- Lamina I** : Posteromarginal N.
II: Substantia gelatinosa
III & IV: N. Proprius
V : Neck of dorsal horn.
VI: Base of dorsal horn.
VII: Clarke's N. & lat. horn.
VIII: Commissural N.
IX: Vent. Horn
X : Grisea centralis around the central canal

Gray Matter

Spinal White Matter

- It consists only of **myelinated nerve fibers**.
- The white matter of each half of the spinal cord can be **divided into** three funiculi (or columns):
 - a- **Ventral (Anterior) funiculus:** Lies between the **anterior median fissure** and the **ventral root of spinal nerve**.
 - b- **Lateral funiculus:** lies between the **ventral and the dorsal roots** spinal nerve .
 - c- **Dorsal (Posterior) funiculus:** lies between the **dorsal root** of spinal nerve root and the **posterior median sulcus & septum**.
- Each funiculus consists of tracts which may be ascending or descending.
- The white matter of **both halves** of the spinal cord are **connected** across the middle line by the **white commissure** which lies **between** the gray commissure & the anterior median fissure.

★ **N.B:**

- **Funiculus:** A part of white matter of the spinal cord formed of many longitudinal tracts of **different** functions, origins & terminations
- **Tract:** A large bundle of nerve fibers having the **same** function, origin & termination.

II. Blood Supply of Spinal Cord

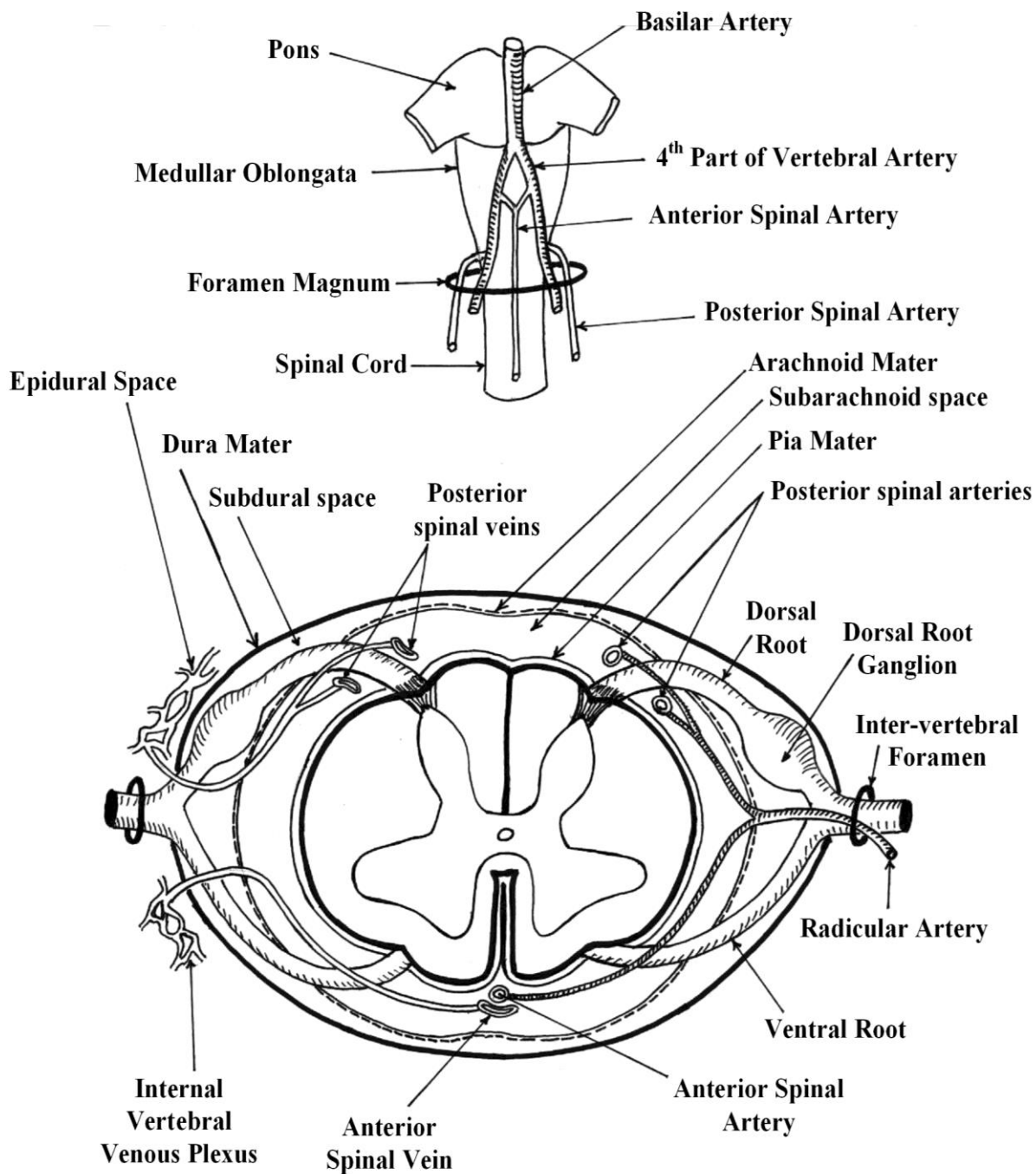
A) Arterial Supply

1. One anterior spinal artery:

- It **arises inside the skull** as two arteries, one from the 4th part of each **vertebral artery**, which unite together to form one anterior median artery.
- It **descends** to leave the skull through the **foramen magnum** and continues downwards along the **anterior median fissure** of the spinal cord.
- It gives **central branches** to supply the **anterior 2/3** of the spinal cord.

2. Two posterior spinal artery:

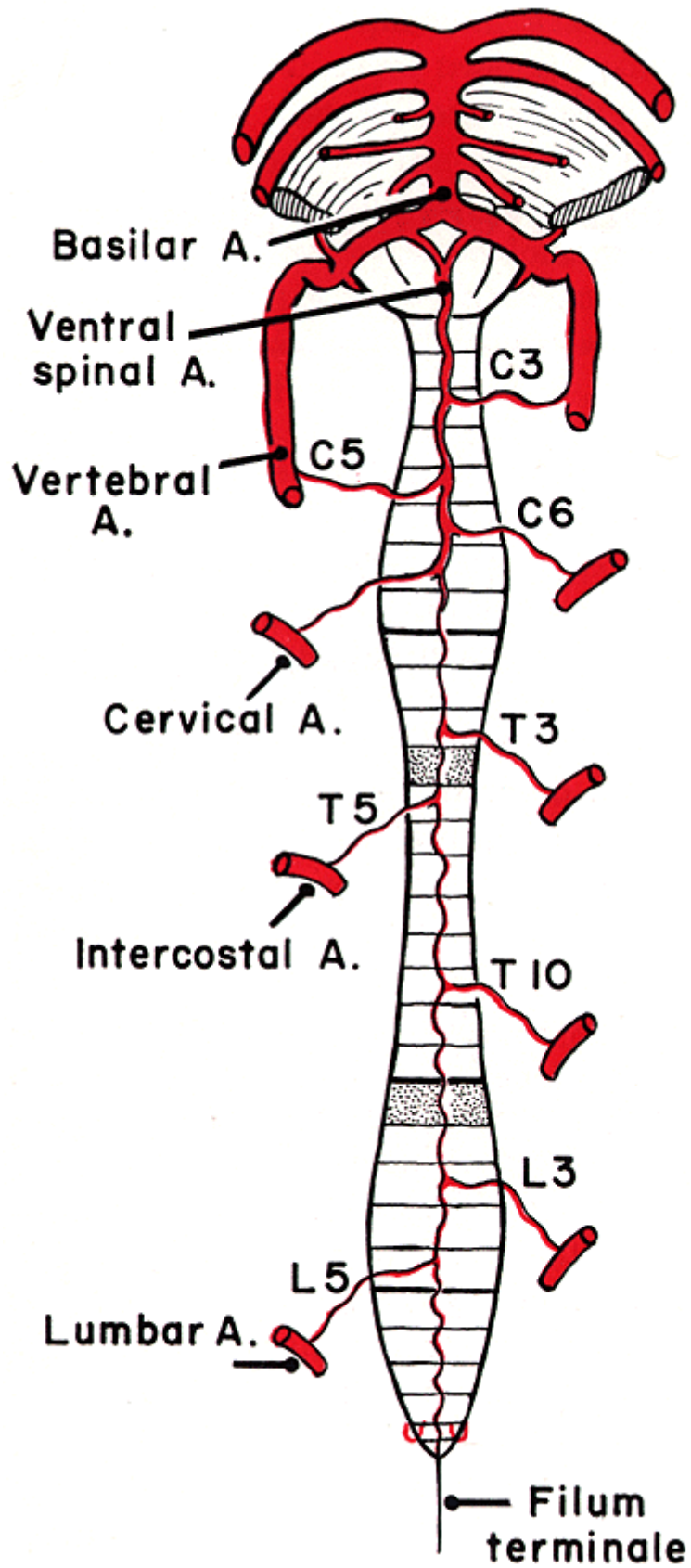
- It **arises inside the skull** as a branch from the 4th part of the **vertebral** artery.
- Each artery **descends** to leave the skull through the **foramen magnum** and continues downwards along the the **postero-lateral sulcus** and dorsal nerve roots.
- Each artery **divides** into **2 branches** which descend one in front and one behind the dorsal nerve roots.
- They **supply** the **posterior 1/3** of the spinal cord including the dorsal horn and the posterior white funiculus.
- **Anasomosis** between anterior and posterior spinal arteries occurs **around the conus medullaris**.

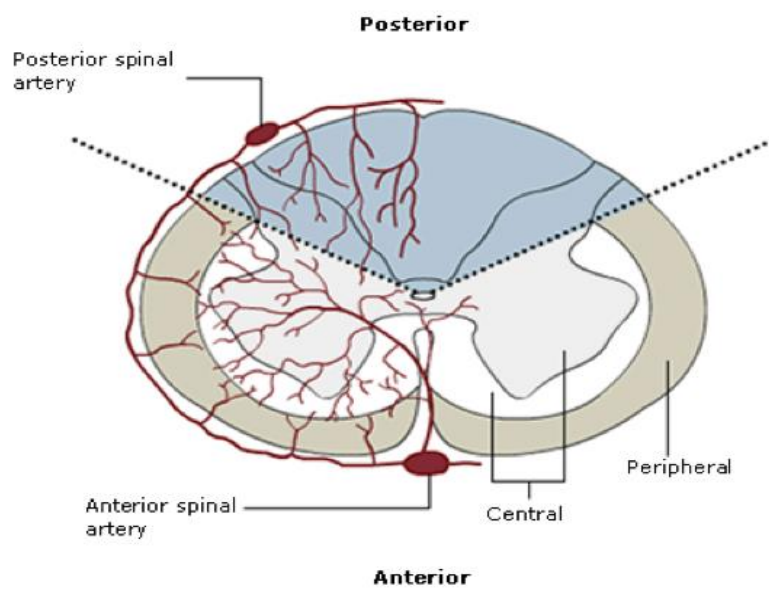
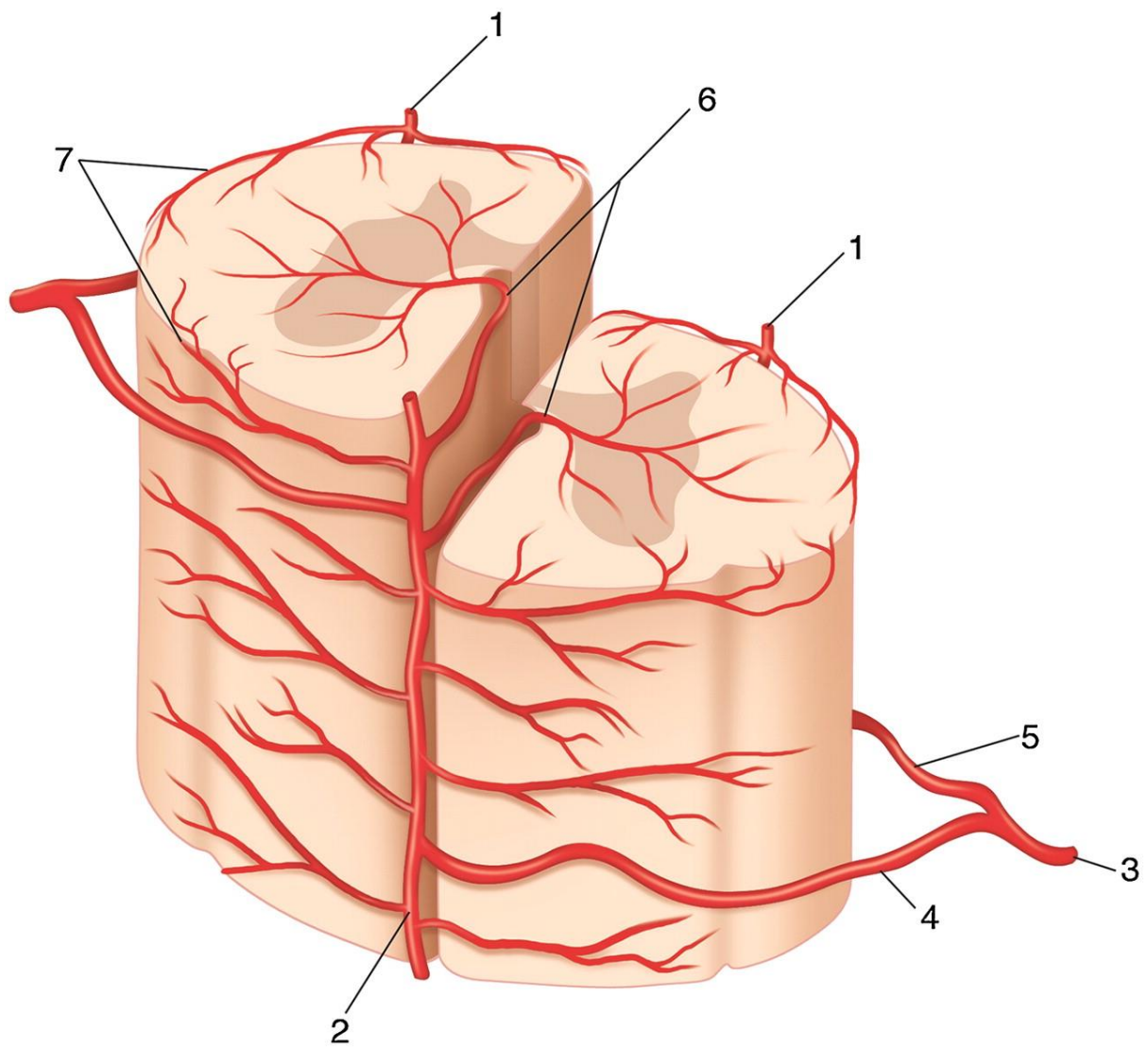


* Veins

* Arteries

Blood Supply of the Spinal Cord



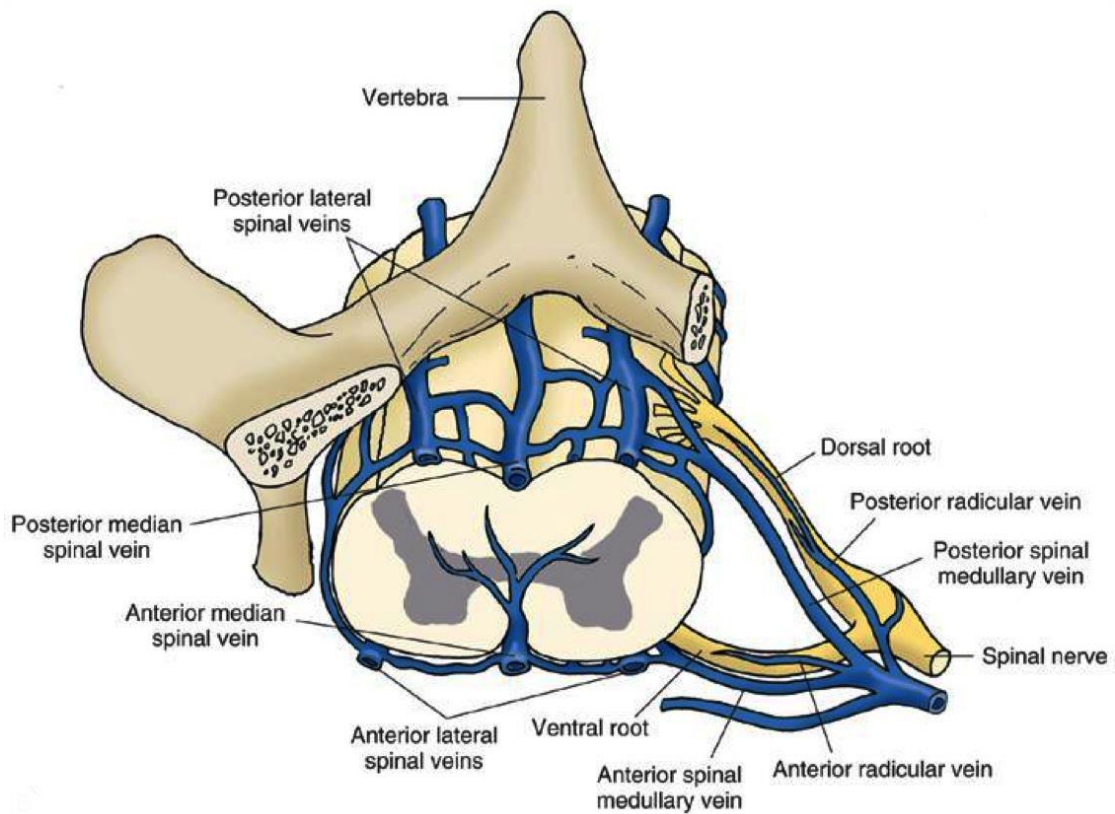


3. Radicular Spinal Arteries:

- They arise from the **vertebral** arteries (in the neck), the **posterior intercostal** arteries (in the thorax), **lumbar** arteries (in the abdomen) and **lateral sacral** arteries (in the pelvis) on either side.
- They **enter** the vertebral canal through the **intervertebral foramina** and **divide** into anterior and posterior branches which **run along the ventral and dorsal spinal nerve roots** respectively.
- They **end** on the surface of the spinal cord by **anastomosing** with both anterior and posterior spinal arteries.
- **The arteria radicularis magna** : is one large radicular artery supplies the **lumbar** enlargement .

B) Venous Drainage:

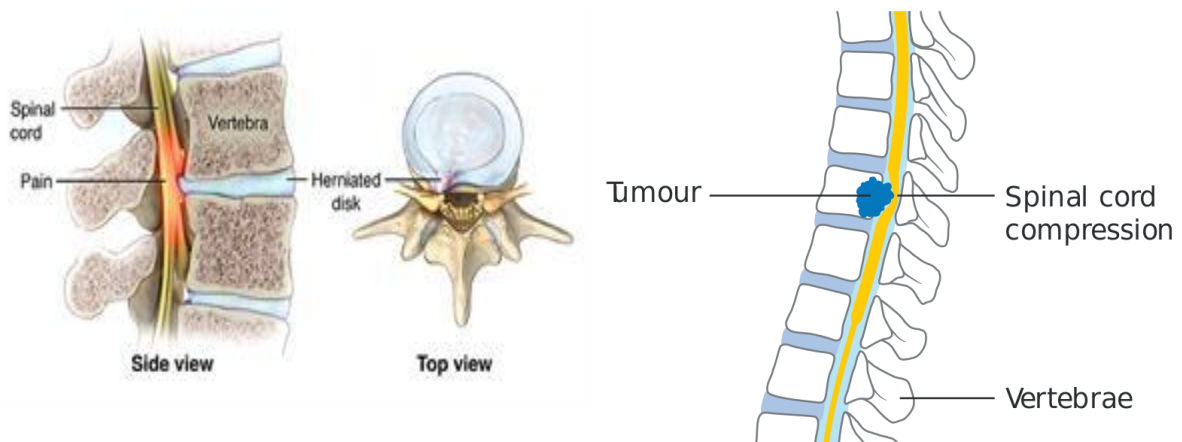
- There are 6 longitudinal venous channels:
 - Anteromedian and posteromedian channels.
 - 2 anterolateral channels.
 - 2 posterolateral channels.
- These venous channels are drained by radicular Veins and internal vertebral venous plexus present in the epidural space.

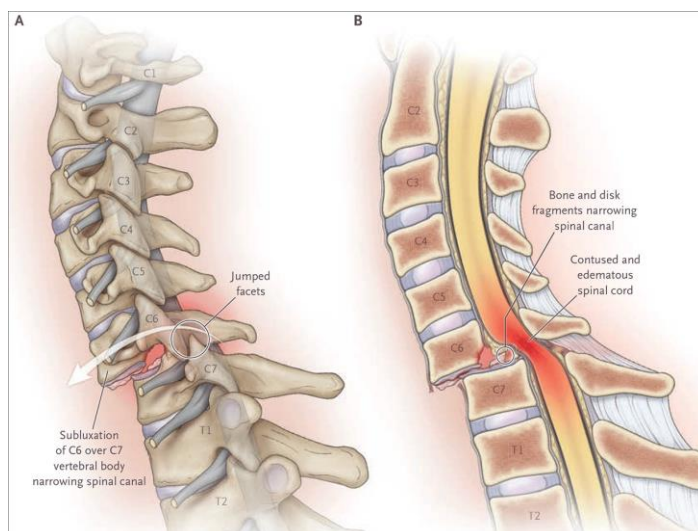


★ **Applied anatomy:**

2) Spinal Cord compression:

- **The commonest** cause of spinal cord compression is **intervertebral disc prolapse** or less commonly fracture vertebrae, tumor, stenosis of spinal canal or cold abscess.





2) Complete Transection of the Spinal Cord:

a) Above the lumbar region:

- **Paraplegia:** Paralysis of both lower limbs.

b) In the cervical region below the level of C5 segment:

- **Quadriplegia:** Paralysis of the 4 limbs.

c) In the cervical region above the level of C3:

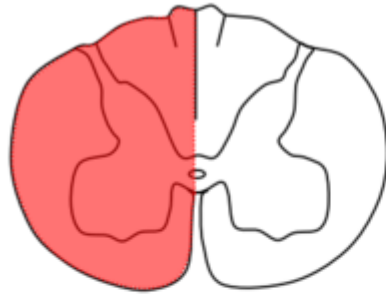
- **Death** due to respiratory failure as a result of complete paralysis of muscles of respiration including the **diaphragm** (phrenic nerve C3,4,5).

3) Hemisection of the Spinal Cord: (Brown-Sequard Syndrome)

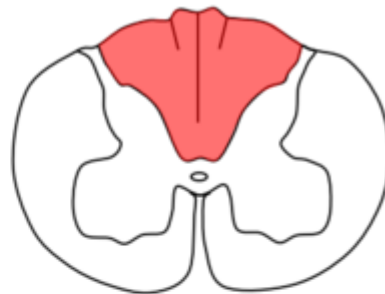
4) Tabes Dorsalis: Syphilitic affection of the spinal cord results in selective destruction of the **large sized nerve cells** of the **dorsal root ganglia** as well as of **posterior white funiculus tracts** (gracile and cuneate tracts) on both sides.

5) Syringomyelia: It is a pathological dilatation of localized segments of the central canal, usually in the cervical region.

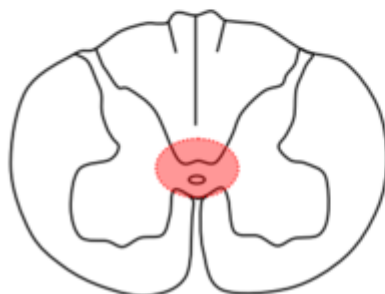
A. Hemisection (Brown-Sequard)



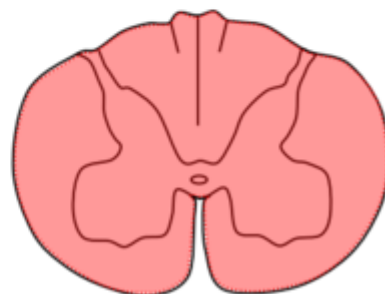
C. Posterior column syndrome



B. Syringomyelic syndrome



D. Complete transection



6) Conus Medullaris Syndrome: (Cauda Equina Syndrome)

2. It is due to direct injury of the sacral spinal segments in the conus medullaris or the sacral nerve roots in the cauda equina.

Cauda Equina Syndrome

