*Spinal Cord *

I. External Features

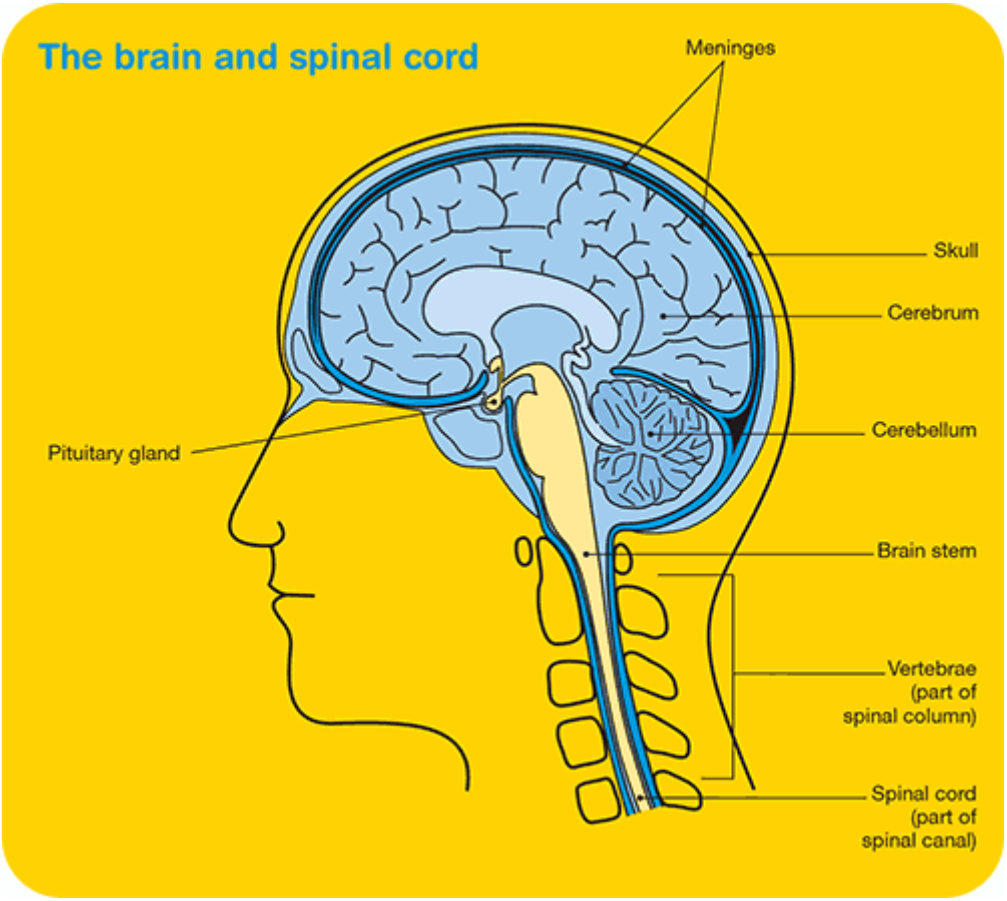
- ***Site:*** It occupies the upper 2/3 of the **vertebral canal in adults** .
- ***Extent:***

a- It **begins**, above, at the lowr border of **foramen magnum** as a continuation of the **medulla** oblongata.

b- It **ends**, below, at the level of the disc between **L1/L2** vertebrae. The lower end of the spinal cord tappers off into a conical extremity called **conus medullaris**.

- **Applied anatomy :** Lumbar puncture can be safely done below L2 vertebra without any danger of injury of the spinal cord.

- ***Length:*** It is aveage **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.

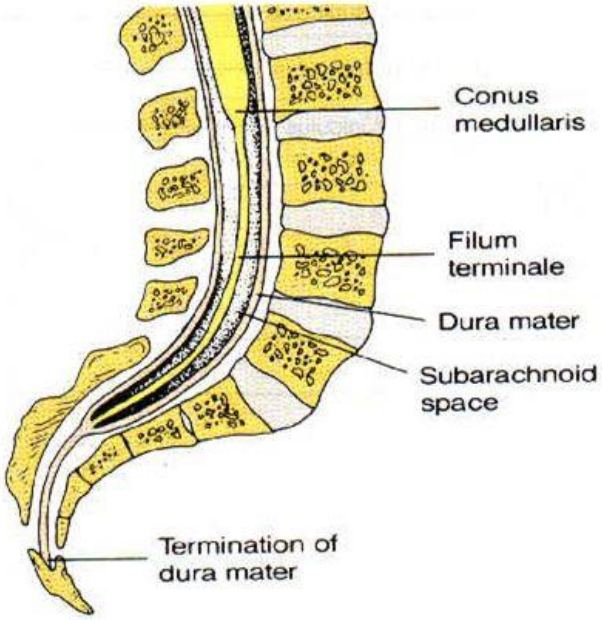
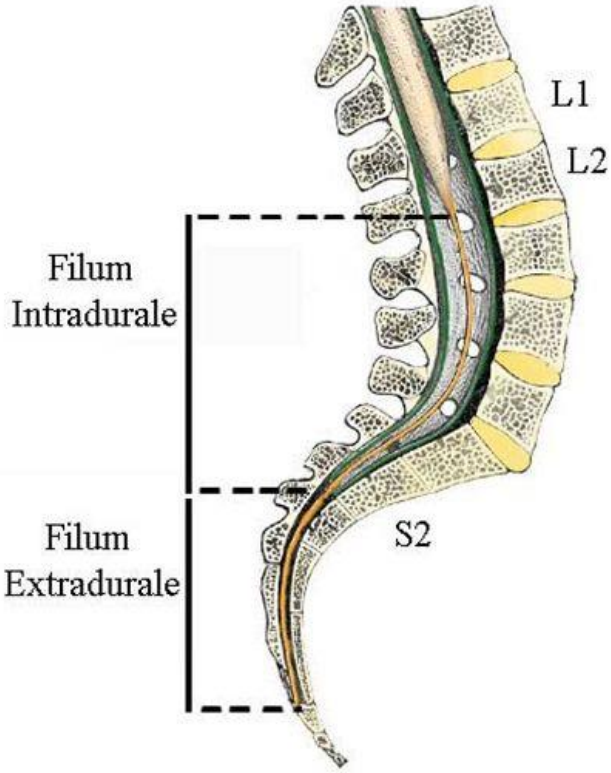


FIGURE 2.1 Longitudinal Spine



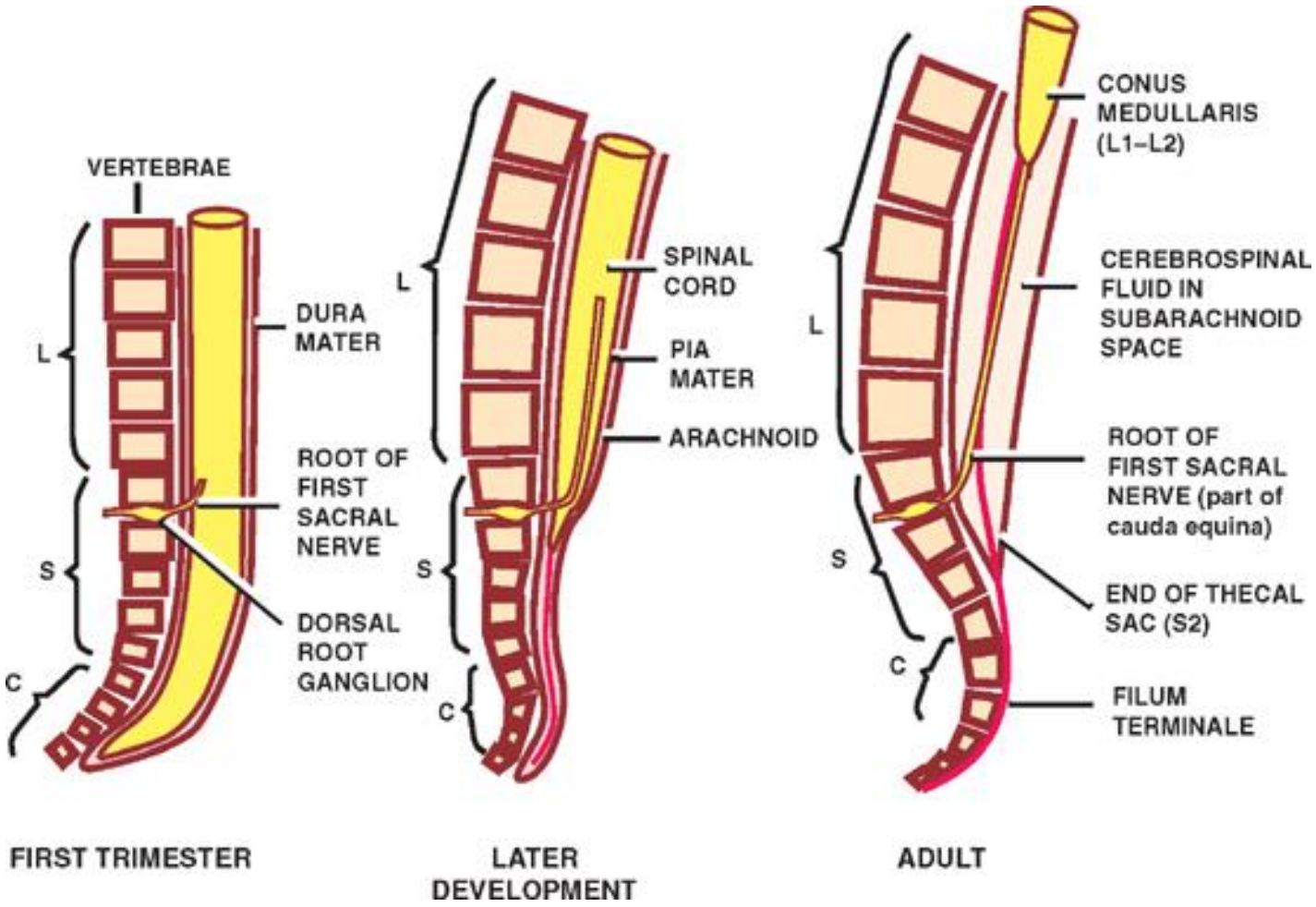
- ***Changes in the length of the spinal cord according to age:***

  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 **cylinderical**, It shows two **enlargements**:

a- **Cervical enlargement:** opposite C2 & T1 vertebrae, where the spinal cord give origin to the **brachial plexus** of the upper limb.

b- **Lumbar enlargement:** reaching maximal diameter opposite T_9 & L_1 vertebrae , where the spinal cord gives origin of **lumbosacral plexuses** of the lower limb.

- ***External features:***
  - The external surface of the spinal cord shows **5 sulci & 1 fissure** :

1- **Anterior median fissure**: is the deepest.

2- **Posterior median sulcus**.

3- & 4- **Two anterolateral sulci:** one on each side, along which emerge the **ventral (motor) roots** of the spinal nerves.

5- & 6- **Two posterolateral sulci:** one on each side, along which enter the **dorsal (sensory) roots** of the spinal nerve.

Spinal Cord

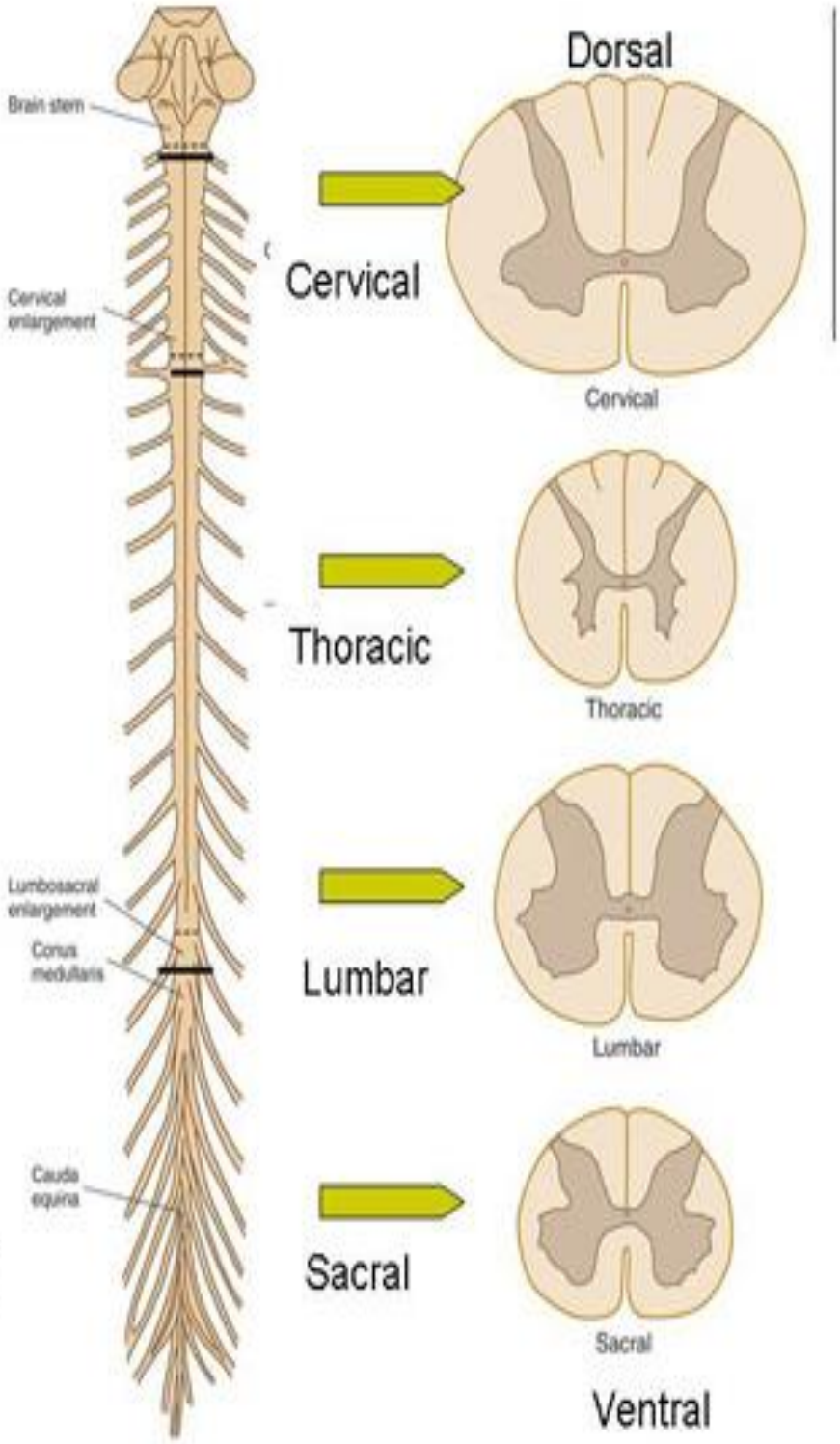
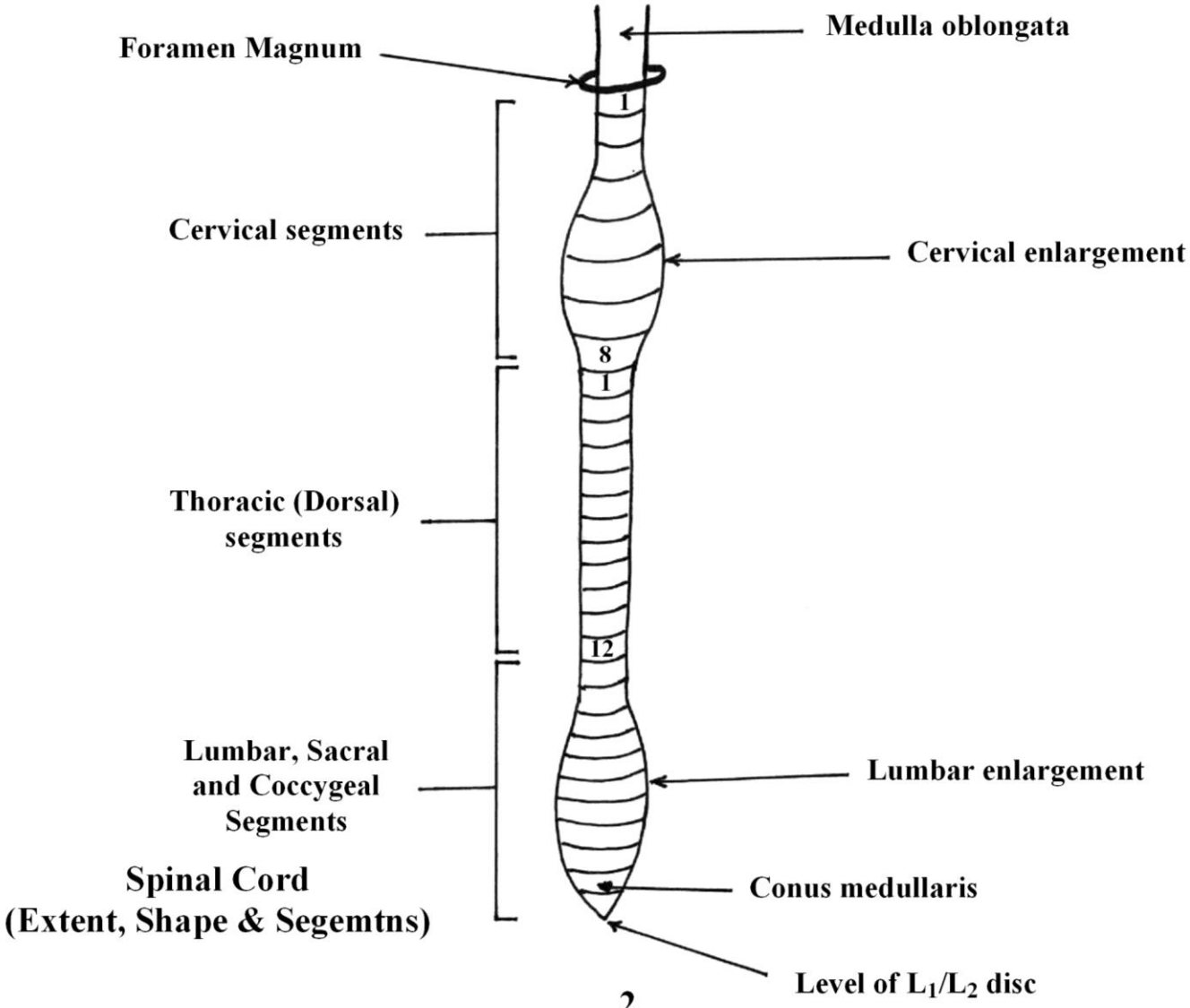
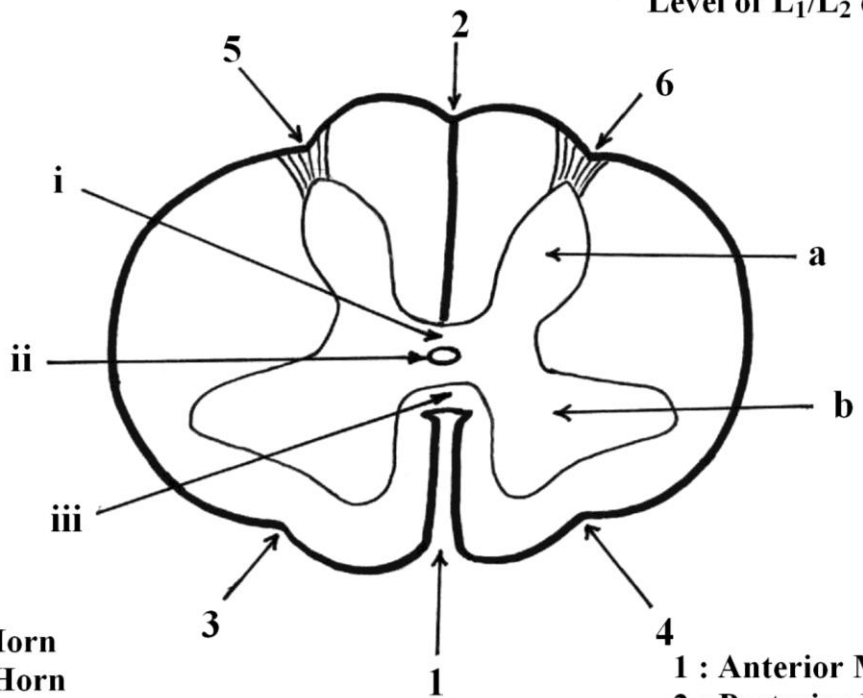


Figure 5-3 & 10. (5-3) Schematic dorsal view of isolated spinal cord and nerves (10)Transverse sections of the spinal cord at various levels. In: Waxman SG. *Clinical Neuroanatomy*. 26th ed. http://www.accessmedicine.com. Accessed January 3, 2010.



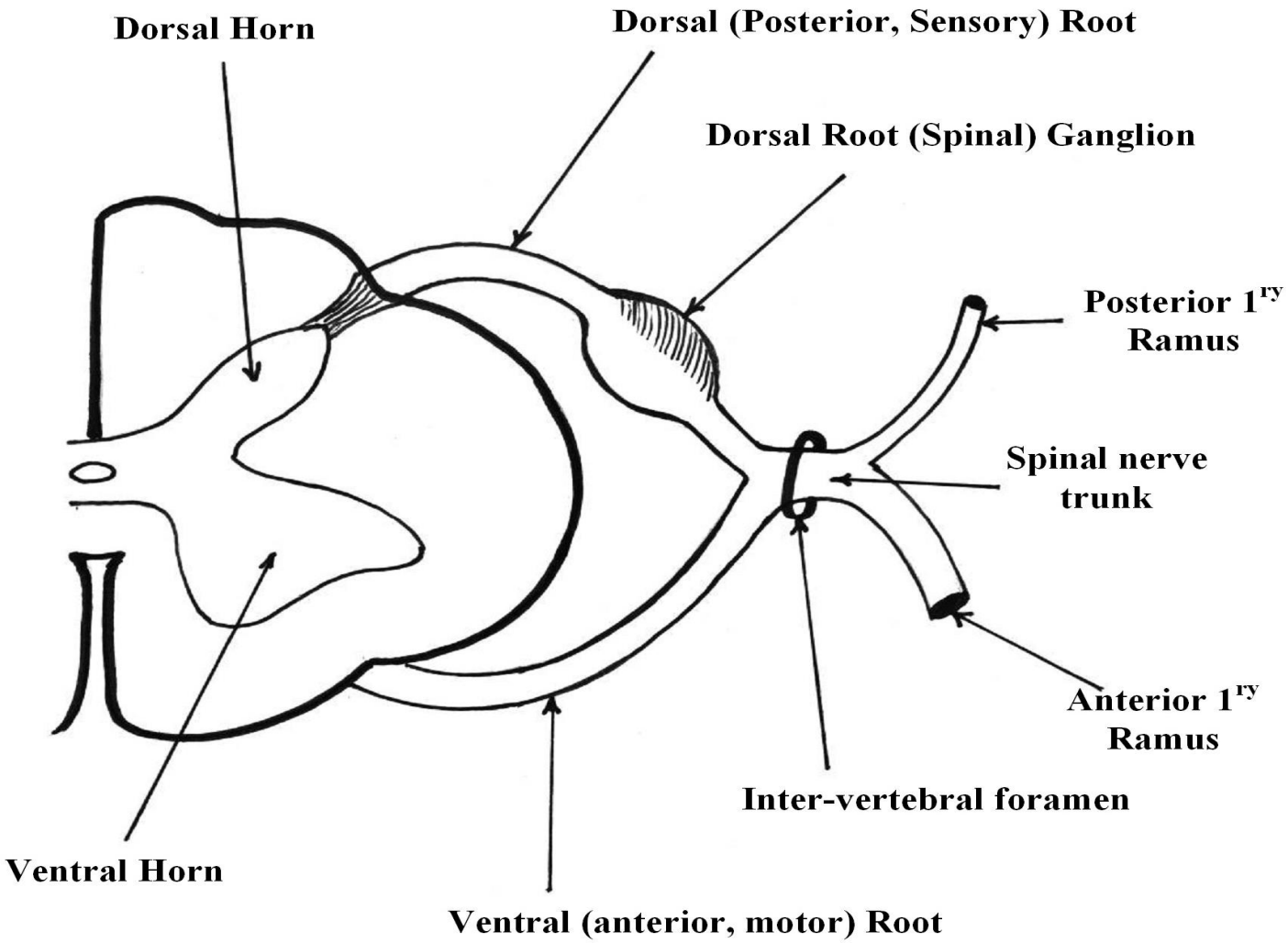
Spinal Cord (Extent, Shape & Segemtns)

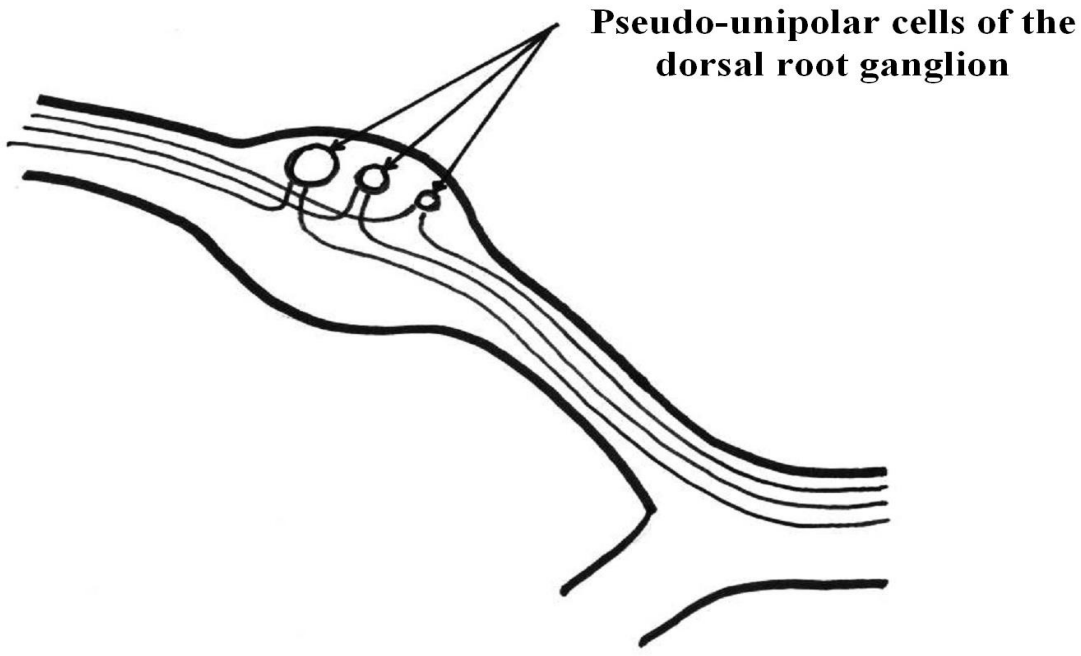


a : Posteior Horn
b : Anterior Horn
i : Grey Commissure
ii: Central Canal
iii: White Commissure

1 : Anterior Median Fissure
2 : Posterior Median Sulcus
3 & 4: Two Anterolateral Sulci
5 & 6: Two posterolateral Sulci

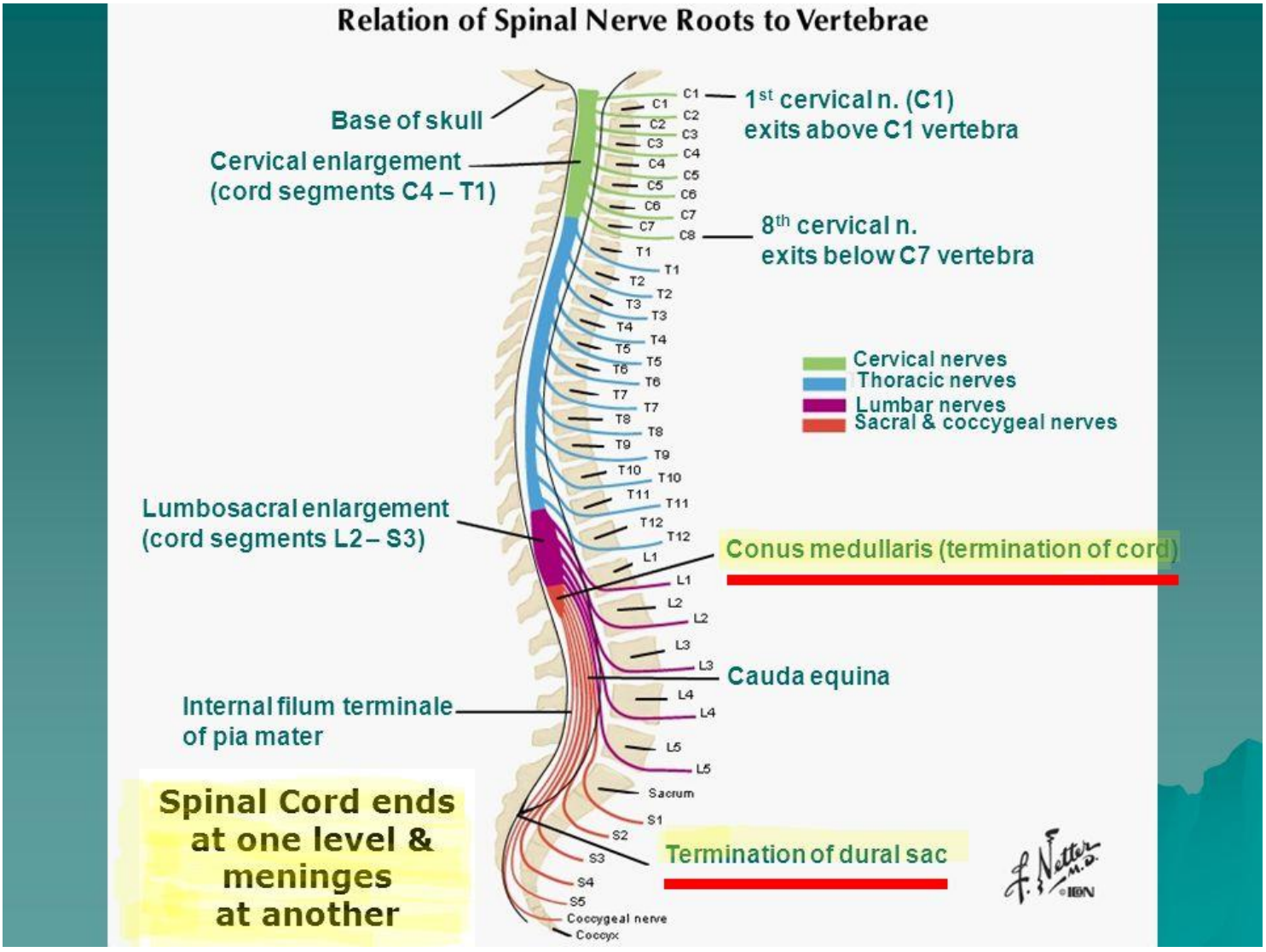
Spinal Cord (External & Internal Features)





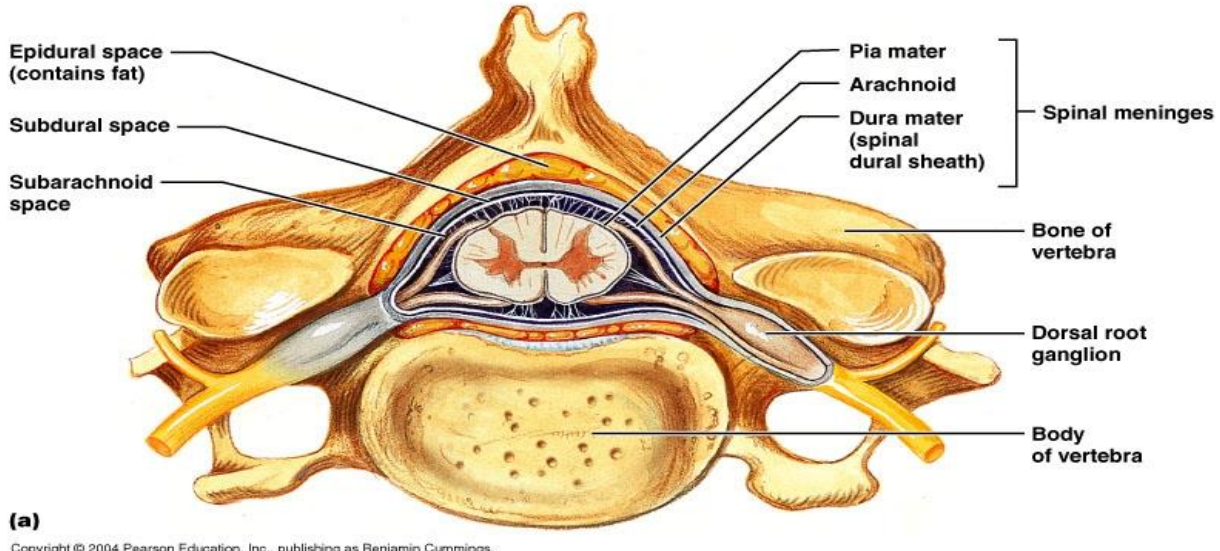
Spinal Nerve
(Roots, Ganglion & Rami)

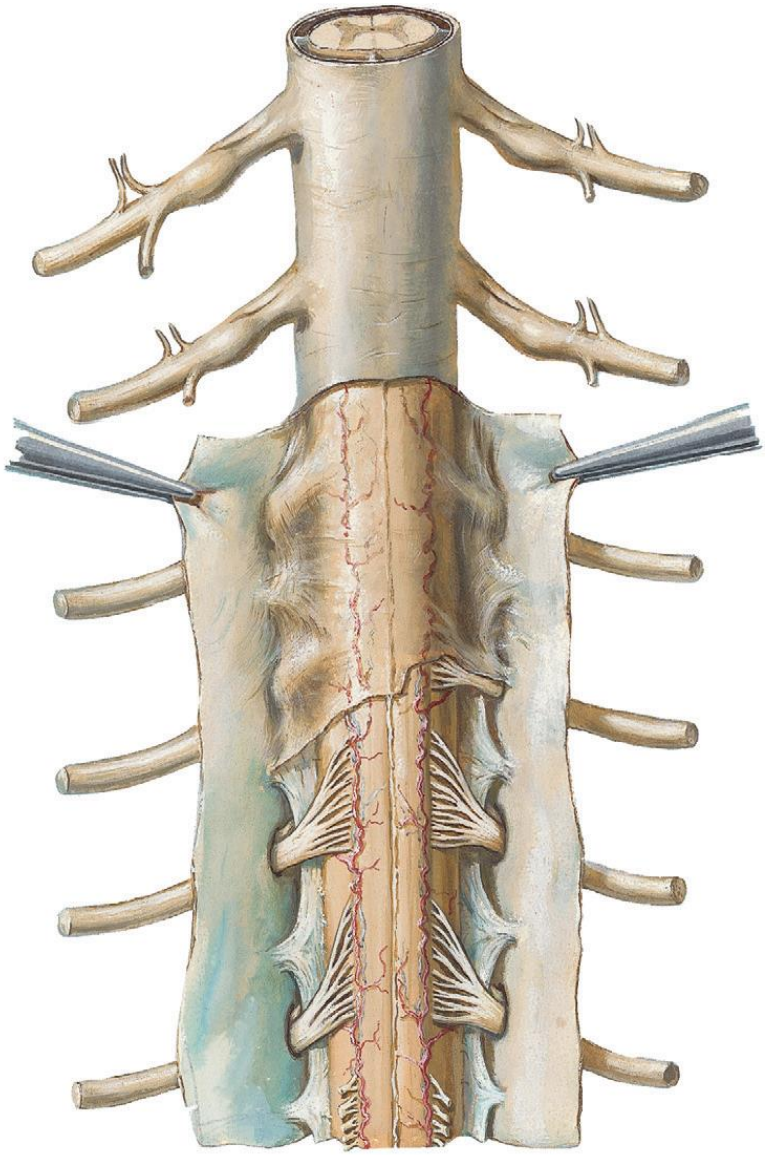
- ***Segments:*** The spinal cord is divided into **31** segments, arranged as follows:
  - 8 cervical segments.
  - 12 thoracic segments.
  - 5 lumbar segments.
  - 5 sacral segments.
  - 1 (one) coccygeal segment.
  - Since the spinal **cord is shorter** than the vertebral column, therefore , the segments of the spinal cord are **not in level** with their **corresponding vertebrae .**



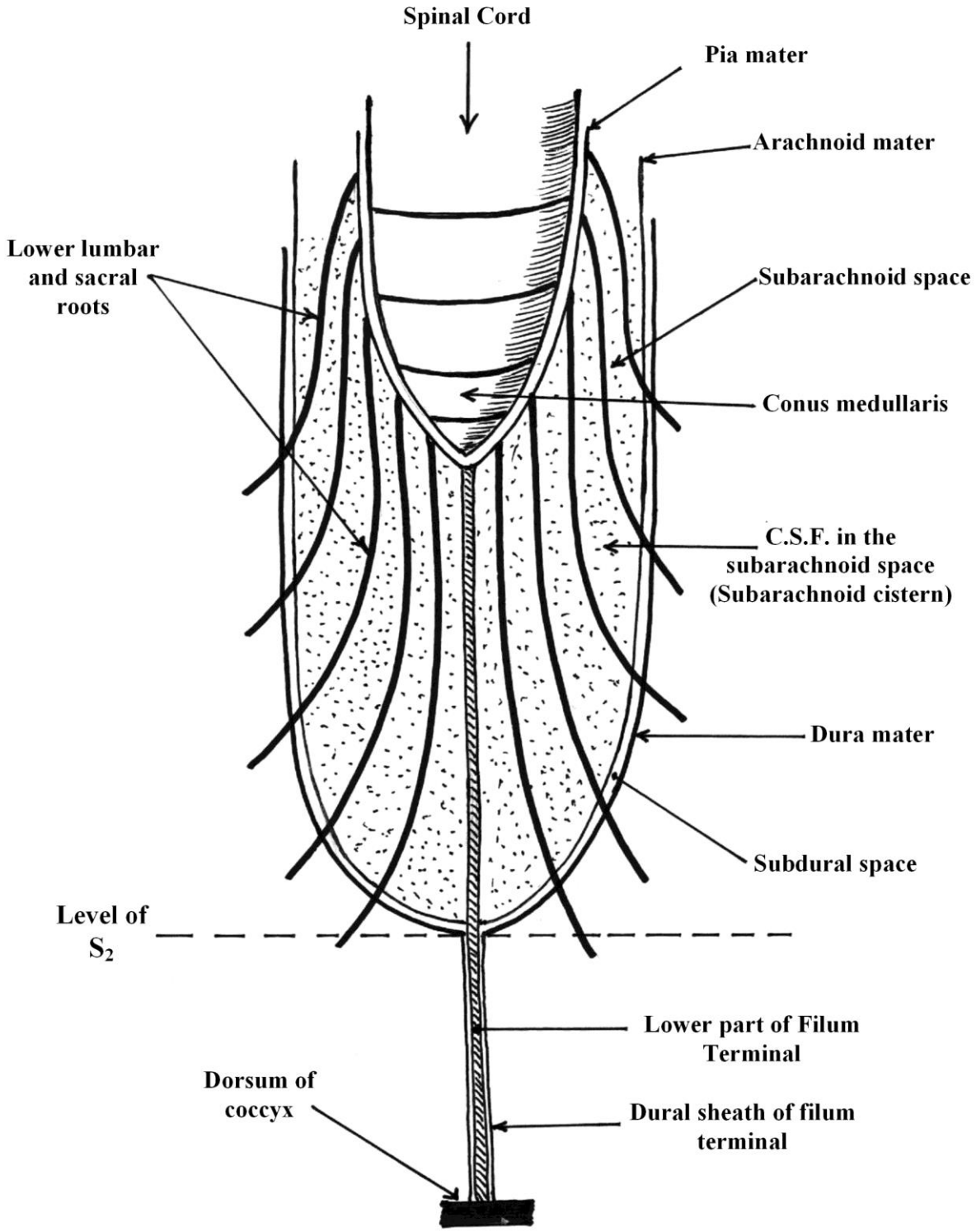
- ***Spinal nerves:***
  - **Each segment** of the spinal cord **gives origin** to a **pair of spinal nerves**, one on each side (right and left). Accordingly, there are **31 pairs** of spinal nerves (8 cervical, 12 thoracic, 5 lumbar, 5 sacral and one pair coccygeal nerves).
  - Each spinal nerve is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

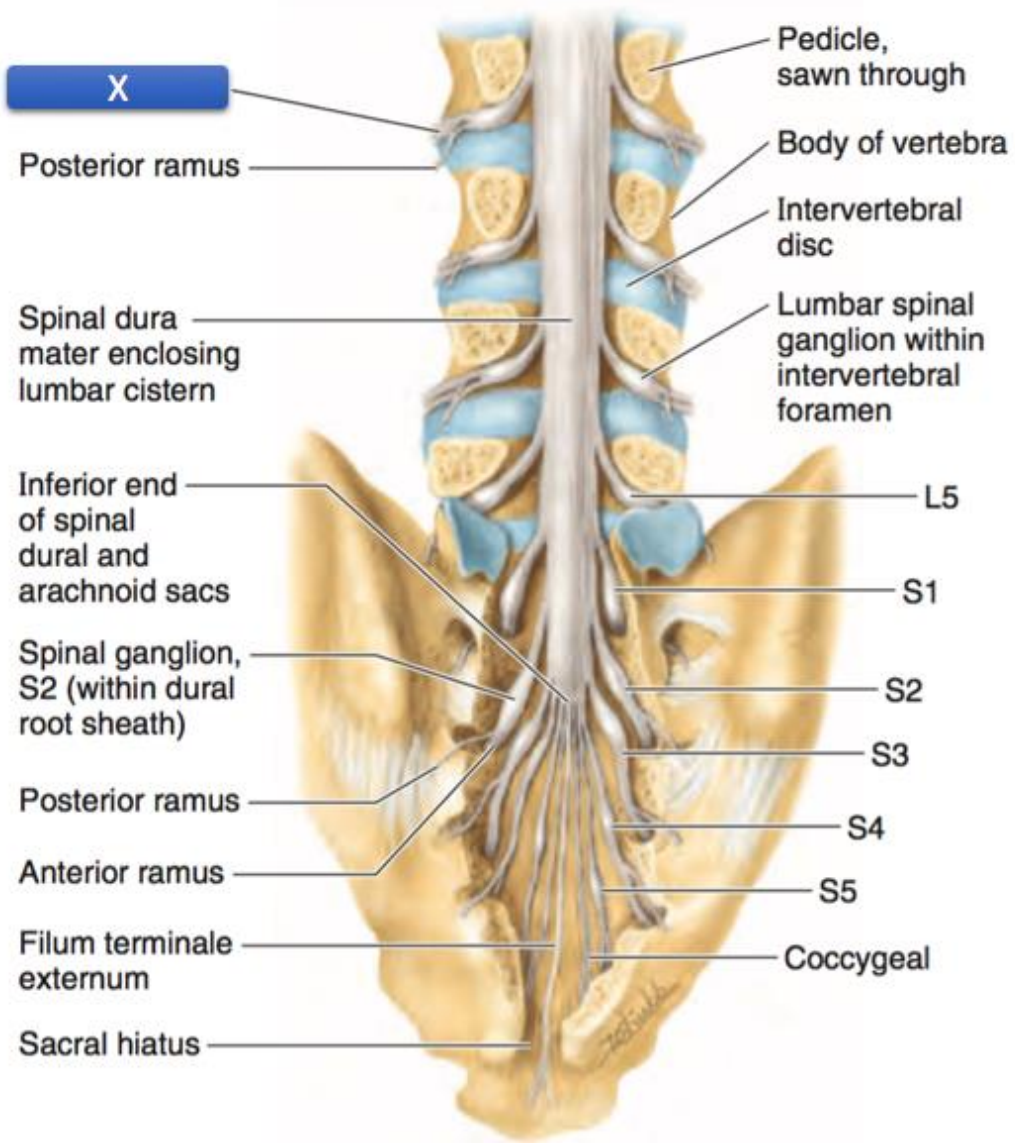
Ventral root (motor)	Dorsal root (sensory)
- It emerges from the ***antero-lateral sulcus***.	- It enters through the ***postero-lateral*** **sulcus** .
- It contains ***general somatic efferent*** (motor) fibers. - It *also contains sympathetic preganglionic fibers* in the all **thoracic & upper 2 lumbar** ventral roots. - It also contains *parasympathetic preganglionic fibres* in **2nd, 3rd and 4th sacral ventral roots** .	- It consists of ***general somatic afferent*** (sensory) fibres 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.
	- Each dorsal root carries the ***dorsal root or spinal ganglion***. - Cells in this ganglion 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 fibres. It leaves the vertebral canal through the ***intervertebral foramen***.
- 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 ***intervrertebral 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***.
  - Accodingly, 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 verteba***), 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 **subarachnoid space (subarachnoid cistern)**.


Spinal Cord
Pia mater
Arachnoid mater
Lower lumbar and sacral roots
Subarachnoid space
Conus medullaris
C.S.F. in the subarachnoid space (Subarachnoid cistern)
Dura mater
Subdural space
Level of S_2
Lower part of Filum Terminal
Dorsum of coccyx
Dural sheath of filum terminal


X
Posterior ramus
Spinal dura mater enclosing lumbar cistern
Inferior end of spinal dural and arachnoid sacs
Spinal ganglion, S2 (within dural root sheath)
Posterior ramus
Anterior ramus
Filum terminale externum
Sacral hiatus
Pedicle, sawn through
Body of vertebra
Intervertebral disc
Lumbar spinal ganglion within intervertebral foramen
L5
S1
S2
S3
S4
S5
Coccygeal

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

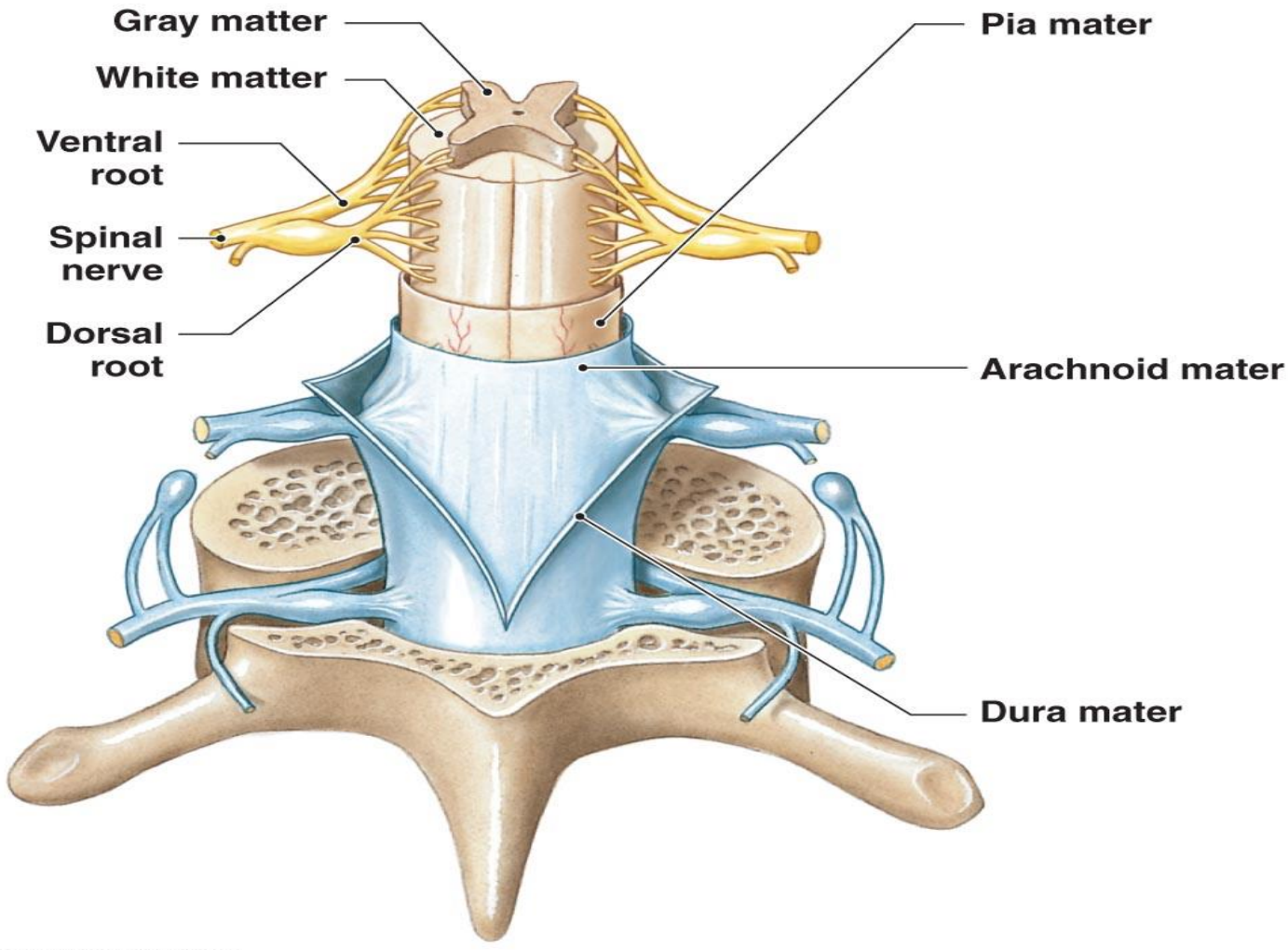
- The CNS (spinal cord & brain) is surrounded by **three meninges**; from inside outwards they are: the **pia**, the **arachnoid** and the **dura** maters.

A) The spinal pia mater :

- It is delicate membrane , closely ***adherent*** to the surface of the spinal cord.

- The pia mater is ***separated*** from the arachnoid mater by a space filled with cerebro-spinal fluid (***CSF***) and is called the ***subarachnoid space***.

A posterior view of the dissected spinal cord showing the basic relationships among the spinal meninges



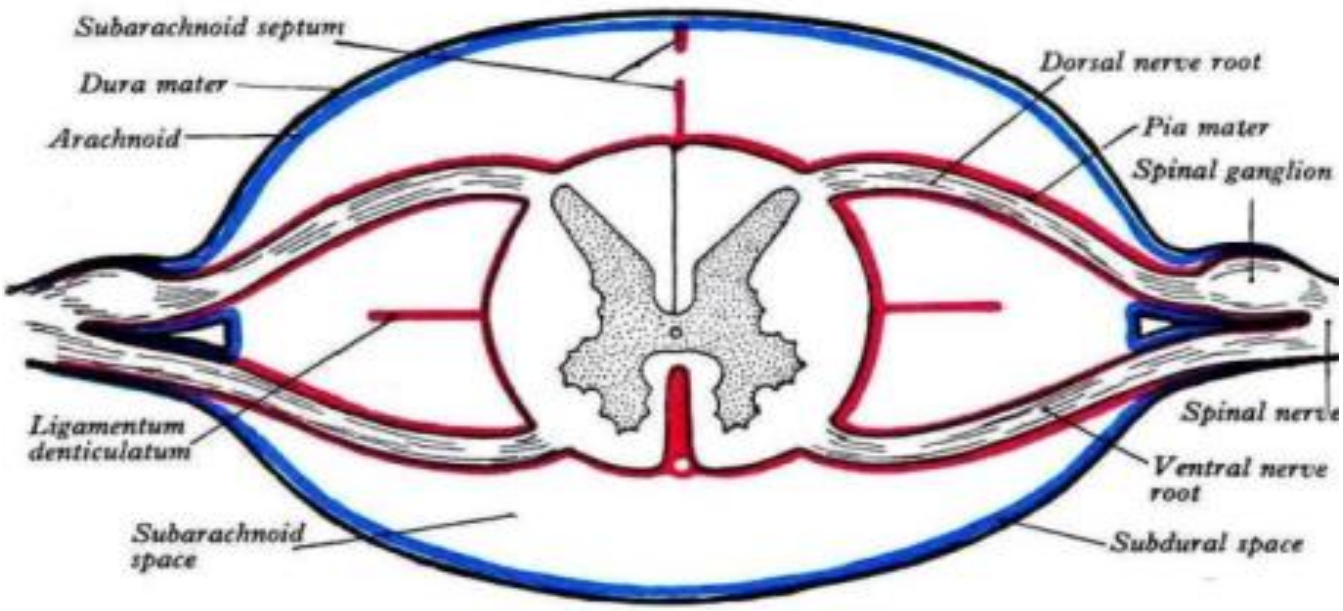
- It sends **prolongations**:
  - **Outwrds** forming sheaths aound the ventral and dorsal spinal ***nerve roots***.
  - **Inwards** forming sheths around the ***blood vessels*** which ***pierce*** the substance of the spinal cord and the brain.
- It is **thickened at 4 sites** to form strong fibrous bands:

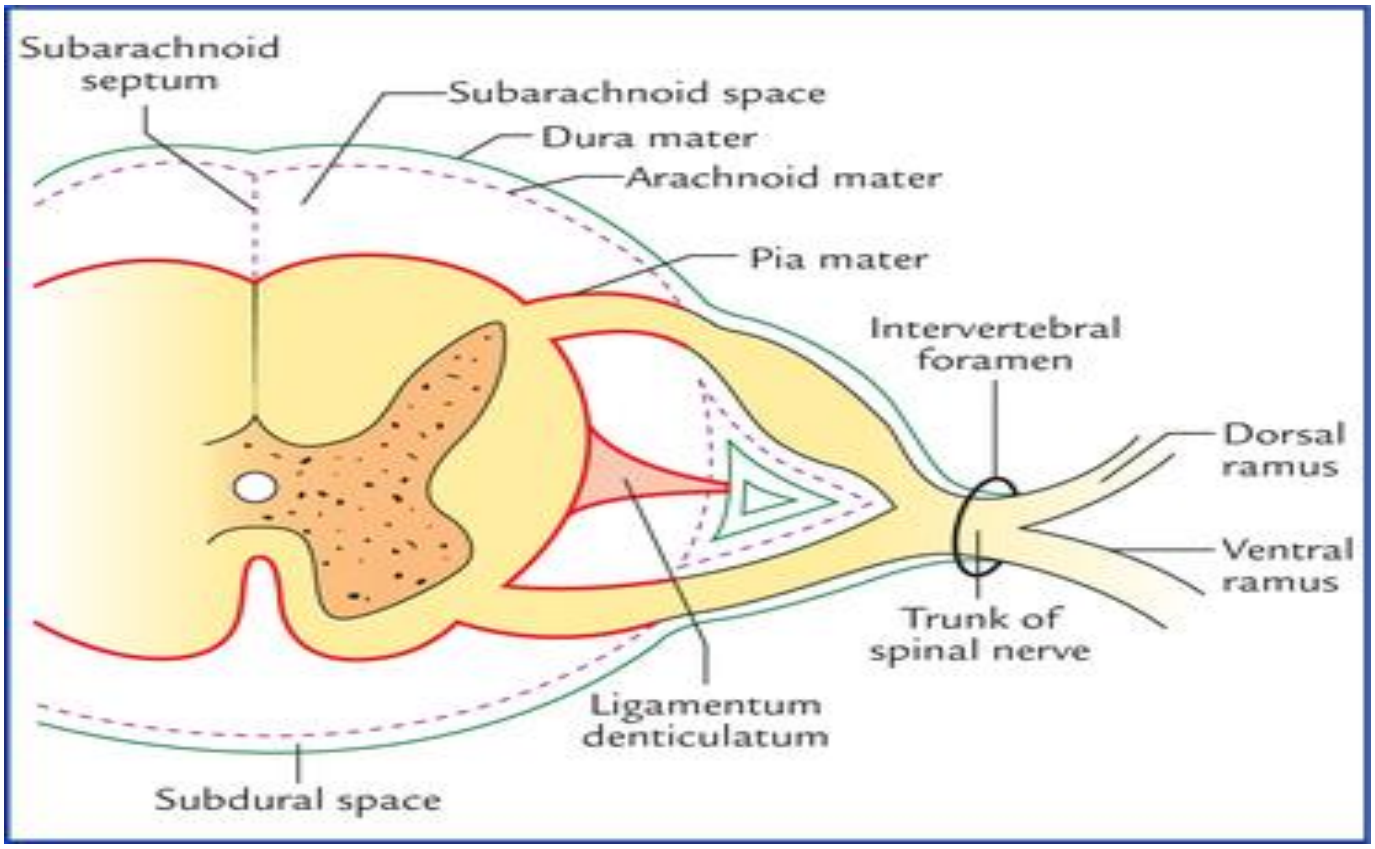
a- Denticulate ligaments :

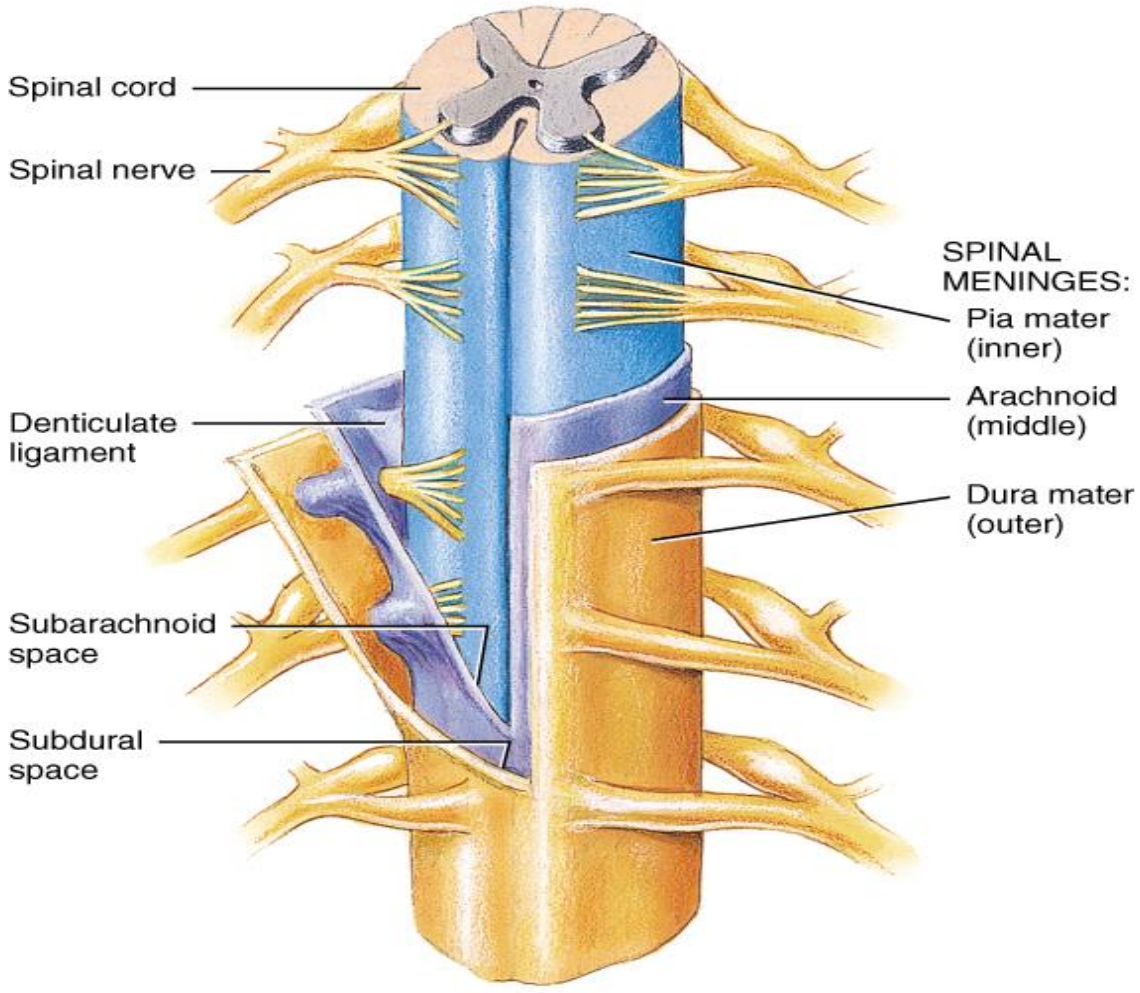
- Each ligament **extends** from the ***foramen magnum*** (above) down to the level of L_1 vertebra (below).
- Each ligament extends **laterally** one on each side , ***midway*** between the ventral and dorsal spinal nerve root , to attach laterally to the ***dura mater***.
- Each ligament has a **serrated** lateral border (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 dura mater.

c- ***Linea splendens:*** Is median longitudinal band of pia mater extend **along the surface** of the anterior median **fissure** .



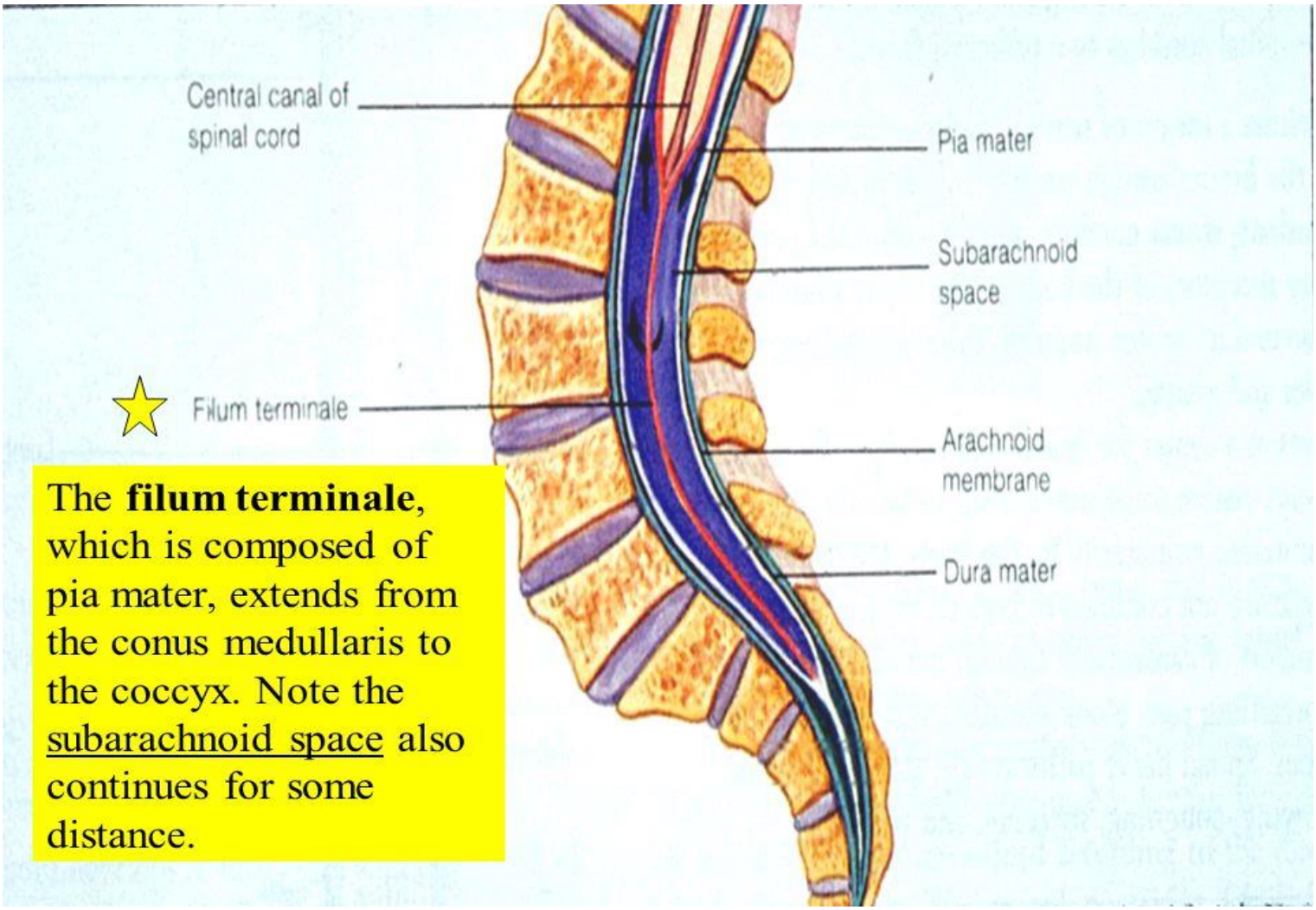




(a) Anterior view and transverse section through spinal cord

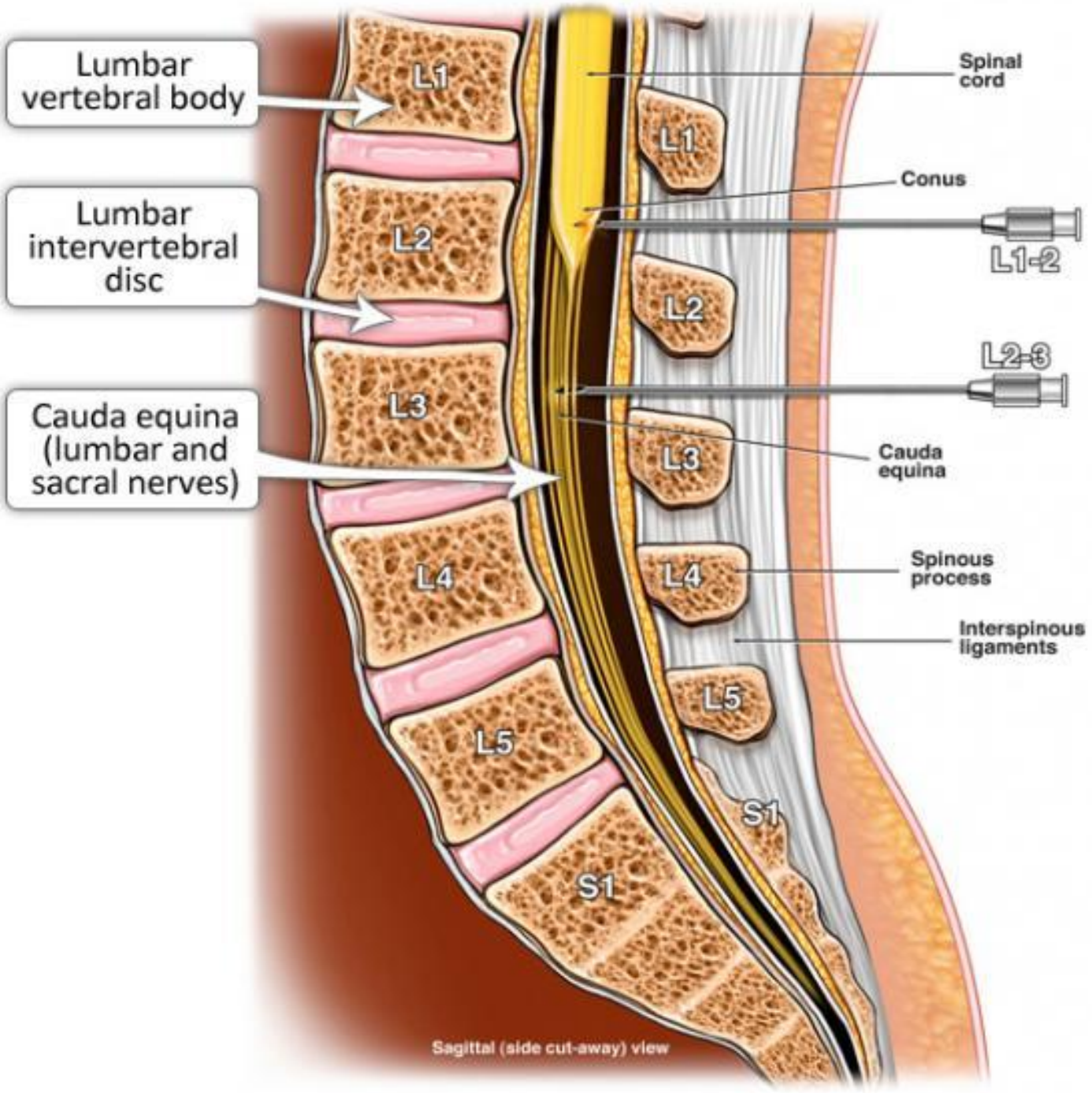
d- ***Filum terminale:***

- 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 centre of the **cauda equina** floating in the **CSF** in the **subarachnoid cistern** .
- At the level of the **S_2** 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 the **back of the coccyx**.
- It is distinguished from the nerve roots of the cauda equina by having a **glistening slivery appearance** and by being **attached** to the tip of the conus medullaris.



B) *Spinal Arachnoid Mater:*

- It is a **delicate** membrane which lies **outside** the pia· mater and **deep** to the dura mater.
- It is **separated** from the pia mater (inside it) by the **subarachnoid space** which is filled with **CSF**.
- It is separated from the dura mater (outside it) by a **narrow subdural space** which contains a **thin film** of serous fluid.
- **Above**, it is **continuous** through the foramen magnum with the arachnoid mater of the brain.
- **Below**, it ends at the level of the S_2 vertebra where it is **pierced** by the filum terminale.
- **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 trabeclae disappear and the subarachnoid space becomes widened forming **subarachnoid cistern** to lodge the cauda equina.
- The subarachnoid space : contains
  - Cerebro-spinal fluid (CSF).
  - Spinal blood vessels.
  - Spinal nerve roots.
- **Applied anatomy : *Lumbar puncture***: is done by introducing a needle into the subarachnoid space either to obtain a sample of CSF or to inject a drug. It is safe to be done **below of the level (L2)** vertebra 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 and are not injured.



C- *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 **S_2** 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 (** around the filum terminale).
- It sends tubular **prolongations** (sheaths) around the **spinal nerve trunks** in the intervertebral foramina. These dural sheaths blend with the **epineurium** of the nerve outside the intervertebral foramina.
- It is **separated** from the arachnoid mater (inside it) by a narrow capillary space called the **subdural space** which contains a **thin film of serous fluid**.
- **Unlike the cranial dura** mater, the spinal dura mater is separated from the periosteal lining of the vertebral canal by a space called the **extradural or epidural space** which lies outside the spinal dura mater. This space **contains**:
  - loose areolar tissue.
  - Semiliquid fat.
  - Internal vertebral venous plexus.
- The spinal dura mater receives **nerve supply** from the meningeal branches of the spinal nerves. It receives **blood supply** from the radicular spinal 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:*** The spinal cord is fixed 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 dura 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. Blood Supply of the Spinal Cord

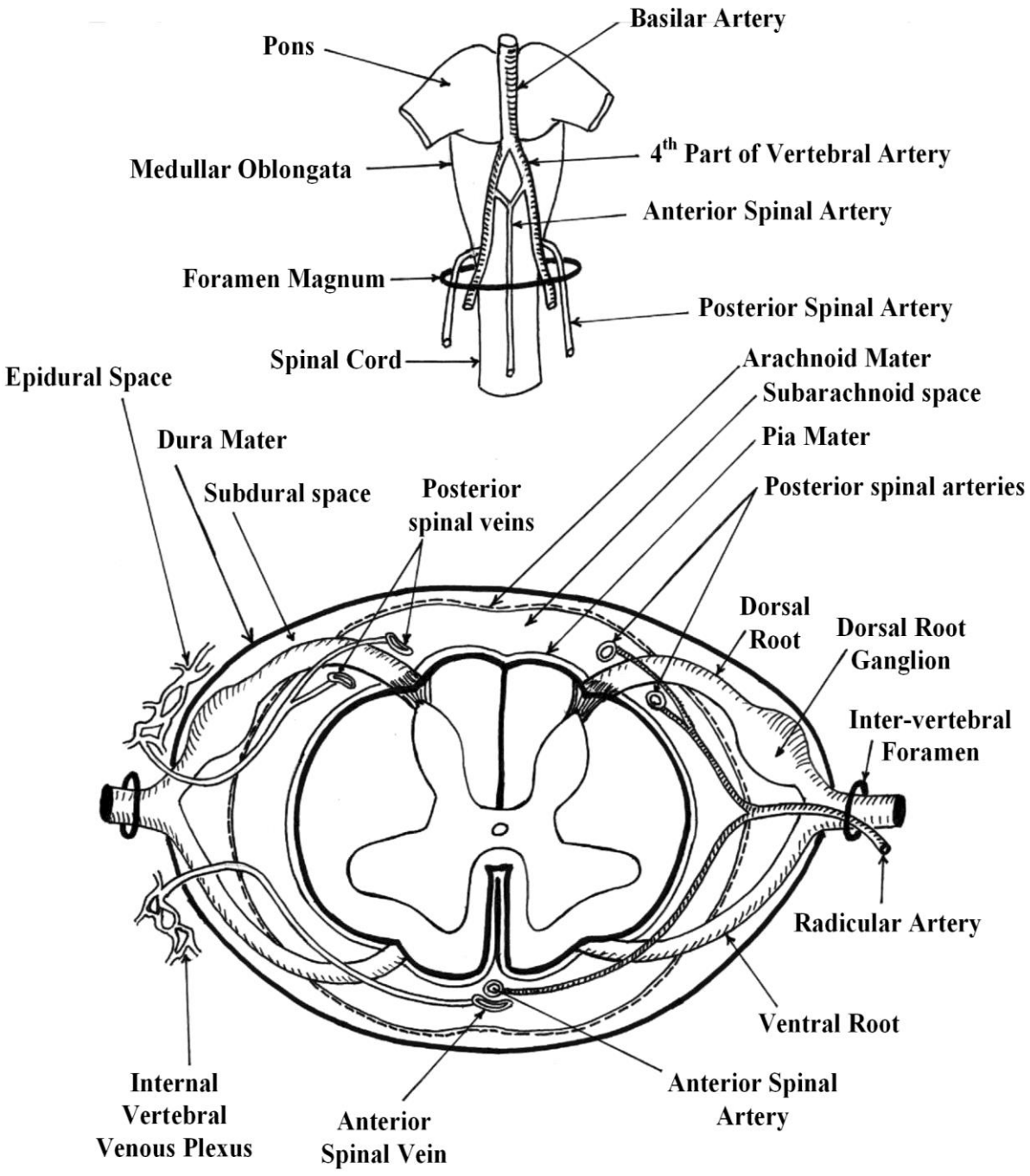
A- Arterial Supply

1. Anterior Spinal Artery: (One median longitudinal trunk):

- 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 thickness of the spinal cord .

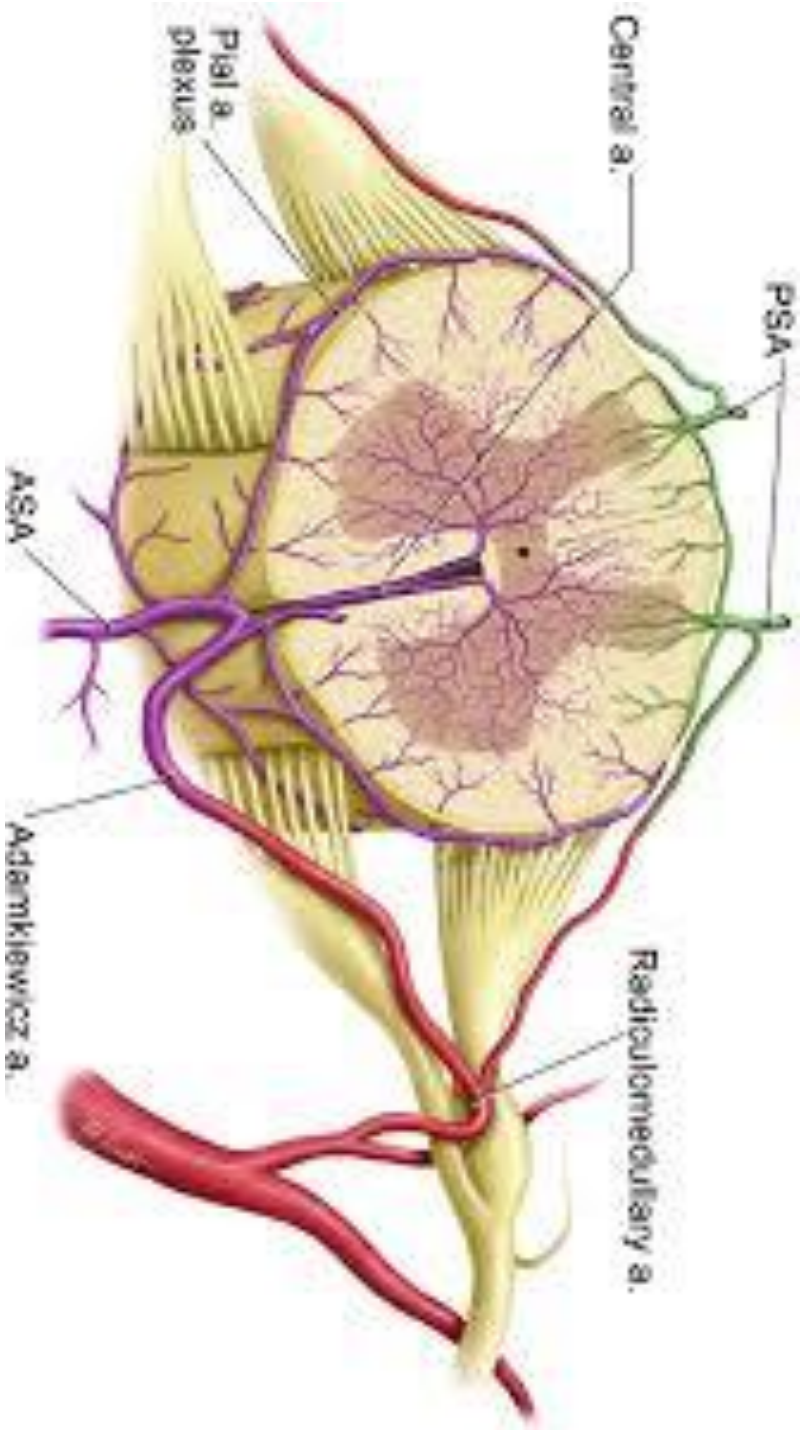
2. ***Posterior Spinal Artery:*** (Two longitudinal arteries):

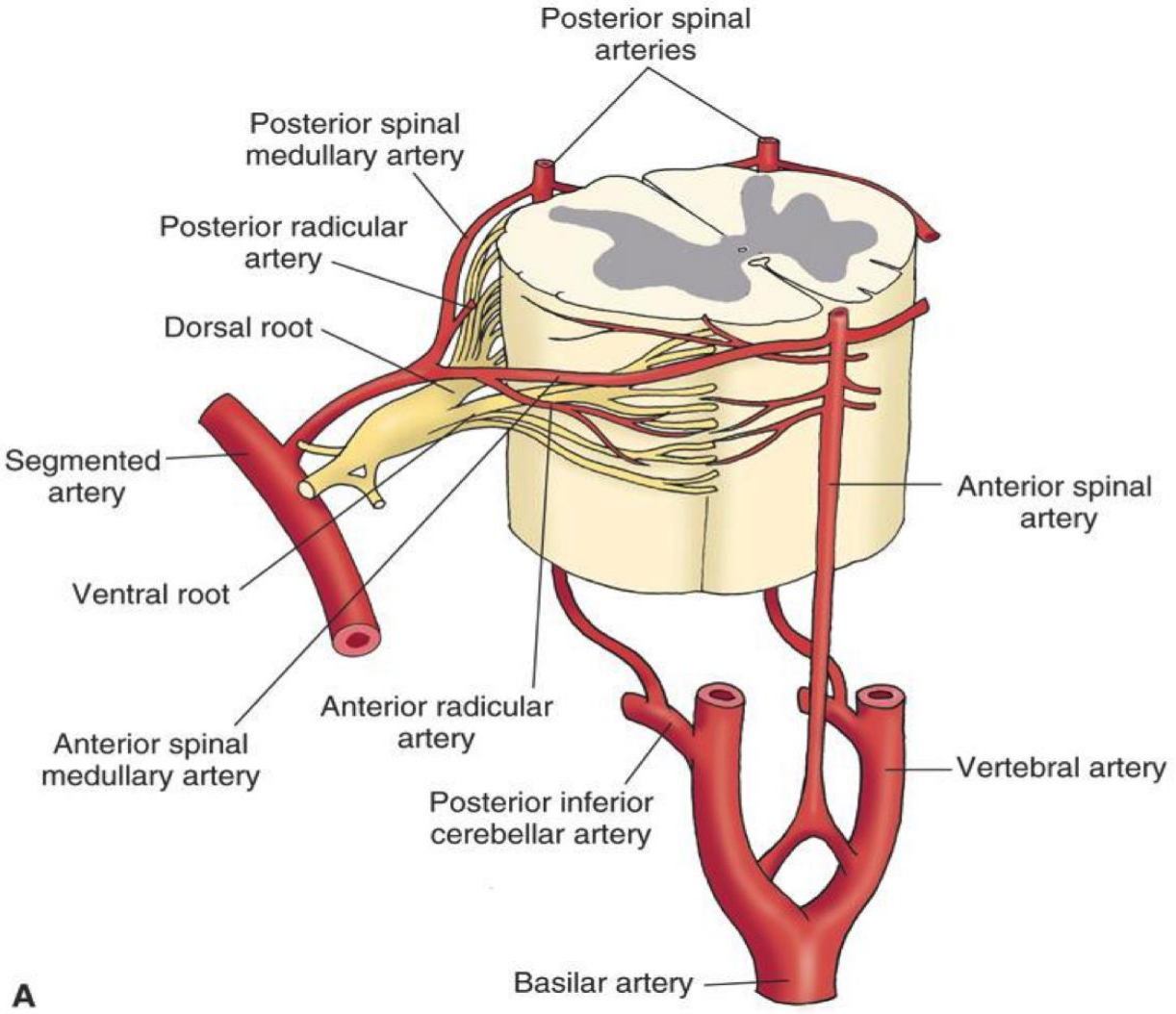
- It **arises inside the skull** as a branch from the 4th part of the **vertebral** artery.
- Each artery **descends** to leave the skull through the **foramen magnum** and continues downwards along the **dorsal nerve roots** (the **posterolateral sulcus**).



* Veins * Arteries

Blood Supply of the Spinal Cord





- 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**.

3. ***Radicular Spinal Arteries:*** (Transverse 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 i**nto anterior and posterior branches which **run along the ventral and dorsal spinal nerve roots** respectively **.**
   - They **end** of the surface of the spinal cord by **anastomosing** with both anterior and posterior spinal ateries.
   - **The arteria radicularis magna** : is one large radicular artery supplies the **lumbar** enlargement .

B- Venous Drainage

★ Veins corresponding to anterior, posterior and radicular spinal arteries drain into the internal vertebral venous plexus present in the epidural space.

III. Internal Structure

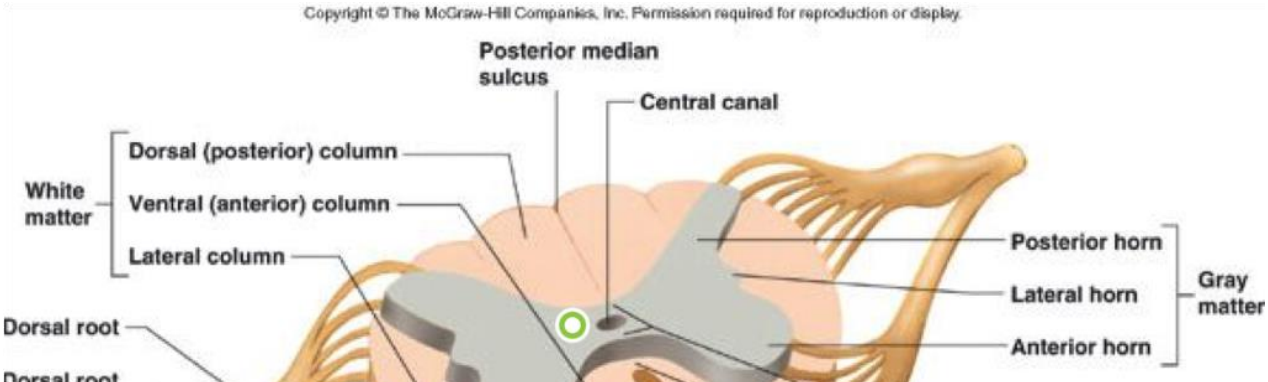
*Transverse section of the spinal cord:

- Shows **centrally** located **H** shaped **gray matter** surrounded by **peripherally** located **white matter.**
- The spinal cord is divided into **two symmetrical halves** (right and left) by the **posterior medium sulcus , posterior median septum** and the **anterior median fissure**. The 2 halves are **connected** together by:
- **Gray commissure** which contains the central canal of spinal cord.
- **White commissure** which lies in front of the gray commissure.

★ Important note : Dear medical students , First of all , you should study (Nervous Pathways) very well before reading the following subjects .

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 fomed of** :
  - **V*entral (anterior, motor) horns***.
  - **D*orsal (posterior, sensory) horns***.
  - These horns form the **anterior & posterior grey columns** which extend longitudinally along the whole length of the cord .



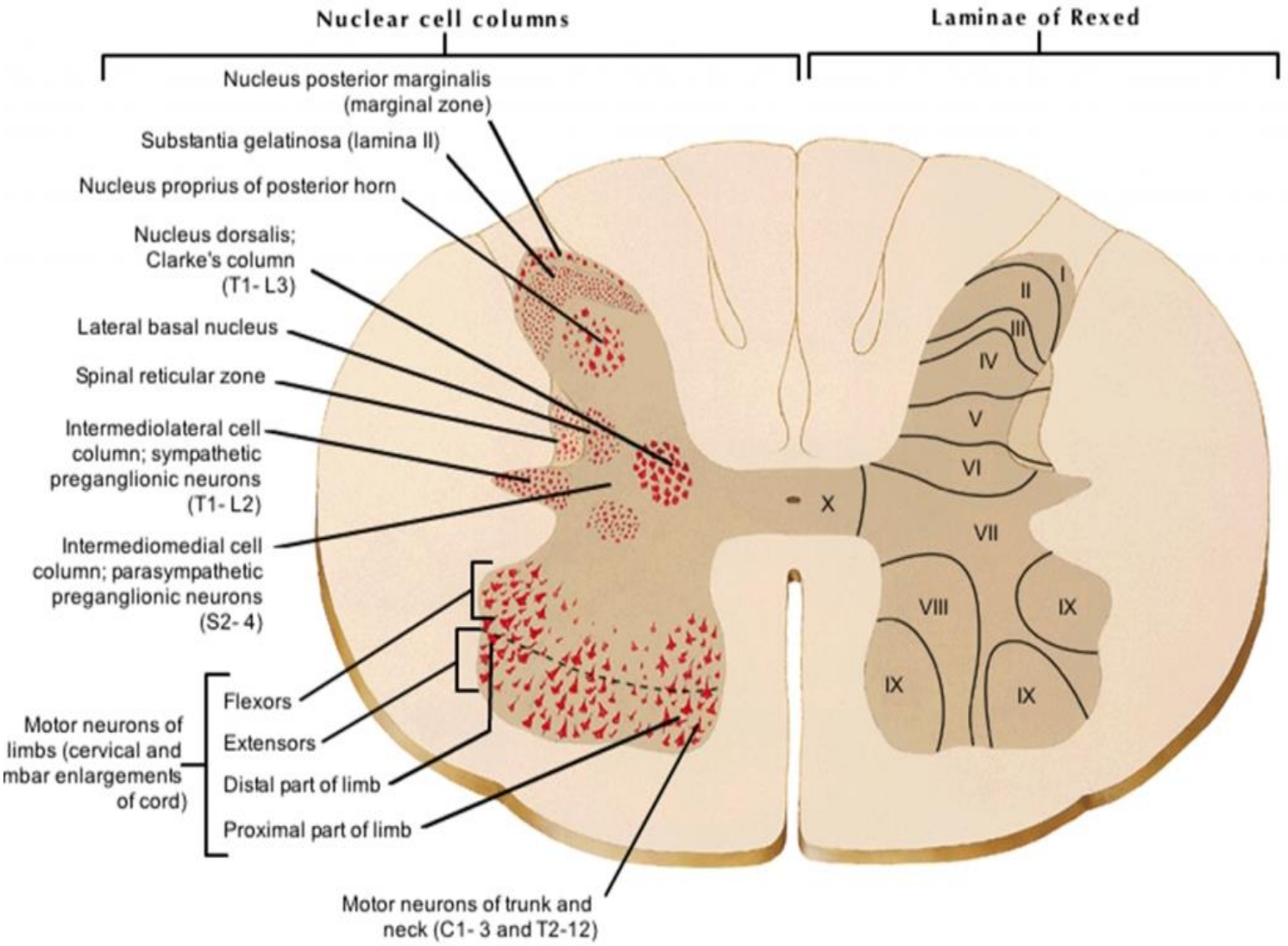
- ***Gray commissure*** is a transverse band connecting the 2 sides which is traversed longitudinally by the ***central canal*** of the spinal cord.
- The gray commissure is related **posteriorly** directly to the posterior median septum while **anteriorly** it is related to the white commissure .
- 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; the **terminal ventricle**, in the conus medullaris.

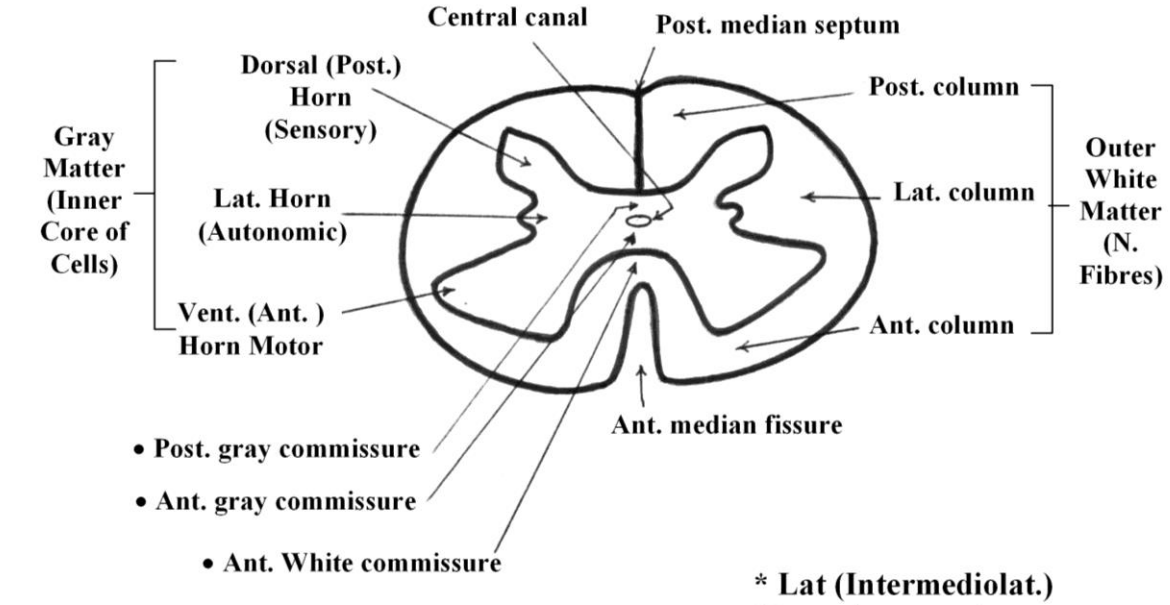
- ***The ventral (anterior) horn or column : (motor or efferent)***
  - It is short , wide & contains **motor (*efferent)* somatic nuclei** arranged in **3 groups**:
    - **Medial group**: their axons supply the muscles of the **trunk** both flexors and extensors, therefore it is present in **all segments** of the spinal cord.
    - **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.
    - **Central group:** is present **only** in the **cervical** region and include **:**

1- ***Phrenic nucleus***: lies opposite C 3rd , 4th & 5th spinal cord segments. The axons of its cells form the ***phrenic nerve***.

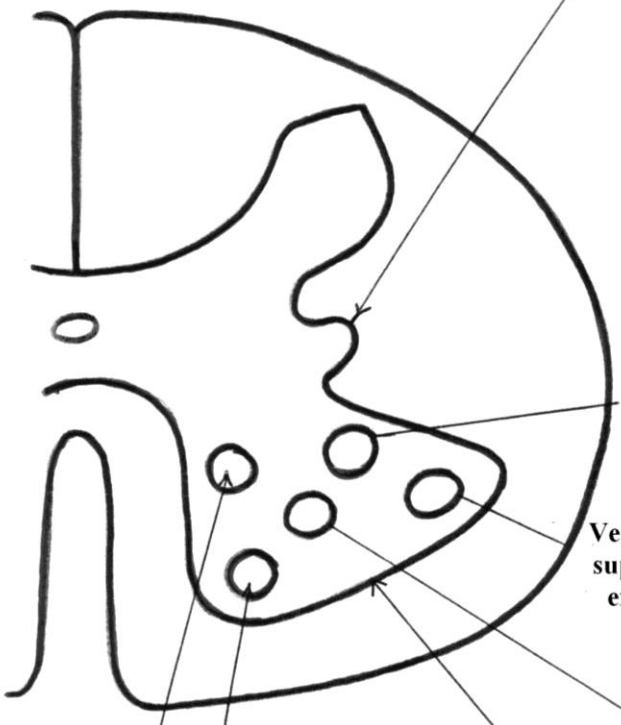
2- ***Spinal accessory nucleus***: lies in the upper 6 cervical segments. The axons of its cells form the ***spinal root of accessory nerve***.

- The anterior horn cells (**AHCs**) and their axons represent the **lower motor neurons (LMNs).**





Internal Structure of Spinal Cord



* Lat (Intermediolat.) Horn: Autonomic:

Present in:

- All thoracic & upper 2 or 3 lumbar segments → symp. Preganglionic cells
- $S_{2,3,\&4}$ → parasymp. Preganglionic cells

Dorsal part supplies the flexors

Ventral part supplies the extensors

* Lat. Group: Innervate muscle of the limbs (present in cervical & lumbar enlargement)

* Gentral Group:

* Med. Group: Innervates muscles of the trunk (present in all spinal cord segments)

Ventral component supplies the extensors

Dorsal component supplies the flexors

* Vent. (Ant.) Horn (Motor)

Gray Matter

- ***The dorsal (posterior) horn or column: (sensory or afferents)***
  - It is longer and narrower & contains **somatic afferent** (**sensory)nuclei** which represent the **2nd order neurons of many sensory pathways**.
  - They **receive central processes** of the sensory nerve cells of the **dorsal root spinal ganglia** (the **1st order neurons** of the **somatic sensory pathways** below the head **).**
  - The nuclei of the dorsal horn are:

1- Substantia gelatinosa of Rolandi:

- Lies at the **apex** of the dorsal horn.
- Its cells represent the **2nd order neurons** in the pathway of **pain and temperature** from the trunk below the head.
- Their **axons cross** the middle line in the white commissure in front of the central canal to ascend in the **opposite lateral funiculus** of the white matter as the **lateral spino-thalamic tract.**

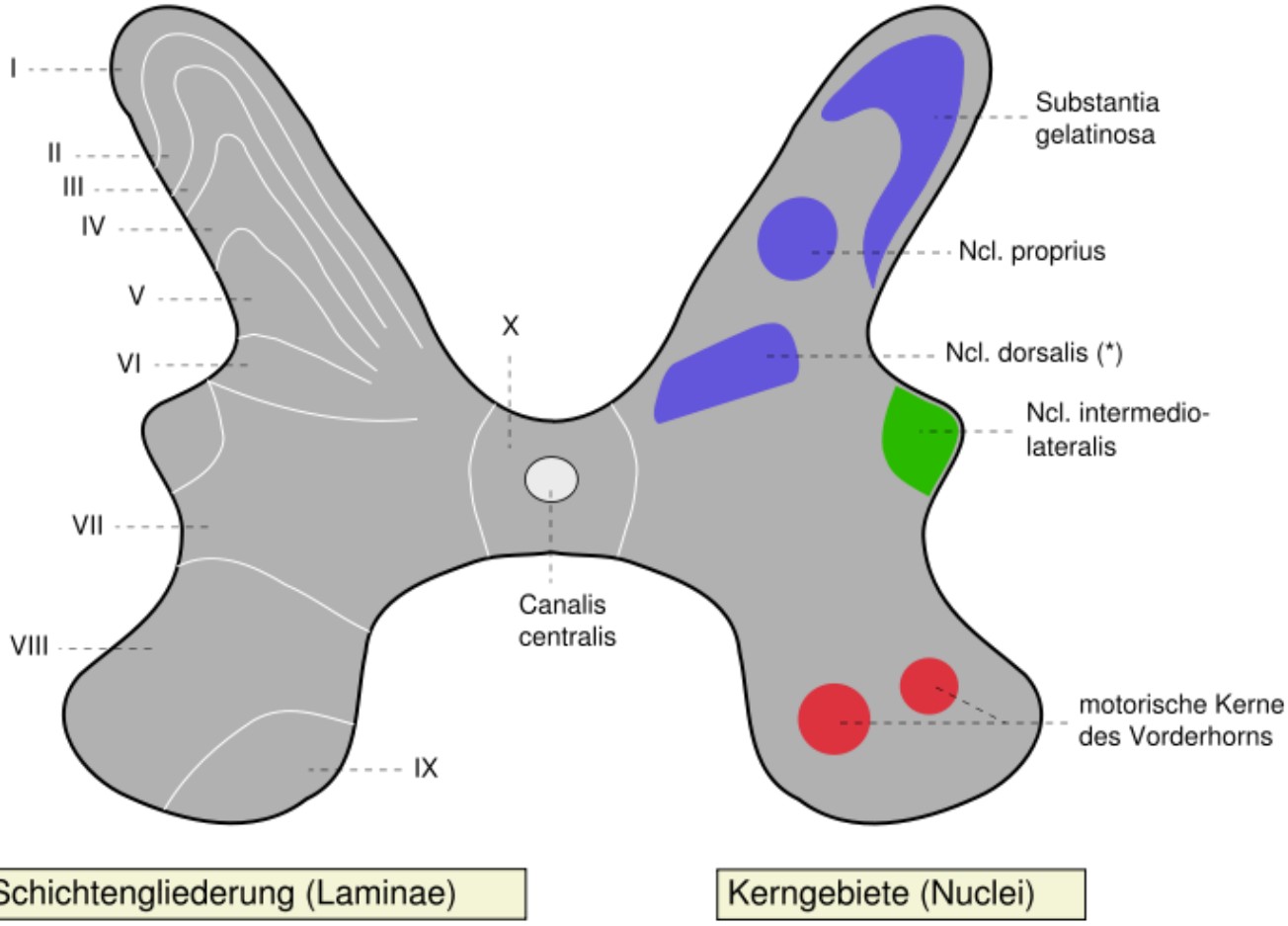
2-Nucleus proprius:

- Lies at the **centre** of the dorsal horn.
- Its cells represent the **2nd order neurons** in the pathway of **crude touch and light pressure** from the body below the head.
- Their axons **cross** the middle line in the white commissure to ascend in the **opposite anterior funiculus** of the white matter as the **anterior** (**ventral) spino-thalamic tract**.

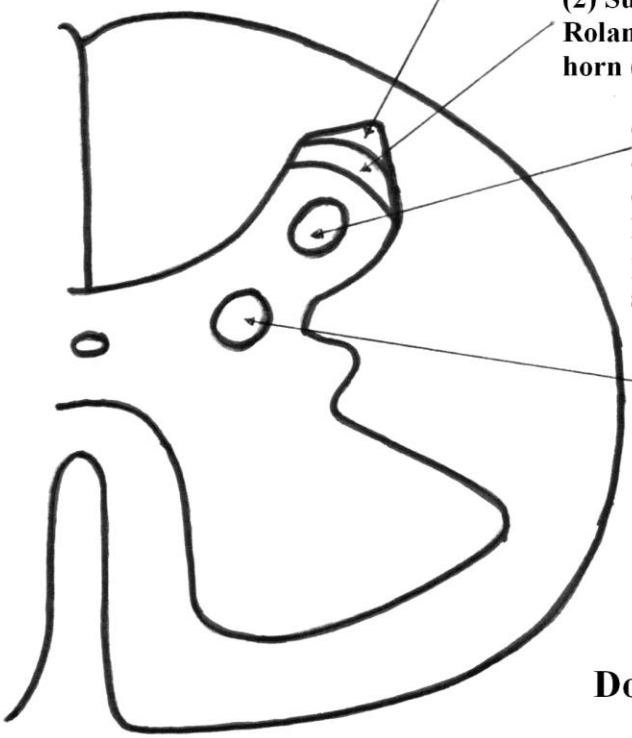
3- Clarke's nucleus : (Thoracic or dorsal nucleus)

- It lies at the **base** of the dorsal horn .
- Its cells represent the **2nd order neurons** in the pathway of the **unconscious proprioceptive** sensations to the **cerebellum**.
- Their axons ascend in the **lateral funiculus** of white on the **same side** as the **posterior spino-cerebellar tract**.

- ***Lateral (Autonomic) horn:***
  - It is found only in all **thoracic and upper 2 lumbar segments**.
  - It **projects** laterally at the level of central canal.
  - It contains a **general visceral motor** (efferent) nuclei.
  - Its cells give origin to **sympathetic preganglionic** fibres which leave the spinal cord via the **anterior (ventral) roots** of the spinal nerves.
  - A similar cell group is found in the **S** **2nd, 3rd & 4th** segments, but unlike the thoraco-lumbar cells, it does not form a visible lateral projection. It is the source of the **sacral outflow of parasympathetic preganglionic** nerve fibres.



* auch *Ncl. thoracicus posterior* bzw. *Stilling-Clarke*



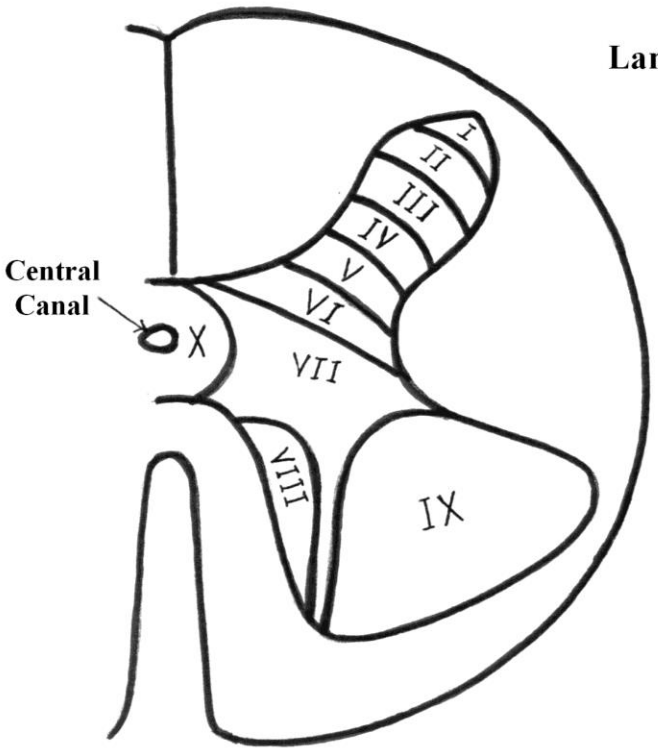
(1) Posteromarginal N. at the tip of post. horn (Pain & Temp.)

(2) Substantia gelatenosa of Rolandi at apex of dorsal horn (pain & temp.)

(3) N. proprius: at the centre of the dorsal horn (crude touch & pressure) NB: (1), (2) & (3) are present in all segments of spinal cord.

(4) Nucleus Dorsalis (Clarke's N.): at the base of dorsal horn (Unconcious propriocepts present only in C_8 to L_2 segments

Dorsal (Post.) Horn (Sensory)



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 fibres** arranged in the form of tracts .
- The white matter of each half of the spinal cord can be **divided into** three columns or funiculi:
  a- ***Ventral (Anterior) column (or funiculus):*** Lies between the **anterior median fissure** and the **ventral root of spinal nerve .**
  b- ***Lateral column (or funiculus):*** lies between the **ventral and the dorsal roots** spinal nerve .
  c- ***Dorsal (Posterior) column (or funiculus):*** lies between the **dorsal root** of spinal nerve root and the **posterior median sulcus & septum**.
- 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.
- The nerve bundles of the white matter can be divided into **2 groups**:
  - ***Short intersegmental tracts (ascending and descending) .***
  - ***Long tracts (ascending and descending) .***
- ***Short intersegmental tracts:***
  - These are **short ascending and descending tracts** connecting the gray matter of the different segments of the spinal cord.
  - They lie in the white matter **around the gray matter**.
  - **According to their position**, they are called anterior, lateral and posterior intersegmental tracts.
  - They establish a pathway for **local reflexes and coordinate** the functions of the different segments of the spinal cord.

** Long tracts in the posterior white column (funiculus):*

- Are ascending sensory tracts concerned with **proprioceptive and fine touch sensations** below the head :

a-Gracile tract:

- Ascends **medially**, close to the posterior median **septum** .
- Is formed by the **central processes** of the **large**-sized cells in the dorsal root (spinal) ganglia of the same side. They represent the **1st order neurons** in the pathway of **proprioceptive and fine touch** sensations from the **lower ½ of the body (below T6) including the lower limb.**

b- Cuneate tract:

- Ascends **lateral** to gracile tract.
- Is formed by the central processes of the large-sized cells in the dorsal root (spinal) ganglia of the same side. They represent the **1st order** neurons in the pathway of the same sensations from the **upper 1/2 of the body (above T6, below the head) including the upper limb.**

***N.B.:**

- Both tracts **ascend** to enter the closed **medulla** to synapse with the cells of gracile and cuneate **nuclei (the 2nd order neurons)**.

- The most **lateral fibres of cuneate** tract end in the **accessory cuneate nucleus to form cuneocerebellar tract .**

- Fibres of both tracts are **laminated from medial to lateral** as follows: sacral, lumbar, thoracic and finally cervical fibres.

- As they ascend, fibres of both tracts give **collateral branches** to synapse with **the posterior horn nuclei** throughout the whole length of the cord (for coordination & begins the pathway to the cerebellum) .

**Long tracts in the lateral white column (funiculus):*

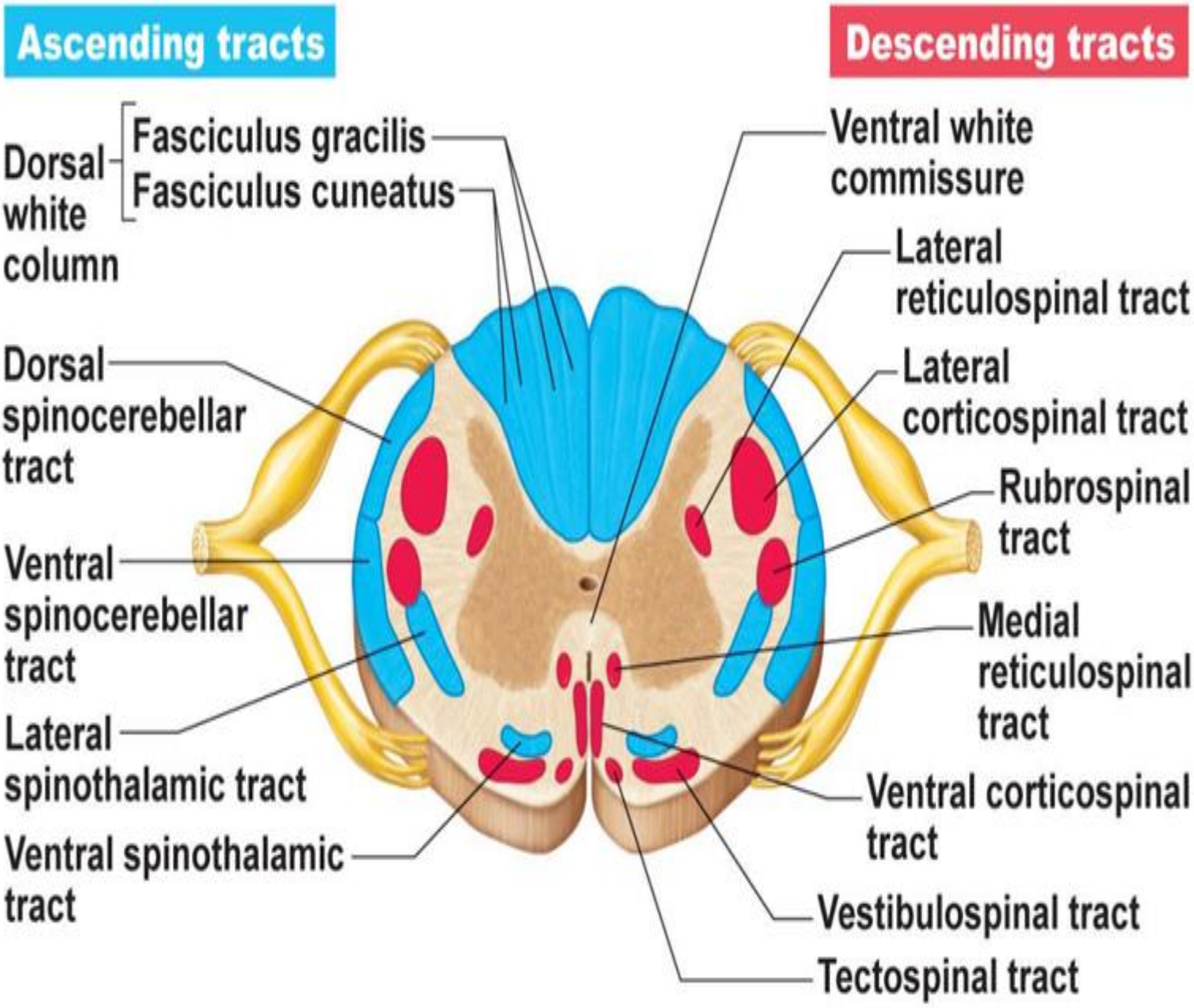
- ***Descending tracts (motor):***

1- Lateral cortico-spinal (crossed pyramidal) tract:

- Lie **just deep** to posterior spinocerebellar tract .
- Consists of the **crossed pyramidal fibres** arising from the **cerebral cortex of the opposite side**, and **cross** the middle line in the pyramidal (motor) decussation of the **closed medulla**.

- These fibres represent the upper motor neurons **(UMNs)** which **end on the AHCs** of the spinal cord which represents the lower motor neurons **(LMNs)**

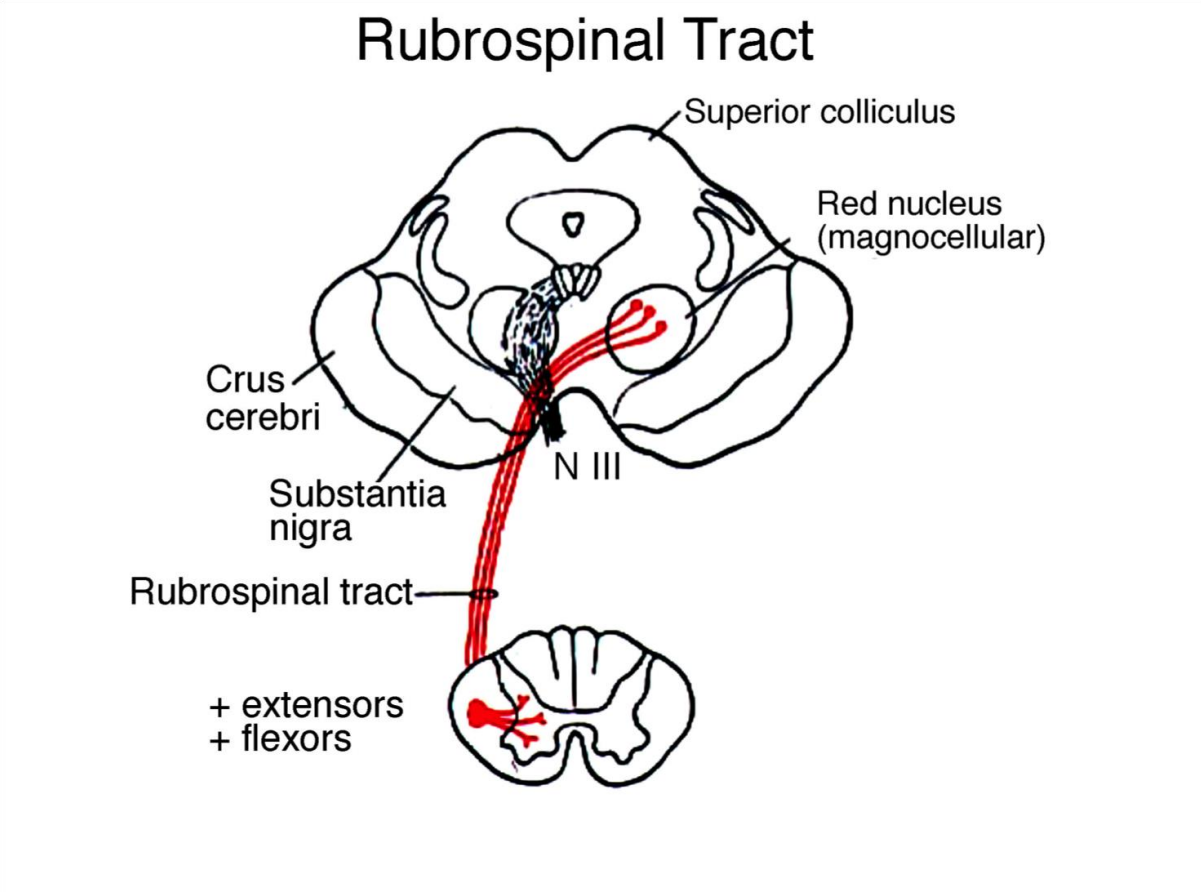
  - The **lamination** of the fibres of this tract: **from lateral** to medial (sacral, lumbar, thoracic and the most medial are cervical fibres) .

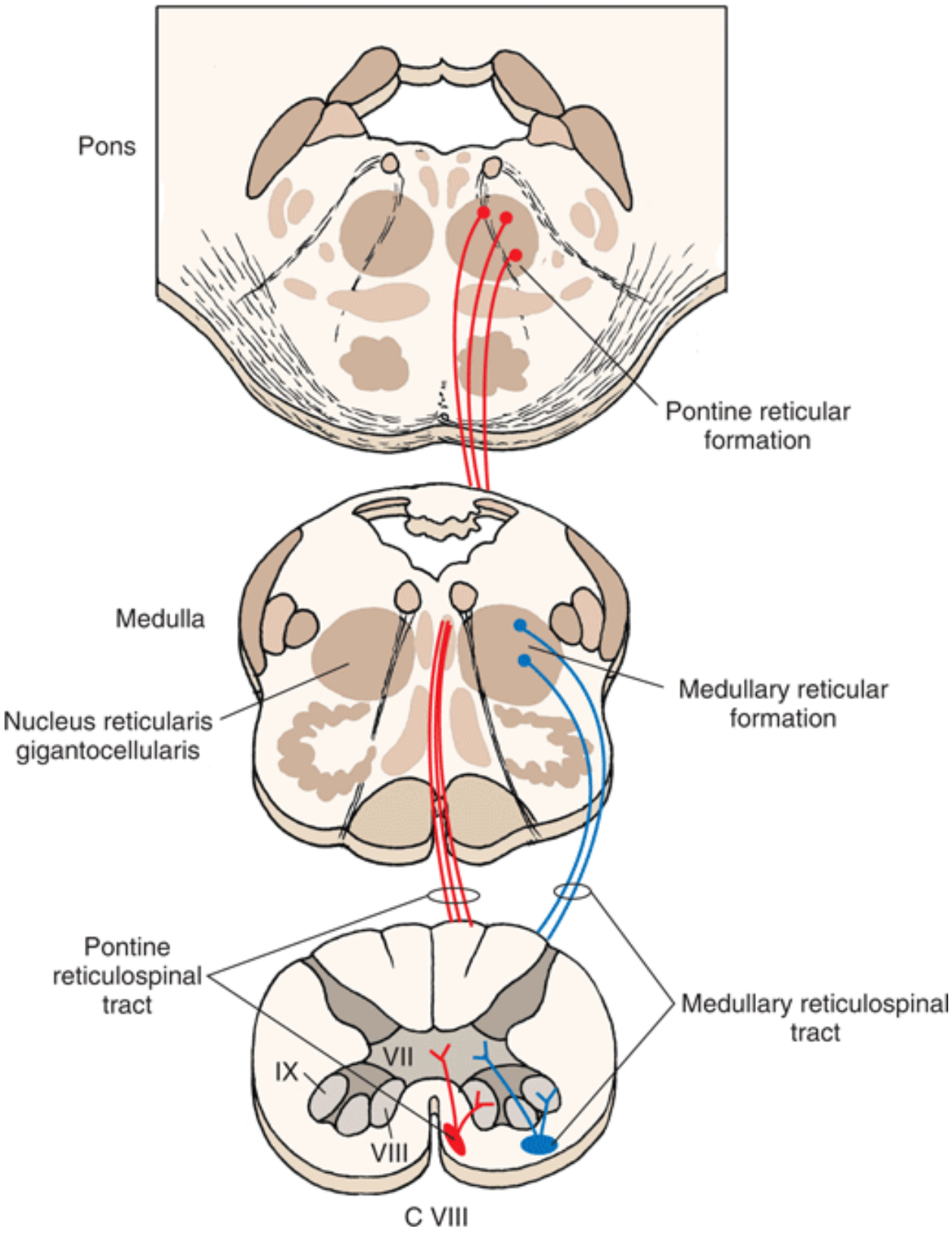


2- ***Exrapramidal tracts:***

- These are **Rubro-spinal** (anterior to lateral corticospinal tract) , **olivo-spinal** and **lateral reticulo-spinal tracts** (deep to lateral corticospinal tract) .

- Their fibres **arise** from the **red nucleus** of the **opposite** side (in the midbrain), the **inferior olivary** nucleus of the **same** side (in the medulla oblongata) and the nuclei of the **reticular formation** in the medulla oblongata of the **same** side **respectively**.
- They **end** on the anterior horn cells **AHCs** of the spinal cord. The fibres of the **olivo-spinal** tract end mainly on the AHCs of the **cervical** region.




Pons
Pontine reticular formation
Medulla
Nucleus reticularis gigantocellularis
Medullary reticular formation
Pontine reticulospinal tract
Medullary reticulospinal tract
VII
IX
VIII
C VIII

3- ***Autonomic fibres:***

- They arise from the visceral centres in the **hypothalamus** and in the **reticular formation** of the brain stem.
- They descend close to the extrapyramidal tracts to end on the autonomic cells in **the lateral horns** of the thoraco-Iumbar and sacral segments.
- **Applied anatomy** : due to **close relation** of these autonomic fibres to the extrapyramidal & pyramidal fibres therefore, spinal cord **injury** may affect all these fibres leading to **paralysis associated with autonomic symptoms** as disturbances in micturation & defaecation .

- ***Ascending tracts: (sensory)***

1- ***Lissauer's tract:***

- It lies at the **tip** of the posterior horn of grey matter .
- It **consists of** central processes of the **small sized cells** in the dorsal root (spinal) ganglia which represent the **1st order neurons** in the pathway of **pain** and temperature from the body below the head.
- On entering the spinal cord, these fibres **ascend for 1 or 2 segments** forming Lissauer's tract which **terminate** on the cells of the **substantia gelatinosa** (the 2nd order neurons).

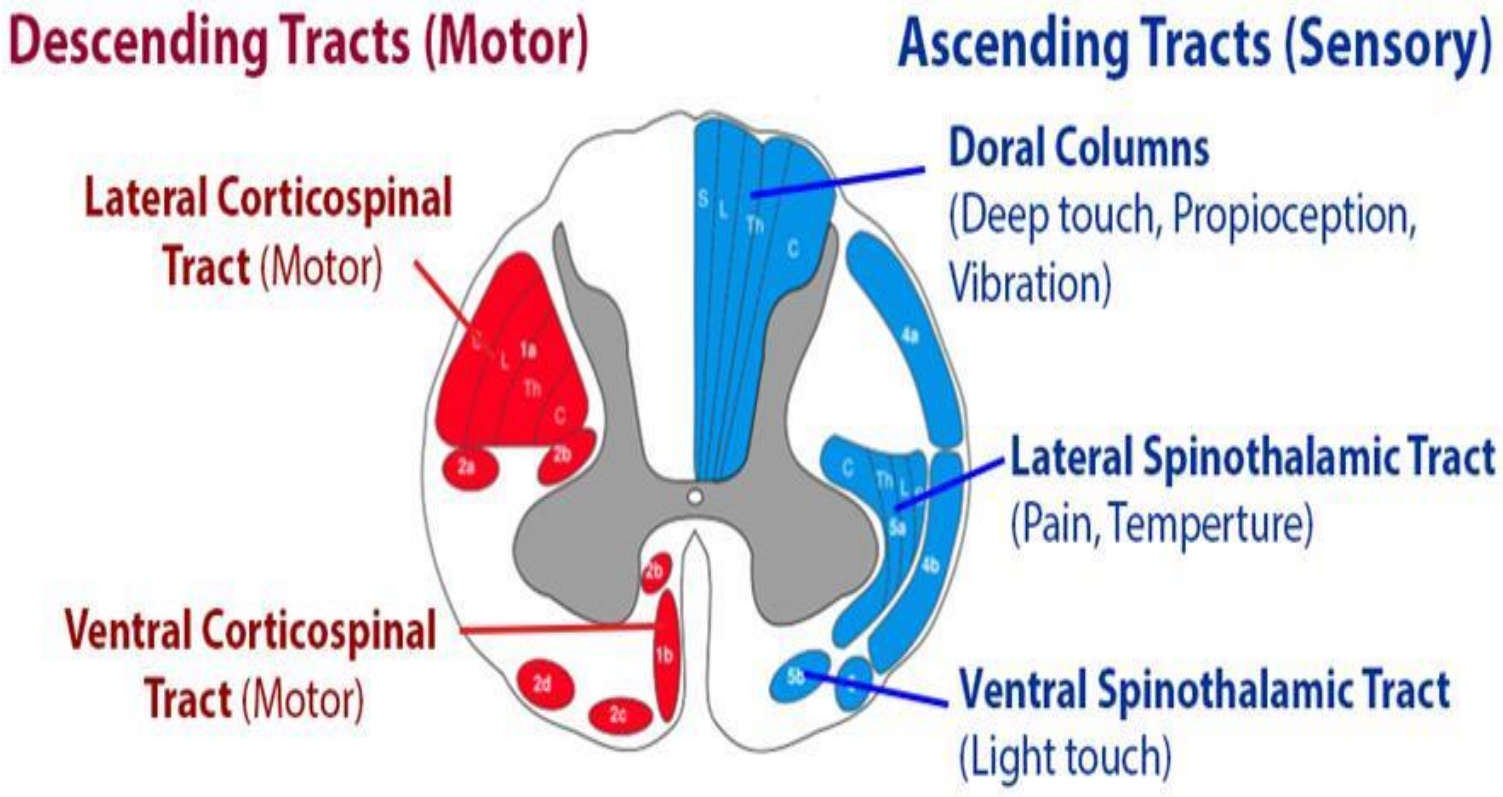
2- ***Lateral spinothalamic tract:***

- It lies **deep to** anterior spinocerebllar tract .
- Its fibres are the axons of the cells of the **substantia gelatinosa** of the opposite side (the **2nd order neurons** in the pathway of **pain** and temperature from the body below the head).
- These axons **cross** the middle line in the **white commissure** to ascend as lateral spinothalamic tract.
- On reaching the **closed medulla**, this tract joins the **spinal lemniscus** which ends on the cells of the posterolateral ventral nucleus of **thalamus** (**the 3rd order neurons**).
- The **lamination** of the fibres of this tract: **from lateral** to medial (

sacral, lumbar, thoracic and the most medial are cervical fibres) .

3- & 4- ***Posterior and anterior spinocerebellar tracts:***

- The fibres of the **posterior** tract are the axons of the cells of the **Clarke's nucleus** while those of the **anterior** tract arise from the large nerve cells scattered at the **base** of the posterior horn.
- Both tracts represent the **2nd order neurons in the pathway of unconscious proprioceptive s**ensations from the **lower 1/2** of the body (including the lower limb) to the cerebellum.
- **Both tracts end** in the **ipsilateral** cerebellar hemisphere but in **2 different ways**:
- The **posterior** tract ascends on the same side to enter **directly** into ipsilateral cerebellar hemisphere
- While most of the fibres of the **anterior** tract make **double cross** to end in the ipsilateral cerebellar hemisphere.



5- Spino-tectal tract:

- Its fibres **arise** from the cells of the **posterior horn, cross** to the opposite side, and ascend to **end** in the superior colliculus of the **tectum** (of the midbrain).
- **It is concerned with the** spino-visual reflexes (reflex movements of the head, neck and limbs in response to light stimuli.**).**

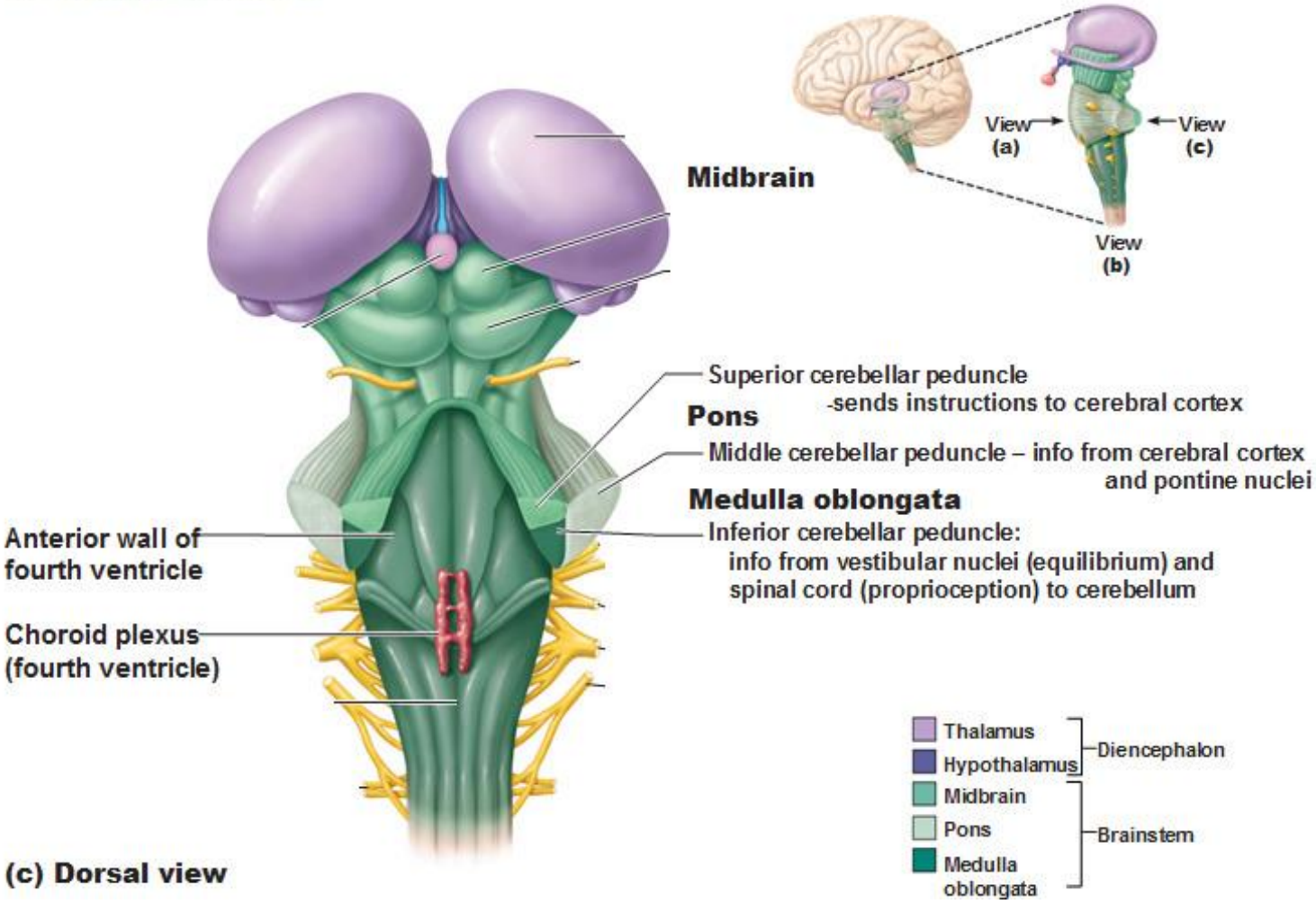
6- Spino-olivary tract:

- Its fibres end on the **accessory olivary** nuclei in the medulla oblongata.

7- ***Spinoreticular fibres:***

- Its fibres end end on the nuclei of the **reticular formation** in the brain stem .

The Brain Stem and Cerebellar Peduncles-*Note that there is NO crossing of fibers*



**Long tracts in the anterior white column (funiculus):*

- ***Descending tracts:***

1- Anterior cortico-spinal tract: (uncrossed Pyramidal)

- Consists of the few **uncrossed pyramidal** , (not cross in the motor (pyramidal) decussation of the medulla oblongata) , representing upper motor neurons (**UMNs**) .
- They **descend** without crossing into the anterior white funiculus of the spinal cord, lying **close to the anterior median fissure** to **end at the level of T6 spinal segment.**
- In the spinal cord, these fibre **cross gradually** in all cervical and upper 6 thoracic segments to **end on the AHCs of the opposite side.**

2- ***Lateral and medial vestibulo-spinal tracts:***

- Their fibres **arise** mainly from the **lateral vestibular nucleus** in the brain stem.
- They descend mostly on the **same side** (uncrossed), and **few cross** to the opposite side to end at the **AHCs** of the spinal cord.
- They transmit **equilibrium** impulses to the muscles of the trunk and limbs.

3- ***Tecto-spinal tract:***

- Arises from the **superior colliculus** of the tectum of midbrain and descends to ends on the **AHCs** to control **spinovisual reflexes**.

4- ***Medial reticuospinal fibres:***

- They arise from the nuclei of **reticular formation** in the brain stem to end on the **AHCs** of the spinal cord.

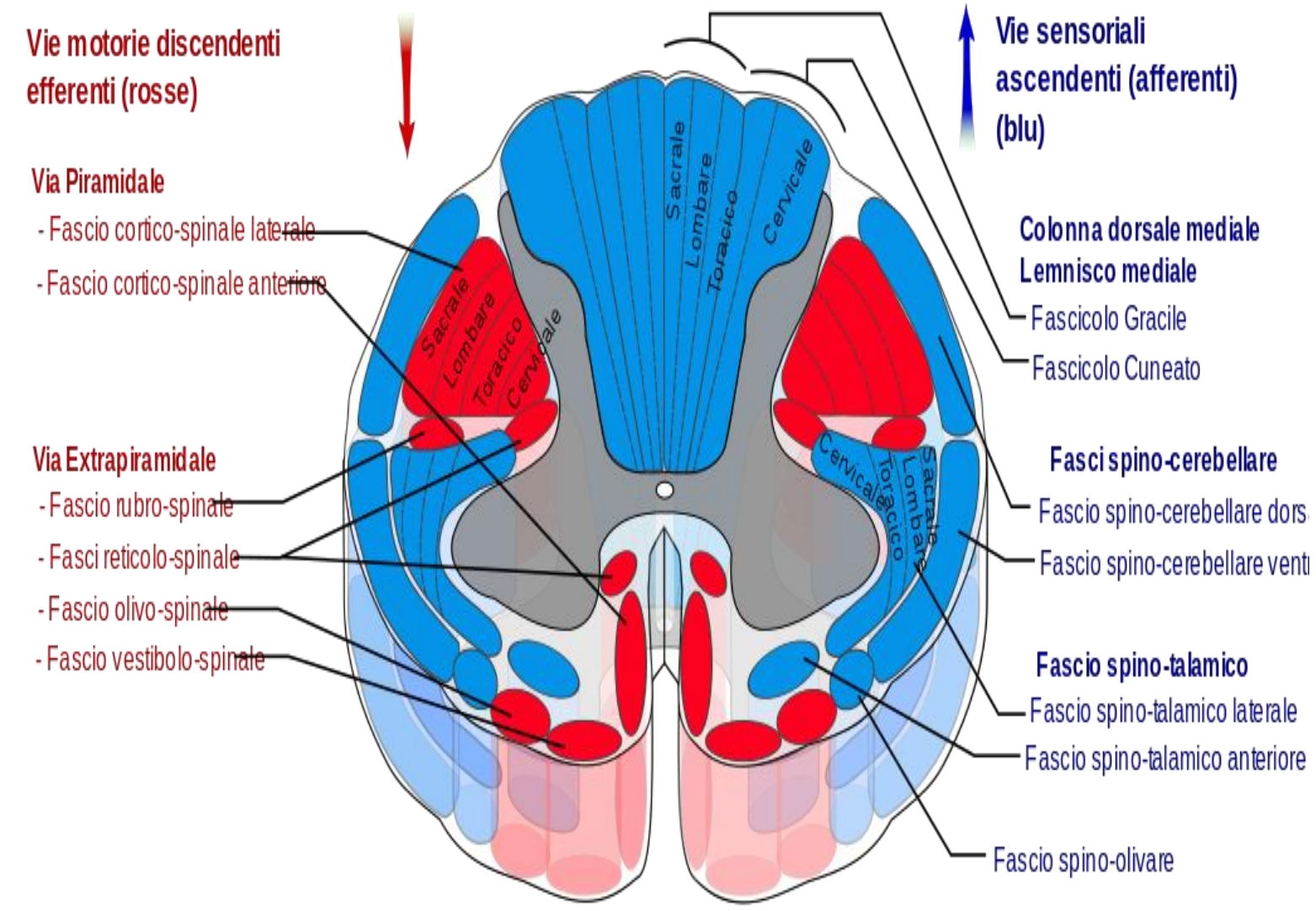
- ***Ascending tract:***

1-Anterior (ventral) spino-thalamic tract:

- Its fibres are the axons of the cells of the **nucleus proprius**, in the centre of the posterior horn of the opposite side which represent the **2nd order neurons** in the pathway of **crude touch** and light

pressure sensations from the body below the head.

- These fibres **cross** the middle line in the **white commissure** of the spinal cord to **ascend** as the anterior spino-thalamic tract.
- In the closed **medulla**, this tract joins the **spinal lemniscus** which ascends to end in the postero-Iateral ventral nucleus of the **thalamus** (the 3rd order neurons).



Cross Section of the Spinal Cord

- ***Ascending Tracts:***
  1- Gracie tract.
  2- Cuneate tract.
  3- Lissauer's tract.
  4- Dorsal spino-cerebellar tract.
  5- Ventral spino-cerebellar tract.
  6- Lateral spino-thalamic tract.
  7- Spino-olivary tract.
  8- Spino-tectal tract.
  9- Spino-reticular
  10- Ventral spino-thalamic tract.
- ***Descending Tracts:***
  10- Sulco-marginal tract.
  11- Ventral tecto-spinal tract.
  12- Direct pyramidal tract.
  13- Ventral vestibula-spinal tract.
  14- Lateral vestibula-spinal tract.
  15- Ventral reticula-spinal tract.
  16- Olivo-spinal tract.
  17- Lateral tecto-spinal tract.
  18- Lateral reticula-spinal tract.
  19- Rubro-spinql tract.
  20- Crossed pyramidal tract.
- ***Sensory Nuclei of the Dorsal Horn:***
  i. Substantia gelatinosa.
  ii. Nucleus proprius.
- ***Motor Nuclei of the Ventral Horn:***
  a. Dorso-medial nucleus.

b. Ventro-medial nucleus.

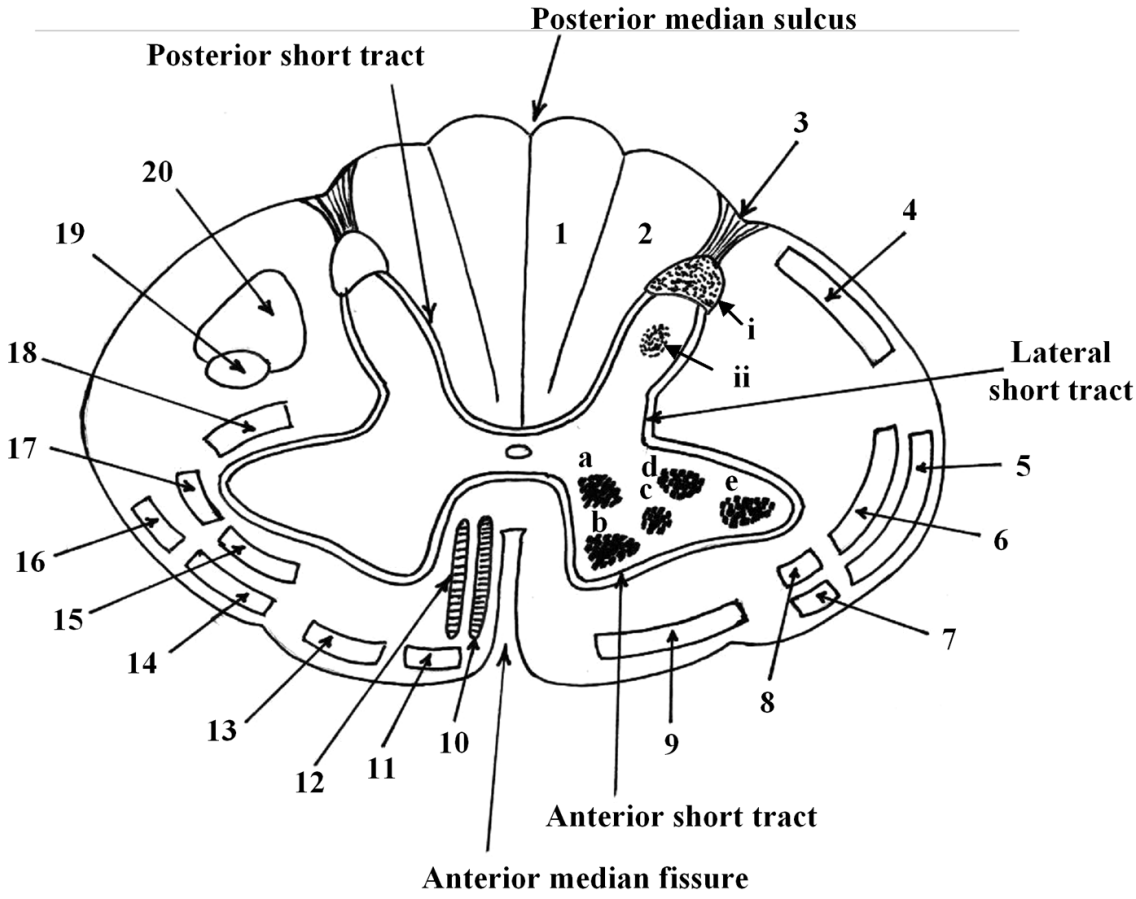
c. Central nucleus.

d. Dorso-lateral nucleus.

e. Ventro-Iateral nucleus.

- ***Sympathetic Nucleus of the Lateral Horn:***

  (L) Intermedio-lateral nucleus.

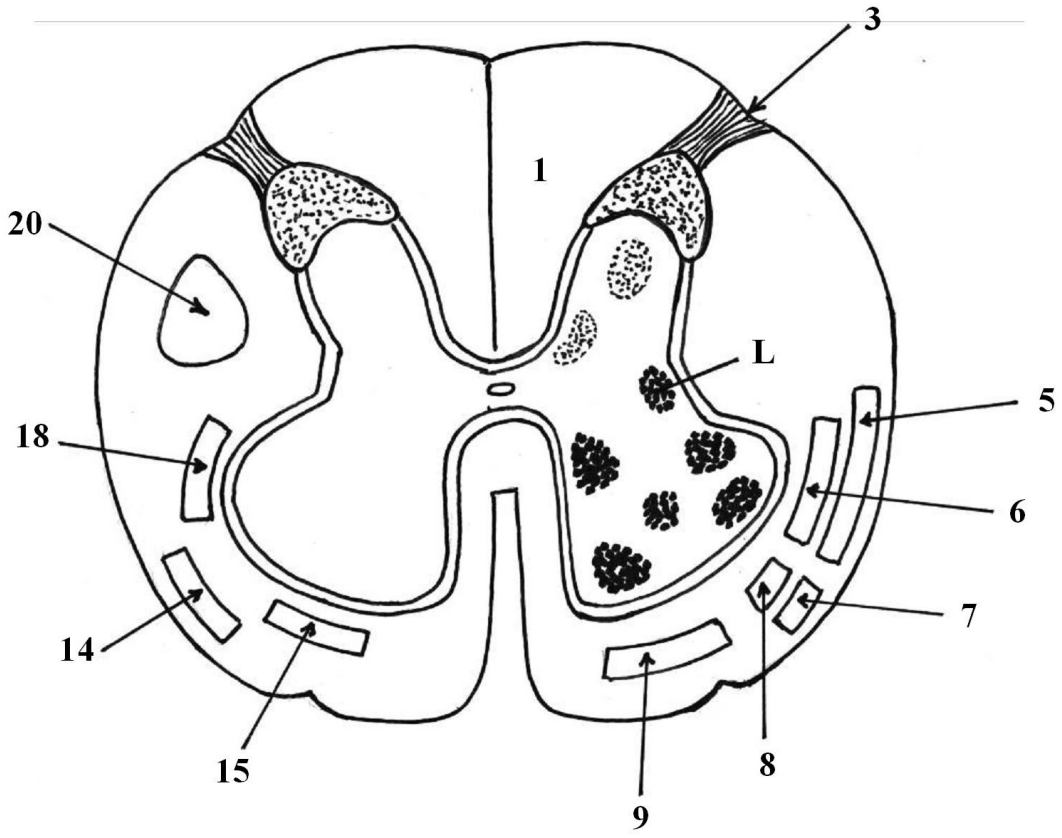


* <u>Descending Tracts</u> * <u>Ascending Tracts</u>

Transvers Section in the Cervical Region of the Spinal Cord

*** <u>Ascending Tracts:</u>**
1: Gracile tract
3: Lissaure's tract
5: Ventral spino-cerebellar tract
6: Lateral Spino-thalamic tract
7: Spino-olivary tract
8: Spino-tectal tract
9: Ventral spino-thalamic tract

*** <u>Descending tracts:</u>**
14: Lateral vestibule-pinal tract
15: Ventral reticulo-spinal tract
18: Lateral reticulo-spinal tract
20: Crossed pyramidal tract



*** <u>Descending Tracts</u>** *** <u>Ascending Tracts</u>**

L : Intermedio-lateral Nucleus

Upper Lumbar Region

IV. Common Lesions of the Spinal Cord

A- Complete Transection of the Spinal Cord

- ***Above the lumbar region:*** (Paraplegia)
  - Paralysis of both lower limbs.
  - Disturbed bladder and bowel voluntary control (incontinence).
- ***In the cervical region below the level of C5 segment:*** (Quadriplegia)
  - Paralysis of the 4 limbs (both upper and lower limbs).
  - Disturbed bladder and bowel voluntary control (incontinence).
- ***In the cervical region above the level of C3:*** (Respiratory failure)
  - Death due to respiratory failure as a result of complete paralysis of muscles of respiration including the diaphragm (phrenic nerve C3,4,5).

B- Hemisection of the Spinal Cord

(Brown-Sequard Syndrome)

A- Signs below the lesion level:

- ***Ipsilateral signs:***

1- Loss of **proprioceptive and fine touch** sensations (Kinesthesia, discriminative touch and sense of vibration) due to damage of gracile and cuneate tracts (in lesions **above T6** segment) and damage of gracile tract only (in lesions **below T6** segment).

2- **UMN paralysis** due to damage to cortico-spinal (**pyramidal**) and **extrapyramidal** tracts.

3- **Horner's syndrome:** in lesions **above T1** segment due to damage of the descending sympathetic fibres. (Ptosis, Miosis, Anhydrosis of the face, Flushing of the face and Enophthalmos).

- ***Contralateral signs:***
  - Loss of **pain and temperature** sensations below the level of the lesion due to damage of the **lateral spinothalamic** tract (usually evident 1 or 2 segments below the level of the lesion).

B- Signs at the level of the lesion:

- ***Ipsilateral LMN paralysis*** of the muscles supplied by damaged AHCs in the segment of the lesion.
- ***Ipsilateral loss of all sensations*** in the dermatomes supplied by the damaged dorsal nerve root entering the segment of the lesion.

C- 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. Its signs are:

a- Bilateral **proprioceptive** loss (sense of position, movement and vibration).
b- **Ataxia** because the patient is unaware of the positions of his feet and legs.
c- Positive **Romberg's Sign**: falling down on closure of the eyes.
d- Hyper or hyporeflexia due to affection of the dorsal root fibres which represent the **afferents of the stretch reflexes**).

D- Syringomyelia

- It is a pathological dilatation of localized segments of the central canal, usually in the cervical region.
- It causes damage of the **white commissure** destroying the decussating fibres of the **lateral spinothalamic tracts of both sides** leading to **dissociated sensory loss** at the level of the affected segments (loss of pain and temperature with preservation of touch and proprioceptive sensations).

E- Conus Medullaris Syndrome
(Cauda Equina Syndrome)

- It is due to direct injury of the sacral spinal segments in the conus medullaris or the sacral nerve roots in the cauda equina.
- Damage of the **sacral parasympathetic** results in paralysis of the **urinary bladder and rectum as well as impotence** (failure of erection of the penis).
- Weakness of the **muscles** of the foot and impaired **sensations** from the foot and buttocks may occur.