# CNS
# Spinal cord

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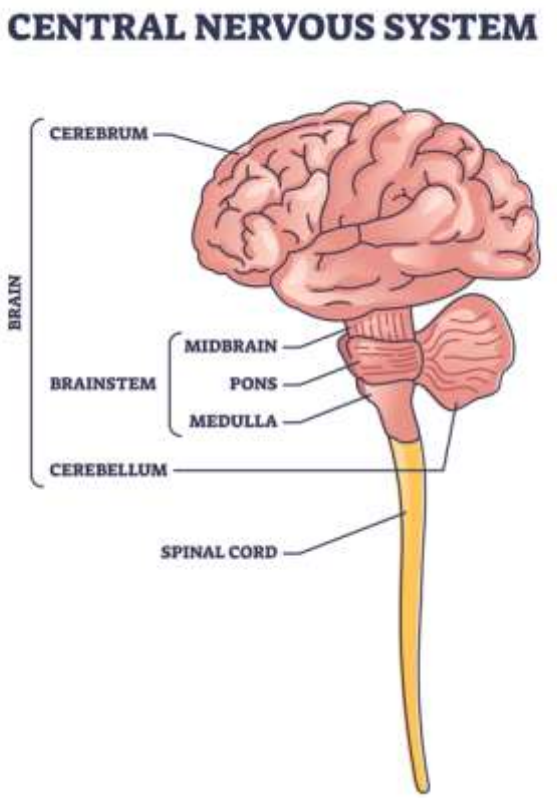
# CENTRAL NERVOUS SYSTEM

- The major regions of the central nervous system (CNS) are the cerebrum, cerebellum, and spinal cord.
- The CNS is covered by three connective tissue layers, the meninges, but contains very little collagen or fibrous tissue throughout its substance, making it relatively soft and easily damaged by injuries.

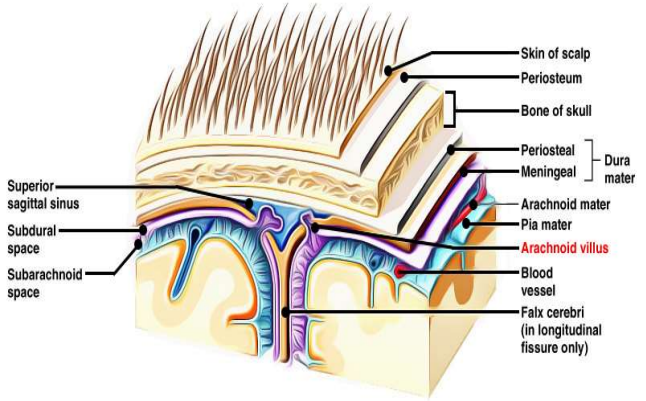


# Meninges

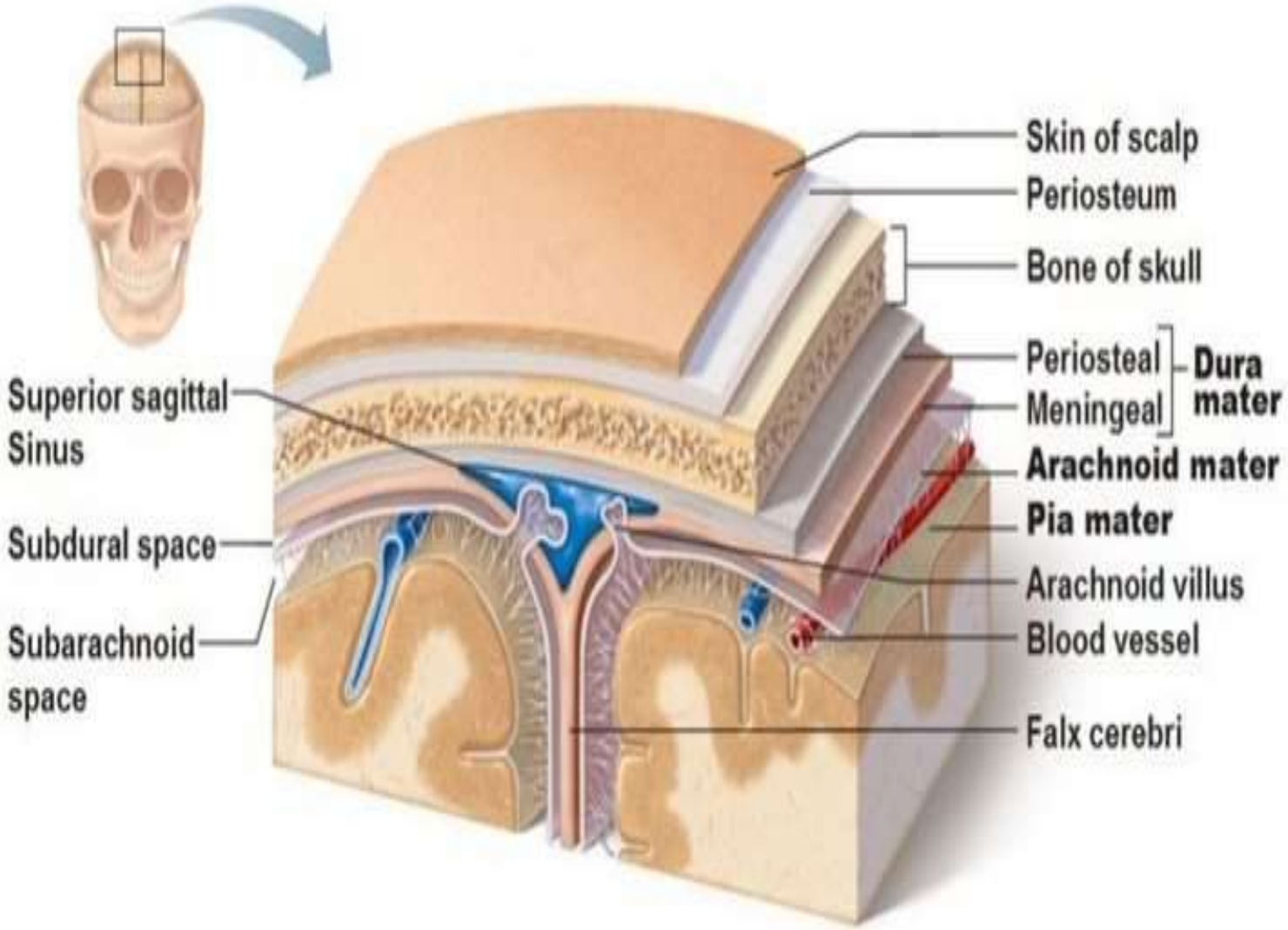
- The skull and the vertebral column protect the CNS, but between the bone and nervous tissue are membranes of connective tissue called the meninges. Three meningeal layers are distinguished: the dura, arachnoid, and pia maters.

- **Dura Mater:**

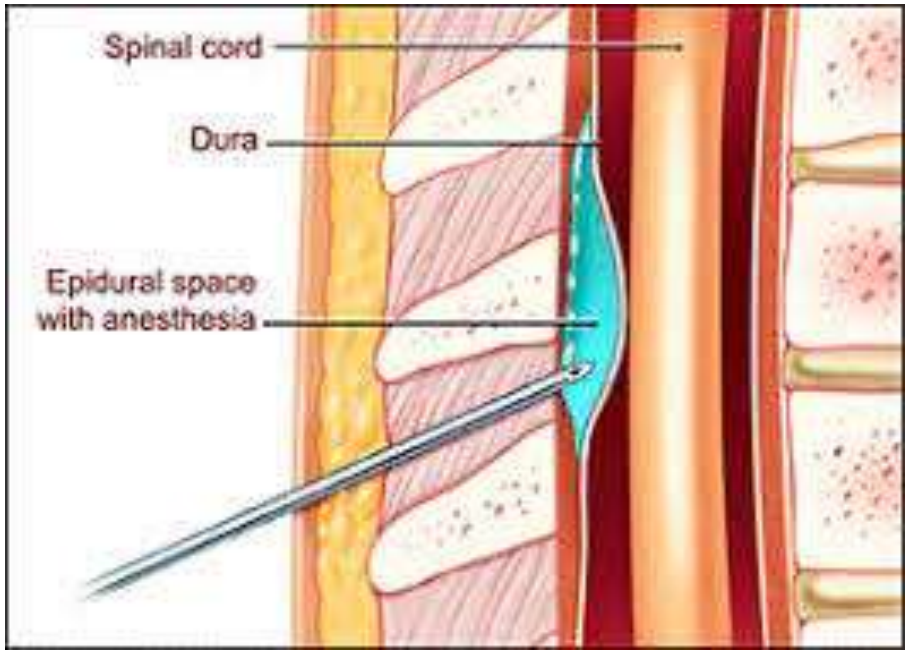
The thick external dura mater (tough mother) consists of dense, fibroelastic connective tissue that is continuous with the periosteum of the skull.



# The Dura Mater



- Around the spinal cord the dura mater is separated from the periosteum of the vertebrae by the epidural space, which contains a plexus of thin-walled veins and areolar connective tissue. The dura mater is always separated from the arachnoid by the thin subdural space.




- The internal surface of all dura mater, as well as its external surface in the spinal cord, is covered by simple squamous epithelium of mesenchymal origin.

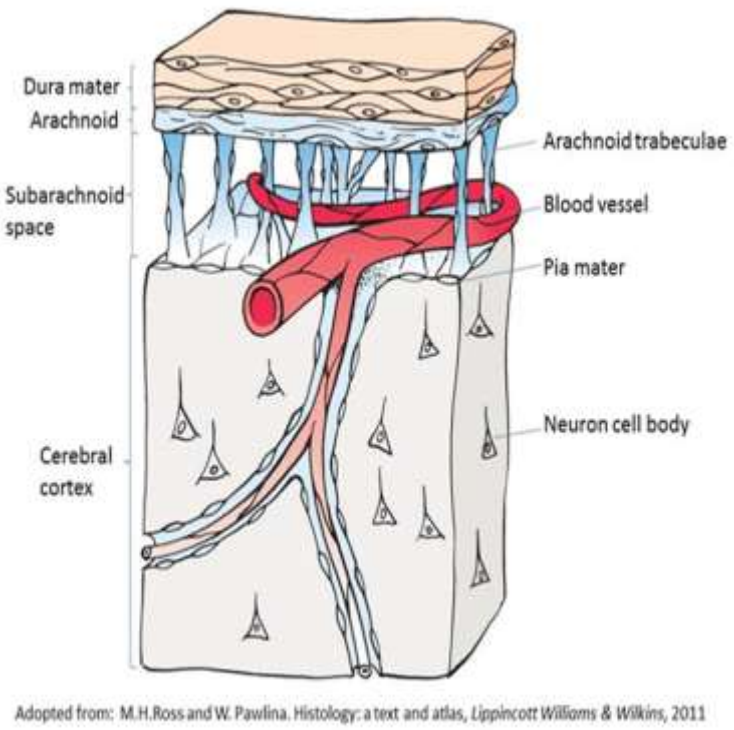
# Arachnoid mater:

- The arachnoid (spiderweblike) has two components:

(1) a sheet of connective tissue in contact with the dura mater and

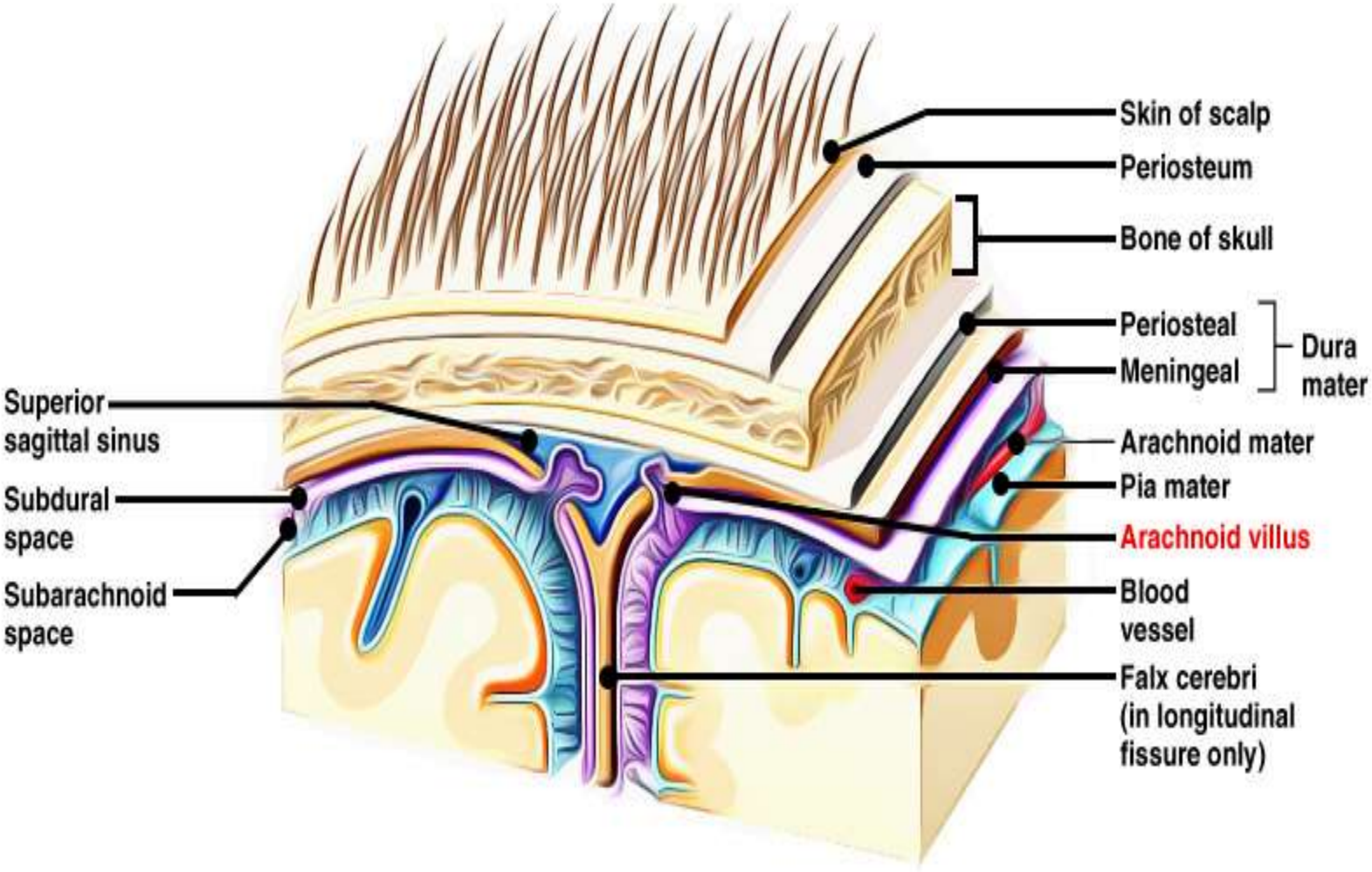
(2) a system of loosely arranged trabeculae composed of collagen and fibroblasts, continuous with the underlying pia mater layer.

- Surrounding the trabeculae is a large, sponge-like cavity, the subarachnoid space, filled with CSF.




Adopted from: M.H.Ross and W. Pawlina. Histology: a text and atlas, *Lippincott Williams & Wilkins*, 2011

# Meninges


Skin of scalp
Periosteum
Bone of skull
Periosteal
Meningeal
Dura mater
Superior sagittal sinus
Arachnoid mater
Pia mater
Subdural space
Arachnoid villus
Subarachnoid space
Blood vessel
Falx cerebri (in longitudinal fissure only)

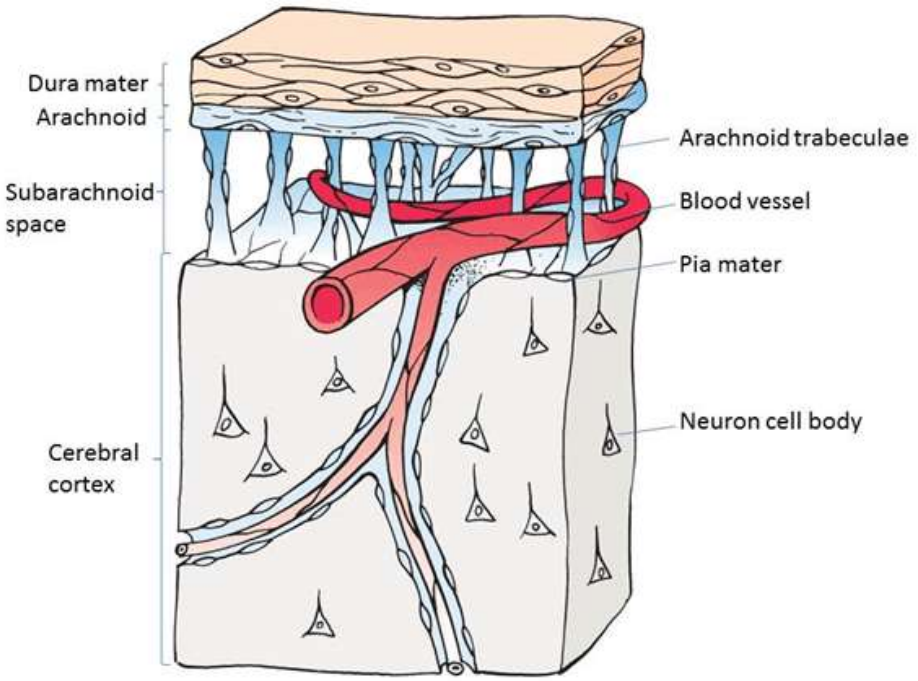
- This fluid-filled space protect the CNS from minor trauma. The subarachnoid space communicates with the ventricles of the brain where the CSF is produced.

- In some areas, the arachnoid penetrates the dura mater and protrudes into blood-filled venous sinuses located within that layer. These CSF-filled protrusions, which are covered by vascular endothelial cells lining the sinuses, are called **arachnoid villi**, which function as a site for absorption of CSF into the blood of the venous sinuses.

# Pia Mater:

- The innermost pia mater (tender mother) consists of flattened, mesenchymally derived cells closely applied to the entire surface of the CNS tissue.
- The pia does not directly contact nerve cells or fibers, being separated from the neural elements by the very thin superficial layer of astrocytic processes, which adheres firmly to the pia mater.
- Together, the pia mater and the layer of astrocytic end feet form a physical barrier separating CNS tissue from CSF in the subarachnoid space

- Blood vessels penetrate the CNS through long perivascular spaces covered by pia mater, although the pia disappears when the blood vessels branch to form the small capillaries. However, these capillaries remain completely covered by the perivascular limiting layer of astrocytic processes.

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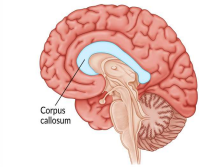
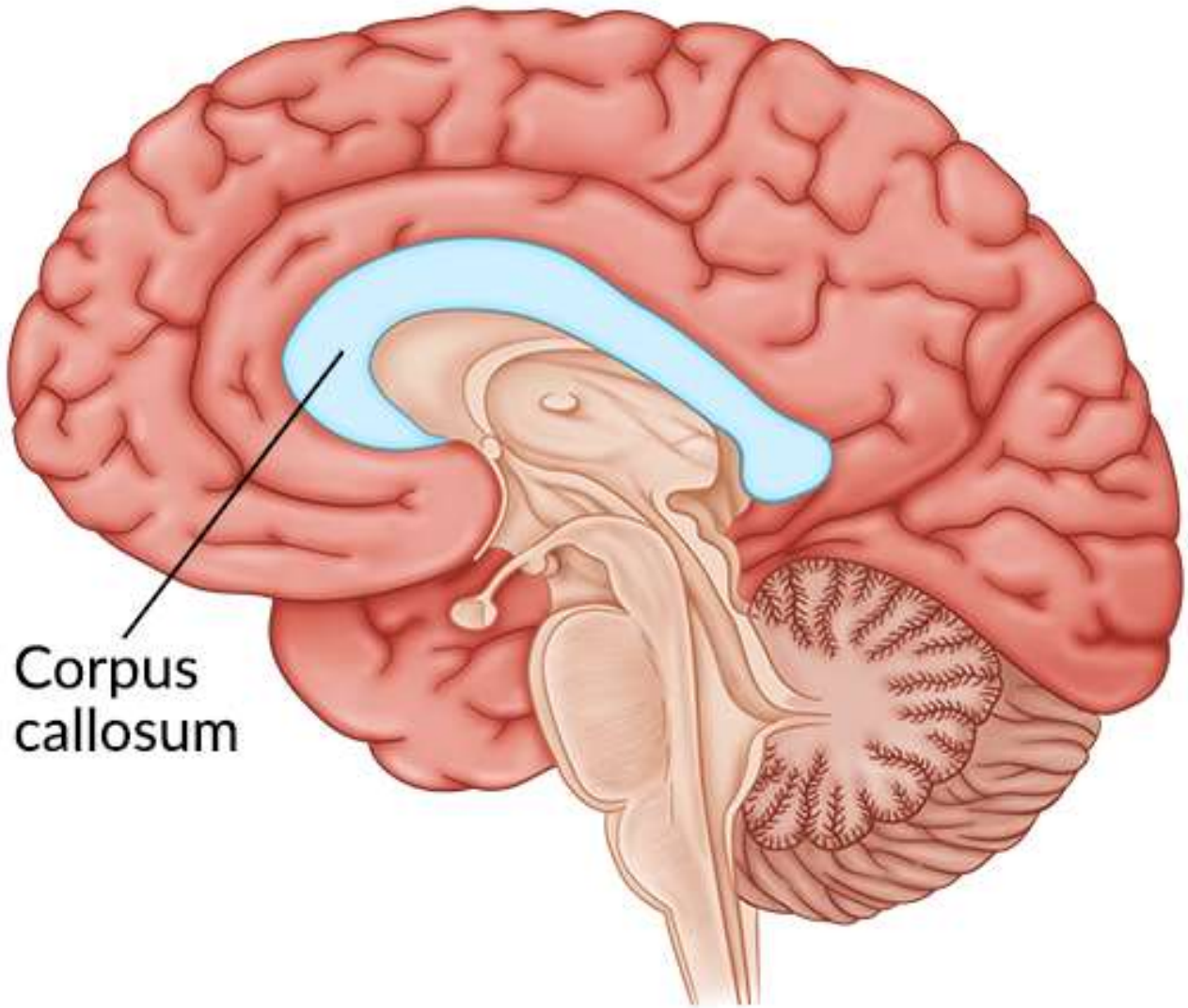
# Some terms related to the C.N.S

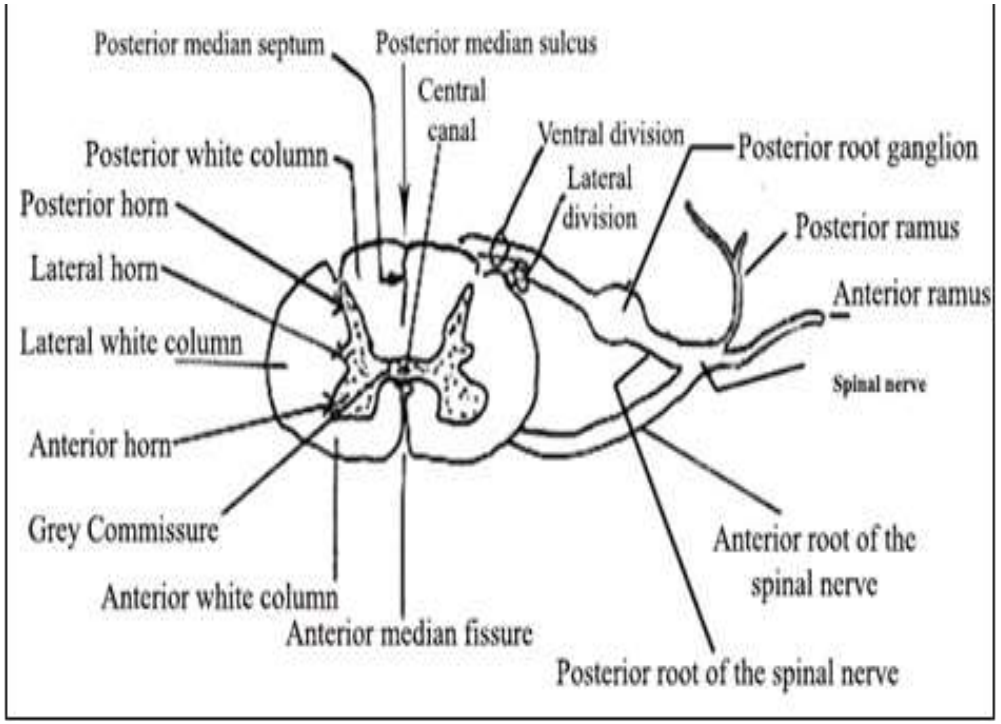
| Terms | Definition | Examples |
|---|---|---|
| A nucleus | A group of nerve cells lying very close to each other inside CNS and having the same function. | -Substantia gelatinosa of Rolandi (S.G.R). -Central motor nucleus |
| A ganglia | A group of nerve cells lying very close to each other outside nervous system. | Sensory: dorsal root ganglia<br>Motor(Autonomic): Sympathetic (paravertebral & prevertebral) & Parasympathetic |
| A commissure | A band of grey or white matter connecting a part of C.N.S on one side with the same on the other side | Corpus callosum   |
| A decussation | The site of intersection of fibers of right and left identical tracts which cross the midline from both sides. | -Pyramidal decussation |
| A pathway | It is the series of neurons that transmit certain excitation from the body to CNS (sensory) or from CNS to the body (motor pathway). | pathway for pain sensation |

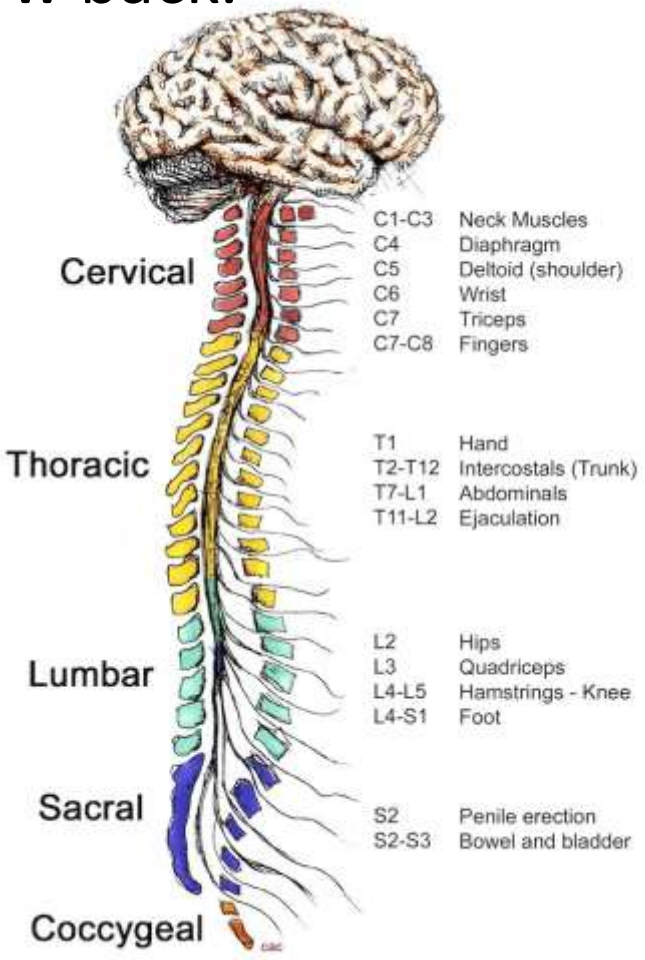

Corpus
callosum

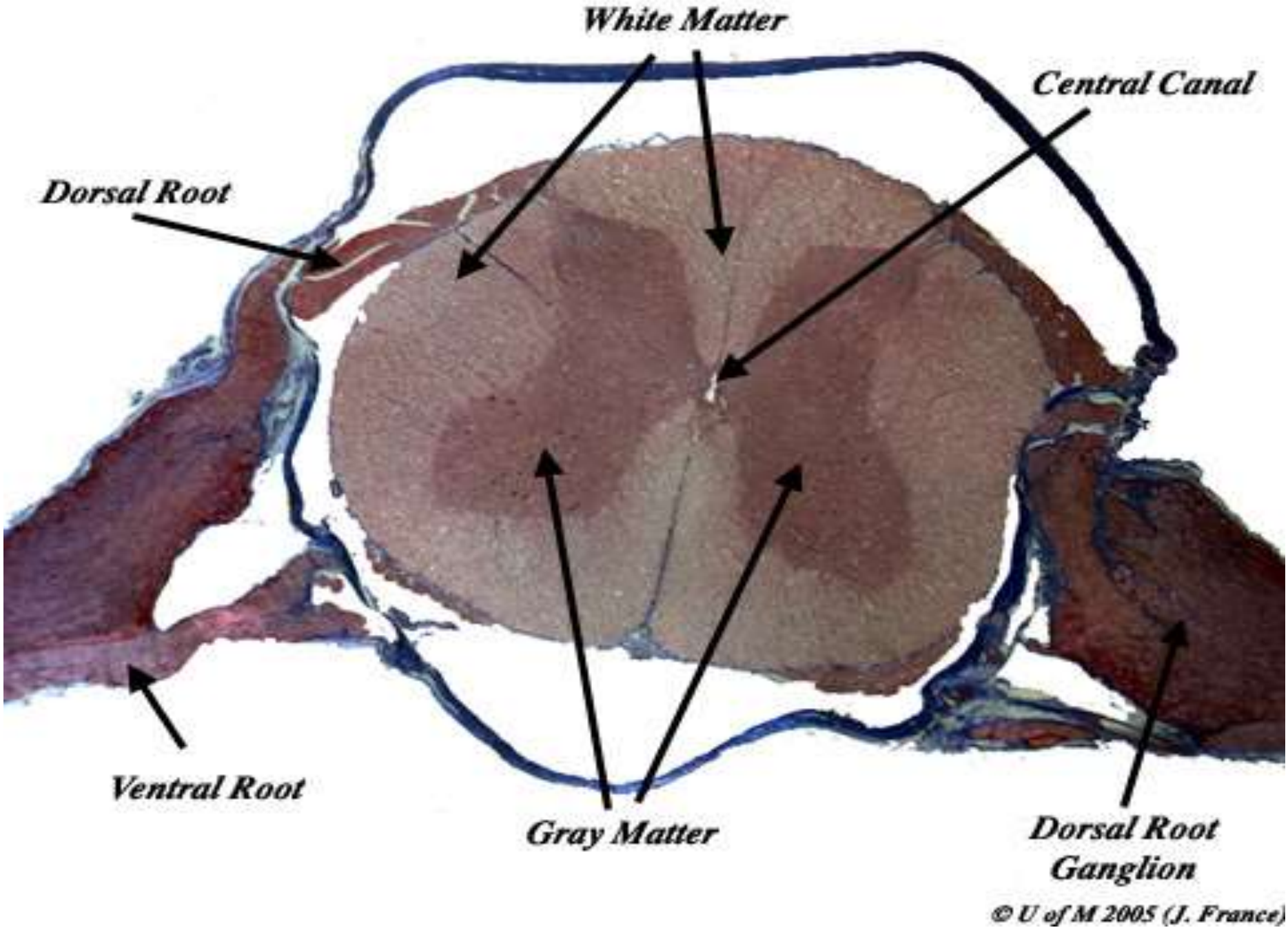
| | | |
|---|---|---|
| A tract | group of nerve fibers (axons) which arise from the same origin and terminate at the same site and they have the same function. It is a part of a pathway. | Ascending (sensory); e.g. spinothalamic tract -Descending (motor); e.g. pyramidal tract |
| A fasciculus (bundle): | Group of nerve fibers, some ascending (sensory) and others descending (motor). Arise from different origins, end at different terminations and carry different function. | Medial longitudinal bundle (M.L.B.) |
| A synapse or relay | They are the sites where nerve impulses are transmitted from a neuron (presynaptic) to a postsynaptic cell (another neuron, muscle or gland). | Axon terminal of one neuron and part of another neuron (perikaryon, dendrite or axon). |
| Grey matter | Bodies of nerve cells, dendrites, unmyelinated axons and neuroglia. | H-shaped centrally located in the spinal cord -Peripheral part of cerebrum and cerebellum |
| White matter | Many myelinated axons (form tracts which convey information into & out of CNS), few unmyelinated axons & neuroglia | -Peripheral part of the spinal cord -Central part of cerebrum & cerebellum. |
| Nerve ending | Specialized structures at the nerve terminals, it may be: I-At sensory nerve: Receptors or sense organs (receive stimuli) II-At motor nerve: Effector organs (transmit response) | -Receptors as Pacinian corpuscle -Effector organ as Motor end plate |

# THE SPINAL CORD

- The main sensory and motor link between brain and body. Spinal cord is a cylindrical structure that runs through the centre of spine, from brainstem to low back.



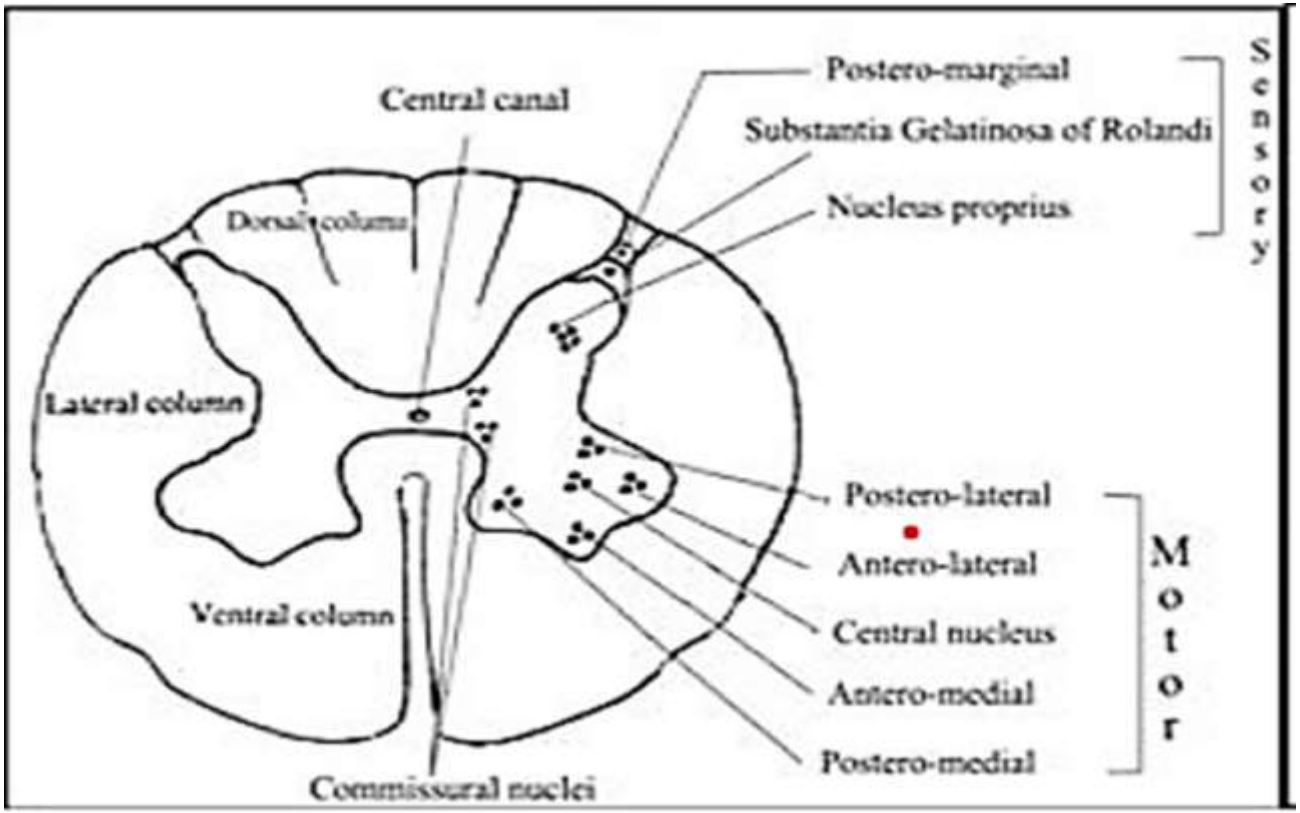

White Matter
Central Canal
Dorsal Root
Ventral Root
Gray Matter
Dorsal Root Ganglion
© U of M 2005 (J. France)

# Internal structure of the spinal cord

- The spinal cord contains a central canal in the middle that is surrounded by central **grey matter** and outer **white matter**. The central canal runs longitudinally through the length of the entire spinal cord and contains cerebrospinal fluid (C.S.F.)
- On cross section, the spinal cord is oval in shape. It has grey matter as central H shaped with two anterior and two posterior horns connected by thin grey commissure containing small central canal. - In thoracic and upper lumber segments two small lateral horns are seen.

- **The grey matter** of the spinal cord consists of multipolar nerve cells with their naked fibers (no sheaths) and dendrites, neuroglial cells and blood vessels.

- The anterior horns (contain motor nuclei), posterior horns (contain sensory nuclei), and lateral horns (contain sympathetic nuclei) while grey commissure contains anterior and posterior commissural nuclei



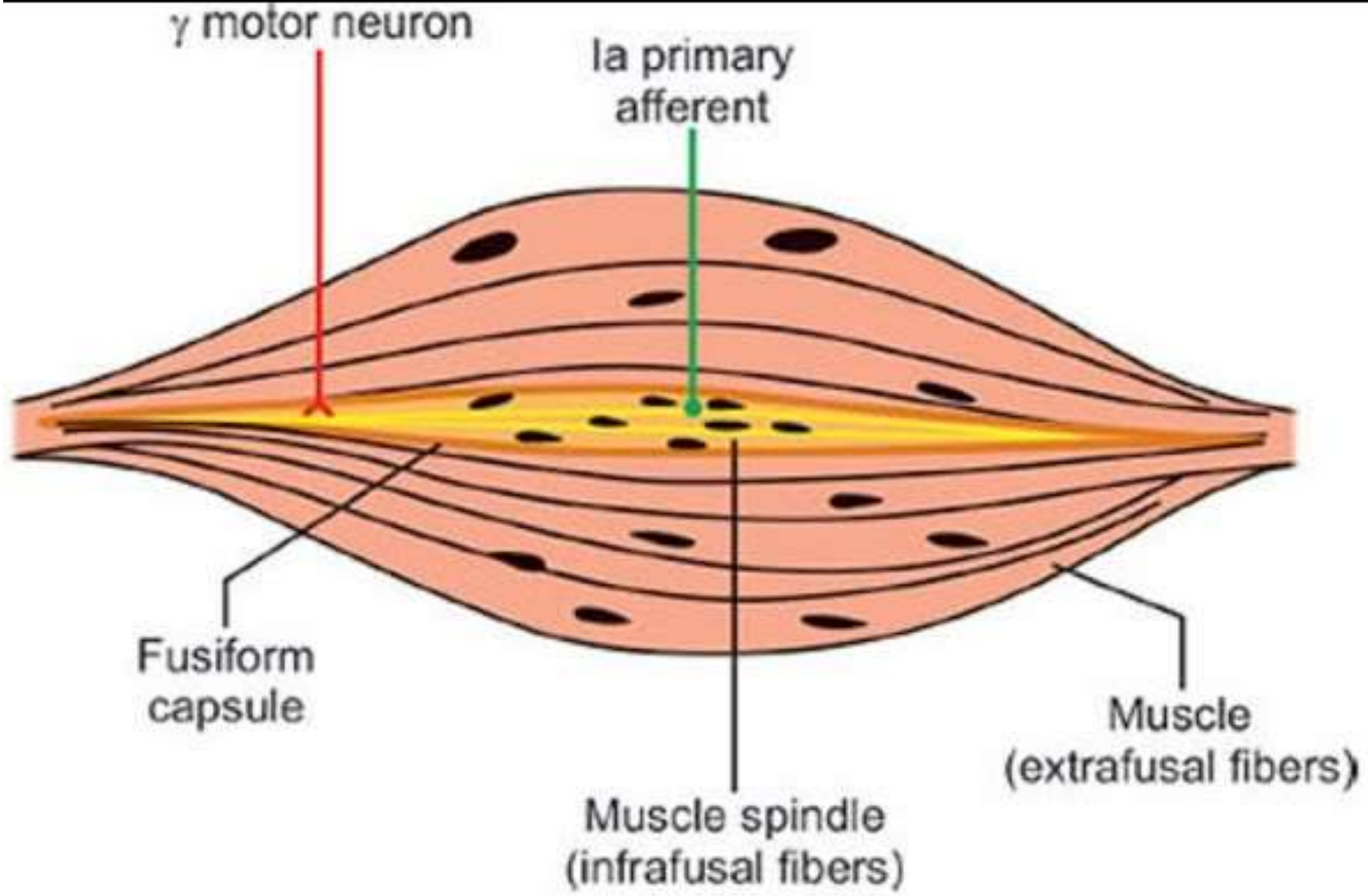
**A) Anterior horns` nuclei (motor nuclei):** - Each nucleus of anterior horn contains:

- -Large multipolar nerve cells which give α-efferents that innervate extrafusal skeletal muscle.
- -Small multipolar nerve cells which give ϑ-efferents which innervate contractile elements of muscle spindles (intrafusal muscle fibers of neuromuscular spindles). the 2nd order neurons of the somatic motor pathway.
- Three groups of nuclei are present in the anterior horns:

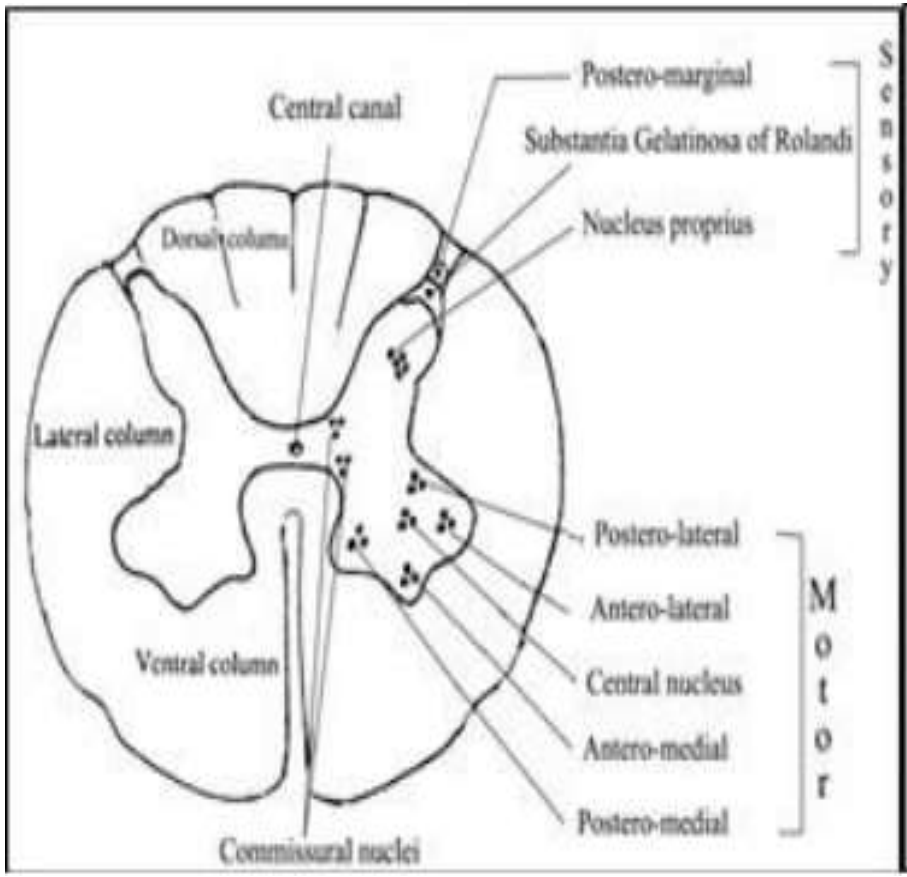
**(1) Medial group:** It includes: antero-medial group and postero-medial group. It is present in all segments of spinal cord. It innervates axial muscles (intercostal & abdominal).

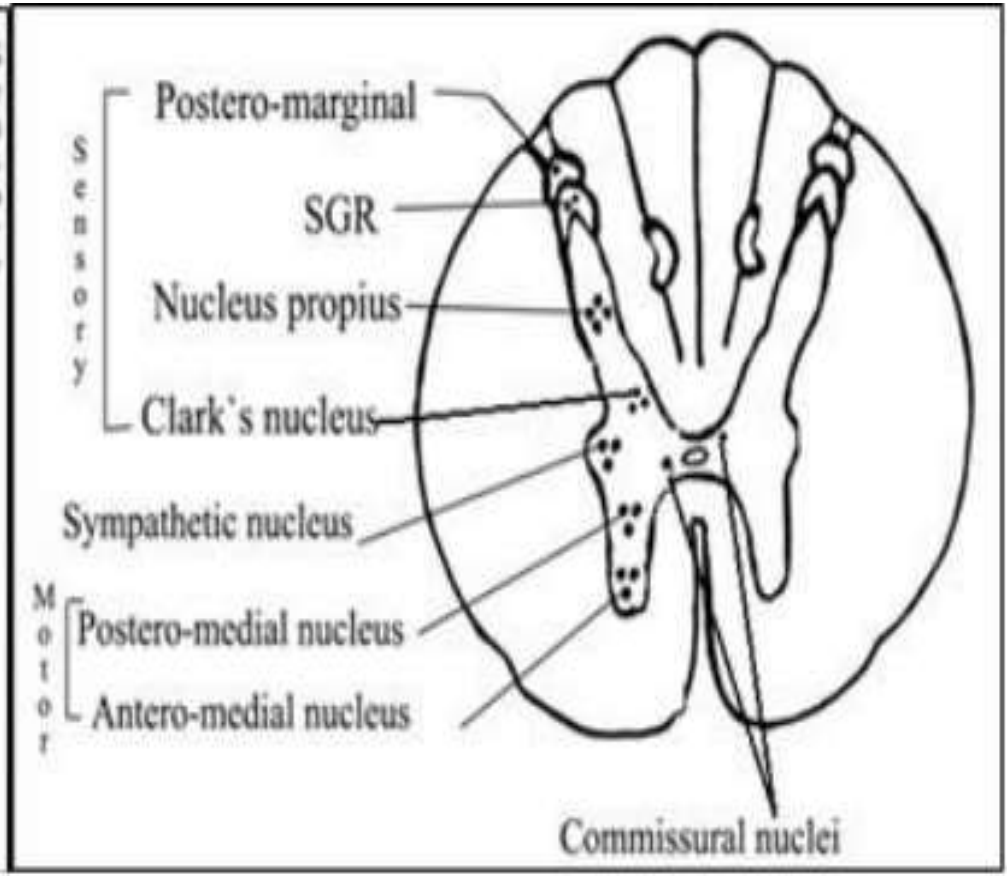
**(2) Central group:** Present in all the segments except thoracic segments. It innervates some muscle of the neck (spinal XI), diaphragm & external anal and urethral sphincters.

**(3) Lateral group:** It includes antero-lateral and postero-lateral. Present in all the segments except thoracic segments It innervates the skeletal muscles of upper and lower limbs.


γ motor neuron
Ia primary afferent
Fusiform capsule
Muscle spindle (infrafusal fibers)
Muscle (extrafusal fibers)

**B) Posterior horns nuclei (sensory nuclei):** They contain medium sized cells and are the 2nd order neurons of the sensory pathway.



(1) **Posteromarginal nucleus:** It covers the tip of posterior horn In all levels of spinal segments. It mediates pain and temperature sensation.

(2) **Substantia gelatinosa of Rolandi:** Its nerve cells are present at the apex of the posterior horns beneath the posteromarginal nucleus. Present in all levels of spinal segments. Its cells form the 2nd order neurons in the pathway of pain and temperature sensations (lateral spino–thalamic tract). It is the homologue of spinal trigeminal nucleus.

(3) **Main sensory nucleus (Nucleus proprius):** Its cells are present in the centre of the posterior horns. Present in all levels of spinal segments. Its cells form the 2nd order neurons in the pathway of crude (light) touch (anterior spino–thalamic tract).

(4) **Clark's nucleus (nucleus dorsalis):** Its cells present at the base of posterior horn. Present in 8 th cervical and all thoracic up to 3rd lumbar (C8 – L3). Its cells form the 2nd order neurons of anterior and posterior spino– cerebellar tracts (unconscious proprioception).

**C) Lateral horns nuclei** contain: (1) Sympathetic nuclei: The thoracic and upper two lumbar segments contain intermediolateral sympathetic nuclei. They give preganglionic fibers which pass in anterior root of spinal nerve. (2)Parasympathetic nuclei: Present in sacral segments (S.2,3&4). ~~No lateral horns in sacral region.~~

**D) Commissural nuclei:** Present in all segments of spinal cord ? They surround the central canal. They act as interneurons between sensory and motor nuclei. There are anterior and posterior commissural nuclei.

**N. B.** Some segments contain some specific nuclei as:

- **Phrenic nucleus:** Is a part of central nucleus of anterior horn of C2- C5 for innervations of diaphragm.
- **Spinal accessory nucleus:** Is a part of central nucleus of anterior horn of C1- C5 for innervations of trapezoid and sternomastoid muscles.

# Rexed Laminae

As an alternative to spinal cord nuclei, Bror Rexed (1950s) identified layers, or laminae, within the spinal cord where cells were grouped according to their structure and function, rather than location

## Lamina I

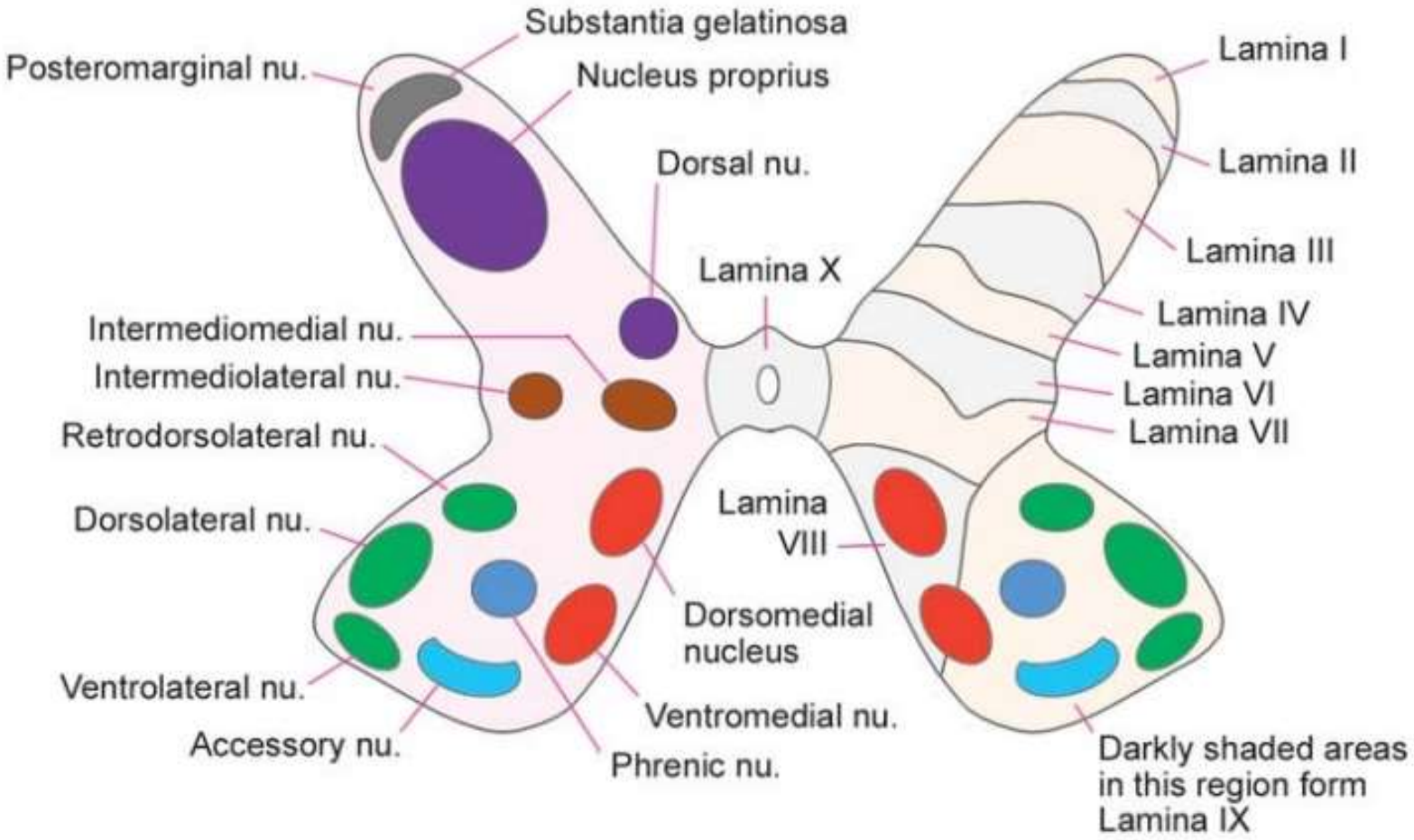
- tip of the dorsal horn
- cells respond to noxious or thermal stimuli
- sends information to the brain by the contralateral spinothalamic tract
- corresponds to the marginal zone

## Lamina II

- Involved in sensation of noxious and non-noxious stimuli, and modulating sensory input to contribute to the brain's interpretation of incoming signals as painful, or not.
- Sends information to Lamina III and IV
- Corresponds to substantia gelatinosa

## Lamina III

- Involved in proprioception and sensation of light touch.
- Cells in this layer connects with cells in layers IV, V and VI.
- Partially corresponds to nucleus proprius




Subdivisions of the grey matter of the spinal cord. The left half of the figure shows the cell groups usually described. The right half shows the newer concept of laminae.

## Lamina IV

- Involved in non-noxious sensory information relay and processing.
- Cells connect with those in lamina II
- Partially corresponds to nucleus proprius

## Lamina V

- Relays sensory, including nociceptive (potentially painful), information to the brain via the contralateral and spinothalamic tracts
- Receives descending information from the brain via the corticospinal and rubrospinal tracts.

## Lamina VI

- Contains many small interneurons involved in spinal reflexes
- Receives sensory information from muscle spindles (involved in proprioception).
- Sends information to the brain via ipsilateral spinocerebellar pathways

## Lamina VII

- Large, heterogenous zone that varies through the length of the spinal cord.
- Receives information from Lamina II to VI, and from viscera
- Relays motor information to the viscera
- Gives rise to cells involved in the autonomic system
- Dorsal nucleus of Clarke is part of Lamina VII

## Lamina VIII

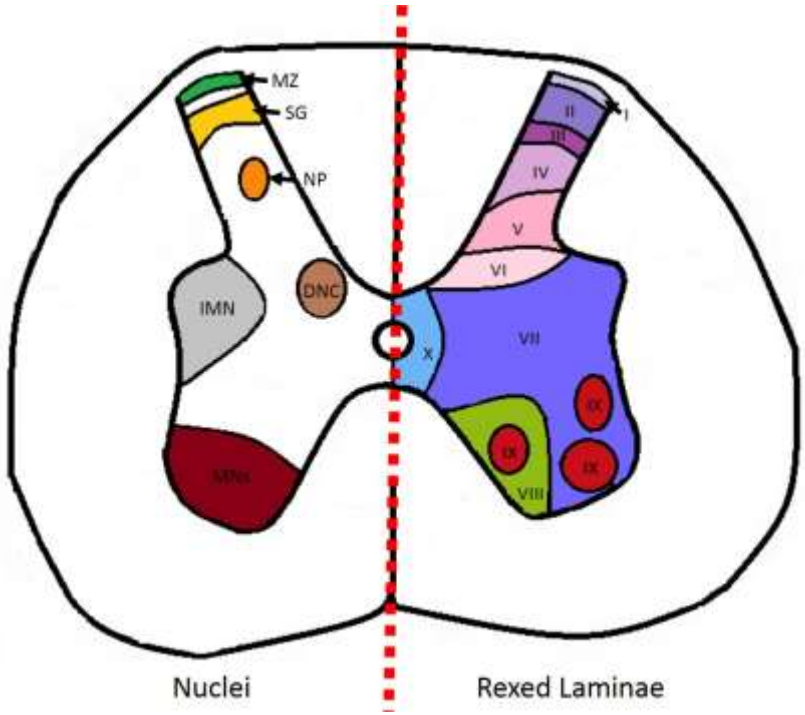
- Varies depending on spinal cord level, but is most prominent in cervical and lumbar enlargements
- Cells are involved in modulating motor output to skeletal muscle

## Lamina IX

- Size and shape varies between spinal cord levels
- Distinct groups of motor neurons that innervate skeletal muscle.

## Lamina X

- Surrounds the central canal – the grey commissure
- Axons decussate (cross over) from one side of the spinal cord to the other

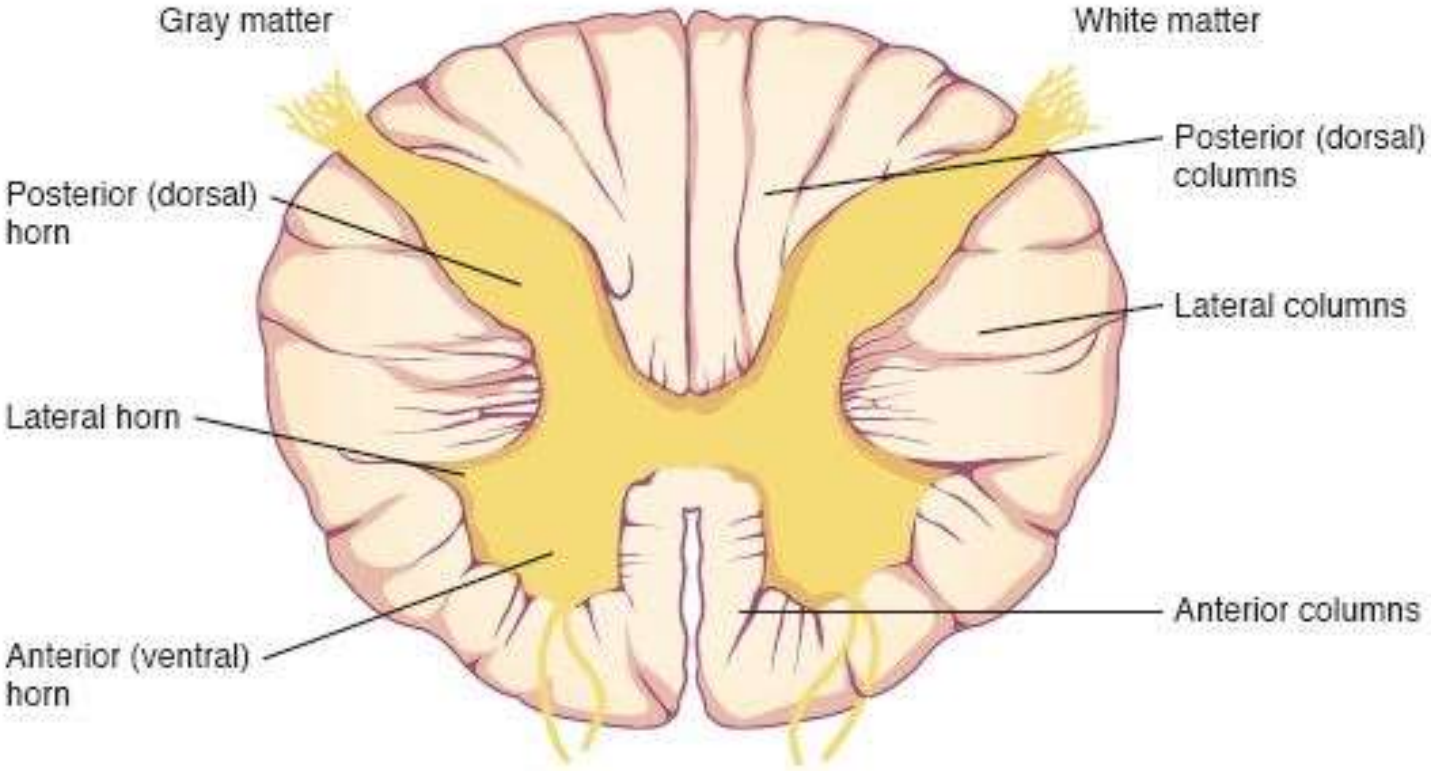


- **The white matter:** - In fresh state, it appears grossly white in colour because it contains many myelinated nerve fibers which are grouped to form tracts and few unmyelinated nerve fibers, neuroglia and few blood capillaries. - For simple description, the white matter of each half of the spinal cord is divided into three longitudinal columns (funiculi).

**1. Posterior column** between the posterior horn of grey matter and the dorsal median septum in the midline. It contains mainly ascending tracts.

**2. Anterior column** between the anterior median fissure & the point of emergence of anterior nerve roots. It contains ascending & descending tracts.

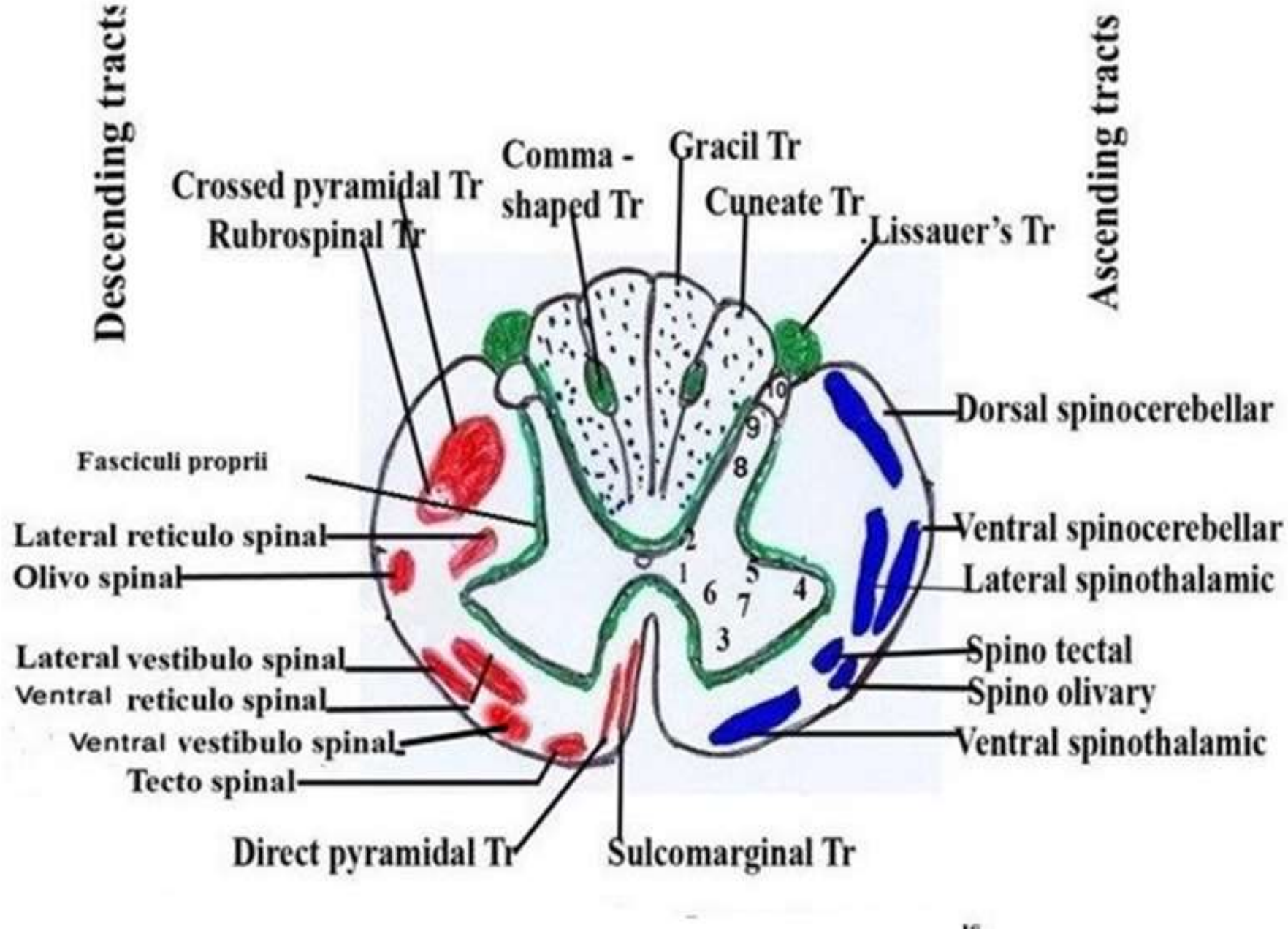
**3. Lateral column** between the emergence of the anterior nerve roots and the entry of the posterior nerve roots. It contains ascending & descending tracts.


Gray matter
White matter
Posterior (dorsal) horn
Posterior (dorsal) columns
Lateral columns
Lateral horn
Anterior columns
Anterior (ventral) horn

# The tracts in white matter of spinal cord

**I-Short associative tracts** (ascending or descending tracts that begin and terminate in the spinal cord. Their functions are association and coordination of the different movements of the body with each other). - There are four short tracts in spinal cord (Fasciculi proprii, Lissauer's, Comma shaped and Septo–marginal)

**II - Long tracts:** * Long ascending tracts (sensory) * Long descending tracts (motor)


Descending tracts
Ascending tracts
Crossed pyramidal Tr
Rubrospinal Tr
Comma - shaped Tr
Gracil Tr
Cuneate Tr
Lissauer's Tr
Dorsal spinocerebellar
Fasciculi proprii
Lateral reticulo spinal
Olivo spinal
Ventral spinocerebellar
Lateral spinothalamic
Lateral vestibulo spinal
Ventral reticulo spinal
Ventral vestibulo spinal
Tecto spinal
Spino tectal
Spino olivary
Ventral spinothalamic
Direct pyramidal Tr
Sulcomarginal Tr
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3
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10

## A-The LONG ASCENDING (SENSORY) TRACTS: -

The sensory tracts are long ascending tracts carry sensation from all the body except the head. The sensations from the head are carried by trigeminal nerve (cranial V).

- These sensory tracts are divided into three categories according to their termination:

**I- Sensory tracts that reach cerebral cortex (C.C.):** - All these tracts are known to carry conscious sensations which reach the cerebral cortex of opposite side (crossed) and any lesion in one of them leads to loss of sensation on the opposite side. They are four tracts:

1- Lateral spinothalamic

2- Ventral (anterior) spinothalamic.

3- Gracile tract.

4- Cuneate tract.

**II - Sensory tracts that reach cerebellum** (spinocerebellar pathway): - These tracts do not reach C.C. but carry sensation to cerebellar cortex of the same side for coordination (uncrossed) except anterior spinocerebellar. - Lesion in one of them dose not lead to loss of sensation but leads to loss of coordination.

They are four tracts:

1- Dorsal (posterior) spinocerebellar

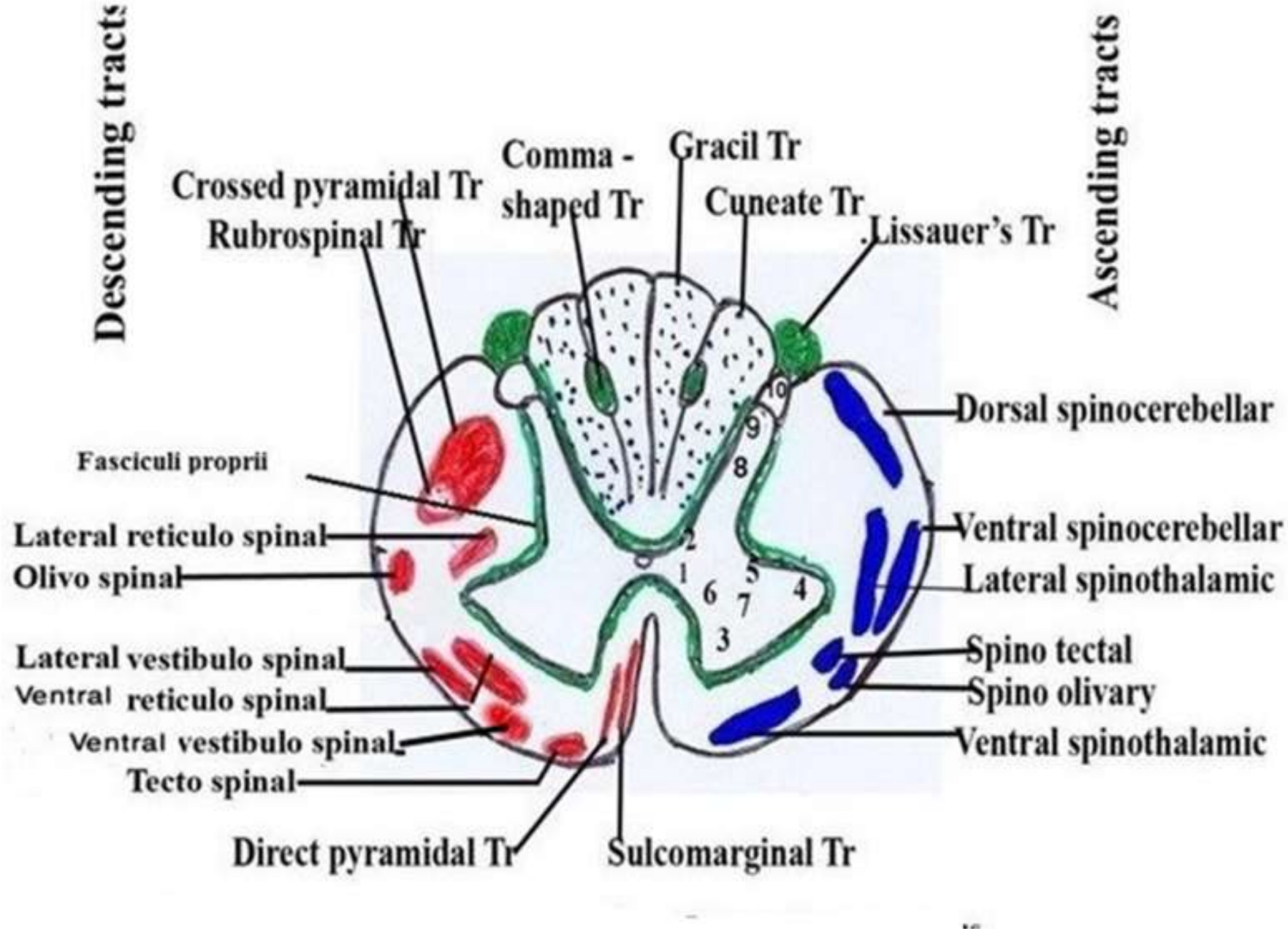
2- Cuneocerebellar.

3- Ventral (anterior) spinocerebellar.

4- Rostral spinocerebellar.

**III-Sensory tracts that reach brain stem**:

1- Spino-tectal. 2- Spino-olivary.


Descending tracts
Ascending tracts
Crossed pyramidal Tr
Rubrospinal Tr
Comma - shaped Tr
Gracil Tr
Cuneate Tr
Lissauer's Tr
Dorsal spinocerebellar
Fasciculi proprii
Lateral reticulo spinal
Olivo spinal
Ventral spinocerebellar
Lateral spinothalamic
Lateral vestibulo spinal
Ventral reticulo spinal
Ventral vestibulo spinal
Tecto spinal
Spino tectal
Spino olivary
Ventral spinothalamic
Direct pyramidal Tr
Sulcomarginal Tr
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- **B- LONG DESCENDING (MOTOR) TRACTS:**
- All voluntary movements are done by nerve impulse starting from cerebral cortex, to Anterior Horn Cells of spinal cord or motor nuclei of cranial nerves then go to skeletal muscle.
- This pathway is divided into upper and lower motor neuron.
- The axons of upper motor neuron reach lower motor neuron through long descending tracts.
- The lower motor neuron includes anterior horn cells of the spinal cord and motor cranial nuclei of the brain stem.

- - The long descending tracts are classified into:

**I- Pyramidal tracts:** that include:

1) Cortico-spinal tract → to spinal cord

2) Cortico-bulbar (cortico nuclear) → to cranial nerve nuclei

- Each pyramid in lower medulla contains about 1 million axons. Most of pyramidal cells are 10-50 µm.
- Axons of the largest pyramidal cells supplying the digits arise from Betz cells (3.5%). These cells are the largest in size 120 µm in height.

**II- Extra–pyramidal tracts:** that includes 4 single tracts and 2 paired tracts:

1) Rubrospinal tract.

2) Olivospinal tract.

3) Sulco-marginal tract (medial longitudinal bundle or fasciculus MLB=MLF)

4) Tecto-spiral tract.

5) Lateral & ventral (anterior) reticulo-spinal tracts

6) Lateral & ventral (medial) vestibulo-spinal tracts

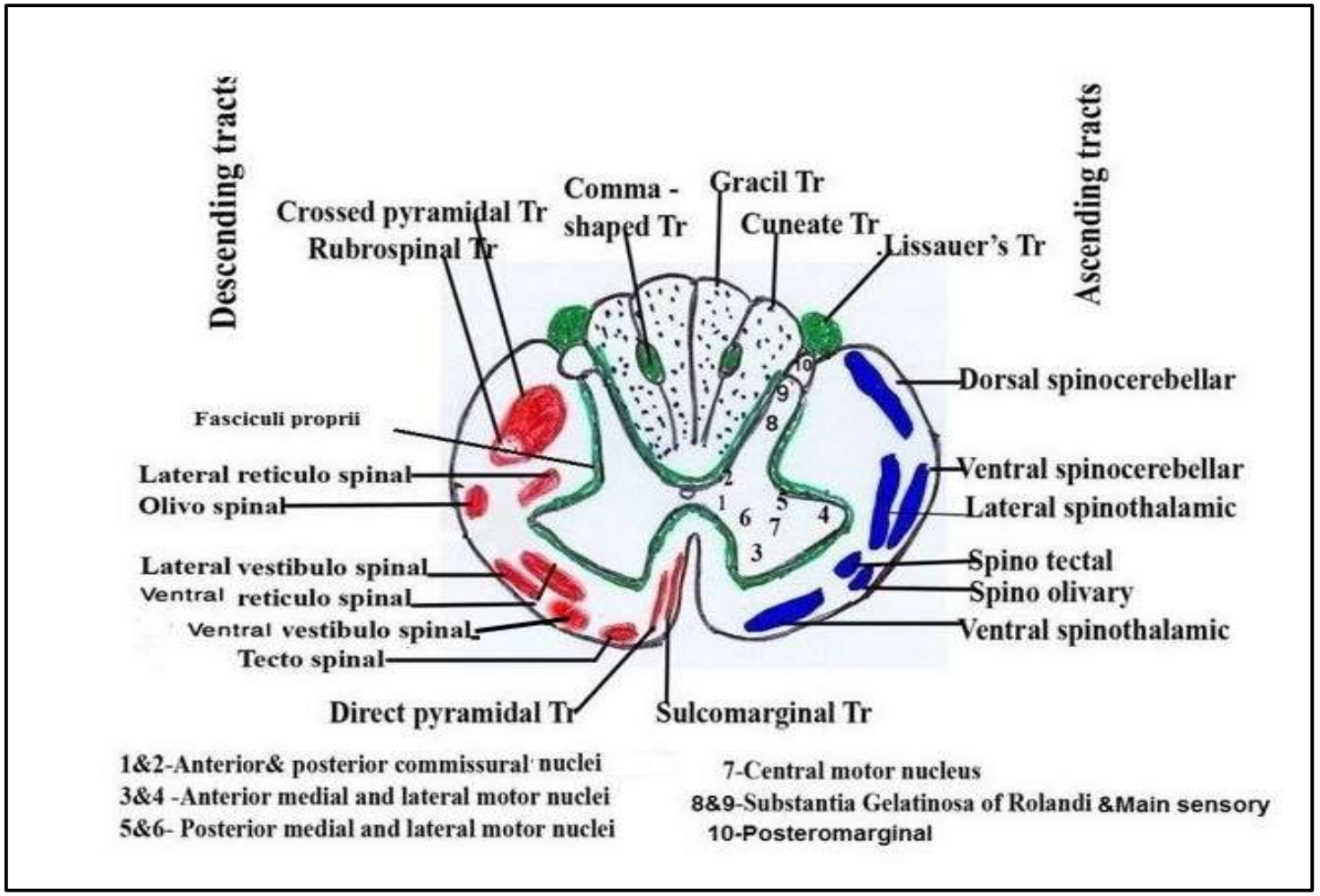
| | Cervical | Lower Thoracic | Lumbar |
|---|---|---|---|
| Shape | Oval | Round | Oval |
| Central canal | More anterior | Slight anterior | Central |
| Posterior horns | Thin & diverging | Thin & parallel | Thick & parallel |
| Anterior horns | Thick | Thin & parallel | Thick & parallel |
| Lateral horns | ---------- | present | Present (L1-L3) only |
| White matter | | Large compared to grey matter | Very little compared to grey matte |

# Levels of the spinal cord:

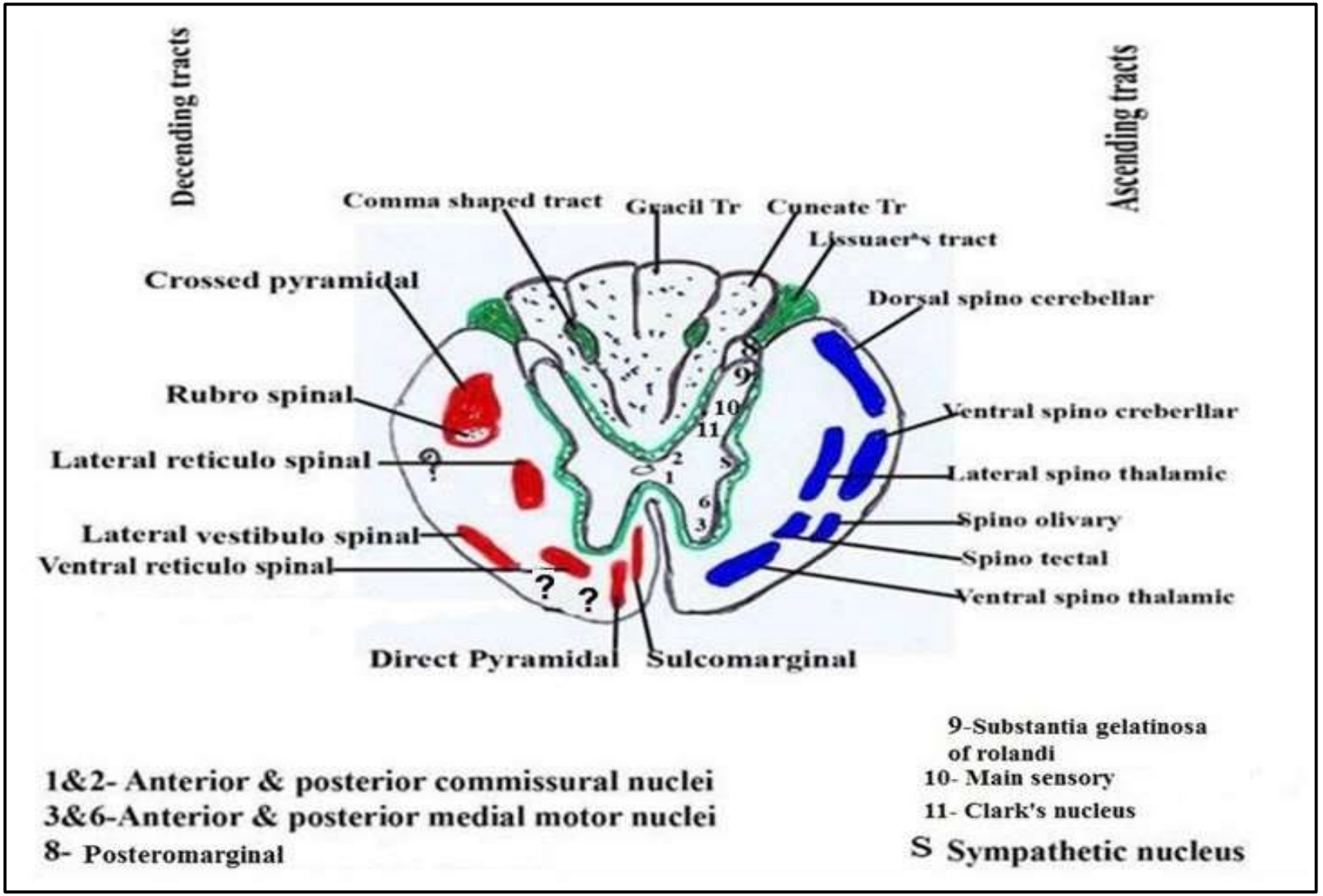
- Spinal cord at the cervical region.
- Spinal cord at the upper thoracic region.
- Spinal cord at the lower thoracic region.
- Spinal cord at the lumber region.

# Spinal cord at the cervical region:

- The grey matter contains all motor, sensory and commissural nuclei except Clark`s nucleus (only present in C8).
- The white matter is abundant and full of almost all short and long tracts.



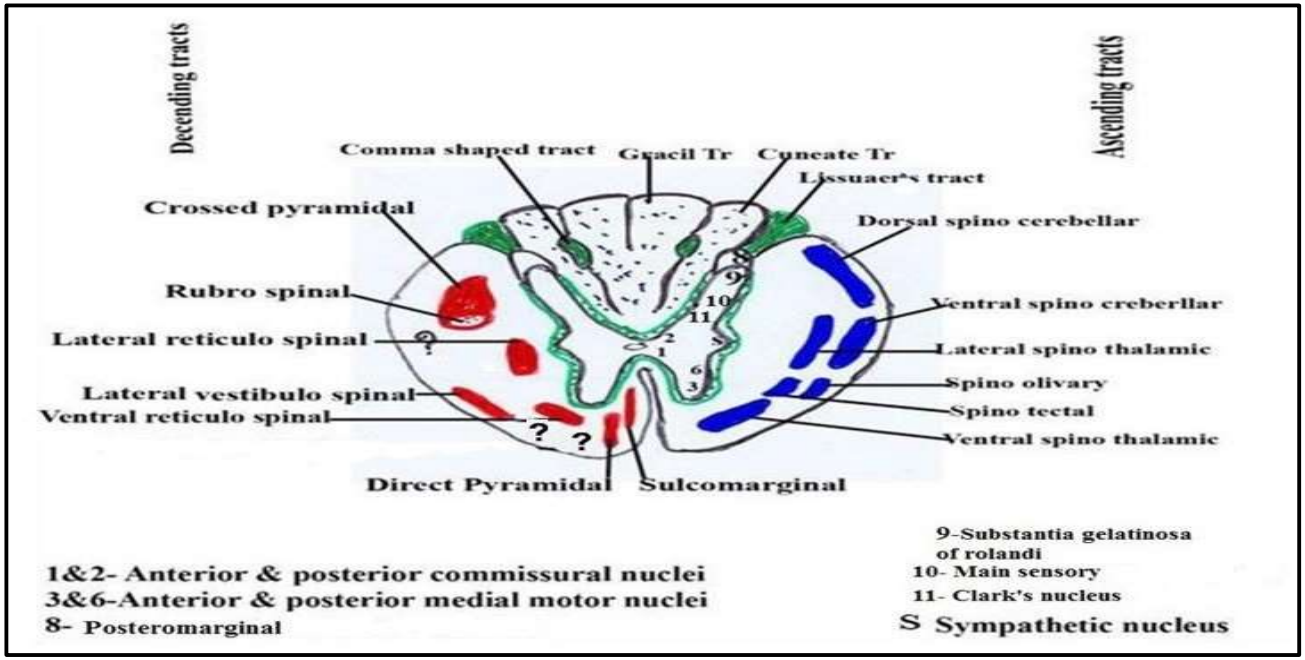
# Spinal cord at the upper thoracic region



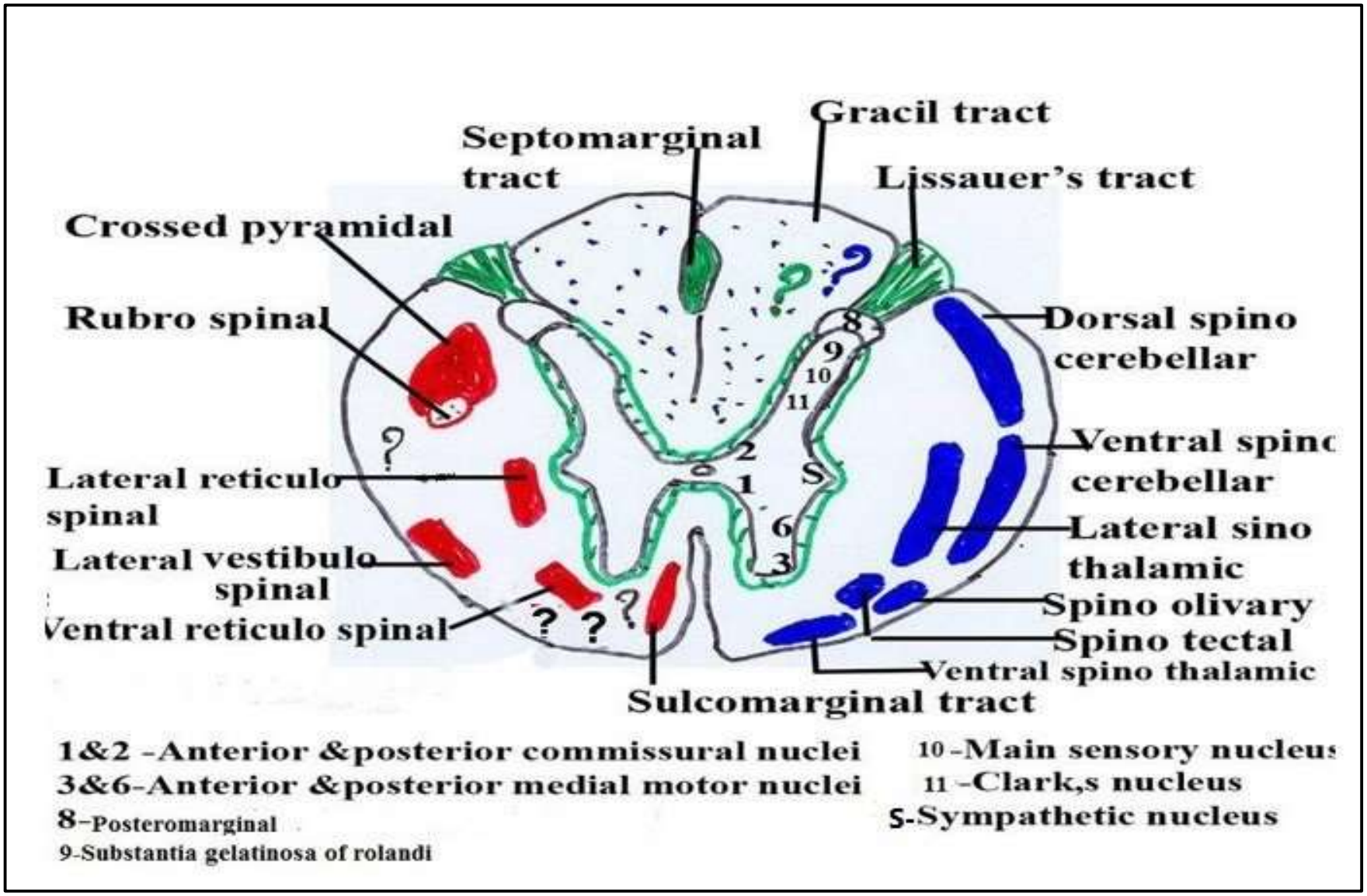
# Spinal cord at the upper thoracic region

- The posterior horns contain Clark`s nucleus in addition to the same nuclei in the cervical region while the anterior horns contain the medial nuclei only. It has lateral horns which contain sympathetic nuclei.

- The white matter contains the same tracts as in cervical region except olivospinal, ventral vestibulospinal & tectospinal tract that are absent.



# Spinal cord at lower thoracic region



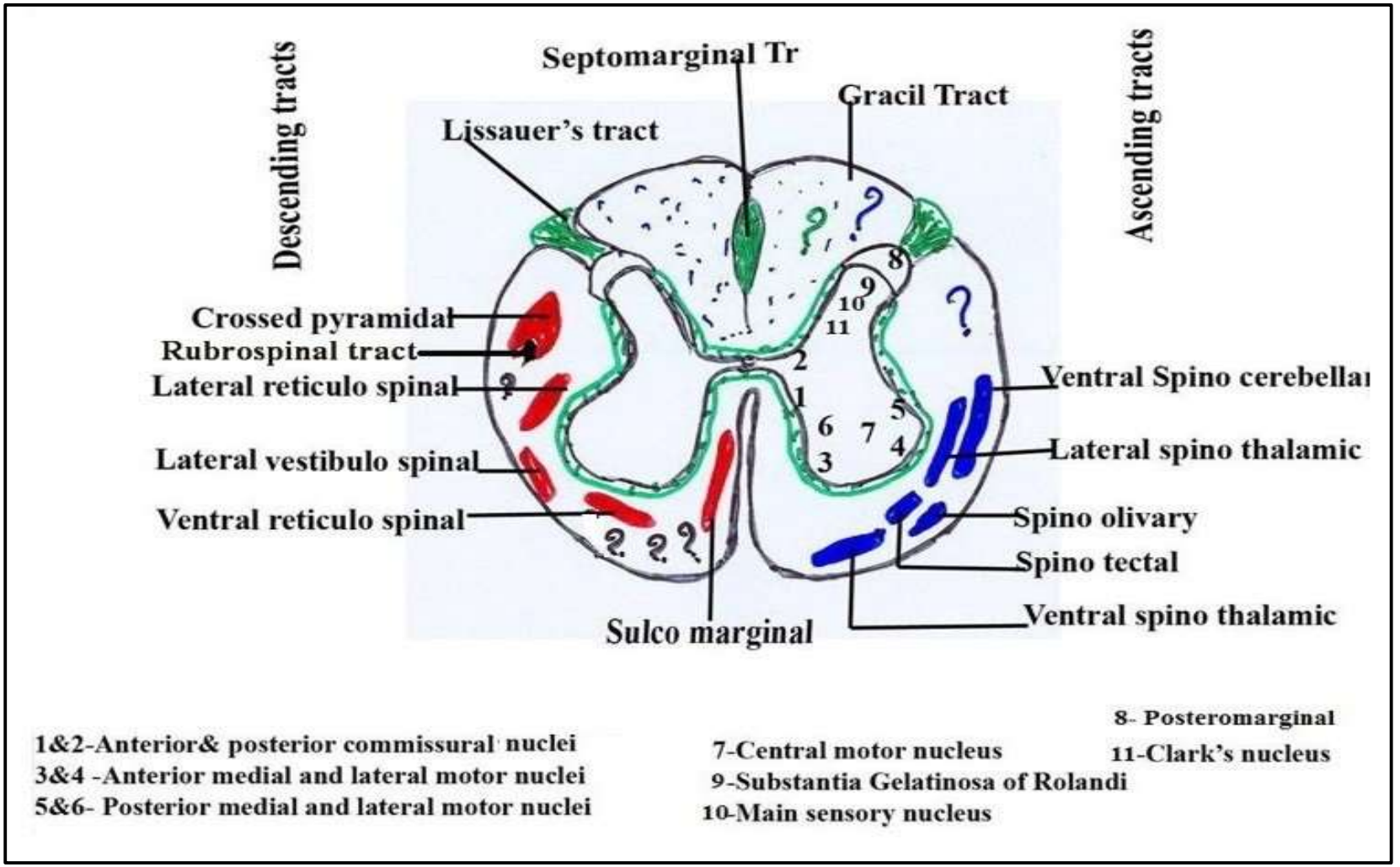
# Spinal cord at lower thoracic region:

- The posterior horns contain Clark`s nucleus in addition to the same nuclei in the cervical region while the anterior horns contain the medial nuclei only. It has lateral horns which contain sympathetic nuclei.
- The white matter contains the same tracts as in cervical region except comma shaped tract, cuneate tract and direct pyramidal tract in addition to the three previous absent tracts. The septomarginal short tract appears.

# Spinal cord at the lumbar region:

- The grey matter contains all motor, sensory and commissural nuclei

- The white matter contains the same tracts as in lower thoracic but; posterior spinocerebellar tract is absent.



# THANK YOU