

• Dura mater

- The thick dura mater (tough mother) consists of **dense, fibro-elastic connective tissue**.
- It contains **venous sinuses** which drain **blood** and **C.S.F** from the brain.
- The **internal surface** of all dura mater, as well as its **external surface** in the spinal cord, is covered by **simple squamous epithelium**.
- The **external dura mater** is continuous with the **periosteum of the skull**.

• Arachnoid mater

- The arachnoid (spider-weblike) has two components:
 1. **A sheet of connective tissue** in contact with the dura mater.
 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**.
- This space **communicates with the ventricles of the brain** where the CSF is produced.

Arachnoid Villi

- In some areas, the arachnoid **penetrates the dura mater** and protrudes into **dural venous sinuses**.
- These **CSF-filled protrusions**, which are covered by vascular endothelial cells (lining the sinuses), are called arachnoid villi.
- They function as a **site for drainage of CSF into the blood** of the venous sinuses.

• Pia mater

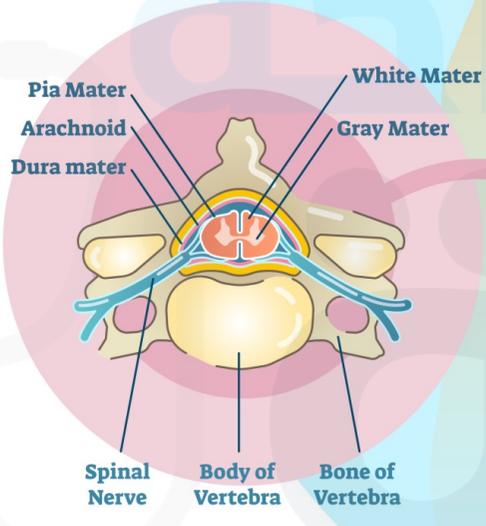
- Formed of:
 - **Outer layer:** collagenous bundles.
 - **Inner layer:** flattened simple squamous cells.
 - It is **closely applied to the entire surface of the CNS tissue**.
 - The pia does **not directly** contact **nerve cells or fibers**, being separated from neural elements by a **very thin superficial layer of astrocytic processes**, which adheres firmly to the pia mater.
 - Together, the **pia mater and the astrocytic end-feet with its basement membrane** form a **physical barrier** separating CNS tissue from CSF in the subarachnoid space.

Cerebrospinal Fluid (CSF)

- CSF is a clear, watery liquid that surrounds and protects the brain and spinal cord.
- It is produced in the brain's ventricles.
- It circulates in the central canal and the subarachnoid space.

(grey mater)

SPINAL CORD



VERTEBRA



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

Phrenic nucleus: Is a part of central nucleus of anterior horn of **C2- C5** for innervations of diaphragm.

Cervical Nerves

- C1 Head and neck
- C2 Diaphragm
- C3 Deltoids, Biceps
- C4 Wrist Extenders
- C5 Triceps
- C6 Hand
- C7
- C8

ant. motor
post. sensory
lat. sympathetic.

Thoracic Nerves

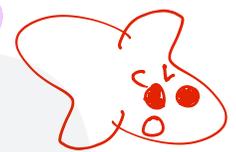
- T1
- T2
- T3
- T4
- T5
- T6 Chest Muscles
- T7 Abdominal Muscles
- T8
- T9
- T10
- T11
- T12

2 lat. horn

No central anterior nuclei in thoracic

In thoracic and upper lumber segments two small lateral horns are seen.

No lat. anterior nuclei in thoracic



Lumber Nerves

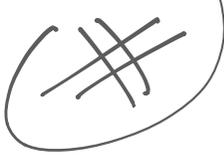
- L1
- L2
- L3 Leg Muscles
- L4
- L5

Sacral Nerves

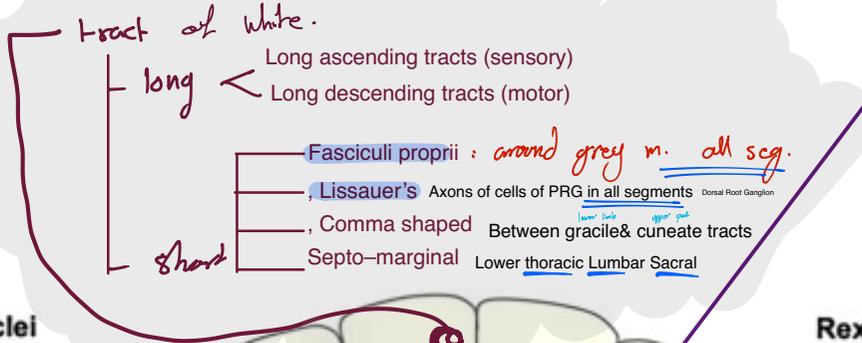
- S1
- S2
- S3 Bowel, Bladder
- S4 Sexual Function
- S5

Coccygeal

C8-L3
"Clarks"
"post. nuclei"

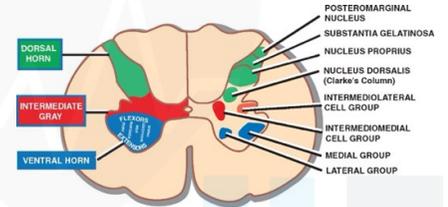
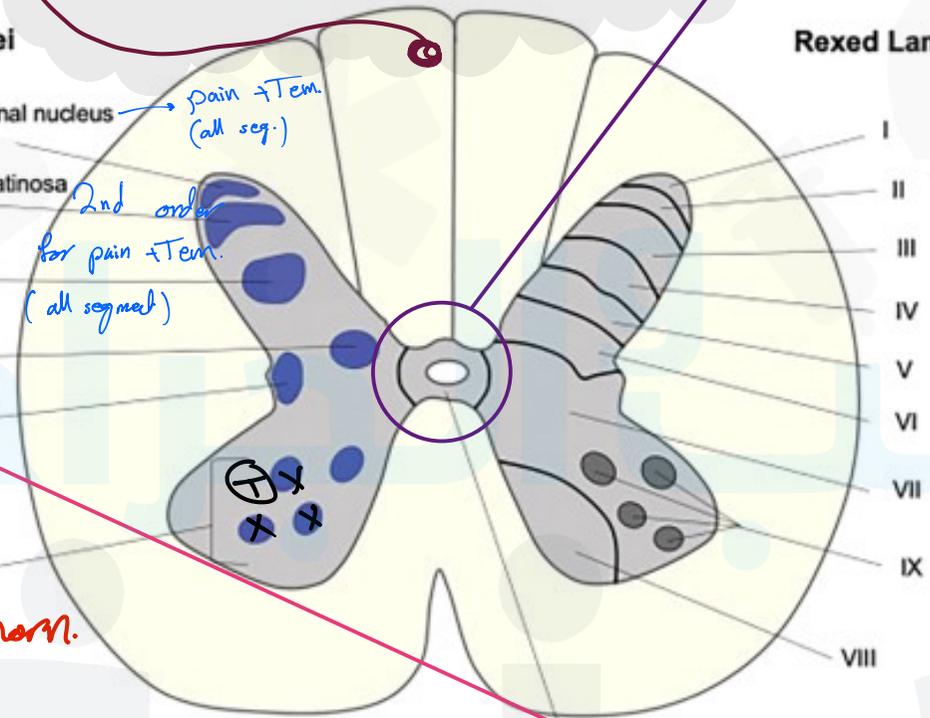


White matter



Nuclei

Rexed Lamina



- Posteromarginal nucleus → pain + Tem. (all seg.)
- Substantia gelatinosa → 2nd order for pain + Tem. (all segment)
- Nucleus proprius → (main sensory nucleus) 2nd order in cranial-nerve roots. (all seg.)
- Clarke's nucleus

Intermediolateral nucleus

(center) 2nd order in cranial-nerve roots. (all seg.)

(base) 2nd order of unconscious proprioception

C8 - L3

Motor nuclei
Anterior horn.

* grey matter

lat. horn nuclei

• In thoracic and upper lumbar segments two small lateral horns are seen.

α-efferents = extrinsic skeletal m.
γ-efferents = intrinsic skeletal m. (contractile elements)
"2nd order"

- Medial = intercostal + abdominal
- central
 - in all the segments except thoracic segments. It innervates some muscle of the neck, diaphragm & external anal and urethral sphincters.
- lat.
 - in all the segments except thoracic segments. It innervates the skeletal muscles of upper and lower limbs.

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

4) Anterior Horn Nuclei

Group	Medial	Central	Lateral
Location	All segments	Except thoracic	Except thoracic
Function	Axial muscles	Neck muscles, diaphragm, sphincters	Limb muscles

sym → Para

* Thoracic + 2 Lumbar
interomedial sympathetic.

sacral seg.
S1 XX
S2, 3, 4.



"postero marginal n."

pain + temp.

pain + temp. + sexual sens.

"substantia gelatinosa"

"nucleus proprius"

III → light touch.

"Clarke nucleus" . proprioception.

abr.

Laminae de rexed

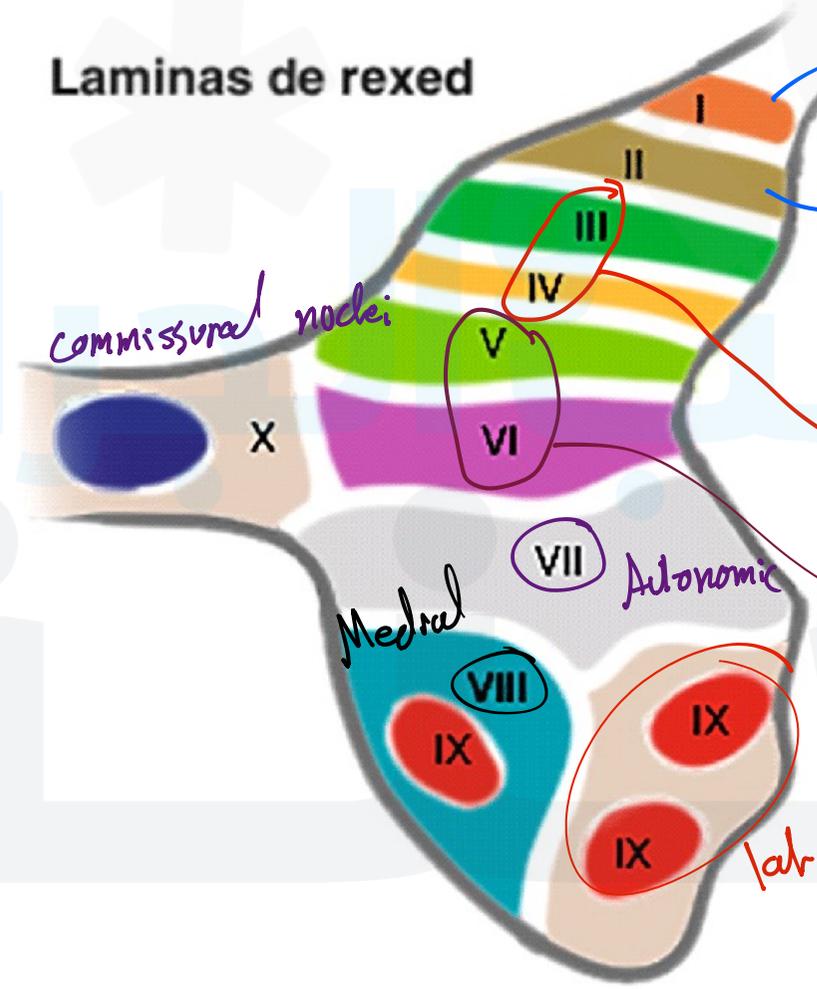
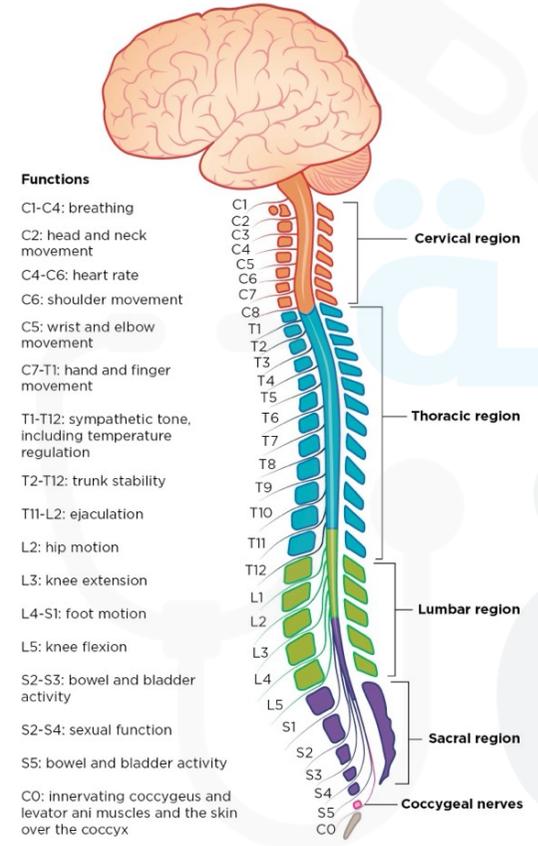


Fig 2. The spinal nerves and their functions



Functions

- C1-C4: breathing
- C2: head and neck movement
- C4-C6: heart rate
- C6: shoulder movement
- C5: wrist and elbow movement
- C7-T1: hand and finger movement
- T1-T12: sympathetic tone, including temperature regulation
- T2-T12: trunk stability
- T11-L2: ejaculation
- L2: hip motion
- L3: knee extension
- L4-S1: foot motion
- L5: knee flexion
- S2-S3: bowel and bladder activity
- S2-S4: sexual function
- S5: bowel and bladder activity
- C0: innervating coccygeus and levator ani muscles and the skin over the coccyx

L2

I. Pyramidal Tracts

These are the main voluntary motor pathways.
Called "pyramidal" because they pass through the pyramids of the medulla.

1) Corticospinal Tract

Function:
Carries voluntary motor signals from cerebral cortex → spinal cord → body muscles.
Pathway:
Motor cortex → internal capsule → brainstem → pyramids → spinal cord → synapse in anterior horn (LMN) → muscles of limbs and trunk.
Controls:
Movement of body & limbs (not the face).

2) Corticobulbar (Corticoculbar) Tract

Function:
Carries voluntary motor signals from cortex → motor cranial nerve nuclei.
Controls:
Muscles of face, head, and neck.
Crossing:
Most fibers cross to the opposite side before reaching cranial nerve nuclei.

A) Medial Corticobulbar Tract
 - CN III (oculomotor)
 - CN IV (trochlear)
 - CN V (trigeminal)
 - CN VI (abducens)
 - CN VII (facial)
 - CN VIII (vestibulocochlear)
B) Lateral Corticobulbar Tract
 - CN IX (glossopharyngeal)
 - CN X (vagus)
 - CN XI (accessory)
 - CN XII (hypoglossal)

I - Sensory tracts that reach cerebral cortex (C.C.):

II - Sensory tracts that reach cerebellum

III - Sensory tracts that reach brain stem:

- 1- Lateral spinothalamic tract
- 2- Ventral (anterior) spinothalamic tract ✓
- 3- Gracil tract
- 4- Cuneate tract

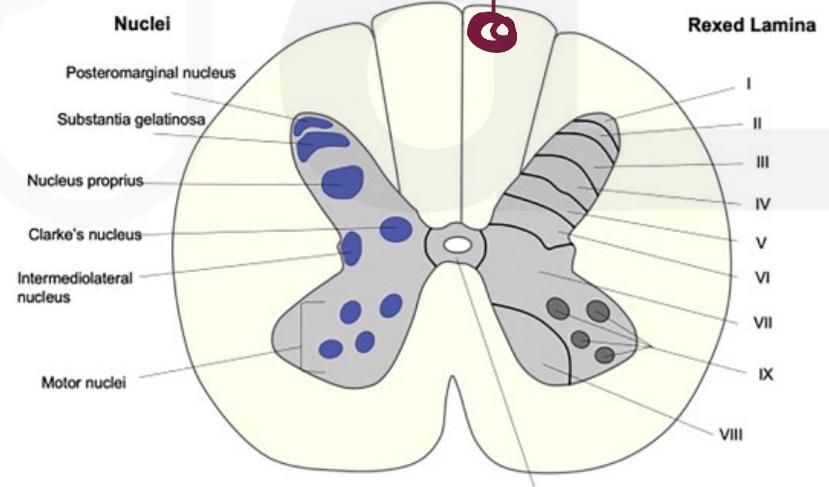
- 1) Dorsal (Posterior) Spinocerebellar Tract
- 2) Ventral (Anterior) Spinocerebellar Tract
- 3) Cuneocerebellar Tract
- 4) Rostral Spinocerebellar Tract

- 1) Spino-tectal Tract
- 2) Spino-olivary Tract

Tract of white.

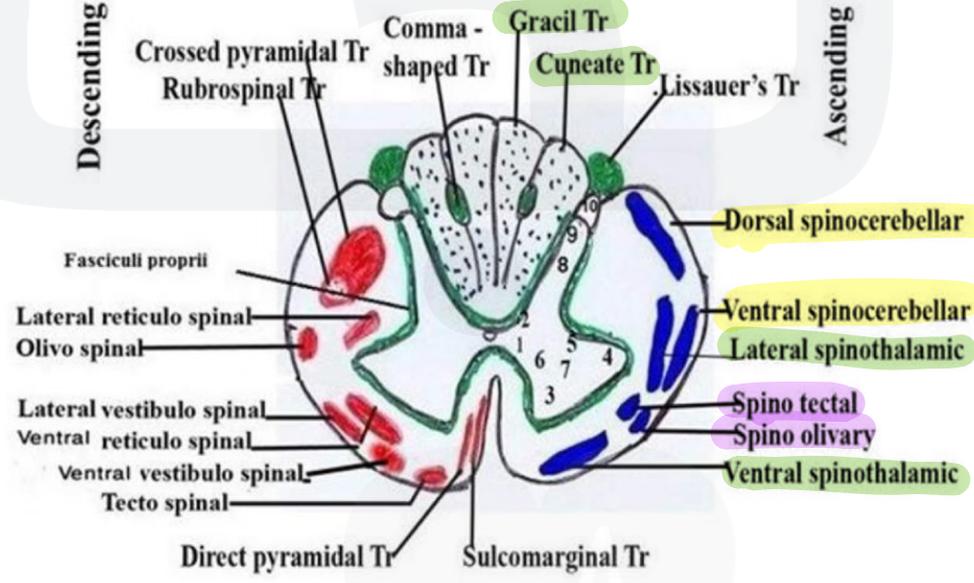
long ← Long descending tracts (motor)
 ← Long ascending tracts (sensory)

- Fasciculi proprii : around grey m. all seg*
- Lissauer's Axons of cells of PRG in all segments* Dorsal Root Ganglion
- Comma shaped* Between gracile & cuneate tracts
- Septo-marginal* Lower thoracic Lumbar Sacral



Descending tracts

Ascending tracts



- 1) Rubrospinal tract. (red nucleus of midbrain)
- 2) Olivospinal tract. (olivary nucleus of medulla)
- 3) Sulco-marginal tract (join ventral vestibulo spinal tract medial longitudinal bundle or fasciculus in brain stem)
- 4) Tecto-spinal tract. (tectum of midbrain)
- 5) Lateral & ventral (anterior) reticulo-spinal tracts reticular formation in brain stem)
- 6) Lateral & ventral (medial) vestibulo-spinal tracts (vestibular nuclei in pons)

II- Extra-pyramidal tracts

I. Pyramidal Tracts

1) Corticospinal Tract

Function: Corticospinal tract signals from cerebral cortex → spinal cord → body muscles.
Pathway: Motor cortex → internal capsule → pyramids → spinal cord → synapse in anterior horn (LMN) → muscles of limbs and trunk.
Controls: Movement of body & limbs (not the face).

2) Corticobulbar (Corticoulnuclear) Tract

Function: Corticobulbar tract signals from cerebral cortex → motor cranial nerve nuclei.
Controls: Muscles of face, head, and neck.
Crossing: Most fibers cross to the opposite side before reaching cranial nerve nuclei.

Corticospinal tracts
 Origin: Motor cortex and descend through the brain stem to the spinal cord.
 Pathway: Descend through the brain stem, crossing to the opposite side in the midbrain. They descend in the middle part of the corticospinal tracts.
 In the pons, they cross to the opposite side of the corticospinal tracts.
 In the medulla, they cross to the opposite side of the corticospinal tracts.
 In the spinal cord, they descend in the lateral part of the white matter.
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I- Sensory tracts that reach cerebral cortex (C.C.):

- 1- Lateral spinothalamic tract
- 2- Ventral (anterior) spinothalamic tract
- 3- Gracil tract
- 4- Cuneate tract

II - Sensory tracts that reach cerebellum

- 1) Dorsal (Posterior) Spinocerebellar Tract
- 2) Ventral (Anterior) Spinocerebellar Tract
- 3) Cuneocerebellar Tract
- 4) Rostral Spinocerebellar Tract

III- Sensory tracts that reach brain stem:

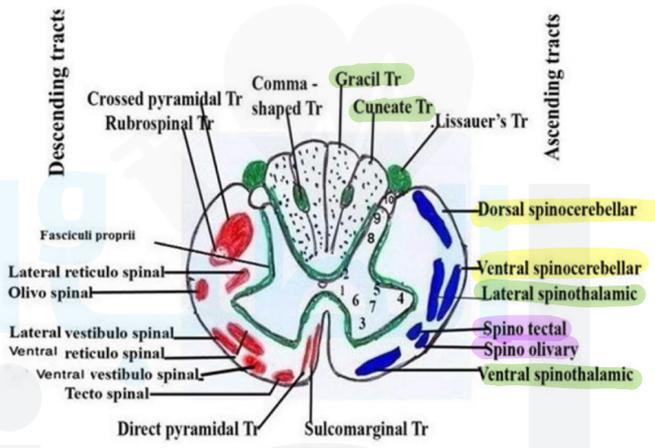
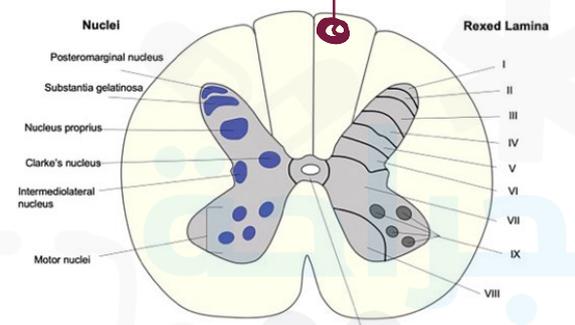
- 1) Spino-tectal Tract
- 2) Spino-olivary Tract

This pathway consists of two neurons:
 Upper Motor Neuron (UMN): Located in the cerebral cortex → sends long axons down through descending tracts.
 Lower Motor Neuron (LMN): Located in anterior horn of spinal cord or motor nuclei of cranial nerves → sends axons directly to skeletal muscles.
 The descending tracts = pathways that carry LMN signals → LMN.

Tract of white.

long ← Long descending tracts (motor)
 ← Long ascending tracts (sensory)

Fasciculi proprii : around grey m. all seg
 , Lissauer's Axons of cells of PRG in all segments Dorsal Root Ganglion
 , Comma shaped Lower thoracic upper sacral
 Septo-marginal Lower thoracic Lumbar Sacral



1) Lateral Spinothalamic Tract

What sensations does it carry?

- Pain
- Temperature
- Sexual sensation

Where does it start?

- Neurons originate from Substantia Gelatinosa of Rolando (SGR)
- from the opposite side (contralateral).

Crossing (Decussation):

- Fibers cross in front of the central canal.

Pathway:

1. Posterior root ganglion (PRG) fibers enter → synapse in SGR
2. Second-order neurons cross to the opposite side
3. Ascend in lateral funiculus of spinal cord
4. Continue through medulla
5. In the pons, they join ventral spinothalamic → form Spinal Lemniscus
6. End in Posterior Lateral Ventral Nucleus (PLVN) of Thalamus
7. Project to sensory cortex (postcentral gyrus)

Clinical point:

- Lesion → loss of pain & temperature on opposite side starting ~2 segments below lesion.

3) Gracile Tract

Where is it present?

- All spinal segments, but functionally for lower half of body + lower limbs

What sensations does it carry?

- Fine touch (discriminative)
- Proprioception

(position of joints, vibration)

Origin:

- Axons from large PRG neurons of:
- Lower 6 thoracic (T7–T12)
- Lumbar
- Sacral nerves

Pathway:

1. Fibers ascend uncrossed in dorsal column (medially) → Gracile fasciculus
2. Reach medulla → synapse in Gracile nucleus

4) Cuneate Tract

Where is it present?

- Cervical & upper 6 thoracic segments
- carries info from upper limbs + upper trunk

What sensations does it carry?

- Fine touch
- Proprioception

Origin:

- From PRG neurons of:
- Cervical levels
- Upper 6 thoracic (T1–T6)

Pathway:

1. Ascend uncrossed in dorsal column (laterally) → Cuneate fasciculus
2. Synapse in Cuneate nucleus (medulla)

2) Ventral (Anterior) Spinothalamic Tract

What sensations does it carry?

- Crude touch (non-discriminative)

Where does it start?

- From Main Sensory Nucleus (laminae III–IV)
- from the opposite side (after crossing)

Crossing:

- Fibers also cross in front of central canal

Pathway:

1. PRG → synapse in main sensory nucleus
2. Second-order fibers cross
3. Ascend in anterior funiculus
4. In the pons, join Lateral spinothalamic → form Spinal Lemniscus
5. End in PLVN of thalamus
6. Project to sensory cortex

Clinical point:

- Lesion → loss of crude touch on opposite side.

Sensory Decussation (for gracile + cuneate pathways):

In the medulla:

- Axons from Gracile and Cuneate nuclei form Internal Arcuate Fibers
- These fibers cross to opposite side → called Sensory Decussation
- Then ascend as Medial Lemniscus
- End in PLVN of thalamus → sensory cortex

Clinical point:

- Lesion in dorsal column (before crossing) → ipsilateral loss of fine touch & proprioception.

1) Dorsal (Posterior) Spinocerebellar Tract

- Arises from Clark's nucleus (nucleus dorsalis)
- Carries proprioception from lower limb
- Uncrossed → ends in cerebellum (same side)

2) Ventral (Anterior) Spinocerebellar Tract

- Also from Clark's nucleus, but from opposite side (double-crossed pathway)
- Carries proprioception from lower limb
- Eventually reaches same side of cerebellum (due to double crossing)

3) Cuneocerebellar Tract

- Upper limb equivalent of dorsal spinocerebellar
- Carries proprioception from upper limb
- Ends in ipsilateral cerebellum

4) Rostral Spinocerebellar Tract

- Upper limb equivalent of ventral spinocerebellar
- Carries proprioception from upper limb + neck
- Ends in ipsilateral cerebellum

1) Spino-tectal Tract

Function:

- Carries spinovisual reflexes (reflex turning of head/eyes toward a painful stimulus)

Pathway:

- Origin: Main sensory nucleus (contralateral after crossing)
- Ascends to → Superior colliculus (tectum of midbrain)

2) Spino-olivary Tract

Function:

- Carries proprioception to the inferior olivary nucleus, then to the cerebellum

Pathway:

- Origin: Main sensory nucleus (contralateral)
- Ascends → Inferior olivary nucleus (medulla)
- Then projects to cerebellum

Table 1 — Spinothalamic Tracts (Pain, Temp, Touch)

Ventral (Anterior) Spinothalamic	Lateral Spinothalamic	Feature
Crude touch	Pain, Temperature, Sexual sensation	Type of sensation
Main Sensory Nucleus	Substantia Gelatinosa (SGR)	Origin (2nd-order neuron)
Cross in front of central canal	Cross in front of central canal	Crossing
Anterior funiculus	Lateral funiculus	Cord location
Joins lateral in the pons → Spinal Lemniscus	Joins ventral in the pons → Spinal Lemniscus	Join together?
PLVN of thalamus → Sensory cortex	PLVN of thalamus → Sensory cortex	Ends in
Loss of crude touch on opposite side	Loss of pain & temp on opposite side	Clinical lesion

Table 2 — Dorsal Column Tracts (Fine Touch & Proprioception)

Cuneate Tract	Gracile Tract	Feature
Upper limb + upper half of trunk	Lower limb + lower half of trunk	Body region
Present in cervical & upper 6 thoracic	Present in all segments (functionally T7–down)	Spinal cord levels
Large PRG neurons (C1–T6)	Large PRG neurons (T7–S5)	Fiber origin
Lateral in dorsal column	Medial in dorsal column	Cord position
Same	Do NOT cross in spinal cord	Crossing?
Cuneate nucleus	Gracile nucleus	Relay nucleus (medulla)
Same	Sensory decussation (internal arcuate fibers)	Crossing site
Same	Medial lemniscus → PLVN → sensory cortex	After crossing
Same (for upper limb)	Ipsilateral loss of vibration & proprioception	Clinical lesion

Table 3 — Spinocerebellar Tracts (Unconscious Proprioception)

Rostral Spinocerebellar	Cuneocerebellar	Ventral Spinocerebellar	Dorsal Spinocerebellar	Feature
Upper limb + neck	Upper limb	Lower limb	Lower limb	Region carried
Spinal interneurons	Accessory cuneate nucleus	Clark's nucleus (contralateral—double crossing)	Clark's nucleus (ipsilateral)	Origin
No crossing	No crossing	Double crossing (cross → recross)	No crossing	Crossing
Ipsilateral cerebellum	Ipsilateral cerebellum	Ipsilateral cerebellum	Ipsilateral cerebellum	Ends in
Upper limb proprioception	Upper limb proprioception	Proprioception → coordination	Proprioception → coordination	Function
Ipsilateral ataxia	Ipsilateral ataxia	Ipsilateral ataxia	Ipsilateral ataxia	Clinical lesion

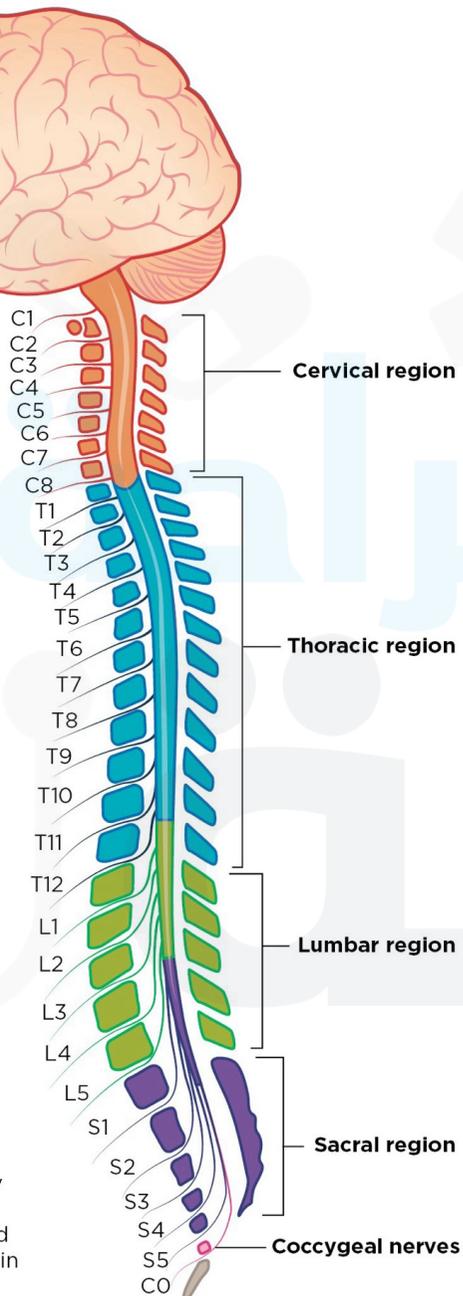
Table 4 — Brainstem Sensory Pathways

Spino-olivary tract	Spino-tectal tract	Feature
Main sensory nucleus (crossed)	Main sensory nucleus (crossed)	Origin
Cross in front of central canal	Cross in front of central canal	Crossing
Inferior olivary nucleus → cerebellum	Superior colliculus (midbrain)	Terminates in
Proprioception to cerebellum	Spinovisual reflexes (turning head/eyes to stimulus)	Function
Coordination problems	Defective visual-motor reflexes	Clinical lesion

Fig 2. The spinal nerves and their functions

Functions

- C1-C4: breathing
- C2: head and neck movement
- C4-C6: heart rate
- C6: shoulder movement
- C5: wrist and elbow movement
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- T11-L2: ejaculation
- L2: hip motion
- L3: knee extension
- L4-S1: foot motion
- L5: knee flexion
- S2-S3: bowel and bladder activity
- S2-S4: sexual function
- S5: bowel and bladder activity
- C0: innervating coccygeus and levator ani muscles and the skin over the coccyx



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

- 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 (three extrapyramidal tracts) olivospinal, ventral vestibulospinal & tectospinal tract that are absent.

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.

1) Cervical Region — Most Complete Region

Grey Matter

- Contains all motor, sensory, and commissural nuclei
- Except Clark's nucleus → present only at C8

White Matter

- Very abundant
- Contains all short and long tracts

👉 The cervical region has the richest white matter.

2) Upper Thoracic Region

Grey Matter

- Posterior horn: Clark's nucleus present (starting from T1)
- Anterior horn: Only medial motor nuclei
- Lateral horn: Sympathetic nuclei present

White Matter

- Contains same tracts as cervical region
- Except these 3 extrapyramidal tracts (ABSENT):
 1. Olivospinal tract
 2. Ventral vestibulospinal tract
 3. Tectospinal tract

3) Lower Thoracic Region

Grey Matter

- Posterior horn: Clark's nucleus present
- Anterior horn: Only medial motor nuclei
- Lateral horn: Sympathetic nuclei

White Matter

Contains most cervical tracts, except:

- ✗ Cuneate tract (upper limb only → not needed below T6)
- ✗ Comma-shaped tract
- ✗ Direct pyramidal tract
- ✗ The same 3 extrapyramidal tracts missing in upper thoracic
- ✓ Septomarginal short tract appears (unique to this level)

4) Lumbar Region

Grey Matter

- Contains all motor, sensory, and commissural nuclei

White Matter

Similar to lower thoracic, but one important tract is absent:

- ✗ Posterior spinocerebellar tract

(لأنه يعتمد على Clark's nucleus الذي ينتهي عند L2-L3)

🌟 Final Quick Comparison Table

White Matter (Key Differences)	Grey Matter (Key Points)	Level
All tracts present (richest white matter)	All nuclei present except Clark (only at C8)	Cervical
Missing 3 extrapyramidal tracts (olivospinal, ventral vestibulospinal, tectospinal)	Clark present; medial motor only; sympathetic present	Upper Thoracic
Missing: cuneate, comma-shaped, direct pyramidal + the 3 absent extrapyramidal; septomarginal tract appears	Same as upper thoracic	Lower Thoracic
Same as lower thoracic but posterior spinocerebellar tract absent	All nuclei present	Lumbar

