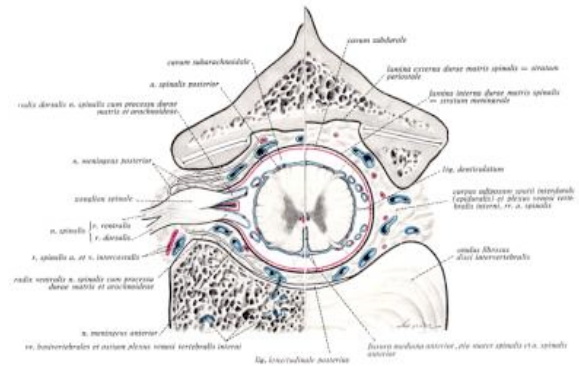
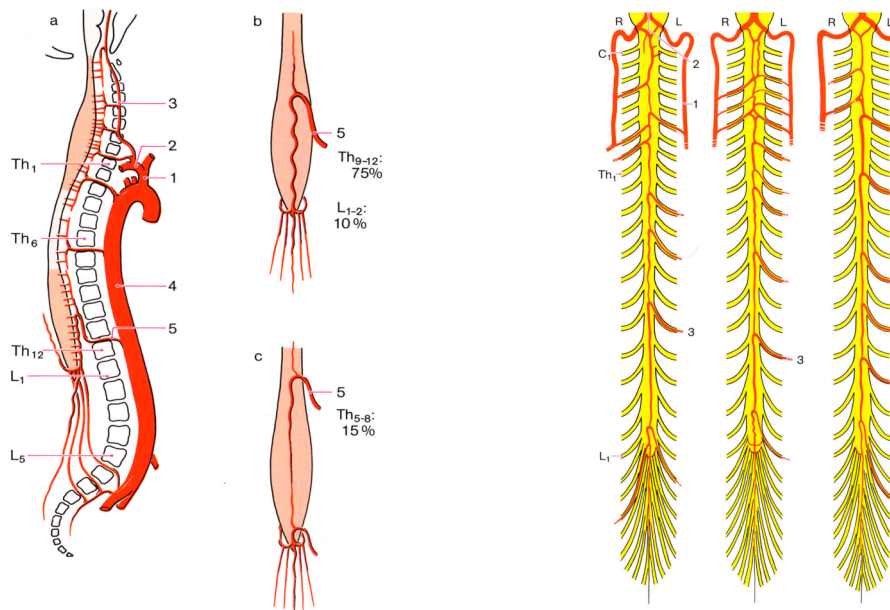


## IV. THE SPINAL CORD



- Spinal cord is covered by
  - Pia Mater Spinalis
    - Film Terminale
    - Denticulate Ligament ----- Cordotomy
  - Arachnoid Membrane
    - Subarachnoid Space ----- Lumbar Puncture  
Spinal Anaesthesia
  - Dura Mater Spinalis
    - Epidural Space ----- Epidural Anaesthesia
  - Periosteum of Vertebra
- Cord suspended in dural sheath by denticulate ligament on each side
  - Specialization of the pia mater
  - Landmarks for Cordotomy
  - Attached along lateral surface of cord midway between dorsal and ventral roots
- Cord is enlarged in cervical (C4-T1) and lumbosacral regions (L2-S3)
- Cord contains grey matter, white matter tracts, and central canal
- Central canal lined by *Ependyma*

## BLOOD SUPPLY



- Spinal Arteries
  - Anterior (1) & Posterior (2) Spinal Artery
    - from Vertebral artery
  - Radicular Arteries ----- Segmental arteries

- from Vertebral, Ascending Cervical, Intercostal and Lumbar Artery
- Venous Drainage
  - Longitudinal & Radicular Veins
    - to Intervertebral veins → to Internal Vertebral Venous Plexus
    - to external vertebral venous plexus → to segmental veins
  - External plexus has anterior part (anterior to vertebral body) and posterior part (over posterior elements including laminae and spinous processes)
    - Anterior and posterior parts freely anastomose
  - Internal plexus: anterior part is on each side of PLL, posterior to vertebral body; posterior part is interior to *ligamentum flavum*
    - Vertebral body drained by *basivertebral veins* which enter anterior external plexus
  - Veins of cord mirror related arteries in distribution
  - Venules drain into *anterior* and *posterior veins*, which drain into two *median longitudinal veins*, and into *anterolateral* and *posterolateral longitudinal veins* lying adjacent to the nerve roots
  - Radicular veins join branches from internal plexus forming intervertebral veins (have valves), which exit intervertebral foramina and join their respective segmental veins

## INTERNAL STRUCTURE

### White Matter

Ventral Funiculus (Anterior White Column)

Dorsal Funiculus (Posterior White Column):

Fasciculus Gracilis

Fasciculus Cuneatus

Lateral Funiculus (Lateral White Column)

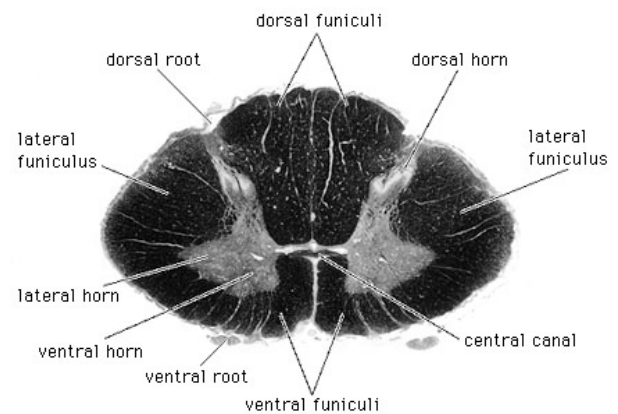
### Gray Matter

Ventral Horn ----- Motor

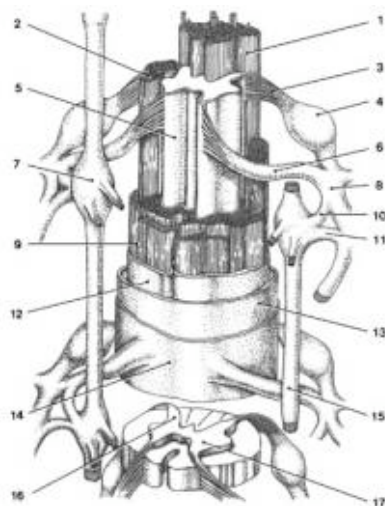
Dorsal Horn ----- Sensory

Lateral Horn ----- Autonomic (Sympathetic)

Gray Commissure --- Anterior and posterior



## PRINCIPLES OF CORD ORGANIZATION



**Columnar arrangement**

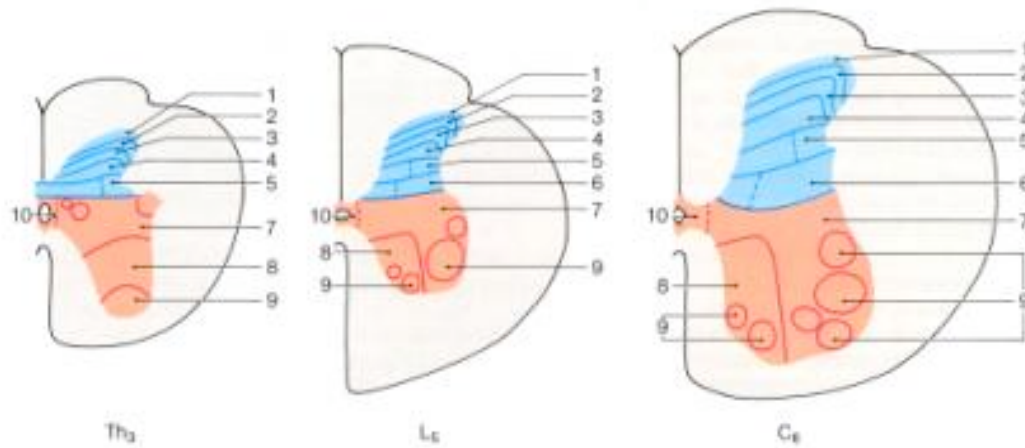


**Somatotopical arrangement**

- Longitudinal Arrangement
  - Fibers (White Matter) ----- White Column
  - Cell Groups (gray Matter) ----- Gray Column
- Transverse Arrangement
  - Afferent & Efferent Fibers
  - Crossing (Commissural & Decussating Fibers)

- Somatotopical Arrangement

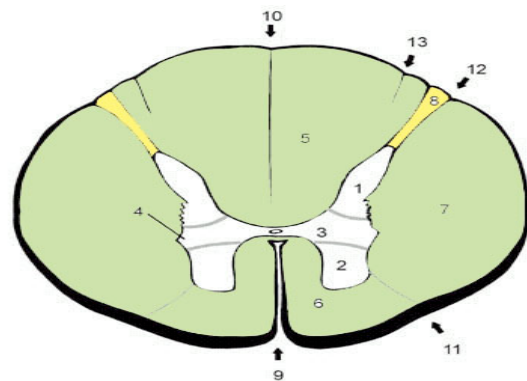
## LAMINA OF REXED



- Lamina I ----- *Posteromarginal Nucleus* (Pain pathway to Thalamus)
- Lamina II, III - *Substantia Gelatinosa of Rolando* (functions in regulating afferent input to the spinal Cord)
- Lamina IV ---- *Nucleus Proprius* (projects to the lateral cervical nucleus and the thalamus - *Spinothalamic*)
- Lamina V, VI - (from C8 to L3 is *Clarke's column*, within lamina 6 contains *Dorsal Spinocerebellar Tract*)
- Lamina VII --- Intermediate Gray
  - *Intermediolateral Cell Column (IML)* - (present in thoracic and sacral segments & contains neurons of origin of pre-ganglionic autonomic fibers)
  - Intermediomedial Cell Column (IMM)
- Lamina VIII- (highly related to lamina IX, and participates in movements of muscles in the head and neck)
- Lamina IX ----- *Anterior Horn (Motor) Cell* (Subdivided into flexor and extensors (flexors are dorsal) and also subdivided into distal and proximal (distal is more lateral).)
- Lamina X ----- *Gray Commissure* (surrounds central canal).

## FUNICULI OF SPINAL CORD

1. *Dorsal Horn*
2. *Ventral Horn*
3. *Intermediate Zone (Intermediate Gray)*
4. *Lateral Horn*
5. *Dorsal Funiculus*
6. *Ventral Funiculus*
7. *Lateral Funiculus*
8. *Lissauer's Tract*
9. *Ventral Median Fissure*
10. *Dorsal Median Fissure*
11. *Ventrolateral Sulcus*
12. *Dorsolateral Sulcus*
13. *Dorsal Intermediate Sulcus*



- **DORSAL FUNICULUS (5):** The Funiculus between the *Dorsolateral Sulci (12)* on either side, and the *Dorsal Median Fissure (10)* in the middle.
  - SEGMENTOTOPIC ORGANIZATION: The segmentotopic organization of the sensory dorsal columns is Sacral -----> Cervical as you go from Medial -----> Lateral.
- **LATERAL FUNICULUS (7):** The Funiculus between the *Dorsolateral Sulcus (12)* and *Ventrolateral Sulcus (11)*.

- **VENTRAL FUNICULUS (6)**: The Funiculus between the *Ventrolateral Sulci (11)* on either side, and the *Ventral Median Fissure (9)* in the middle.

**SENSORY (ASCENDING) TRACTS**: Sensory Tracts are **Three- Neuron Chains**.

- **Fasciculus Gracilis**: Median half of Dorsal Funiculus.
  - MODALITY: *Discriminative touch and proprioception*. The fasciculus gracilis consists of *large myelinated fibers*.
  - LESION: **Ipsilateral** loss of discriminative touch for all levels **below** (distal) to the lesion.
  - SEGMENTOTOPIC ORGANIZATION: Sacral is most medial and T7 is most lateral. As you continue laterally from there, you get into the Fasciculus Cuneatus.
- **Fasciculus Cuneatus**: Lateral half of Dorsal Funiculus
  - MODALITY: *Discriminative touch and proprioception*.
  - LESION: **Ipsilateral** loss of discriminative touch for all levels **below** (distal) to the lesion, down to level T7.
  - SEGMENTOTOPIC ORGANIZATION: T6 is the most medially placed in this tract, while Cervical levels are most lateral. Segmentotopically, the Fasciculus Cuneatus is simply an extension of the Gracilis above.

The two **Fasciculi (Gracilis et Cuneatus)** constitute the **Posterior Columns**, hence the name **Posterior Column System**.

#### Posterior Column-Medial Lemniscal Pathway

Modality: Discriminative Touch Sensation (include Vibration) and Conscious Proprioception (Position Sensation, Kinesthesia)

Receptor: Most receptors except free nerve endings

**1st Neuron**: Dorsal Root Ganglion (Spinal Ganglion)  
Dorsal Root - Posterior White Column.

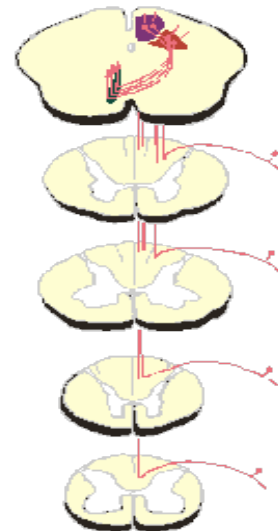
**2nd Neuron**: Dorsal Column Nuclei (Nucleus Gracilis et Cuneatus) in the **Medulla**.

The second order neurons cross to the opposite side in the Internal Arcuate Fibers → **Lemniscal Decussation** and ascend in a tract called Medial Lemniscus to **Thalamus**.

**3rd Neuron**: Synapse in a particular part of the thalamus called the Ventral Posterior Lateral nucleus (**VPLc**).

The third order neurons course through the **Internal Capsule** (posterior limb) → **Corona Radiata**

**Termination**: Synapse in the Somatosensory Cortex of the Parietal Lobe (**Primary Somatic Area - SI**).



- **Lateral Spinothalamic Tract**: Part of the **Anterolateral System**, located in both the *Lateral* and *Ventral Funiculi*.

#### Spinothalamic Tract

Modality: Pain & Temperature Sensation & Light Touch

The Lateral Spinothalamic Tract contains *small myelinated fibers*.

Receptor: Free Nerve Ending

**1st Neuron**: Dorsal Root Ganglion (Spinal Ganglion) and enter the Spinal Cord over Posterior Rootlets in the Dorsolateral Fasciculus (**Lissauer's Tract**).

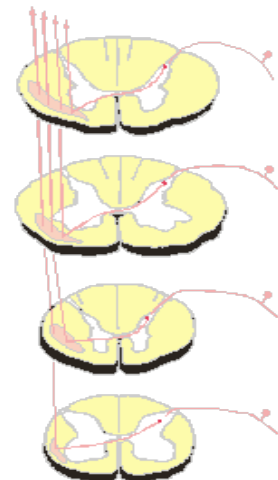
**2nd Neuron**: Dorsal Horn (Lamina I, IV, V)

The second order neurons angle upward and cross to the opposite side (**Decussation**) → **Anterior White Commissure** → and ascend in either the **Lateral Spinothalamic Tract** (carries Pain and Temperature) or **Anterior Spinothalamic Tract** (carries Light Touch and Pressure sensation).

**3rd Neuron**: Thalamus (VPLc, CL & POm) → Internal Capsule → Corona Radiata

**Termination**: Primary Somesthetic Area (S I) & Diffuse Widespread Cortical Region

- LESION: **Contralateral** loss of pain and temperature sensation **below** the level of lesion.
- SEGMENTOTOPIC ORGANIZATION: Sacral is most laterally placed and Cervical is most medially placed.





- **Note** that in the **posterior column system** the somatotopic organization in the cord is: leg is medial and arm is lateral. The opposite is true for the **anterolateral system**: the leg is lateral or dorsolateral and arm is medial.
- **Spinocerebellar Tracts**: Dorsal and Ventral Spinocerebellar Tracts located next to each other, on the lateral aspect of the cord, in the Lateral and Ventral Funiculi respectively.
  - PATH: Spinal Cord → Cerebellum.
  - MODALITY: *Unconscious Proprioception*.
  - LESION: **Ipsilateral** (&/or **Contralateral**) loss of coordination of balance.

**1a. Dorsal Spinocerebellar Tract** (fine coordination of posture and muscle movement): Collateral axons from groups Ia (from muscle spindles), Ib (from Golgi tendon organs), and II (from flower spray; Paciniform & Pacinian corpuscles) that originate in lower limbs enter spinal cord caudal to L3 and synapse in the **Dorsal Nucleus (Clarke)** at L3 level.

From L3 to C8 the Ia, Ib, and II axons synapse in the **Dorsal Nucleus (Clarke)** at the same level. The second order neurons exit from the dorsal nucleus and ascend in the **Dorsal Spinocerebellar Tract**.

**1b.** Fibers that enter above C8 ascend in the **Fasciculus Cuneatus** (as a first order neuron) to the lower **Medulla** and synapse in **Accessory (Lateral) Cuneate Nucleus**. This system is called the **Cuneocerebellar Tract**.

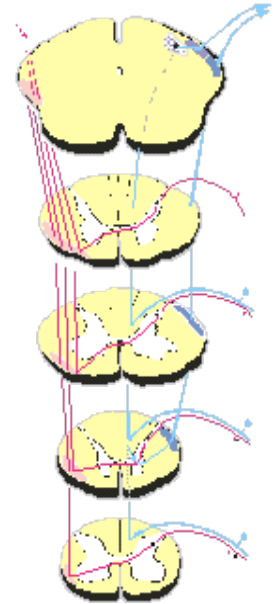
Both **Dorsal** and **Cuneocerebellar Spinocerebellar Tracts** enter the cerebellum via **Inferior Cerebellar Peduncle**.

**2. Ventral Spinocerebellar Tract** (coordination of gross muscles and joints movement): Differs from the **Dorsal Spinocerebellar Tract** in that it is **crossed**. Second order neurons of the dorsal horn cross to the opposite side of the spinal cord via the **anterior white commissure** → **Ventral Spinocerebellar Tract** → passes through **Medulla** to enter the **Cerebellum** via the **Superior Cerebellar Peduncle**.

**3. Rostral Spinocerebellar Tract**: equivalent to the Ventral Spinocerebellar Tract but differs from it in that it is **uncrossed** and enters both **Inferior** and **Superior Cerebellar Peduncles**.

**4. Spino-Olivary Tract**: Ascends from all level of the spinal cord and terminates in the accessory olive in the **Medulla**, then → **Cerebellum**.

- Lateral Cervical System (**Spinocervical Thalamic**): This ascending tract system transmits all modalities from Spinal Cord to Thalamus. Second order neurons from the dorsal horns ascend and synapse in a nucleus just lateral to the dorsal horn of the first and second cervical segments of the cord. Third order neurons ascend and cross to the opposite side and join the **Medial Lemniscus** on its way to the **Thalamus**.



## DESCENDING (MOTOR) TRACTS in SPINAL CORD: Motor Tracts are **Two-Neuron Chains**.

- **Lateral Corticospinal Tract**: The main voluntary (i.e. skeletal) motor tract, containing 90% of motor fibers.
  - MODALITY: *Voluntary skeletal motor activity*.
  - SEGMENTOTOPIC ORGANIZATION: Sacral is most lateral and cervical is most medial.

### Corticospinal Tract

**Origin**: Cerebral Cortex

Brodmann Area 4 (Primary Motor Area, MI)  
 Brodmann Area 6 (Pre-Motor Area, PM)  
 Brodmann Area 3,1,2 (Primary Somatic Area, SI)  
 Brodmann Area 5 (Ant. Portion of Sup. Parietal Lobe)  
 Corona Radiata

Internal Capsule, Posterior Limb

Crus Cerebri, Middle Portion

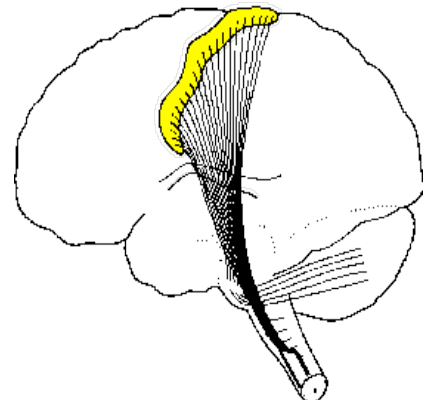
Longitudinal Pontine Fiber

Pyramid - pyramidal decussation

Corticospinal Tract - Lateral and Anterior

**Termination**: Spinal Gray (Rexed IV-IX)

**Lesion**: Ipsilateral UMN syndrome at the level of lesion.



- **Anterior Corticospinal Tract:** Contains the 10% of motor fibers that did not cross in the Pyramidal Decussation. Thus it is controlled by the ***Ipsilateral Motor Cortex*** throughout its path.

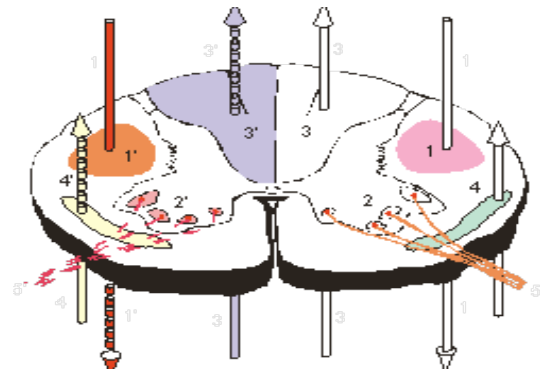
**PYRAMIDAL MOTOR SYSTEM:** The Lateral Corticospinal Tract, Anterior Corticospinal Tract, and Corticobulbar Tract. All other motor systems are called **extrapyramidal**. Within the pyramidal system:

- **UPPER MOTOR-NEURON LESIONS:** You lose control over the lower (alpha-Motor) neurons, but they can still fire spontaneously by themselves. Thus you get the classic triad of symptoms:
  - **Spastic Paralysis:** Rigid paralysis. No muscle wasting.
  - **Hyperreflexia:** For patellar reflex.
  - **Positive Babinski Sign:** Dorsiflexion and flaring of toes when you stroke the sole of the foot.
- **LOWER (alpha-MOTOR) NEURON LESION:** This is a peripheral lesion. **Wallerian Degeneration** of the nerve will occur leading to denervation of muscles.
  - **SYMPTOMS:**
    - Flaccid paralysis
    - Hyporeflexia
    - Weakness & Muscle Wasting
  - *You can only lose lower motor innervation for one myotome at a time.* If you cut the spinal cord, lower motor innervation will be lost at that level (**Ipsilateral Lower-Motoneuron loss**), and upper motor innervation will be lost at all levels distal to that level (**Contralateral Upper-Motoneuron loss**).

**BROWN-SEQUARD SYNDROME:** (Spinal Cord Hemisection)

**Major Symptoms:**

1. **Ipsilateral UMN** syndrome below the level of lesion (Corticospinal tract lesion)
2. **Ipsilateral LMN** syndrome at the level of lesion (Ventral Horn lesion)
3. **Ipsilateral** loss of discriminative touch sensation and conscious proprioception below the level of lesion (Dorsal white column lesion)
4. **Contralateral** loss of pain and temperature sensation below the level of lesion (Spinothalamic tract lesion)



**Example:** Oblique hemisection of spinal cord at C8:

LOST STRUCTURE	SYMPTOM	NOTES
Dorsal Columns (3)	Ipsilateral loss of proprioception and vibratory sense below C8	Only gracilis is affected at this level, and not cuneatus.
Anterolateral System, containing Lateral Spinothalamic Tract (4)	Contralateral loss of pain and temperature <b>below T1</b>	Fibers ascend one level before crossing through Anterior Commissure. <i>In case of partial lesion, remember segmentotopic org.: Sacral = lateral &amp; Cervical = medial</i>
C8 Dorsal Root	Complete loss of sensation over C8 dermatome: Ulnar hand and wrist	SEGMENTAL MARKER
C8 Ventral Horn (2)	<b>Ipsilateral Lower-Motoneuron</b> loss over C8 myotome	Flaccid paralysis, hyporeflexia, weakness and wasting. SEGMENTAL MARKER
Lateral Corticospinal Tract (1)	<b>Contralateral Upper-Motoneuron</b> loss, below level C8	Spastic Paralysis, hyperreflexia, Positive Babinski. <i>In case of partial lesion: Sacral = lateral &amp; Cervical = medial</i>