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 \(\rightarrow\) to Internal Vertebral Venous Plexus
    - to external vertebral venous plexus \(\rightarrow\) 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 \(\ldots\) Motor
- Dorsal Horn \(\ldots\) Sensory
- Lateral Horn \(\ldots\) Autonomic (Sympathetic)
- Gray Commissure \(\ldots\) Anterior and posterior

**PRINCIPLES OF CORD ORGANIZATION**

- Columnar arrangement
- Somatotopical arrangement

- Longitudinal Arrangement
  - Fibers (White Matter) \(\ldots\) White Column
  - Cell Groups (gray Matter) \(\ldots\) 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) and enter the Spinal Cord over Posterior Rootlets in the Dorsolateral Fasciculus (Lissauer’s Tract).
- **2nd Neuron**: Dorsal Horn (Lamina I, IV, V)
- **3rd Neuron**: Synapse in a particular part of the thalamus called the Ventral Posterior Lateral nucleus (VPLc).

**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
- **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)
- **3rd Neuron**: Thalamus (VPLc, CL & POm) and Internal Capsule

**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 (and/or Contralateral) loss of coordination of balance.

1a. **Dorsal Spinocerebellar Tract** (fine coordination of posture and muscle movement): Collaterals 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 (Spinthalamic tract lesion)

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

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