At the end of this lecture, the students should be able to:

- Describe the external anatomy of the spinal cord.
- Describe the internal anatomy of the spinal cord.
- Describe the spinal nerves: formation, branches and distribution via plexuses.
- Define ‘Dermatome’ and describe its significance.
- Describe the meninges of the spinal cord.
### Spinal Cord

- **An Elongated, almost Cylindrical structure**, about the thickness of the little finger.
- It is suspended in the vertebral canal & surrounded by the meninges and cerebrospinal fluid (CSF).
- In adults, its **Length** is approximately 45 cm
- Extends from foramen magnum to L1-L2
  - (In children it extends to L3)
- Continuous above with the medulla oblongata.
- The tapered inferior end forms **conus medullaris**, which is connected to the coccyx by a non-neuronal cord called **filum terminale**.
- Gives rise to 31 pairs of spinal nerves

### Spinal Meninges

- Three connective tissue membranes surround spinal cord and brain
  - **Dura mater**: tough outer layer, continuous with epineurium of the spinal nerves
  - **Arachnoid mater**: thin membrane deeper to dura mater
  - **Pia mater**: delicate membrane bound tightly to surface of brain and spinal cord and carries blood vessels.
  - Forms the **filum terminale**, which anchors spinal cord to coccyx and the denticulate ligaments that attach the spinal cord to the dura mater
- **Spaces**
  - **Epidural**: Contains blood vessels, areolar connective tissue and fat.
  - **Subdural**: a potential cavity between the dura and arachnoid mater, contains a small volume of serous fluid.
  - **Subarachnoid**: Contains cerebrospinal fluid (CSF) and blood vessels

### Terms:

- **Conus medullaris**: The most distal bulbous part of the spinal cord.
- **Filum terminale "Termenal thread"**: is a delicate strand of fibrous tissue, about 20 cm in length, proceeding downward from the apex of the conus medullaris

### Notes:

- In children it extends to L3 so, we cannot give children spinal Anastasia to prevent spinal cord injury.

### Terms:

- **Epineurium**: is the outermost layer of dense irregular connective tissue surrounding a peripheral nerve. "Extension from the Dura mater"
- **Denticulate ligaments**: The Pia mater of the spinal cord form a pair of denticulate ligaments (one on each side of the spinal cord). "To fix the spinal cord in position"
- **Epidural**: The space between the bone and Dura mater.

### Notes:

- Anastasia during delivery in "Epidural space"
- Spinal Anastasia in "Subarachnoid space"
- Two structures are responsible for fixation of the spinal cord in its position: **Filum terminale & denticulate ligaments.**
• The spinal cord is a **Segmented** structure, has
  • **Cervical**
  • **Thoracic**
  • **Lumbar**
  • **Sacral** segments
• Not uniform in diameter,
• Has **two enlargements**:  
  • **Cervical enlargement**: supplies upper limbs  
  • **Lumbosacral enlargement**: supplies lower limbs
• The bundle of spinal nerves extending inferiorly from lumbosacral enlargement and conus medullaris surround the filum terminale and form **cauda equina** (because of its resemblance to a horse’s tail)

Terms:
• **Cauda equina**: (Latin for “horse’s tail”) is a bundle of spinal nerves and spinal nerve roots all of which arise from dorsal root of lumbar, sacral and coccygeal spinal nerves.

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**Cross Section of Spinal Cord**

The spinal cord is:
• Incompletely divided into two equal parts,
  • **anteriorly** by a short, shallow **median fissure** and
  • **posteriorly** by a deep narrow septum, the **posterior median septum**.
• Composed of **grey matter** in the centre surrounded by **white matter**

The arrangement of grey matter resembles the shape of the letter **H**, having two **posterior**, two **anterior** and two **lateral** horns/columns
Central canal

- A cerebrospinal-filled space that runs longitudinally through the entire length of the spinal cord.
- Lined by ependyma (ciliated columnar epithelium)
- Continuous with the ventricular system of the brain
- Superiorly opens into the 4th ventricle
- Inferiorly in the conus medullaris, it expands into the fusiform terminal ventricle and terminates below at the root of filum terminale

Terms:

- **Ependyma**: is the thin epithelial lining of the ventricular system of the brain and the central canal of the spinal cord, made up of ependymal cells

Commissures of the Spinal Cord

**Grey commissure:**
- A transverse bridge of grey matter connecting the anterior and posterior gray horns on each side
- Is pierced by the central canal that divides it into anterior and posterior parts

**White Commissure:**
- Lies ventral to the gray commissure
- Mainly contains decussating nerve fibers
Grey matter

- Consists of nerve cell bodies and their processes, neuroglia, and blood vessels
- The nerve cells are multipolar and are of three main categories:
  1. **Sensory neurons** (Tract cells), which receive impulses from the periphery of the body and whose axons constitute the ascending fasciculi of the white matter, are located in the Dorsal horns.
  2. **Lower motor neurons**, which transmit impulses to the skeletal muscles, are located in the ventral horns (similar neurons in the lateral horn are the preganglionic neurons of the autonomic system)
  3. **Interneurons (connector neurons)**: linking sensory and motor neurons, at the same or different levels, which form spinal reflex arcs.

Neuronal Architecture of Spinal Grey Matter

- Cells of the same type are clustered into groups, which occur in long columns
- In transverse section, these columns appear as layers, especially within the dorsal horn
- These layers are called the Laminae of Rexed, that are numbered consecutively by Roman numerals, starting from the tip of the dorsal horn and moving ventrally into the ventral horn

Notes:

- 3 categories of nerve cells in the spinal cord:
  1. **In the Dorsal horn** > contains the axons of sensory neurons whole the cell bodies in the dorsal root ganglion.
  2. Two LMN
     - **In the ventral horn** > motor somatic. "muscles"
     - **In the lateral horn** > motor autonomic.
  3. **Interneurons** (connector neuron) > linking sensory & motor.

Notes:

- Called Rexed b/c it is identified in the early 1950s by Bror Rexed to label portions of the grey columns of the spinal cord.
Nerve Cell Groups in Dorsal Horn

4 main groups
1. Substantia gelatinosa
2. Nucleus proprius
3. Nucleus dorsalis
   (Clark’s column, nucleus thoracis)
4. Visceral afferent nucleus

Notes:
- All of these groups are **Sensory** in function.

<table>
<thead>
<tr>
<th>Nucleus</th>
<th>Lamina</th>
<th>Located in:</th>
<th>Composed of:</th>
<th>Extends:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Substantia Gelatinosa</td>
<td>II</td>
<td>at the apex of the posterior horn</td>
<td>large neurons</td>
<td>throughout the length of spinal cord</td>
</tr>
<tr>
<td>Nucleus Proprius</td>
<td>IV</td>
<td>anterior to substantia gelatinosa</td>
<td>large neurons</td>
<td>throughout the length of spinal cord</td>
</tr>
<tr>
<td>Nucleus Dorsalis</td>
<td>VII</td>
<td>at the base of dorsal horn</td>
<td>mostly of large neurons</td>
<td>from <strong>C8 to L3-4</strong> segments</td>
</tr>
<tr>
<td>Visceral Afferent Nucleus</td>
<td>VII</td>
<td>lateral to nucleus dorsalis</td>
<td>mostly of medium size neurons</td>
<td>from <strong>T1 to L3</strong> segments</td>
</tr>
</tbody>
</table>
**Nucleus Dorsalis (Clark’s column, Nucleus thoracis)**
- Rexed Lamina VII
- Located at the base of dorsal horn
- Composed mostly of large neurons
- Extends from C8 to L3-4 segments
- Associated with proprioceptive endings
- Afferents: dorsal root fibers concerned with information from muscle spindles and tendon organs.

**Visceral Afferent Nucleus**
- Rexed Lamina VII
- Located lateral to nucleus dorsalis
- Composed mostly of medium size neurons
- Extends from T1 to L3 segments
- Afferents: Visceral afferents

**Nerve Cell Groups in Ventral Horn**
The ventral horns contain:
1. **Motor neurons**, also called lower motor neurons.
2. **Interneurons**, the (Renshaw cells), whose branched axons form inhibitory synaptic junctions on motor neurons.

**Afferent action:**
- **Substantia Gelatinosa**
  - Dorsal root fibers concerned with pain, temperature and crude touch.
- **Nucleus Proprius**
  - Dorsal root fibers concerned with fine touch (senses of position & movement (proprioception) and two point discrimination & vibration)
- **Nucleus Dorsalis**
  - Dorsal root fibers concerned with information from muscle spindles and tendon organs.
- **Visceral Afferent Nucleus**
  - Visceral afferents.

**Notes:**
- Autonomic Afferents (Sensory) inter the CNS Through the "Visceral Afferent Nucleus" at the base of "Dorsal horn"
- Autonomic Efferent (Motor) exit the CNS through the "Lateral horn"
Types of Motor Neurons in Ventral Horn

Are of **Two types**
- **Large** multipolar cells
  - Numerous
  - Axons pass out in the ventral roots of spinal nerves as alpha efferents
  - Innervate extramuscular muscle fibers
- **Smaller** multipolar cells
  - Less numerous
  - Axons pass out in the ventral roots of spinal nerves as gamma efferents
  - Innervate intramuscular muscle fibers of neuromuscular spindles

Both alpha and gamma motor neurons are under the influence of descending pathways (upper motor neurons) from brain.

Notes:
- If the UMN is not working & LMN is working > Nothing will happen. B/c the main control is UMN from the brain.

Dr. Najeeb:
- UMN lesion > Spastic muscles & Hyper-reflexia.
- LMN lesion > paralysis muscles.

<table>
<thead>
<tr>
<th>Large cells</th>
<th>Small cells</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Numerous</strong></td>
<td><strong>Numerous</strong></td>
</tr>
<tr>
<td>Alpha efferents</td>
<td>Gamma efferents</td>
</tr>
<tr>
<td>Innervates &quot;Extramuscular muscle fibers&quot;</td>
<td>Innervate &quot;Intramuscular muscle fibers&quot;</td>
</tr>
</tbody>
</table>

Both in the "Ventral horn"
Both are under influence of "Descending pathways UMN"

Organization of Motor Neurons in Ventral Horn

- Motor neurons are organized in **3 groups**:
  - **Medial**: present in most segments
    - Innervate muscles of Neck and Trunk (including intercostal and abdominal muscles)
  - **Central**: smallest, present in some segments: cervical (phrenic C3-5, spinal accessory C1-6) and lumbosacral (L2-S1)
  - **Lateral**: present in cervical and lumbosacral segments
    - Innervates muscles of the Limbs

Neurons supplying flexor muscles are located dorsal to neurons for extensor muscles.

Motor neurons in ventral horn:
- **Medial** "in most segments"
  - *Neck&Trunk muscles.
  - *Intercostal&Abdominal muscles.
- **Central** "in some segments"
  - *C3-5 (Phrenic n.) supply "Diaphragm"
  - *C1-6 (spinal accessory) supply trapezius & sternomastoid muscles.
- **Lateral** "in cervical & Lumbosacral segments"
  - *L2-S1 supply muscles of abdomin & pelvic.
- **Cervical**
- **Lumbosacral**
- **Muscles of limbs**
Nerve Cell Groups in Lateral Horn

- Small column composed of small neurons extend from:
  - **T1 to L2-3** segments, give rise to preganglionic sympathetic fibers
  - **S2-4** segments, give rise to preganglionic parasympathetic fibers

White Matter

- Consists of mixture of nerve fibers, neuroglia and blood vessels. White color is due to high proportion of myelinated nerve fibers
- Arranged in columns/funiculi; **anterior, posterior and lateral**.
- The nerve fibers are arranged as bundles, running vertically through the cord. A group of nerve fibers (axons) that share a common origin, termination and function form a **tract or fasciculus**
- Tracts are often named according to their points of origin and destination, e.g. spinothalamic, corticospinal.

Depending on their function, the spinal tracts are divided into **ascending and descending tracts**
Regional Differences

- Although the general pattern of gray matter is the same throughout spinal cord, regional differences are apparent in transverse sections.
- The amount of white matter increases in a caudal-to-cranial direction because fibers are added to ascending tracts.
- The gray matter is increased in volume in cervical & lumbosacral enlargements for innervation of upper & lower limbs.
- The lateral horn is characteristics of thoracic and upper lumbar segments.

Spinal Nerves

- Thirty-one pairs of spinal nerves.
- First pair exit vertebral column between skull and atlas, last four pair exit via the sacral foramina and others exit through intervertebral foramina.
- Eight pair cervical, twelve pair thoracic, five pair lumbar, five pair sacral, one pair coccygeal.
- Each spinal nerve arises as rootlets which then combine to form dorsal (posterior) purely sensory & ventral (anterior) purely motor Roots.
- Two roots merge laterally and form the spinal nerve.
- Dorsal (posterior) root has a ganglion (dorsal root/sensory ganglion) that contains the cell bodies of the sensory neurons.
- Each spinal nerve then divides into a MIXED smaller dorsal and a larger ventral Ramus.

Notes:

- More White matter > in Cervical region.
- Less White matter > in Sacral region.
- More Gray matter > in cervical & Lumbosacral enlargements.
- Less Gray matter > in Thoracic region.
- More Lateral Horn > is characteristics of thoracic & upper lumbar regions.

Notes:

- We have 33 vertebra & 31 Spinal nerves.
- We have 7 cervical segments & 8 cervical nerves.
**Branches of Spinal Nerves**

- **Dorsal Rami** innervate:
  - Deep muscles of the trunk responsible for movements of the vertebral column
  - Skin near the midline of the back.

- **Ventral Rami**:
  - In the thoracic region form intercostal nerves that innervate the intercostal muscles and the skin over the thorax
  - Remaining ventral rami form five plexuses:
    - C1 - C4 = Cervical plexus
    - C5 - T1 = Brachial plexus
    - L1 - L4 = Lumbar plexus
    - L4 - S4 = Sacral plexus
    - S5 & Co = Coccygeal plexus

The spinal nerves are connected to the sympathetic chain of ganglia by communicating rami.

- **Deep muscles of the trunk.**
- **Responsible for movements of the vertebral column.**
- **Skin near the midline of the back.**

**Intercostal nerves** that innervate:
- Intercostal muscles.
- Skin over the thorax.

**Plexuses:**
- C1 - C4 = Cervical plexus
- C5 - T1 = Brachial plexus
- L1 - L4 = Lumbar plexus
- L4 - S4 = Sacral plexus
- S5 & Co = Coccygeal plexus
Dermatomes

- ‘Dermatome’ is a **segment** of skin supplied by a specific segment of the spinal cord (segmental spinal nerve).
- Cutaneous areas supplied by adjacent spinal nerves **overlap**. There is therefore little or no sensory loss after interruption of a single spinal nerve or dorsal root.

Notes:

- Dermatome: related to skin.
- Myotome: related to muscles.

Reflex & Reflex Arc

A reflex is a **rapid, involuntary, predictable** response brought by a **sensory stimulus**.

The neural pathway mediating the reflex actions is called **reflex arc**.
Components of a Reflex Arc

Action potentials produced in Sensory neuron → Sensory receptor → Sensory neuron
Interneuron → Motor neuron → Effector organ which responds with a reflex

Variety of Reflexes

- Some integrated within spinal cord; some within brain
- Some involve excitatory neurons yielding a response; some involve inhibitory neurons that prevent an action
- Higher brain centers can influence, suppress, or exaggerate reflex responses