ANATOMY OF SPINAL CORD

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OBJECTIVES

At the end of the lecture, 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.
✓ Define a reflex and reflex arc, and describe the components of the reflex arc.
The nervous system has 3 functions:

- **Collection of Sensory Input**
  - Identifies changes occurring inside and outside the body by using sensory receptors. These changes are called stimuli

- **Integration**
  - Processes, analyses & interprets these changes and makes decisions

- **Motor Output**
  - It then effects a response by activating muscles or glands (effectors) via motor output
ORGANIZATION

STRUCTURAL

○ Central Nervous System (CNS)
  ▪ Brain & Spinal Cord

○ Peripheral Nervous System (PNS)
  ▪ Nerves & Ganglia
    • Cranial nerves
    • Spinal nerves
FUNCTIONAL

- Sensory Division (Afferent)
- Motor Division (Efferent)
  - Autonomic
  - Somatic

CNS = Central nervous system
PNS = Peripheral nervous system
ANS = Autonomic nervous system
SNS = Somatic nervous system
**Ganglion**
A group of neurons outside the CNS

**Nerve**
A group of nerve fibers (axons) outside the CNS

**Nucleus**
A group of neurons within the CNS

**Tract**
A group of nerve fibers (axons) within the CNS
The main pathway for information connecting the brain and peripheral nervous system.

- It is elongated, cylindrical, suspended in the vertebral canal and protected by vertebrae.
- Surrounded by the meninges and cerebrospinal fluid (CSF).
- The primary function of spinal cord is a transmission of neural signals between the brain and the rest of the body.
  - Sensory
  - Motor
  - Local reflexes
SPINAL CORD

- Extends from foramen magnum to second lumbar vertebra.
- Continuous above with the medulla oblongata.
- The tapered inferior end forms conus medullaris.
- It is connected to the coccyx by a non-neuronal cord called Filum Terminale.
SPINAL CORD

- Gives rise to 31 pairs of spinal nerves
- The bundle of spinal nerves extending inferiorly from **lumbosacral enlargement** and **conus medullaris** surround the **filum terminale** and form **cauda equina**
- Segmented
  - 8 Cervical
  - 12 Thoracic
  - 5 Lumbar
  - 5 Sacral
  - 1 Coccygeal
- Has two enlargements:
  - Cervical Enlargement: supplies upper limbs.
  - Lumbosacral Enlargement: supplies lower limbs.
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 sulcus.

- Composed of grey matter in the center surrounded by white matter supported by neuroglia.

- Commissures: connections between left and right halves
  - Gray with central canal in the center
  - White

- Roots: spinal nerves arise as rootlets then combine to form roots
  - Dorsal (posterior) root has a ganglion
  - Ventral (anterior)
  - Two roots merge laterally and form the spinal nerve
The arrangement of grey matter in the spinal cord resembles the shape of the letter H.

Having:
- two posterior
- two anterior
- two lateral horns/columns.

Consists of:
- nerve cell bodies and their processes
- neuroglia
- blood vessels
The nerve cells are multipolar, and are of **THREE** main categories:

- **Sensory neurons (Tract cells)**
  - receive impulses from the periphery of the body and whose axons constitute the ascending fasciculi of the white matter.
  - located in the dorsal horns.

- **Lower motor neurons**
  - transmit impulses to the skeletal muscles.
  - located in the ventral horns
    - similar neurons in the lateral horn are the preganglionic neurons of the autonomic system.

- **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 by **Roman numerals**, starting from the tip of the dorsal horn and moving ventrally into the ventral horn.
- The Rexed laminae comprise a system of ten layers of grey matter (I-X), identified in the early 1950s by Swedish neuroscientist.
NERVE CELL GROUPS IN DORSAL HORN

Four main groups

1. Substantia Gelatinosa
2. Nucleus Proprius
3. Nucleus Dorsalis
   - Clark’s column
   - Nucleus thoracis
4. Visceral Afferent Nucleus
Substantia Gelatinosa

- Rexed Laminae II
- Located at the apex of the horn
- Composed of large neurons
- Extends throughout the length of spinal cord
- **Afferents**: dorsal root fibers concerned with pain, temperature and touch

Nucleus Proprius

- Rexed Lamina IV
- Located anterior to substantia gelatinosa
- Composed of large neurons
- Extends throughout the length of spinal cord
- **Afferents**: dorsal root fibers concerned with senses of position & movement (proprioception)
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

- Motor neurons, also called lower motor neurons.
- A special type of interneurons, the Renshaw cells, whose branched axons form inhibitory synaptic junctions on motor neurons.
MOTOR NEURONS IN VENTRAL HORN

- Are of Two types
  - Large multipolar cells
    - whose axons pass out in the ventral roots of spinal nerves as alpha efferents which innervate extrafusal muscle fibers of skeletal muscles.
  - Less numerous smaller multipolar cells
    - whose axons pass out in the ventral roots of spinal nerves as gamma efferents which innervate intrafusal muscle fibers of neuromuscular spindles.

Both alpha and gamma motor neurons are under the influence of descending pathways from brain.
Motor neurons are organized in 3 groups:

- **Medial:**
  - Present in **most segments**, innervates muscles of **neck and trunk** (including intercostal and abdominal muscles)

- **Central:**
  - Smallest, present in some **cervical** (phrenic C3-5, spinal accessory C1-6) and **lumbosacral** (L2-S1) segments

- **Lateral:**
  - Present in **cervical** and **lumbosacral** segments, innervates muscles of the limbs

Neurons supplying flexor muscles are located dorsal to neurons for extensor muscles
NERVE CELL GROUPS IN LATERAL HORN

- Small Column composed of small neurons
  - Extends from T1 to L2-3 segments:
    - Give rise to preganglionic sympathetic fibers
  - Extends from 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
- The white matter of the spinal cord is 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
- These tracts are formed by sensory nerve fibers ascending to the brain, motor nerve fibers descending from the brain and fibers of connector neurons.
- 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.
Dorsal columns:
1. Fasciculus gracilis
   (conscious muscle sense concerned with awareness of body position; crossed touch, pressure, vibration)
2. Fasciculus cuneatus
   (conscious muscle sense—important in control of muscle tone and posture)
Dorsal spinocerebellar (uncrossed; unconscious muscle sense)
   important in control of muscle tone and posture
Ventral spinocerebellar (crossed; unconscious muscle sense)
Lateral spinothalamic (crossed; pain and temperature)
Ventral spinothalamic (crossed; touch)

Lateral corticospinal (crossed; voluntary control of skeletal muscles)
Rubrospinal (crossed; involuntary control of skeletal muscle concerned with muscle tone and posture)
Ventral corticospinal (uncrossed; voluntary control of skeletal muscles)
Vestibulospinal (uncrossed; involuntary control of muscle tone to maintain balance and equilibrium)
COMMISSURES OF THE SPINAL CORD

- **Grey Commissure:**
  - 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
The 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
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 and fibers leave descending tracts.
- The gray matter is in increased 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 pairs 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) & ventral (anterior) 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 smaller dorsal and a larger ventral ramus
Branches of Spinal Nerves

- **Dorsal Ramus**: innervate deep muscles of the trunk responsible for movements of the vertebral column and skin near the midline of the back.

- **Ventral Ramus**: what they innervate depends upon which part of the spinal cord is considered.
  - **Thoracic region**: form intercostal nerves that innervate the intercostal muscles and the skin over the thorax
  - **Remaining spinal nerve ventral rami (roots of the plexus)**: form five plexuses (intermingling of nerves).

- Ventral rami of C1-C4 = cervical plexus
- Ventral rami of C5-T1 = brachial plexus
- Ventral rami of L1-L5 = lumbar plexus
- Ventral rami of L4-S4 = sacral plexus
- Ventral rami of S4 & S5 = coccygeal plexus

- **Communicating Rami**: communicate with sympathetic chain of ganglia.
DERMATOMES

- Dermatome is a segment of skin supplied by one spinal nerve.
- Cutaneous areas supplied by adjacent spinal nerves overlap.
- There is therefore little or sensory loss after interruption of a single spinal nerve or dorsal root.
SPINAL MENINGES

- Connective tissue membranes surrounding spinal cord and brain
  - Dura mater: continuous with epineurium of the spinal nerves
  - Arachnoid mater: thin and wispy
  - Pia mater: bound tightly to surface of brain and spinal cord.
    - 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, connective tissue and fat.
  - Subdural: Contains serous fluid
  - Subarachnoid: Contains CSF and blood vessels within web-like strands of arachnoid tissue
A reflex is a **rapid, involuntary, stereotyped pattern** of response brought by a **sensory stimulus**

A neural pathway mediating the reflex actions is called **reflex arc**.
COMPONENTS OF A REFLEX ARC

Action potentials produced in

Sensory receptor  →  Sensory neuron

Motor neuron  ←  Interneuron

Effector organ which responds with a reflex

Skin

Spinal cord

Dorsal root

Dorsal root ganglion

Sensory receptor

Motor neuron

Effector organ

Skeletal muscle
QUESTIONS!