Chapter 12

Spinal Cord & Spinal Pathways

Embryonic Development of the Spinal Cord
- Develops from caudal portion of neural tube
- By week 6, there are two clusters of neuroblasts:
  - Alar (dorsal) plate – will become interneurons
  - Basal (ventral) plate – will become motor neurons
- Neural crest cells form the dorsal root ganglia (DRG) – sensory neurons that conduct impulses along afferent pathways to the CNS for interpretation.

Spinal Cord: Gross Anatomy
- Enclosed within the vertebral column
- Extends from the foramen magnum to L₁ or L₂
- Provides two-way communication to and from the brain
- Protected by bone, meninges, and CSF
- Epidural space – space between the vertebrae and the dural sheath (dura mater) filled with fat and a network of veins
**Spinal Cord**
- *Conus medullaris* – terminal portion of the spinal cord
- *Filum terminale* – fibrous extension of the pia mater; anchors the spinal cord to the coccyx
- *Denticulate ligaments* – delicate shelves of pia mater; attach the spinal cord to the vertebrae

**Spinal Cord**
- Spinal nerves – 31 pairs attach to the cord by paired roots
- Cervical and lumbar enlargements – sites where nerves serving the upper and lower limbs emerge
- *Cauda equina* – collection of nerve roots at the inferior end of the vertebral canal

**Gray Matter and Spinal Roots**
- Gray matter consists of soma, unmyelinated processes, and neuroglia
- *Gray commissure* – connects masses of gray matter; encloses central canal
- *Posterior (dorsal) horns* – interneurons
- *Anterior (ventral) horns* – interneurons and somatic motor neurons
- *Lateral horns* – contain sympathetic nerve fibers

**Cross-Sectional Anatomy of the Spinal Cord**
- *Anterior median fissure* – separates anterior funiculi
- *Posterior median sulcus* – divides posterior funiculi
**Gray Matter: Organization**

- Dorsal half – sensory roots and ganglia
- Ventral half – motor roots
- Dorsal and ventral roots fuse laterally to form spinal nerves
- Four zones are evident within the gray matter – somatic sensory (SS), visceral sensory (VS), visceral motor (VM), and somatic motor (SM)

**White Matter in the Spinal Cord**

- Fibers run in three directions – ascending, descending, and transversely
- Divided into three funiculi (columns) – posterior, lateral, and anterior
- Each funiculus contains several fiber tracts
  - Fiber tract names reveal their origin and destination
  - Fiber tracts are composed of axons with similar functions

**White Matter: Pathway Generalizations**

- Pathways decussate
- Most consist of two or three neurons
- Most exhibit somatotopy (precise spatial relationships)
- Pathways are paired (one on each side of the spinal cord or brain)

**Neuronal Composition: 1st Order Neurons**

- First-order neurons
  - Sensory neurons
  - Cell bodies reside in a dorsal root ganglion
  - Cell bodies reside in a cranial nerve ganglion
  - Conduct sensory input such as touch and proprioception to the CNS (spinal cord or brain stem)
Neuronal Composition: 2nd Order Neurons
- Second-order neurons
  - Interneurons (association neuron)
  - Cell bodies reside in the dorsal horn of the spinal cord
  - Cell bodies reside in medullary nuclei
  - Delivers info to the thalamus or cerebellum

Neuronal Composition: 3rd Order Neurons
- Third-order neurons
  - Interneurons
  - Cell bodies reside in the thalamus
  - Conducts impulses to somatosensory cortex of cerebrum.
  - Conducts sensory impulses, usually through chains of three successive neurons (1-2-3)

Three Ascending (Sensory) Pathways
- Somatosensory Pathways
- Nonspecific & Specific ascending pathways
  - Send impulses to the sensory cortex
  - These pathways are responsible for discriminative touch and conscious proprioception
- The spinocerebellar tracts
  - Send impulses to the cerebellum and do not contribute to sensory perception

Nonspecific Ascending Pathways
- Anterolateral pathways
  - Lateral spinothalamic tract
  - Transmits impulses for pain, temperature, crude touch, and pressure

Specific Ascending Pathways
- Posterior Column-Medial lemniscal pathway
  - Medial lemniscal system (MLS)
  - Posterior Column
  - Carry sensory info for fine touch, vibrations, and proprioception
    - fasciculus cuneatus tracts – upper limbs, upper trunks and neck
    - fasciculus gracilis – lower limbs and inferior body trunk
  - Medial lemniscal tracts

Spinocerebellar pathways
- Anterior spinocerebellar
- Posterior spinocerebellar
- Conveys info from trunk and lower limbs’ muscles, joints, tendon stretch to cerebellum in order to form coordinated skeletal muscle activity
**Descending (Motor) Pathways**

- Descending tracts deliver efferent impulses from the brain to the spinal cord, and are divided into two groups
  - Direct pathways equivalent to the pyramidal tracts
  - Indirect pathways, essentially all others
- Motor pathways involve two neurons (upper and lower)

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**Somatic Motor Pathways**

- Upper motor neurons
  - Cell bodies in the cerebral cortex
- Lower motor neuron
  - Cell body located in a motor nucleus of the brainstem or spinal cord

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**The Direct (Pyramidal) System**

- Direct pathways originate with the pyramidal neurons in the precentral gyri
- Impulses are sent through the corticospinal tracts and synapse in the anterior horn
- Stimulation of anterior horn neurons activates skeletal muscles
- Parts of the direct pathway, called corticobulbar tracts, innervate cranial nerve nuclei
- The direct pathway regulates fast and fine (skilled) movements

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**Indirect (Extrapyramidal) System**

- Includes the brain stem, motor nuclei, and all motor pathways not part of the pyramidal system
- Issue motor commands as a result of subconscious processing
- Stimulate, facilitate, or inhibit LMN
- This system includes the rubrospinal, vestibulospinal, reticulospinal, and tectospinal tracts

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**Indirect (Extrapyramidal) System**

- These motor pathways are complex and multisynaptic, and regulate:
  - Axial muscles that maintain balance and posture
  - Muscles controlling coarse movements of the proximal portions of limbs
  - Head, neck, and eye movement
**Indirect (Extrapyramidal) System**
- Rubrospinal tracts
  - Controls muscle tone and movements of distal muscles of the upper limbs.
- Vestibulospinal tracts
  - Carry subconscious regulation of balance and posture
- Reticulospinal tract
  - Carries subconscious regulation of reflex activity
- Tectospinal tracts
  - Carries subconscious regulation of visual and auditory reflex stimulus

**Extrapyramidal (Multineuronal) Pathways**
- Reticulospinal tracts – maintain balance
- Rubrospinal tracts – control flexor muscles
- Superior colliculi and tectospinal tracts mediate head movements

**Spinal Cord Trauma: Paralysis**
- Paralysis – loss of motor function
  - Flaccid paralysis – severe damage to the ventral root or anterior horn cells
    - Lower motor neurons are damaged and impulses do not reach muscles
    - There is no voluntary or involuntary control of muscles

**Spinal Cord Trauma: Paralysis**
- Spastic paralysis – only upper motor neurons of the primary motor cortex are damaged
  - Spinal neurons remain intact and muscles are stimulated irregularly
  - There is no voluntary control of muscles

**Spinal Cord Trauma: Transection**
- Cross sectioning of the spinal cord at any level results in total motor and sensory loss in regions inferior to the cut
  - Paraplegia – transection between T₁ and L₁
  - Quadriplegia – transection in the cervical region
**Poliomyelitis**
- Destruction of the anterior horn motor neurons by the poliovirus
- Early symptoms – fever, headache, muscle pain and weakness, and loss of somatic reflexes
- Vaccines are available and can prevent infection

**Amyotrophic Lateral Sclerosis (ALS)**
- Lou Gehrig’s disease – neuromuscular condition involving destruction of anterior horn motor neurons and fibers of the pyramidal tract
- Symptoms – loss of the ability to speak, swallow, and breathe
- Death occurs within five years
- Linked to malfunctioning genes for glutamate transporter and/or superoxide dismutase