The Spinal Cord and Spinal Nerves
Chapter 13

General Organization of The Nervous System

- In the CNS
  - A collection of neuron cell bodies with a common function is a center
  - A center with a discrete boundary is termed a nucleus
  - The neural cortex is a thick layer of gray matter covering the surface of the brain
  - Bundles of axons in the CNS are termed tracts
  - Tracts in the spinal cord form columns
  - Pathways link the brain with the rest of the body; e.g., sensory pathways and motor pathways

Gross Anatomy of the Spinal Cord

- The adult spinal cord is approximately 45cm in length and has a maximum width of about 14mm
- The adult spinal cord ends between vertebrae L, and L2
- Localized enlargements are apparent where additional gray matter provides innervation to the limbs
- The cervical enlargement innervates the shoulder girdles and upper limbs, the lumbar enlargement innervates the pelvis and lower limbs

General Organization of The Nervous System

- CNS consists of brain and spinal cord
- PNS is all other neural tissue
- In the PNS
  - Neuron cell bodies are located in ganglia
  - Axons are bundled in nerves, with spinal nerves connected to the spinal cord and cranial nerves connected to the brain

Gross Anatomy of the Spinal Cord

- Below the lumbar enlargement the spinal cord becomes tapered and conical in a region termed the conus medullaris
- The filum terminale is a slender strand of fibrous tissue that extends from the tip of the conus medullaris along the vertebral canal to the second coccygeal vertebra and provides longitudinal support to the spinal cord as part of the coccygeal ligament
Gross Anatomy of the Spinal Cord

- The spinal cord can be divided into 31 segments based on the origins of the spinal nerves.
- Each of these segments is associated with a pair of dorsal root ganglia containing the cell bodies of sensory neurons.
- The axons of these neurons form the dorsal roots, which bring sensory information into the spinal cord.
- The paired ventral roots contain the axons of motor neurons that control somatic and visceral effectors.
- (Show figure, then read slides)

Spinal Nerve Nomenclature

- Each spinal nerve inferior to the first thoracic vertebra takes its name from the vertebra immediately superior to it. Thus, spinal nerve T₁ emerges immediately inferior to vertebra T₁, spinal nerve T₂ emerges below vertebra T₂, and so forth. (continued on next slide)

Spinal Nerve Nomenclature

- The arrangement differs in the cervical region, because the first pair of spinal nerves, C₁, passes between the skull and the first cervical vertebra. For this reason, each cervical nerve takes its name from the vertebra immediately inferior to it. So, nerve C₂ precedes vertebra C₂, and so on. The transition in numbering occurs between the last cervical vertebra and first thoracic vertebra. The spinal nerve at this location is designated C₈. Therefore, while there are seven cervical vertebra, there are eight cervical nerves.

Sectional anatomy of the spinal cord

- White matter contains myelinated and unmyelinated axons.
- Gray matter contains cell bodies, unmyelinated axons and neuroglia.
- Projections of gray matter toward the outer surface of the cord are called horns.
Spinal Meninges

- The spinal meninges are a series of specialized membranes that provide physical stability and shock absorption for the spinal cord.
- The spinal meninges consist of three layers:
  - Dura mater
  - Arachnoid
  - Pia mater

Dura Mater

- The dura mater forms the outermost covering of the spinal cord.
- It consists of dense collagen fibers oriented along the longitudinal axis of the spinal cord.
- Cranially, it becomes continuous with the cranial dura mater; inferiorly it tapers and blends with the filum terminale to form the coccygeal ligament.
- Between the dura mater and the vertebral canal is the epidural space, containing blood vessels and a protective padding of adipose tissue.
- Anesthetics injected into the epidural space affect only the spinal nerves in the area of the injection.
- This is known as an epidural block.

Arachnoid

- In most anatomical and histological preparations the subdural space separates the dura mater and pia mater.
- In life, the middle meningeal layer, the arachnoid, fills the subdural space.
- The arachnoid trabeculae are a delicate network of collagen and elastic fibers extending between the outer arachnoid membrane and the pia mater.
- This region, the subarachnoid space, is filled with cerebrospinal fluid (CSF), which acts as a shock absorber and medium for the diffusion of dissolved gases, nutrients, and waste products.
- The subarachnoid space is penetrated in the inferior lumbar region by a spinal tap, conducted for the diagnostic withdrawal of cerebrospinal fluid.
**Pia Mater**

- The pia mater is the innermost meningeal layer and consists of a network of elastic and collagen fibers firmly bound to the underlying neural tissue.
- Blood vessels serving the spinal cord run along the surface of the pia mater in the subarachnoid space.
- Denticulate ligaments extend from the pia mater to the dura mater and prevent lateral movement of the spinal cord.

**Sectional anatomy of the spinal cord**

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**Horns of spinal cord**

- The posterior gray horns contain somatic and visceral sensory nuclei.
- The anterior gray horns deal with somatic motor control.
- Lateral gray horns contain visceral motor neurons.
- Gray commissures contain axons that cross from one side to the other.

**White matter of the Spinal Cord**

- The white matter of the spinal cord is divided into six columns (funiculi) containing tracts.
- Ascending tracts relay information from the spinal cord to the brain.
- Descending tracts carry information from the brain to the spinal cord.
- More details in Chapters 15 and 16.
Spinal Nerves

- Each of the 31 segments of the spinal cord is attached to a pair of spinal nerves.
- Each spinal nerve is protected by a series of connective tissue layers that is continuous with the meninges of the spinal cord and extends along the peripheral branches of the spinal nerve.
- The three connective tissue layers are (outside-in); the epineurium, the perineurium, and the endoneurium.

Peripheral distribution of spinal nerves

- The spinal nerve forms just lateral to the intervertebral foramen, where the dorsal and ventral roots unite.
- See Figure.
- The first branch from the spinal nerve carries visceral motor fibers to a sympathetic ganglion.
- These preganglionic axons are myelinated and give this branch a light color, as a result it is called the white ramus.

Peripheral distribution of spinal nerves

- The postganglionic nerve fibers that innervate glands and smooth muscle in the body wall or limbs return from the ganglion to rejoin the spinal nerve.
- These fibers are unmyelinated and have a darker color, giving rise to the name gray ramus.

Peripheral distribution of spinal nerves

- The dorsal ramus of each spinal nerve contains somatic motor and visceral motor fibers that innervate the skin and muscles of the back.
- The ventral ramus innervates the ventrolateral body surface, the body wall, and limbs.
- The specific region of the skin monitored by a single pair of spinal nerves is known as a dermatome.
- Dermatomes are clinically important, because damage to a spinal nerve will produce a characteristic loss of sensation in the skin.
Nerve Plexuses

- Nerve plexuses are complex interwoven networks of nerves
- The ventral rami form four major plexuses
  - The cervical plexus
  - The brachial plexus
  - The lumbar plexus
  - The sacral plexus
- These plexuses contain both sensory and motor fibers

The Cervical Plexus

- The cervical plexus arises from the fusion of the ventral rami of spinal nerves C₁-C₅
- It innervates the muscles of the neck and controls the diaphragmatic muscles
- The major nerve of this plexus, the phrenic nerve, innervates the diaphragm
The Brachial Plexus

- The brachial plexus arises from the fusion of the ventral rami of spinal nerves C5 – T1
- It innervates the pectoral girdle and upper limbs
- Major nerves are shown in the following table

<table>
<thead>
<tr>
<th>Lumbar and Sacral Plexuses</th>
</tr>
</thead>
<tbody>
<tr>
<td>The lumbar and sacral plexuses arise from the lumbar and sacral segments of the spinal cord and innervate the pelvic girdle and lower limbs</td>
</tr>
<tr>
<td>See table for a listing of nerves</td>
</tr>
</tbody>
</table>
Principles of Functional Organization

- The 20 billion interneurons in the CNS are organized into neuronal pools – functional groups of interconnected neurons
- The pattern of interaction among neurons provides information about the function of a neuronal pool
- The five patterns of interaction are:
  - Divergence
  - Convergence
  - Serial processing
  - Parallel processing
  - Reverberation

An introduction to reflexes

- Reflexes are rapid, automatic responses to specific stimuli
- They preserve homeostasis by making rapid adjustments in the function of organs or organ systems
- Neural reflexes, are reflexes in which sensory fibers carry information to the CNS and motor fibers carry commands to effectors

The Reflex Arc

- The nerve pathways of a single reflex are termed a reflex arc
- There are five steps in a neural reflex
  - Arrival of stimulus and activation of receptor
  - Activation of sensory neuron
  - Information processing
  - Activation of motor neuron
  - Response by effector
Classification of Reflexes

- Reflexes are classified on the basis of development (innate or acquired), the site of information processing (spinal or cranial), the nature of the motor response (somatic or visceral), and by the complexity of the neural circuit (monosynaptic or polysynaptic).

- Monosynaptic reflex
  - Sensory neuron synapses directly on a motor neuron

- Polysynaptic reflex
  - At least one interneuron between sensory afferent and motor efferent
  - Longer delay between stimulus and response

Spinal Reflexes

- Spinal reflexes range from simple monosynaptic reflexes involving a single segment of the spinal cord to complex polysynaptic reflexes that involve many segments
Monosynaptic reflexes

- Monosynaptic reflexes are simple rapid stereotypical motor responses to specific stimuli.
- They are the most rapid of the reflex responses.
- The best known of the monosynaptic reflexes is the patellar reflex, a stretch reflex.
- A stretch reflex provides automatic regulation of skeletal muscle length and tone.

Stretch Reflexes

- In a stretch reflex increasing muscle length (the stimulus) activates a sensory neuron, which triggers contraction of the muscle to counteract the stimulus.
- The patellar, or knee-jerk reflex is an example of a stretch reflex.
- Most postural reflexes that help us maintain a normal upright position are stretch reflexes.

Polysynaptic Reflexes

- Polysynaptic reflexes can produce more complicated responses than do monosynaptic reflexes.
- This is the result of the involvement of multiple interneurons.
- These interneurons can produce either IPSPs or EPSPs in the CNS and thus inhibit some muscles and stimulate others.

The Tendon Reflex

- A tendon reflex monitors the external tension produced during a muscle contraction and prevent tearing and breaking of the tendon.
- When the receptors are stimulated, inhibitory interneurons in the spinal cord act on motor neurons controlling skeletal muscle, thus limiting the tension the muscle is capable of producing.
Withdrawal Reflexes

• Withdrawal reflexes are a family of reflexes that move the affected parts of the body away from a source of stimulation
• The strongest of these reflexes are responses to painful stimuli, but responses may also be initiated by stimulation of touch or pressure receptors

Withdrawal Reflexes

• The flexor reflex affects the muscles of a limb
• When you grab a hot frying pan it stimulates contraction of flexor muscles that yank your hand away from the pan
• If the stimulus is strong, interneurons will carry impulses up and down the spinal cord resulting in a coordinated movement away from the stimulus
• Stronger stimuli trigger more dramatic responses

Withdrawal Reflexes

• The stretch, tendon, and withdrawal reflexes are all ipsilateral reflexes, that is the stimulus and response are on the same side of the body
• The crossed extensor reflex is a contralateral reflex, because the motor response occurs on the opposite side from the stimulus
• The crossed extensor reflex compliments the flexor reflex, and the two occur simultaneously
• While a flexor reflex pulls the affected part away from the stimulus, the crossed extensor reflex extends the opposite parts to support the body

Polysynaptic reflexes

• All Polysynaptic reflexes share the same five basic characteristics
  – They involve pools of interneurons
  – They are intersegmental in distribution
  – They involve reciprocal inhibition
  – They have reverberating circuits to prolong the motor response
  – Several reflexes may cooperate to produce a coordinated response
Reflexes and Diagnostic Testing

• The evaluation of somatic reflexes can provide valuable information about the location of damage to the spinal cord or spinal nerves.
• By testing a series of spinal and cranial reflexes, the function of sensory pathways and motor centers throughout the brain and spinal cord can be tested.
• See table 13-4, not in your text.