

THE SPINAL CORD AND SPINAL NERVES

Chapter 13

Anatomy and Physiology Lecture

THE SPINAL CORD AND THE SPINAL NERVES

Spinal Cord and Spinal Nerves form a neuronal circuits that mediate some of your quickest reactions to environment changes.

(For example, if you pick up something hot, the grasping muscle may reflex and you may drop it even before the sensation of extreme heat or pain reaches your conscious perception.)

-A Spinal Cord Reflex - a quick, automatic response to certain kinds of stimuli that needs only neuron (nerve cells) in the spinal nerves and spinal cord.

Overall Functions of the Spinal Cord:

- (i) The site for integration (summing) of nerve impulses that arise locally or arrive from the periphery and brain;
- (ii) The highway traveled by sensory nerve impulses headed for the brain and motor nerve impulses destined for spinal nerves.
- (iii) It is the communication link between the brain and the PNS inferior to the head.
- (iv) It integrates incoming information and produces responses through reflex mechanism.

*Spinal cord is continuous with the brain.

(Spinal cord + Brain => Central Nervous System (CNS))

GENERAL STRUCTURE

External Anatomy of The Spinal Cord

Roughly cylindrical , but flattened slightly in its anterior posterior dimension.

(Looks like a cylinder, but slightly flat in its anterior-posterior dimension)

*Extends from the Foramen magnum to the upper border of the second lumbar vertebra (adults).

*Extends to the third or fourth lumbar vertebra (newborn infant).

(Since the vertebral column continues to elongate, the spinal cord does not extend the entire length of the vertebrae column.)

(Elongation of the spinal cord stops at age 4 or 5)

*Adult spinal cord ranges from 42 to 45 cm (16 to 18 inches)

Two Conspicuous Enlargements seen on Spinal Cord - viewed externally

1. **Cervical Enlargement (superior enlargement)** - Extends from the fourth cervical to the first thoracic vertebra.

-Nerves from and to the upper extremities arise from here.

2. **Lumbar Enlargement (Inferior)** - Extends from the ninth to the twelfth thoracic vertebra.

-Nerves to and from the lower extremities arise from there.

Below the Lumbar Enlargement

(a) **Conus medullaris** - the tapered portion of the spinal cord below the lumbar enlargement.

-Ends at the level of the intervertebral disc between the first and second lumbar vertebrae in an adult.

(b) **Filum Terminale** - arises from the conus medullaris;

An extension of the pia mater that extends inferiorly and attaches the spinal cord to the coccyx.

A nonnervous fibrous tissue of the spinal cord.

(c) **Cauda Equina** (horse's tail) - a taillike collection of roots of spinal nerves at the inferior end of the spinal cord.

Some nerves that arise from the lower part of the cord do not leave the vertebral column at the same level as they exit from the spinal cord.

Although the spinal cord is not actually segmented, it appears that way due to the presence of **31 pairs of spinal nerves** that emerges from it.

MENINGES OF THE SPINAL CORD

Meninges - Are connective tissue that encircle the spinal cord (spinal meninges) and brain (cranial meninges).

Occur in three layers:

a. **Dura mater** - Outermost of the three spinal meninges (dura= tough, mater= mother)

Epidural space – Space between the dura mater around the spinal cord and the periosteum of the vertebral canal.

It is a true space around the spinal cord that contains blood vessels, areolar connective tissues, and fat.

Epidural anesthesia of the spinal nerves is induced by injecting anesthetics into this space. (Example: During child birth).

- b. **Arachnoid mater** - Middle meninx

Because of its spider's web arrangement of delicate collagen fibers and some elastic fibers.

Subdural Space - between dura mater and the arachnoid; contains interstitial fluid.

- c. **Pia mater** - The innermost meninx

-Adheres to the surface of the spinal cord and brain.

Subarachnoid space - between the arachnoid and the pia mater, contains **Cerebrospinal fluid (CSF)**.

Meningitis - is the inflammation of the meninges.

CROSS SECTION OF THE SPINAL CORD

- a. **Anterior Median Fissure** - deep, wide groove on the anterior (ventral) side

- b. **Posterior Median Sulcus** - shallow, narrow groove on the posterior (dorsal) surface

Internal Anatomy of The Spinal Cord

Gray matter - Is shaped like the letter H or a butterfly and is surrounded by white matter.

-**Gray Commissure** forms the cross-bar of the H.

-**Central Canal** small space in the center of gray commissure- extends the entire length of the spinal cord.

-Gray matter consists primarily of cell bodies of neurons and neuroglia and unmyelinated axons and dendrites of association and motor neurons.

Like gray matter, White matter is also organized into region.

-Anterior and Posterior Gray horns divide the white matter on each side into three broad areas called Columns (funiculi):

1. Anterior (ventral) white columns
2. Posterior (dorsal) white columns
3. Lateral white columns

*Each column contains distinct bundles of nerve fibers having a common origin or destination and carrying similar information.

*These bundles are called Tracts (Fasciculi)

Ascending (sensory) tracts consist of axons that conduct (carry) nerve impulses upward to the brain.

Descending (motor) tracts consist of axons that conduct (carry) nerve impulse down the cord.

SPINAL CORD PHYSIOLOGY

-Tracts in white matter of the Spinal cord are highways for nerve impulse conduction.

Sensory Impulses flow from the periphery to the brain.

Motor Impulses flow from the brain to the periphery.

-**Gray matter** of the spinal cord receives and integrates incoming and outgoing information.

Sensory and Motor Tracts

(Often, the name of a tract indicates its position in the white matter, where it begins and ends, and direction of nerve impulse conduction.)

-Example: Anterior Spinothalamic tract

- located in the anterior white column
- begins in the spinal cord
- ends in the thalamus (a region of the brain)

*Since it conveys nerve impulses from the cord upward to the brain, it is a sensory (ascending) tract.

REFLEXES

Reflex Arc and Homeostasis

(The route followed by a series of nerve impulses from their origin in the dendrites or cell body of a neuron in one part of the body to their arrival elsewhere in the body is called a pathway.)

Pathways are specific neuronal circuits and thus include at least one synapse.

Reflex Arc - Is the basic functional unit of the nervous system and is the smallest, simplest portion capable of receiving a stimulus and producing a response.

The shortest route that can be taken by an impulse from a receptor to an effector.

***A Reflex Arc includes five basic Components**

1. A Sensory Receptor
2. A Sensory Neuron
3. An Interneuron
4. A Motor Neuron
5. An Effector Organ

Major Spinal Cord Reflexes Include:

1. The stretch Reflex
2. The Golgi Tendon Reflex
3. Withdrawal Reflex
4. Crossed Extensor Reflex

Stretch Reflex

Stretch Reflex - Is the simplest reflex, a reflex in which muscles contract in response to a stretching force applied to them.

Muscle spindle – Is the sensory receptor of this reflex.

The cells are contractile only at their ends and are innervated by specific

motor neurons called **gamma motor neurons** – originating from the spinal cord and controlling contraction of the ends of the muscle spindle cells.

- Are responsible for regulating the sensitivity of the muscle spindles.

Axons of these sensory neurons synapse directly with motor neurons in the spinal cord called **alpha motor neurons** – which in turn innervate the muscle in which the muscle spindle is embedded.

Functions of the Stretch Reflex

1. Operates as a feedback mechanism to control muscle length.
2. Monitor changes in the length of the muscle.
3. Maintains muscle tone and is important for muscle functions during exercise.
4. Prevents injury from overstretching of muscles.
5. Bases for several tests used in neurological examination.

Example: Patellar reflex (knee jerk)

Golgi Tendon Reflex

Golgi Tendon Reflex – Prevents contracting muscles from applying excessive tension to tendons.

Golgi Tendon Organs – Are encapsulated nerve endings that have at their ends numerous terminal branches with small swellings with bundles of collagen fibers in tendons.

- Are located within tendons near the muscle-tendon junction.

Functions of the Tendon Reflex

1. Operates as a feedback mechanism to control muscle tension by

protecting tendons and their associated muscles from excessive tension.

*(As tension on the tendon organ increases, the frequency of inhibitory impulses increases, and the inhibition of the motor neurons to the muscle developing excess tension causes relaxation of the muscle.) In this way:

- The tendon reflex protects the tendon and muscle from damage from excessive tension.
- The tendon reflex is protective.

Withdrawal Reflex

Withdrawal or Flexor, Reflex – Function to remove a limb or other body parts from a painful stimulus.

The alpha motor neurons stimulate muscles, usually flexor muscles, that remove the limb from the source of the painful stimulus.

Reciprocal Innervation – Is associated with the withdrawal reflex and reinforces its efficiency.

- When the withdrawal reflex is initiated, flexor muscle contract, and reciprocal innervation causes relaxation of the extensor muscles.

Crossed Extension Reflex – Is another reflex associated with the withdrawal reflex.

- When withdrawal reflex is initiated in one lower limb, the crossed extensor reflex causes extension of the opposite lower limb.
- The crossed extensor reflex is adaptive in that it helps prevent falls by shifting the weight of the body from the affected to the unaffected limb.

SPINAL CORD PATHWAYS

Reflexes do not operate as isolated entities within the nervous system because of divergent and convergent pathways.

A pain stimulus, for example, not only initiates a withdrawal reflex, which removes the affected part of the body from the painful stimulus, but also causes perception of the pain sensation as a result of action potentials sent to the brain.

STRUCTURE OF PERIPHERAL NERVES

Peripheral Nerves – Consists of axon bundles Schwann cells and connective tissue.

Endoneurium – Surrounds each axon, or nerve fiber, and its Schwann cell sheath by a delicate connective tissue layer.

Perineurium – A heavier connective tissue layer, surrounds groups of axon to form nerve **fascicles**.

Epineurium – A dense connective tissue, binds the nerve fascicles together to form a nerve.

SPINAL NERVES

31 pairs of spinal nerves are named and numbered according to the region and level of the spinal cord from which they emerge.

All of the 31 pairs of spinal nerves, except the first pair and those of sacrum, exit the vertebral column through **Intervertebral foramina** located between adjacent vertebrae.

First pair of spinal nerve exit between the skull and the first cervical vertebra

Nerves of the sacrum exit from the single bone of the sacrum through the sacral foramina.

Spinal Nerves are:

8 pairs of Cervical Nerves
 12 pairs of Thoracic Nerves
 5 pairs of Lumbar Nerves
 5 pairs of Sacral Nerves
 1 pair of coccygeal Nerves

31 pairs of Spinal Nerves

A. Composition and Coverings

Spinal Nerve has two points of attachment to the spinal cord:

- a. **Posterior root** - contain sensory fibers
- b. **Anterior root** - contain motor fibers

*Posterior Root and Anterior Root unite to form a spinal nerve at the intervertebral foramen.

*Spinal Nerve is a Mixed Nerve since the posterior root contains sensory fibers and the anterior root contains motor fibers.

B. Distribution

I. Branches

-Spinal nerves divides into several branches as it leaves its intervertebral forament.

Rami - branches of the spinal nerve.

Dorsal Ramus - innervates the deep muscles and skin of the dorsal surface of the back.

Ventral Ramus - innervates the muscles and structures of the extremities and the lateral and ventral trunk.

II. Plexuses

Plexuses - a network of nerves, veins, or lymphatic vessels.

(The ventral rami of spinal nerves, except for thoracic nerve T2 - T12, do not go directly to the structure of the body they supply. Instead they form networks on either side of the body by joining with adjacent nerves. Such a network is called Plexus (plexus - braid).

a. Cervical Plexus

Formed by the Ventral Rami of the first four cervical nerves (C1-C4) with contributions from C5.

(Know the Nerves name, origin, and distribution.)

b. Brachial Plexus

Formed by the Ventral Rami of the spinal nerves C5 - T1.

c. Lumbar Plexus

Formed by the Ventral Rami of spinal nerves L1- L4

d. Sacral Plexus

Formed by the Ventral Rami of spinal nerves L4 - S4.

III. **Intercostal (Thoracic) Nerves**

Ventral Rami of Spinal Nerves T2 - T12 do not enter into the formation of Plexus.

T2 - Supplies the intercostal muscle of the second intercostal space and the skin of the axilla and posteromedial aspect of the arm.

T3 and T6 - pass in the costal grooves of the ribs and are distributed to the intercostal muscles of the anterior and lateral chest wall.

T7 - T12 - Supply the intercostal grooves of the ribs and are distributed to the intercostal muscles of the anterior and lateral chest wall.

*The Dorsal Rami of the Intercostal nerves supply the deep back muscles and skin of the dorsal aspect of the thorax.

C. **Dermatomes – Dermatomal Map**

(The skin over the entire body is supplied segmentally by spinal nerves.)

-This means that the spinal nerves innervate specific, constant segments of the skin.

*All spinal nerves except C1 supply branches to the skin.

Dermatome - Is the skin segment supplied by the dorsal root of a spinal nerve.

Function:

- a. It is possible to determine which segment of the spinal cord or spinal nerve is malfunctioning, since physicians know which spinal nerves are associated with each dermatome.
- b. If a dermatome is stimulated and the sensation is not perceived, it can be assumed that the nerves supplying the dermatome are involved.

D. Disorders: Homeostatic Imbalances

Spinal Cord Injury

1. Monoplegia - paralysis of one extremity only
2. Diplegia - paralysis of both upper extremities or both lower extremities.
3. Paraplegia - paralysis of both lower extremities.
4. Hemiplegia - paralysis of the upper extremities, trunk, and lower extremities on one side of the body.
5. Quadriplegia - paralysis of the two upper and two lower extremities.

(Reflexes are associated not only with skeletal muscle contraction but also with body functions such as heart rate, respiration, digestion, urination, and defecation (discharge of feces from the rectum), which involve cardiac and smooth muscle and gland.)