The Central Nervous system

The CNS is formed from the brain and the spinal cord. In this part the structure and the function of the spinal cord and the nerve that originate from it will be studied.

Protection and Coverings

Vertebral Canal

The spinal cord is located in the vertebral canal of the vertebral column. The canal is formed by the vertebral foramina of all the vertebrae arranged on top of each other. Since the wall of the vertebral canal is essentially a ring of bone surrounding the spinal cord, the cord is well protected. A certain degree of protection is also provided by the meninges, cerebrospinal fluid, and the vertebral ligament.

Meninges of the Spinal Cord

Dura Mater

The dura mater is a dense, strong, fibrous membrane encloses the spinal cord and the cauda equina. It is continuous through the foramen magnum with the meningeal layer of the dural covering the brain. Inferiorly, it ends on the filum terminale at the level of the lower border of the second sacral vertebra. It is separated from the wall of the vertebral canal by the extradural space. This contains loose areolar tissue and the internal vertebral venous plexus.

Arachnoid Mater

The arachnoid mater is a delicate, impermeable membrane that covers the spinal cord and lies between the pia mater internally and the dura mater externally. It is separated from the pia mater by a wide space, the subarachnoid space, which is filled with the cerebrospinal fluid. The arachnoid mater is continuous above through the foramen magnum with the arachnoid covering of the brain. Inferiorly, it ends on the filum terminale at the level of the lower border of the second sacral vertebra.

Pia Mater

The pia mater, a vascular membrane that closely covers the spinal cord, is thickened on either side between the nerve roots to form ligament denticulatum, which passes laterally to adhere to the arachnoid and dura. The ligaments protect the spinal cord against shock and sudden displacement. Essentially, the spinal cord is fixed in its position in the

vertebral canal, since it is anchored to the coccyx inferiorly by the filum terminale, laterally to the dura mater by the denticulate ligaments, and superiorly to the brain.

The cerebrospinal fluid (CSF) is removed from the subarachnoid space in the inferior lumbar region of the spinal cord by a *lumbar puncture*. The procedure is normally performed between the third and fourth or fourth and fifth lumbar vertebrae. The spinal process of the fourth lumbar vertebra is easily located; a line drawn across the highest points of the iliac crest will pass through the spinous process. The needle pierces the skin, superficial fascia, supraspinous ligament, interspinous ligament, epidural space, and arachnoid, to enter the subarachnoid space.

Gross Appearance of the Spinal Cord

The spinal cord is roughly cylindrical in shape. It begins superiorly at the foramen magnum in the skull, where it is continuous with the medulla oblongata of the brain, and it terminates inferiorly in the adult at the level of the lower border of the first lumbar vertebra. In the young child, it is relatively longer and usually ends at the upper border of the third lumbar vertebra. Thus it occupies the upper two thirds of the vertebral canal of the vertebral column and is surrounded by the three meninges, the dura mater, the arachnoid mater, and the pia mater. Further protection is provided by the cerebrospinal fluid, which surrounds the spinal cord in the subarachnoid space.

In the cervical region, where it gives origin to the brachial plexus, and in the lower thoracic and lumbar regions, where it gives origin to the lumbosacral plexus, the spinal cord is fusiformly enlarged; the enlargements are referred to as the cervical and lumbar enlargements. Inferiorly the spinal cord tapers off into the conus medullaris, from the apex of which a prolongation of the pia mater, the filum terminale, descends to be attached to the posterior surface of the coccyx. The cord possess in the midline anteriorly a deep longitudinal fissure called the anterior median fissure and, on the posterior surface, a shallow furrow called the posterior median sulus.

Along the entire length of the spinal cord are attached 31 pairs of spinal nerves by the anterior or motor roots and the posterior or sensory roots. Each root is attached to the cord by a series of rootlets, which extend the whole length of the corresponding segment of the cord. Each posterior nerve root possesses a posterior root ganglion. The cells of which, give rise to peripheral and central nerve fibers.

Structure of the Spinal Cord

The spinal cord is composed of an inner core of gray matter, which is surrounded by an outer covering of white matter.

On cross section, the gray matter is seen as an H-shaped pillar with anterior and posterior gray columns, or horns, united by a thin gray commissure containing the small central canal. A small lateral gray column, or horn is present in the thoracic and upper lumbar segments of the cord. The amount of the gray matter at any given level of the spinal cord is related to the amount of the muscle innervated at that level. Thus, its size is greatest within the cervical and lumbosacral segments of the cord, which innervate the muscles of the upper and lower limbs respectively.

Structure

The gray matter of the spinal cord consists of a mixture of nerve cells and their processes, neuroglia, and blood vessels. The nerve cells are multipolar, and the neuroglia forms an intricate network around the nerve cell bodies and their neurites.

Nerve Cell Groups in the Anterior Gray Columns

Most nerve cells are large and multipolar, and their axons pass out in the anterior roots of the spinal nerve as alpha efferents, which innervate skeletal muscles. The smaller nerve cells are also multipolar, and the axons of many of these pass out in the anterior roots of the spinal nerves as gamma efferents, which innervate the intrafusal fibers of the neuromuscular spindles.

For the practical purpose, the nerve cells of the anterior gray column may be divided into three basic groups or columns: medial, central and lateral.

The medial group is present in most segments of the spinal cord and is responsible for innervating the skeletal muscles of the neck and trunk, including the intercostal and abdominal musculature.

The central group is the smallest and is present in some cervical and lumbosacral segments. In the cervical part of the cord, some of these nerve cells (segments C3, 4 and 5) specially innervate the diaphragm and are collectively referred to as the phrenic nucleus. In the upper five or six cervical segments, some of these nerve cells innervate the sternocleidomastoid and trapezius muscles and are referred to as accessory nucleus. The axons of these cells form the spinal part of the accessory nerve. The lumbosacral nucleus present in the second lumbar down to the first sacral segment of the cord is made up of nerve cells whose axons have an unknown distribution.

The lateral group is present in the cervical and lumbosacral segments of the cord and is responsible for innervating the skeletal muscle of the limbs.

Nerve Cell Groups in the Posterior Gray Columns

There are four nerve cell groups of the posterior gray column, two that extends throughout the length of the cord and two that are restricted to the thoracic and lumbar segments.

The substantia gelatinosa group is situated at the apex of the posterior gray column throughout the length of the spinal cords. It is largely composed of Golgi type II neurons and receives afferent fibers concerned with pain, temperature, and touch from the posterior root.

The nucleus proprius is a group of large nerve cells situated anterior to the substantia gelatinosa throughout the spinal cord. It forms the main bulk of cells present in the posterior gray column and receives fibers from the posterior white column that are associated with the senses of position and movement (proprioception), two-points discrimination and vibration.

The nucleus dorsalis (Clark's column) is a group of nerve cells situated at the base of the posterior gray column and extending from the eighth cervical segment caudally to the third or fourth lumbar segment. Most of the cells are comparatively large and are associated with proprioceptive endings (neuromuscular spindles and tendon spindles).

The visceral afferent nucleus is a group of nerve cells of medium size situated lateral to the nucleus dorsalis; it extend from the first thoracic to the third lumbar segment of the spinal cord. It is believed to be associated with receiving visceral afferent information.

Nerve Cell Groups in the Lateral Gray Columns

This group of cells form the small lateral gray column, which extends from the first thoracic to the second or third lumbar segment of the spinal cord. The cells are relatively small and give rise to preganglionic sympathetic fibers.

A similar group of cells found in the second, third, and fourth sacral segments of the spinal cord give rise to preganglionic parasympathetic fibers.

The Gray Commissure and Central Canal

In transverse sections of the spinal cord, the anterior and posterior gray columns on each side are connected by a transverse gray commissure, so that the gray matter resembles the letter H. in the centre of the gray commissure is situated the central canal. The part of the gray commissure that is situated posterior to the central canal is often referred to as the posterior gray commissure; similarly, the part that lies anterior to the canal is called the anterior gray commissure.

The central canal is present throughout the spinal cord. Superiorly, it is continuous with the central canal of the caudal half of the medulla oblongata, and above this, it opens into the cavity of the fourth ventricle. Inferiorly in the conus medullaris, it expands into the fusiform terminal ventricle and terminates below within the root of the filum terminal. It is filled with cerebrospinal fluid and is lined with ciliated columnar epithelium, the ependyma. Thus the central canal is closed inferiorly and opens superiorly into the fourth ventricle.

White Matter

The white matter may be divided into anterior, lateral, and posterior white columns or funiculi. The anterior column on each side lies between the midline and the point of emergence of the anterior nerve roots; the lateral column lies between the emergence of the anterior nerve roots and the entry of the posterior nerve roots; the posterior column lies between the entry of the posterior nerve roots and the midline.

Structure

As in other regions of the central nervous system, the white matter of the spinal cord consists of a mixture of nerve fibers, neuroglia, and blood vessels. It surrounds the gray matter, and its white color is due to the high proportion of myelinated nerve fibers.

For purposes of description, the spinal tracts are divided into ascending, descending, and intersegmental tracts, and their relative position in the white matter are described below.

The Ascending Tracts of the Spinal Cord

On entering the spinal cord, the sensory nerve fibers of different size and functions are sorted out and segregated into nerve bundles or tracts in the white matter. The nerve fiber bundles ascend from the spinal cord to higher centers connecting the spinal cord

with the brain. It is he bundles of the ascending fibers that are referred to as the ascending tracts.

The ascending tracts conduct afferent information, which may or may not reach consciousness. The information may be divided into two main groups: (1) exteroceptive information, which originates from the outside the body, such as pain, temperature, and touch, and (2) proprioceptive information, which originates from inside the body, for example, from muscles and joints.

Anatomical Organization

General information from the peripheral sensory endings is conducted through the nervous system by a series of neurons. In its simplest form, the ascending pathway to consciousness consists of three neurons. The first neuron, the first order-neuron, has its cell body in the posterior root ganglion of the spinal nerve. A peripheral process connects with a sensory receptor ending, whereas a central process enters the spinal cord through the posterior root to synapse on the second-order neuron. The second-order neuron gives rise to an axon that decussate (crosses to the opposite side) and ascend to the higher level of the central nervous system, where it synapses with the third-order neuron. The third-order neuron is usually in the thalamus and gives rise to projection fibers that passes to the sensory region of the cerebral cortex.

Function of the Ascending tracts

Sensations of pain and temperature ascend in the lateral spinothalamic tract; touch and pressure ascend in the anterior spinohalamic tract. Discriminative touch, that is, the ability to localize accurately the area of the body touched and also to be aware that the two points are touched simultaneously, even though they are close together (two-point discrimination), ascends in the posterior white columns. Also ascends in the posterior white column is information from muscles and joints pertaining to movement and position of different parts of the body. In addition, vibratory sensations ascend in the posterior white column.

Unconscious information from muscles, joints, the skin, and subcutaneous tissue reach the cerebellum by way of the anterior and posterior spinocerebellar tracts and by the cuneocerbellar tract. Pain, thermal, and tactile information is passed to the superior colliculus of the midbrain through the spinotectal tract for the purpose of spinovisual reflexes. The spinoreticular tract provides a pathway from muscles, joints, and skin to

the reticular information. While the spino-olivary tract provides an indirect pathway for further afferent information to reach the cerebellum.

Pain and Temperature Pathways

Lateral Spinothalamic Tract

The pain and thermal receptors in the skin and other tissues are free nerve endings. The pain impulses are transmitted to the spinal cord in fast-conducting A-type fibers and slow-conducting c-type fibers. The axons entering the spinal cord from the posterior root ganglion proceed to the tip of the posterior gray column and divide into ascending and descending branches. These branches travel for a distance of one or two segments of the spinal cord and form the posterolateral tract of Lissauer. These fibers of the first-order neuron terminate by synapsing with cells in the posterior gray column, including cells in the substantia gelatinosa.

The axons of the second-order neurons now cross obliquely to the opposite side in the anterior gray and white commissures within one spinal segment of the cord, ascending in the contralateral white column as the lateral spinothalamic tract. The lateral spinothalamic tract lies medial to the anterior spinothalamic tract.

As the lateral spinothalamic tract ascends through the medulla oblongata, it lies near the lateral surface and between the inferior olivary nucleus and the nucleus of the spinal tract of the trigeminal nerve. It is now accompanied by the anterior spinothalamic tract and spinotectal tract; together they form the spinal lemniscus.

The spinal lemniscus continues to ascend through the posterior part of the pons. In the midbrain, it lies in the tegmentum lateral to the medial lemniscus. Many of the fibers of the lateral spinothalamic tract end by synapsing with the third-order neuron in the ventral posterolateral nucleus of the thalamus. It is believed that here crude pain and temperature sensations are appreciated and emotional reactions are initiated.

The axons of the third-order neurons in the ventral posterolateral nucleus of the thalamus now pass through the posterior limb of the internal capsule and the corona radiata to reach the somesthetic area in the postcentral gyrus of the cerebral cortex. The contralateral half of the body is represented as inverted, with the hand and mouth situated inferiorly and the leg situated superiorly. From here, the information is transmitted to other regions of the cerebral cortex to be used by the motor areas and the parietal association area. The role of the cerebral cortex is interpreting the quality of the sensory information at the level of consciousness.

Light (Crude) Touch and Pressure Pathways

Anterior Spinothalamic Tract

The axons entering the spinal cord from the posterior root ganglion proceed to the tip of the posterior gray column, where they divide into ascending and descending branches. These branches travel for a distance of one or two segments of the spinal cord, contributing to the posterolateral tract of Lissauer. It is believed that these fibers of the first-order neuron terminate by synapsing with the cells of the substantia gelatinosa group in the posterior gray column.

The axon of the second-order neuron now cross very obliquely to the opposite side in the anterior gray and white commissures within several spinal segments, and ascend in the opposite anterolateral white column as the anterior spinothalamic tract.

As the anterior spinothalamic tract ascends through the medulla oblongata, it accompanies the lateral spinothalamic tract and the spinotectal tract, all of which form the spinal lemniscus.

The spinal lemniscus continues to ascend through the posterior part of the pons, and the tegmentum of the midbrain and the fibers of the anterior spinothalamic tract terminate by synapsing with the third-order neuron in the ventral posterolateral necleus of the thalamus. Crude awareness of touch and pressure is believed to be appreciated here.

The axons of third-order neurons in the ventral posterolateral neuron of the thalamus pass through the posterior limb of the internal capsule and the corona radiata to reach the somesthetic area in the postcentral gyrus of the cerebral cortex. The contralateral half of the body is represented inverted, with the hand and mouth situated inferiorly.

Posterior White Column: Fasciculuc Gracilis and Fasciculus Cuneatus

The axons enter the spinal cord from the posterior root ganglion and pass directly to the posterior white column of the same side. Here the fibers divide into long ascending and short descending branches. The descending branches pass down a variable number of segments, giving off collateral branches that synapse with the cells in the posterior gray horn, with internuncial neurons, and with anterior horn cells. It is clear that these short descending fibers are involved with intersegmental reflexes.

The long ascending fibers may also end by synapsing with cells in the posterior gray horn, with internuncial neurons, and with the anterior horn cells. The distribution may extend over numerous segments of the spinal cord. As in the case of the short descending fibers, they are involved with intersegmental reflexes.

Many of the long ascending fibers travel upward in the posterior white column as the fasciculus gracilis and fasciculus cuneatus. The fibers of the fasciculus gracilis and fasciculus cuneatus ascend ipsilaterally and terminate by synapsing on the second-order neuron in the neuclei gracilis and cuneatus of the medulla oblongata. The axons of the second-order neurons decussating with the corresponding fibers of the opposite side in the sensory decussation. The fibers then ascend as a single compact bundle, the medial lemniscus, through the medulla oblongata. The fibers terminate by synapsing on the third-order neurons in the ventral posterolateral nucleus of the thalamus.

The axons of the third-order neuron leave and pass through the posterior limb of the internal capsule and corona radiata to reach the somesthetic area in the postcentral gyrus of the cerebral cortex. The contralateral half of the body is represented inverted, with the hand and mouth inferiorly. The impression of touch, exact localization, and two-point discrimination can be appreciated. Vibratory sense and the position of the different parts of the body can be continuously recognized.

Posterior Spinocerebellar Tract

The axons entering the spinal cord from the posterior root ganglion enter the posterior gray horn and terminate by synapsing on the second-order neurons at the base of the posterior gray horn. These neurons are known collectively as the nucleus dorsalis (Clark's column). Axons of the second-order neurons enter the posterolateral part of the lateral white column on the same side and ascend as the posterior spinocerebellar tract to the medulla oblongata. Here the tract join the inferior cerebellar peduncle and terminate in the cerebellar cortex.

The posterior spinocerebellar fibers receive muscle joint information from the muscle spindles, tendon organs, and joint receptors of the trunk and lower limbs. This information concerning tension of muscle tendons and the movements of muscles and joint is used by the cerebellumi in the coordination of limb movements and maintenance of posture.

Anterior spinocerebellar Tract

The axons entering the spinal cord from the posterior root ganglion terminate by synapsing with the second-order neuron in the nucleus dorsalis at the base of the posterior gray column. The majority of the axons of the second-order neurons cross to the opposite side and ascend as the anterior spinocerebellar tract in the contralateral white column; the minority of the axons ascend as the anterior spinocerebellar tract in the lateral white column of the same side. The fibers, having ascended through the medulla oblongata and pons, enter the cerebellum through the superior cerebellar peduncle and terminate in the cerebellar cortex. The anterior spinocerebellar tract conveys muscle joint information from the muscle spindle, tendon organs, and joint receptors of the trunk and the upper and lower limbs. It is also believed that the cerebellum receives information from the skin and superficial fascia by this tract.

Other Ascending Pathways

Spinotectal Tract

The axons enter the spinal cord from the posterior root ganglion and travel to the gray matter where they synapse on unknown second-order neurons. The axons of the second-order neurons cross the median plane and ascend as the spinotectal tract in the anterolateral white column lying close to the lateral spinothalamic tract. After passing through the medulla oblongata and pons, they terminate by synapsing with neurons in the superior colliculus of the midbrain. This pathway provides afferent information for spinovisual reflexes and brings about movements of the eye and head toward the source of the stimulation.

Spinoreticular Tract

The axons enter the spinal cord from the posterior root ganglion and terminate on unknown second-order neurons in the gray matter. The axons from these second-order neurons ascend the spinal cord as the spinoreticular tract in the lateral white column mixed with the lateral spinothalamic tract. Most of the fibers are uncrossed and terminate by synapsing with neurons of the reticular information in the medulla oblongata, pons, and midbrain. The spinoreticular tract provides an afferent pathway for the reticular information, which plays an important role in influencing levels of the consciousness.

Spino-olivary Tract

The axons enter the spinal cord from the posterior root ganglion and terminate on unknown second-order neurons in the posterior gray matter. The axons from these second-order neurons cross the midline and ascend as the spino-olivary tract in the white matter at the junction of the anterior and lateral columns. The axons end by synapsing on the third-order neuron in the inferior olivary nuclei in the medulla oblongata. The axons of the third-order neurons cross the midline and enter the cerebellum through the inferior cerebellar peduncle. The spino-olivary tract conveys information to the cerebellum from the cutaneous and proprioceptive organs.

Visceral Sensory Tract

Sensations that arise in the viscera located in the thorax and abdomen enter the spinal cord through the posterior roots. The cell bodies of the first order-neurons are situated in the posterior root ganglia. The peripheral processes of these cells receive nerve impulses from pain and stretch receptor endings in the viscera. The central processes, having entered the spinal cord, synapse with the second-order neurons in the gray matter, probably in the posterior or lateral gray column.

The axons of the second-order neurons are believed to join the spinothalamic tract and ascend and terminate on the third-order neurons in the ventral posterolateral nucleus of the thalamus. The final destination of the axons of the third-order neurons is probably in the postcentral gyrus of the cerebral cortex.

THE DESCENDING TRACTS OF THE SPINAL CORD

The motor neurons situated in the anterior gray columns of the spinal cord send axons to innervate skeletal muscle through the anterior roots of the spinal nerves. These motor neurons are sometimes referred to as the lower motor neurons and constitute the final common pathway to the muscles.

The nerve fibers that descend in the white matter from different supraspinal nerve centers (from the medulla oblongata, pons, midbrain, and cerebral cortex) are segregated into nerve bundles called descending tracts.

Anatomical Organization

Control of skeletal muscle activity from the cerebral cortex and other higher centers is conducted through the nervous system by a series of neurons. The descending pathway from the cerebral cortex is often made up of three neurons. The first neuron, the first-order neuron, has its cell body in the cerebral cortex. Its axons descend to synapse on the second -order neuron, an internuncial neuron, situated in the anterior gray column of the spinal cord. The axon of the second-order neuron is short and synapses with third-order neuron, the lower motor neuron, in the anterior gray column. The axon of the third-order neuron innervates the skeletal muscle through the anterior root and spinal nerve. In some instances, the axon of the first-order neuron terminates directly on the third order neuron as in reflex arcs.

Functions of the Descending Tracts

The corticospinal tracts are the pathways concerned with voluntary, discrete, skilled movements, especially those of the distal parts of the limbs.

The reticulospinal tracts may facilitate or inhibit the activity of alpha and gamma motor neurons in the anterior gray columns and may, therefore, facilitate or inhibit voluntary movement or reflex activity.

The tectospinal tract concerned with reflex postural movement in response to visual stimuli. Those fibers are associated with the sympathetic neurons in the lateral gray column are concerned with the pupillodilation reflex in response to darkness.

The rubrospinal tract acts on both the alpha and gamma motor neurons in the anterior gray columns and facilitates the activity of flexor muscles and inhibits the activity of extensor or antigravity muscles.

The vestibulospinal tract by acting on the motor neuron in the anterior gray columns, facilitates the activity of extensor muscle, inhibits the activity of the flexor muscles, and is concerned with the postural activity associated with balance.

The olivospinal tract may play a role in the muscular activity, but there is doubt that it exists.

The descending autonomic fibers are concerned with the control of visceral activity.

Corticospinal Tract

Fibers of the corticospinal tract arise as axons of pyramidal cells situated in the fifth layer of the cerebral cortex. Two-thirds of the fibers arise from the precentral gyrus, and one-third of the fibers arise from the postcentral gyrus. Stimulation of different parts of

the precentral gyrus produces movements of different parts of the opposite side of the body. The region controlling the face is situated inferiorly and the region controlling the lower limb is situated superiorly and on the medial side.

The descending fibers converge in the corona radiata and then pass through the posterior limb of the internal capsule. The tract then continues through the basis peduncli of the midbrain. On entering the pons, the tract is broken into many bundles by the transverse pontocerebellar fibers. In the medulla oblongata, the bundles become grouped together along the anterior border to form a swelling known as the pyramid (hence the alternative name, pyramidal tract). At the junction of the medulla oblongata and the spinal cord, most of the fibers cross the midline at the decussation of the pyramids and enter the lateral white column of the spinal cord to form the lateral corticospinal tract. The remaining fibers do not cross in the decussation but descend in the anterior white column of the spinal cord as the anterior corticospinal tract. These fibers eventually cross the midline and terminate in the anterior gray column of the spinal cord segments in the cervical and upper thoracic region.

The lateral corticospinal tract descends the length of the spinal cord; its fibers terminate in the anterior gray column of all spinal cord segments. Most of the corticospinal fibers synapse with internuncial neurons, which in turn synapse with alpha motor neuron and some gamma motor neurons.

Branches pass to the caudate and lentiform nuclei, the red nuclei, and the olivary nuclei and the reticular formation. These branches keep the subcortical regions informed about the cortical motor activity. Once alerted, the subcortical regions may react and send their own nervous impulses to the alpha and gamma motor neurons by other descending pathways.

Reticulospinal Tracts

Throughout the midbrain, pons, and medulla oblongata, groups of scattered nerve cells and nerve fibers exist that are collectively known as the reticular formation. From the pons, these neurons send axons, which are mostly uncrossed, down into the spinal cord and form pontine reticulospinal tract. From the medulla, similar neurons send axons, which are crossed and uncrossed, to the spinal cord and form the medullary reticulospinal tract.

The reticulospinal fibers from the pons descend through the anterior white column, while those from the medulla oblongata descend in the lateral white column. Both sets of

fibers enter the anterior gray columns of the spinal cord and may facilitate the activity of alpha and gamma motor neurons. By this means, the reticulospinal tract influence voluntary movements and reflex activity. The reticulospinal tract also provides a pathway by which the hypothalamus can control the sympathetic outflow and the sacral parasympathetic outflow.

Tectospinal Tract

Fibers of this tract arise from the nerve cells in the superior colliculus of the midbrain. Most of the fibers cross the midline soon after their origin and descend through the brain stem close to the medial longitudinal fasciculus. The tectospinal tract descends through the anterior white column of the spinal cord close to the anterior median fissure. The majority of the fibers terminate in the anterior gray column in the upper cervical segments of the spinal cord by synapsing with internuncial neurons. These fibers are believed to be concerned with reflex postural movements in response to visual stimuli.

Rubrospinal Tract

The red nucleus is situated in the tegmentum of the midbrain at the level of the superior colliculus. The axons of neurons in this nucleus cross the midline at the level of the nucleus and descend as the rubrospinal tract through the pons and medulla oblongata to enter the lateral white column of the spinal cord. The fibers terminate by synapsing with internuncial neurons in the anterior gray column of the cord.

The neurons of the red nucleus receive afferent impulses through the connections with the cerebral cortex and the cerebellum. This is believed to be an important indirect pathway by which the cerebral cortex and the cerebellum can influence the activity of alpha and gamma motor neurons of the spinal cord. The tract facilitates the activity of the flexor muscles and inhibits the activity of the extensor or antigravity muscles.

Vestibulospinal Tract

The vestibular nuclei are situated in the pons and medulla oblongata beneath the floor of the fourth ventricle. The vestibular nuclei receive afferent fibers from the inner ear through the vestibular nerve and from the cerebellum. The neurons of the lateral vestibular nucleus give rise to the axons that form the vestibulospinal tract. The tract descends uncrossed through the medulla and through the length of the spinal cord in the

anterior white column. The fibers terminate by synapsing with internuncial neurons of the anterior gray column of the spinal cord.

The inner ear and the cerebellum, by means of this tract, facilitate the activity of the extensor muscles and inhibit the activity of the flexor muscles in association with maintenance of balance.

Olivospinal Tract

The olivospinal tract was thought to arise from the inferior olivary nucleus and descend in the lateral white column of the spinal cord, to influence the activity of the motor neurons in the anterior gray horns. There is now considerable doubt that it exists.

Descending Autonomic Fibers

The higher centers of the CNS associated with the control of autonomic activity are situated in the cerebral cortex, hypothalamus, amygdaloid complex, and the reticular formation. Although distinct tracts have not been recognized, investigation of spinal cord lesion has demonstrated that the descending autonomic tract do exist and probably form part of the reticulospinal tract.

The fibers arise from the neurons in the higher centers and cross the midline in the brainstem. They are believed to descend in the lateral white column of the spinal cord and to terminate by synapsing on the autonomic motor cells in the lateral gray columns in the thoracic and upper lumbar (sympathetic outflow) and midsacral (parasympathetic) levels of the spinal cord.

Intersegmental Tracts

Short ascending and descending tracts that originate and end within the spinal cord exist in the anterior, lateral, and posterior white columns. The function of these pathways is to interconnect the neurons of different segmental levels, and the pathways are particularly important in intersegmental spinal reflexes.

Reflex Arc

A reflex may be defined as an involuntary response to a stimulus. It depends on the integrity of the reflex arc. In its simplest form, a reflex arc consists of the following

anatomical structures: (1) a receptor organ, (2) an afferent neurone, (3) an effector neuron, and (4) an effector organ. A reflex arc involving only one synapse is referred to as a monosynaptic reflex arc.

In the spinal cord, reflex arc plays an important role in maintaining muscle tone, which is the basis for body posture. The receptor organ is situated in the skin, muscle, or tendon. The cell body of the afferent neuron is located in the posterior root ganglion, and the central axon of this first-order neuron terminates by synapsing on the effector neuron. Since the afferent fibers are of large diameter and are rapidly conducting and because of the presence of only one synapse, a very quick response is possible.