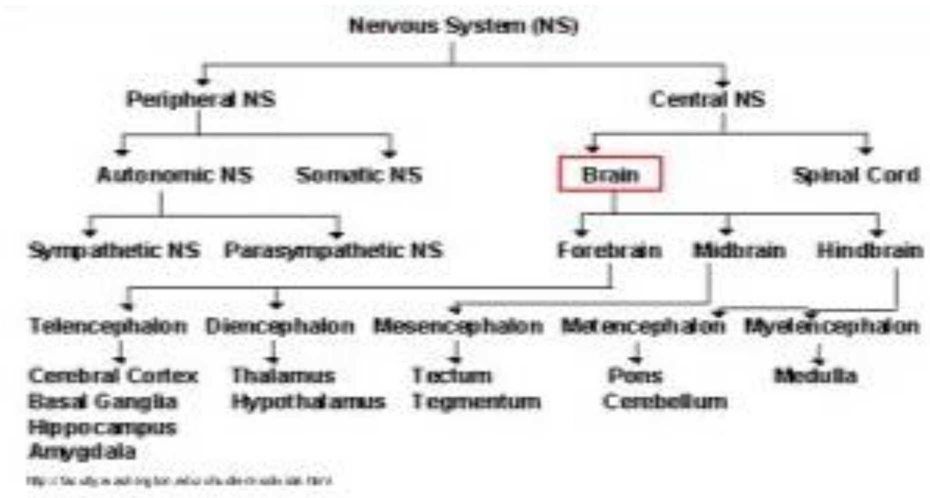
HUMAN ANATOMY AND PHYSIOLOGY

B.PHARM II SEM

UNIT-I

NERVOUS SYSTEM

ORGANIZATION OF NERVOUS SYSTEM



The nervous system commands muscles, controls the functioning of all organs and provides information about the outside world through sensory information.

STRUCTURE AND FUNCTION OF BRAIN

CEREBRAL CORTEX

The cerebral cortex is the outermost layered structure of the brain and controls higher brain functions such as information processing.

Cortex

- The cerebral cortex, the largest part of the mammalian brain, is the wrinkly gray outer covering of the cerebrum. While the cortex is less than 1/4″ thick.
- The "valleys" of the wrinkles are called *sulci* (or sometimes, fissures); the "peaks" between wrinkles are called *gyri*. While there are variations from person to person in their sulci and gyri, the brain has been studied enough to identify patterns. One notable sulcus is the central sulcus, or the wrinkle dividing the parietal lobe from the frontal lobe.
- It is here that all sensation, perception, memory, association, thought, and voluntary physical actions occur. The cerebral cortex is considered the ultimate control and information-processing center in the brain.

Composition

The cortex is made of layers of neurons with many inputs; these cortical neurons function like mini microprocessors or logic gates. It contains glial cells, which guide neural connections, provide nutrients and myelin to neurons, and absorb extra ions and neurotransmitters.

CEREBRUM

Beneath the cerebral cortex is the cerebrum, which serves as the main thought and control center of the brain. It is the seat of higher-level thought like emotions and decision making (as opposed to lower-level thought like balance, movement, and reflexes).

The cerebrum is composed of gray and white matter. Gray matter is the mass of all the cell bodies, dendrites, and synapses of neurons interlaced with one another, while white matter consists of the long, myelin-coated axons of those neurons connecting masses of gray matter to each other.

Cerebral Hemispheres and Lobes of the Brain

The brain is divided into two hemispheres and four lobes, each of which specializes in a different function.

- The brain is separated into the frontal, temporal, occipital, and parietal lobes.
- The frontal lobe is associated with executive functions and motor performance.
- The temporal lobe is associated with the retention of short- and and long-term memories. It processes sensory input, including auditory information, language comprehension, and naming.
- The occipital lobe is the visual-processing center of the brain.
- The parietal lobe is associated with sensory skills.

Corpus Callosum

The two hemispheres communicate with one another through the corpus callosum. The corpus callosum is a wide, flat bundle of neural fibers beneath the cortex that connects the left and right cerebral hemispheres and facilitates interhemispheric communication. The corpus callosum is sometimes implicated in the cause of seizures; patients with epilepsy sometimes undergo a corpus callostomy, or the removal of the corpus callosum.

The Lobes of the Brain

The brain is separated into four lobes: the frontal, temporal, occipital, and parietal lobes.

The Frontal Lobe

The frontal lobe is associated with executive functions and motor performance. Executive functions are some of the highest-order cognitive processes that humans have. Examples include:

- planing and engaging in goal-directed behavior;
- recognizing future consequences of current actions;
- choosing between good and bad actions;
- overriding and suppressing socially unacceptable responses;
- Determining similarities and differences between objects or situations.

The frontal lobe is considered to be the moral center of the brain because it is responsible for advanced decision-making processes. It also plays an important role in retaining emotional memories derived from the limbic system, and modifying those emotions to fit socially accepted norms.

The Temporal Lobe

- The temporal lobe is associated with the retention of short- and long-term memories.
- It processes sensory input including auditory information, language comprehension, and naming.
- It also creates emotional responses and controls biological drives such as aggression and sexuality.
- The temporal lobe contains the hippocampus, which is the memory center of the brain. The hippocampus plays a key role in the formation of emotion-laden, long-term memories based on emotional input from the amygdala.

- The left temporal lobe holds the primary auditory cortex, which is important for processing the semantics of speech.
- One specific portion of the temporal lobe, **Wernicke's area**, plays a key role in speech comprehension.
- Another portion, **Broca's area**, underlies the ability to produce (rather than understand) speech. Patients with damage to Wernicke's area can speak clearly but the words make no sense, while patients with damage to Broca's area will fail to form words properly and speech will be halting and slurred. These disorders are known as Wernicke's and Broca's aphasia respectively; an aphasia is an inability to speak.

The Occipital Lobe

- The occipital lobe contains most of the visual cortex and is the visual processing center of the brain.
- Cells on the posterior side of the occipital lobe are arranged as a spatial map of the retinal field. The visual cortex receives raw sensory information through sensors in the retina of the eyes, which is then conveyed through the optic tracts to the visual cortex.
- Other areas of the occipital lobe are specialized for different visual tasks, such as visuospatial processing, color discrimination, and motion perception.
- Damage to the primary visual cortex (located on the surface of the posterior occipital lobe) can cause blindness, due to the holes in the visual map on the surface of the cortex caused by the lesions.

The Parietal Lobe

- The parietal lobe is associated with **sensory skills**. like spatial processing and navigation.
- Integrating sensory information from various parts of the body,
- Understanding numbers and their relations, and manipulating objects.
- It's also processes information related to the sense of touch.
- It is also important to language and visuo spatial processing; the left parietal lobe is involved in **symbolic functions** in language and mathematics, while the right parietal lobe is specialized to process images and interpretation of maps (i.e., spatial relationships).

BRAINSTEM

The brainstem is the region of the brain that connects the cerebrum with the spinal cord. It consists of the midbrain, medulla oblongata, and the pons. Motor and sensory neurons travel through the brainstem allowing for the relay of signals between the brain and the spinal cord. Most cranial nerves are found in the brainstem.

BRAINSTEM STRUCTURES

Midbrain: The midbrain is located below the cerebral cortex, and above the hindbrain placing it near the center of the brain.

It is comprised of the **tectum, tegmentum, cerebral aqueduct, cerebral peduncles and several nuclei and fasciculi.**

1. **Tectum:** The *Tectum* (Latin for *roof*) is the dorsal side of the midbrain. It is involved in certain reflex actions in connection with visual or auditory stimuli.
2. **Tegmentum:** The tegmentum is the portion of the midbrain ventral to the cerebral aqueduct, and is much larger in size than the tectum. It communicates with the cerebellum by the superior cerebellar peduncles
3. **Cerebral aqueduct:** The cerebral aqueduct is the part of the ventricular system which links the third ventricle (rostally) with the fourth ventricle (caudally); as such it is responsible for continuing the circulation of cerebrospinal fluid.

The primary role of the midbrain is to act as a sort of **relay station** for our visual and auditory systems. Portions of the midbrain called the red nucleus and the substantia nigra are involved in the control of body movement, and contain a large number of dopamine-producing neurons. The degeneration of neurons in the substantia nigra is associated with Parkinson’s disease. The midbrain is the smallest region of the brain, and is located most centrally within the cranial cavity.

Pons

It is a portion of the brain stem, located above the medulla oblongata and below the midbrain. Although it is small, at approximately 2.5 centimeters long, it serves several important functions. It is a bridge between various parts of the nervous system, including the cerebellum and cerebrum, which are both parts of the brain

There are many important nerves that originate in the pons.

The trigeminal nerve

It is responsible for feeling in the face.

It also controls the muscles that are responsible for **biting, chewing, and swallowing.**

The abducens nerve

It allows the eyes to look from side to side.

The facial nerve

It controls facial expressions

Vestibulocochlear nerve: It allows sound to move from the ear to the brain.

A section of the lower pons stimulates and controls the intensity of breathing, and a section of the upper pons decreases the depth and frequency of breaths. The pons has also been associated with the control of sleep cycles.

Medulla Oblongata

Location: in the brain stem, anterior to (in front of) the cerebellum. This is a cone-shaped, neuronal (nerve cell) mass in the hindbrain, which controls a number of autonomic (involuntary) functions.

Function:

1. This section of the brain helps transfer messages to the spinal cord and the thalamus, which is in the brain, from the body.
2. The main function of the thalamus is to process information to and from the spinal cord and the cerebellum.
3. The medulla oblongata helps regulate breathing, heart and blood vessel function, digestion, sneezing, and swallowing. Respiration and circulation.
4. Sensory and motor neurons (nerve cells) from the forebrain and midbrain travel through the medulla.

5. The medulla oblongata receives its blood supply from several arteries, including the anterior spinal artery, posterior inferior cerebellar artery, and the vertebral artery's direct branches.

Function of brainstem

In addition to linking the cerebrum and spinal cord, the brainstem also connects the cerebrum with the cerebellum. The cerebellum is important for regulating functions such as movement coordination, balance, equilibrium, and muscle tone.

The brainstem also controls several important functions of the body including:

- Alertness
- Arousal
- Breathing
- Blood pressure control
- Digestion
- Heart rate
- Other autonomic functions
- Relays information between the peripheral nerves and spinal cord to the upper parts of the brain

CEREBELLUM

The cerebellum (which is Latin for “little brain”) is a major structure of the hindbrain that is located near the brainstem. This part of the brain is responsible for a number of functions including motor skills such as balance, coordination, and posture.

Location of the Cerebellum

- The cerebellum is the largest structure of the hindbrain and can be found in the back portion of the skull below the temporal and occipital lobes and above the brainstem.
- When looking at the brain, the cerebellum looks much like a smaller structure separate from the brain, found beneath the hemispheres of the cerebral cortex.

- It consists of a cortex covering white matter, as well as a ventricle filled with fluid. It is also divided into two hemispheres like the cerebral cortex.
- The cerebellum makes up just 10 percent of the total volume of the brain, yet it contains more than half of the brain's neurons.

Function of the Cerebellum

- The cerebellum plays an important role in motor control, the coordination of motor movements and balance, among other things.
- There are several key functions of the cerebellum.

1. **Coordinating the Body's Voluntary Movements**

   Movement is a complex process that requires a number of different muscles groups working together. Consider how many muscles groups are involved in the process of walking, running or throwing a ball. While the cerebellum is not thought to initiate movement, this part of the brain helps organize all of the actions of the muscle groups involved in a particular movement to ensure that the body is able to produce a fluid, coordinated movement.

2. **Balance and Posture**

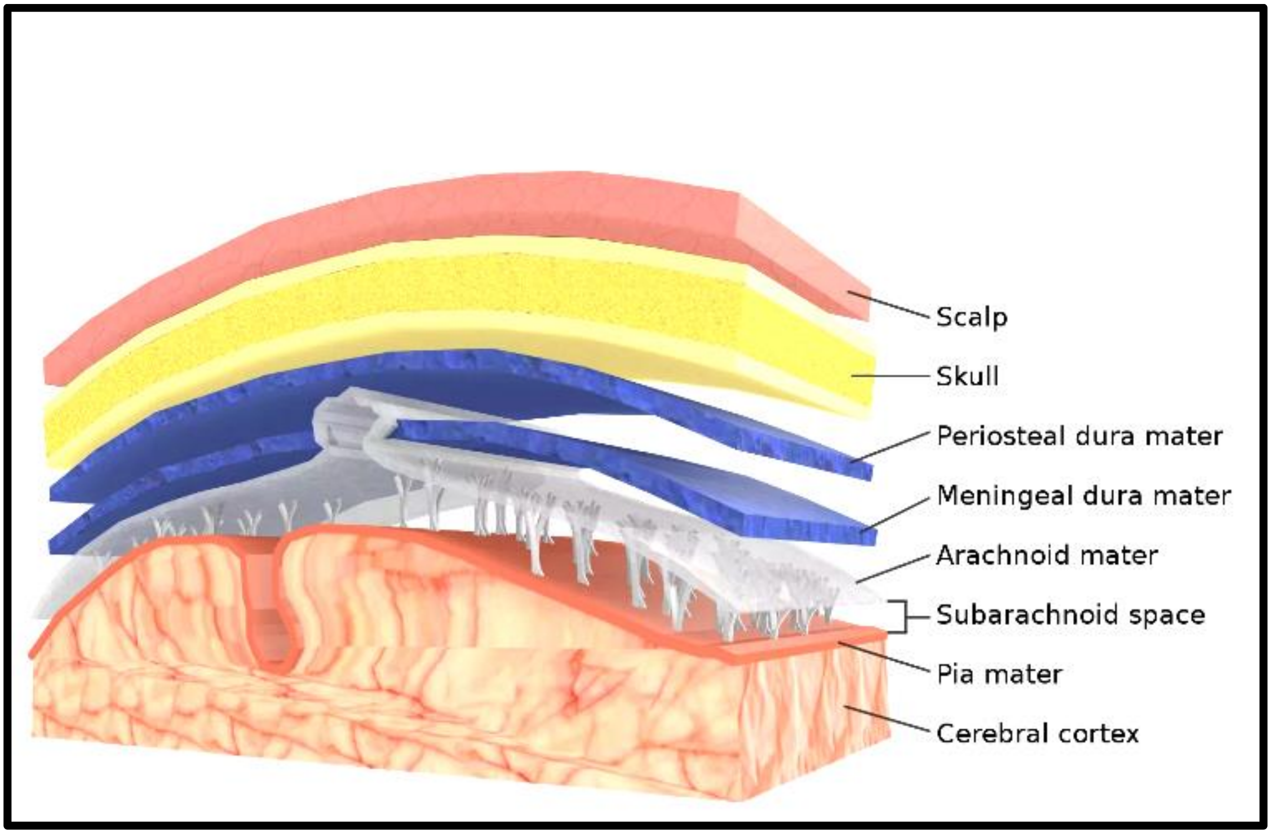
   In order to understand the important role that the cerebellum plays, it can be helpful to look at what happens when the function of this part of the brain is impaired. Drinking alcohol, for example, has an immediate effect on the cerebellum and leads to disruptions in the body's coordination and movements. People who are severely intoxicated might find that they cannot even walk in a straight line or touch their own nose when asked.

3. **Motor Learning**

   When you learn to perform a new skill such as riding a bike or hitting a baseball, you often go through a trial-and-error process. As you fine-tune your motor movements, you eventually become better able to perform the skill and eventually you can perform the action seamlessly. The cerebellum plays a critical role in this motor learning process.

MENINGES

The meninges is a layered unit of membranous connective tissue that covers the brain and spinal cord. These coverings encase central nervous system structures so that they are not in direct contact with the bones of the spinal column or skull. The meninges are composed of three membrane layers known as the dura mater, arachnoid mater, and pia mater.



Dura Mater

1. This outer layer connects the meninges to the skull and vertebral column.
2. It is composed of tough, fibrous connective tissue.
3. Dura mater that surrounds the brain consists of two layers.
4. The outer **periosteal layer** firmly connects the dura mater to the skull and covers the meningeal layer.
5. The **meningeal layer** also forms dural folds that divide the cranial cavity into different compartments, which support and house various subdivisions of the brain.

Arachnoid Mater:

1. This middle layer of the meninges connects the dura mater and pia mater.
2. The arachnoid membrane loosely covers the brain and spinal cord and gets its name from its web-like appearance.
3. The arachnoid mater is connected to the pia mater through tiny fibrous extensions that span the subarachnoid space between the two layers.
4. The subarachnoid space provides a route for the passage of blood vessels and nerves through the brain and collects cerebrospinal fluid that flows from the fourth ventricle.
5. Membrane projections from the arachnoid mater called arachnoid granulations extend from the subarachnoid space into the dura mater. Arachnoid granulations remove cerebrospinal fluid from the subarachnoid space and send it to the dural venous sinuses, where it is reabsorbed into the venous system.

Pia Mater:

1. This thin inner layer of the Meninges is in direct contact with and closely covers the cerebral cortex and spinal cord.
2. The pia mater has a rich supply of blood vessels which provide nutrients to nervous tissue.
3. This layer also contains the choroid plexus a network of capillaries and ependyma (specialized ciliated epithelial tissue) that produce cerebrospinal fluid.
4. The choroid plexus is located within the cerebral ventricles. Pia mater covering the spinal cord is composed of two layers, an outer layer consisting of collagen fibers and an inner layer that encases the entire spinal cord.
5. Spinal pia mater is thicker and less vascular than pia mater that covers the brain.

VENTRICLES OF BRAIN

- Lateral ventricles
- Third ventricle
- Fourth ventricle

Lateral ventricles

- These are the two largest cavities of the ventricular system of the human brain and contain **cerebrospinal fluid (**CSF).
- Each cerebral hemisphere contains a lateral ventricle, known as the left or right ventricle, respectively. Each lateral ventricle resembles a **C-shaped** structure that begins at an inferior horn in the temporal lobe.
- each lateral ventricle connects to the single, central third ventricle.

Third ventricle

- **It** is one of four connected fluid-filled cavities comprising the ventricular system within the mammalian brain. It is a median cleft in the diencephalon between the two thalami, and is filled with cerebrospinal fluid (CSF).
- It is in the midline, between the left and right lateral ventricles. Running through the third ventricle is the interthalamic adhesion, which contains thalamic neurons and fibers that may connect the two thalami.

Fourth ventricle

- **It** is one of the four connected fluid-filled cavities within the human brain.
- These cavities, known collectively as the ventricular system, consist of the left and right lateral ventricles, the third ventricle, and the fourth ventricle.
- The fourth ventricle extends from the cerebral aqueduct (*aqueduct of Sylvius*) to the obex, and is filled with cerebrospinal fluid (CSF).
- The fourth ventricle has a characteristic diamond shape in cross-sections of the human brain.
- It is located within the pons or in the upper part of the medulla oblongata.

- CSF entering the fourth ventricle through the cerebral aqueduct can exit to the subarachnoid space of the spinal cord through two lateral apertures and a single, midline median aperture.

CEREBROSPINAL FLUID

Cerebrospinal fluid (CSF) is a clear, colourless ultrafiltrate of plasma with low protein content and few cells. The CSF is mainly produced by the choroid plexus, but also by the ependymal lining cells of the brain's ventricular system. CSF flows through the ventricular system and then into the subarachnoid space and it is subsequently absorbed through the subarachnoid villi into the venous system.

FUNCTION OF CSF

1. **Protection:** CSF protects the brain tissue from injury when jolted or hit, by providing a fluid buffer that acts as a shock absorber from some forms of mechanical injury.
2. **Prevention of brain ischemia:** The prevention of brain ischemia is aided by decreasing the amount of CSF in the limited space inside the skull. This decreases total intracranial pressure and facilitates blood perfusion.
3. **Homeostasis:** CSF allows for regulation of the distribution of substances between cells of the brain,and neuroendocrine factors, to which slight changes can cause problems or damage to the nervous system. For example, high glycine concentration disrupts temperature and blood pressure control, and high CSF pH causes dizziness.
4. **Clearing waste:** CSF allows for the removal of waste products from the brain, and is critical in the brain's lymphatic system. Metabolic waste products diffuse rapidly into CSF and are removed into the bloodstream as CSF is absorbed.

SPINAL CORD

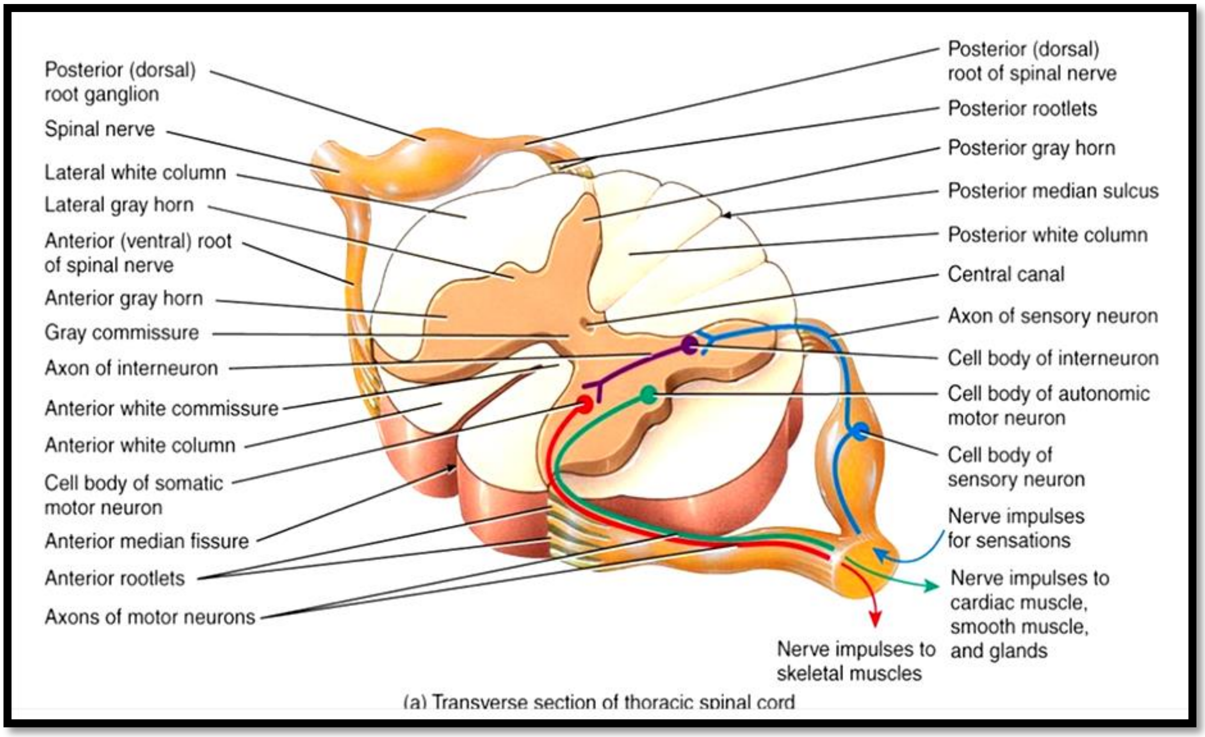
INTRODUCTION

The spinal cord is the most important structure between the body and the brain. The spinal cord extends from the foramen magnum where it is continuous with the medulla to the level of the first or second lumbar vertebrae.

It is a vital link between the brain and the body, and from the body to the brain. The spinal cord is 40 to 50 cm long and 1 cm to 1.5 cm in diameter.

Two consecutive rows of nerve roots emerge on each of its sides. These nerve roots join distally to form 31 pairs of **spinal nerves**.

The spinal cord is a cylindrical structure of nervous tissue composed of white and gray matter, is uniformly organized and is divided into four regions: cervical (C), thoracic (T), lumbar (L) and sacral (S), (Figure 3.1), each of which is comprised of several segments. The spinal nerve contains motor and sensory nerve fibers to and from all parts of the body. Each spinal cord segment innervates a dermatome.



A **dermatome** is an area of skin that is mainly supplied by a single spinal nerve

General Features

1. It carries sensory information (sensations) from the body and some from the head to the central nervous system (CNS) via afferent fibers, and it performs the initial processing of this information.
2. Motor neurons in the ventral horn project their axons into the periphery to innervate skeletal and smooth muscles that mediate voluntary and involuntary reflexes.

3. It contains neurons whose descending axons mediate autonomic control for most of the visceral functions.
4. It is of great clinical importance because it is a major site of traumatic injury and the locus for many disease processes.

Segmental and Longitudinal Organization

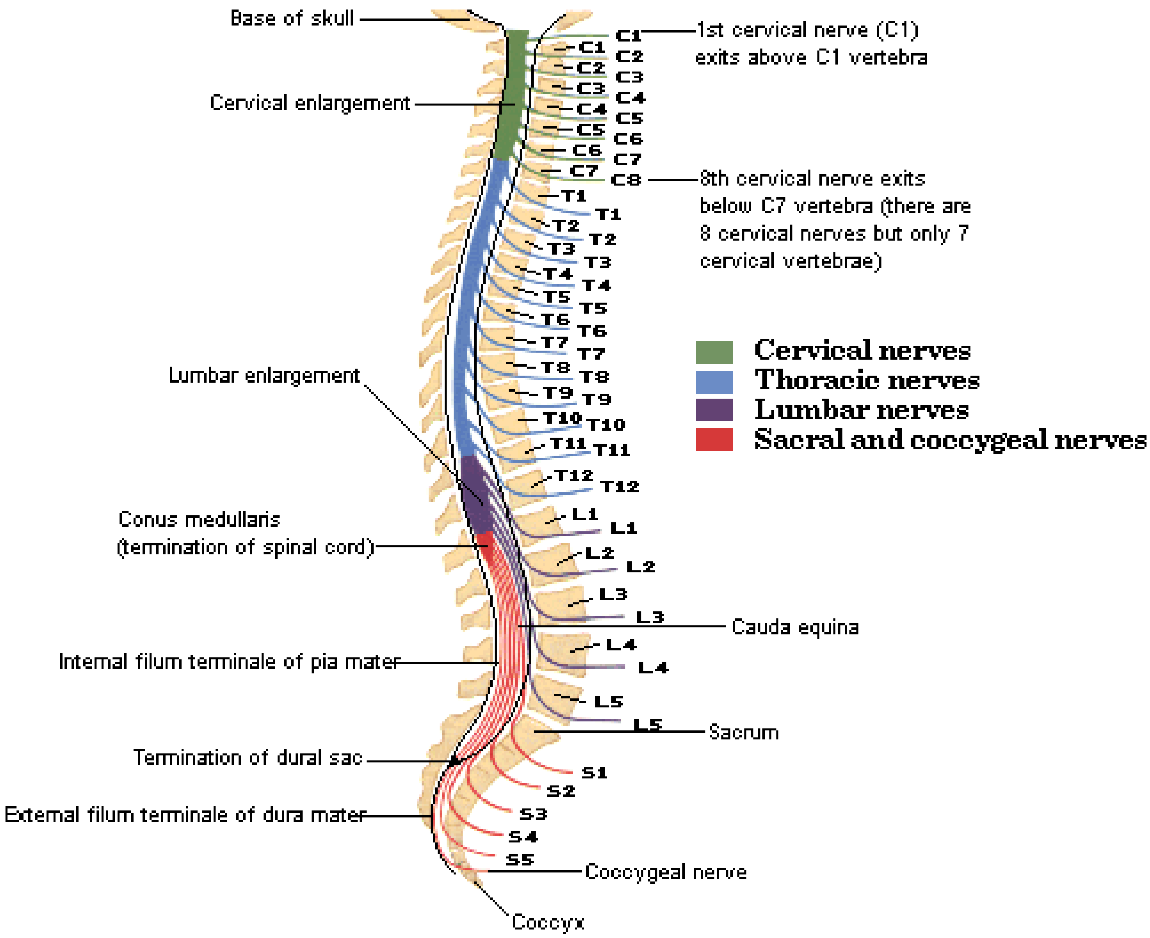
The spinal cord is divided into four different regions:

Cervical, thoracic, lumbar and sacral regions

The cord is segmentally organized. There are 31 segments, defined by 31 pairs of nerves exiting the cord. These nerves are divided into 8 cervical, 12 thoracic, 5 lumbar, 5 sacral, and 1 coccygeal nerve.

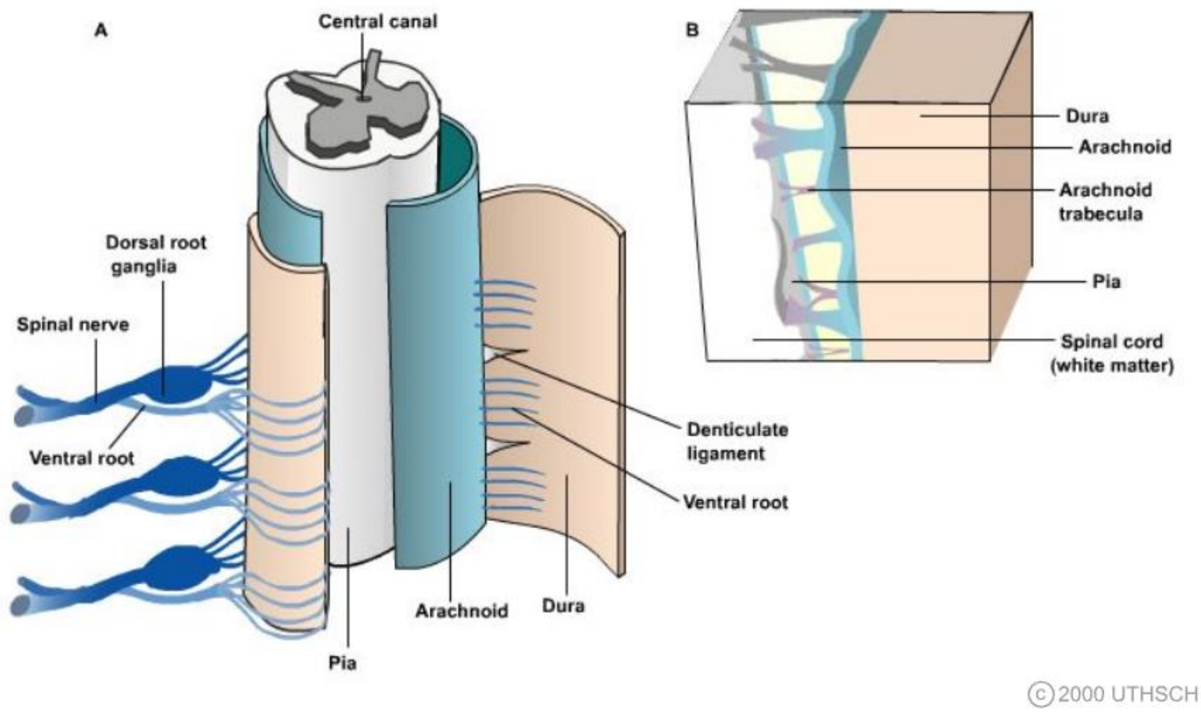
Dorsal and ventral roots enter and leave the vertebral column respectively through intervertebral foramen at the vertebral segments corresponding to the spinal segment.

Relation of Spinal Nerve Roots to Vertebrae



The cord is sheathed in the same three meninges as is the brain:

the pia, arachnoid and dura. The dura is the tough outer sheath, the arachnoid lies beneath it, and the pia closely adheres to the surface of the cord (Figure 3.3).



Internal Structure of the Spinal Cord

1. A transverse section of the adult spinal cord shows white matter in the periphery, gray matter inside, and a tiny central canal filled with CSF at its center.
2. Surrounding the canal is a single layer of cells, the ependymal layer. Surrounding the ependymal layer is the gray matter – a region containing cell bodies – shaped like the letter "H" or a "butterfly".
3. The two "wings" of the butterfly are connected across the midline by the dorsal gray commissure and below the white commissure (Figure 3.6). The shape and size of the gray matter varies according to spinal cord level.

White Matter

Surrounding the gray matter is white matter containing myelinated and unmyelinated nerve fibers.

These fibers conduct information up (ascending) or down (descending) the cord.

The white matter is divided into the dorsal (or posterior) column (or funiculus), lateral column and ventral (or anterior) column. The anterior white commissure resides in the center of the spinal cord, and it contains crossing nerve fibers that belong to the spinothalamic tracts, spinocerebellar tracts, and anterior corticospinal tracts.

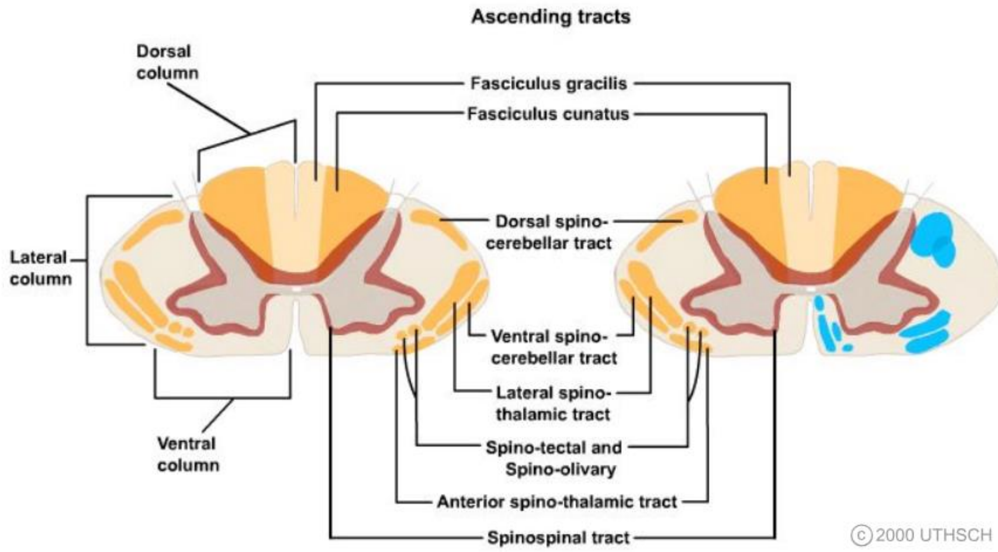


fig. 3.8

Spinal Cord Tracts

The spinal cord white matter contains ascending and descending tracts.

Ascending tracts (Figure 3.8).

The nerve fibers comprise the ascending tract emerge from the first order (1°) neuron located in the dorsal root ganglion (DRG). The ascending tracts transmit sensory information from the sensory receptors to higher levels of the CNS.

The ascending gracile and cuneate fasciculi occupying the dorsal column, and sometimes are named the dorsal funiculus. These fibers carry information related to tactile, two point discrimination of simultaneously applied pressure, vibration, position, and movement sense and conscious proprioception.

In the lateral column (funiculus), the neospinothalamic tract (or lateral spinothalamic tract) is located more anteriorly and laterally, and carries pain, temperature and crude touch information from somatic and visceral structures. Nearby laterally, the dorsal and ventral spinocerebellar tracts carry unconscious proprioception information from muscles and joints of the lower extremity to the cerebellum.

In the ventral column (funiculus) there are four prominent tracts:

1) the paleospinothalamic tract (or anterior spinothalamic tract) is located which carry pain, temperature, and information associated with touch to the brain stem nuclei and to the diencephalon

2) the spinoolivary tract carries information from Golgi tendon organs to the cerebellum

3) the spinoreticular tract

4) the spinotectal tract. Intersegmental nerve fibers traveling for several segments (2 to 4) and are located as a thin layer around the gray matter is known as fasciculus proprius, spinospinal or archispinothalamic tract. It carries pain information to the brain stem and diencephalon.

Descending tracts (Figure 3.9). The descending tracts originate from different cortical areas and from brain stem nuclei. The descending pathway carry information associated with maintenance of motor activities such as posture, balance, muscle tone, and visceral and somatic reflex activity. These include the lateral corticospinal tract and the rubrospinal tracts located in the lateral column (funiculus). These tracts carry information associated with voluntary movement. Other tracts such as the reticulospinal vestibulospinal and the anterior corticospinal tract mediate balance and postural movements (Figure 3.9). Lissauer's tract, which is wedged between the dorsal horn and the surface of the spinal cord carry the descending fibers of the dorsolateral funiculus (DFL), which regulate incoming pain sensation at the spinal level, and intersegmental fibers. Additional details about ascending and descending tracts are described in the next few chapters.

Ventral Root

Ventral root fibers are the axons of motor and visceral efferent fibers and emerge from poorly defined ventral lateral sulcus as ventral rootlets. The ventral rootlets from discrete spinal cord section unite and form the ventral root, which contain motor nerve axons from motor and visceral motor neurons. The α motor nerve axons innervate the extrafusal muscle fibers while the small γmotor neuron axons innervate the intrafusal muscle fibers located within the muscle spindles. The visceral neurons send preganglionic fibers to innervate the visceral organs. All these fibers join the dorsal root fibers distal to the dorsal root ganglion to form the spinal nerve (Figure 3.10).

3.12 Spinal Nerve Roots

The spinal nerve roots are formed by the union of dorsal and ventral roots within the intervertebral foramen, resulting in a mixed nerve joined together and forming the spinal nerve (Figure 3.10). Spinal nerve rami include the dorsal primary nerves (ramus), which innervates the skin and muscles of the back, and the ventral primary nerves (ramus), which innervates the ventral lateral muscles and skin of the trunk, extremities and visceral organs. The ventral and dorsal roots also provide the anchorage and fixation of the spinal cord to the vertebral cauda.