1. Details of Module and its structure

Module Detail	
Subject Name	Biology
Course Name	Biology 02 (Class XI, Semester - 2)
Module Name/Title	Neural Coordination - Brain and Spinal cord: Part – 2
Module Id	kebo_22102
Pre-requisites	Basics about brain and spinal cord.
Objectives	After going through this lesson, the learners will be able to understand the following: • get a clear conception regarding origin and development of central nervous system. • understand the structural organisation of brain and spinal cord • analyse the functioning of reflex action. • develop knowledge about the functioning of central nervous system.
Keywords	Neural tube, meninges, cerebrospinal fluid, thalamus, hypothalamus

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1. Introduction

Structurally and functionally the central nervous system constituting brain and spinal cord is most complicated and amazing system of hmass euman body.

Central nervous system along with its nerves maintain neural coordination between external and internal environment.

Understanding a question and giving reply, dreaming, feeling emotional after watching a movie:- the neural processes for conducting these activities take place in different parts of brain.

Brain can be compared with a super computer which receives stimulus, process it with the help of previous experience stored as memory and expresses in the form of response.

Brain is made up of 100 billion neurons and 10-50 trillion neuroglia. Brain in average has a mass of 1300-1600 gms; male brain possessing more mass than female brain.

During the animal evolution, 'cephalisation' a unique process of brain formation occurred.

2. Central Nervous System

Central Nervous System is rightly named as locationwise it occupies central axial postion and functionally it is the main part of neural system.

2.a Origin and development of Central Nervous System

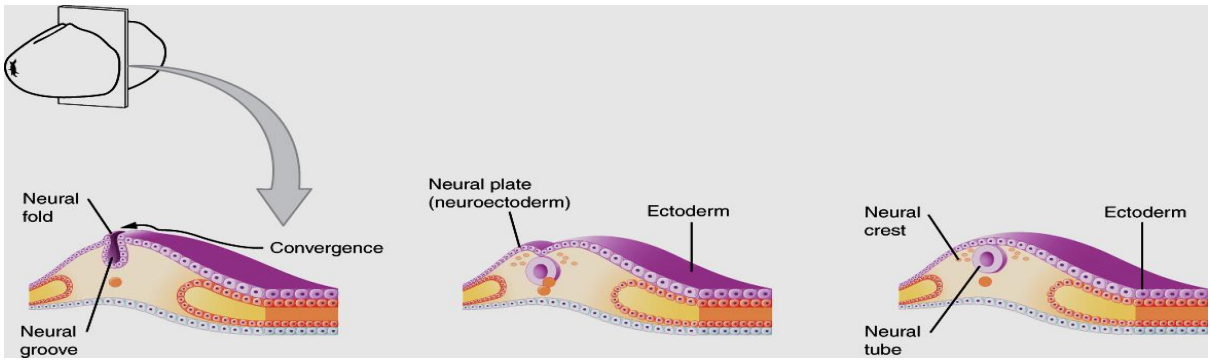
Brain development starts in three week old embryo. The developmental sequences are as follows:

- At the dorsal side of the embryo the ectoderm layer thickens along the mid dorsal axis of the embryo to form a **neural plate** .
- Neural plate invaginates to raised lateral structures called **neural folds,** flanked by neural plates to form **neural groove.**

- The neural groove gradually deepens and the upper edges of neural folds fuse to form **neural tube** which later detaches from the surface ectoderm and sinks to deeper layers.
- Neural tube which has been formed during the fourth week of pregnancy develops into CNS. The brain is formed from the anterior region and spinal cord is formed from the caudal region.
- Small groups of cells detach from neural folds and go down and occupy position in between surface ectoderm and neural tube and forms **neural crest.** Some neurons which are located inside ganglia arise from neural crest.

As soon as the structure of neural tube has been established, its anterior end begins to expand and gets marked by constrictions to form three **primary brain vesicles.** From anterior to posterior, these are **Prosencephalon** or fore brain, **Mesencephalon** or Mid brain and **Rhombencephalon** or Hind brain; the rest of the neural tube becomes spinal cord.

In fifth week of pregnancy, primary brain vesicles get modified to **Secondary brain vesicles.** The Prosencephalon or Fore brain divides into **Telencephalon** and **Diencephalon** and **Rhombencephalon** constricts into **Metencephalon** and **Mylencephalon.**



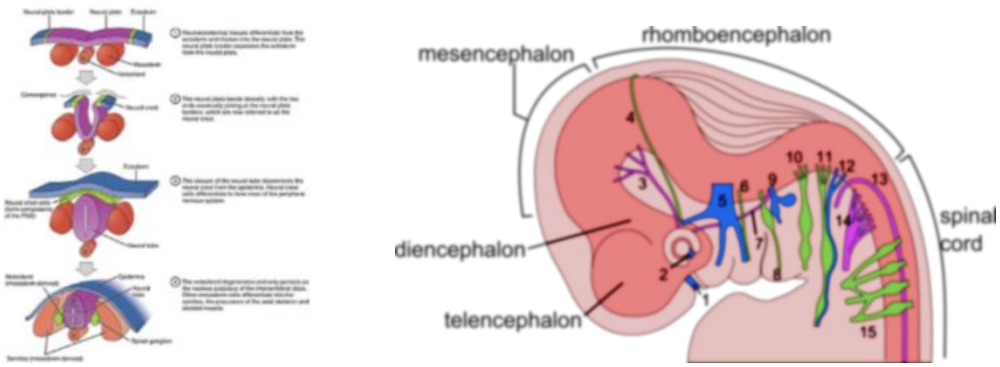


Fig. 2 A diagram showing the brain and major nerves of a 6 week old human fetus.

i. olfactory
ii. optic
iii. oculomotor
iv. trochlear

v. trigeminal sensory
vi. trigeminal motor
vii. abducens
viii. facial
ix. vestibulocochlear
x. glossopharyngeal
xi. vagus
xii. cranial accessory
xiii. spinal accessory
xiv. hypoglossal
xv. cervical I, II, III and IV

The five vesicles, telencephalon, diencephalon, metencephaalon, myelencephalon and rhombencephalon expand and modify into adult brain.

Telencephalon develops two lateral outgrowths which expand and form **Cerebral hemispheres.** Two cerebral hemispheres are collectively called as **Cerebrum**. The diencephalon undergoes specialisation and forms **hypothalamus** and **epithalamus**.

Mesencephalon, metacephalon and myelencephalon do not undergo much changes and form **midbrain**, **pons** and **cerebellum** and **medulla oblongata** respectively. All these parts except cerebellum form **brain stem**.

The space at the centre of neural tube remains continuous and enlarges at four specific regions to form **ventricles**.

As the space within cranium is much less compared to the vast enlargement taking place in brain, so the brain experiences posterior and lateral pressure due to which the fore brain bends towards the brain stem. Forebrain is forced to take a horse shoe shape and grows posteriorly and laterally. During the growth, forebrain completely grows over **diencephalon** and **midbrain**.

By 26^{th} week, the continued growth of cerebral hemispheres causes the surfaces to form creases forming **gyri** and **sulci**. These creases cause accommodation of larger number of neurons.

Central nervous system occupies the central and axial position in the body. Functionally also it occupies central and main part in neural coordination. It consists of two major parts; **Brain** and **Spinal cord**. Central nervous system remains protected by protective coverings.

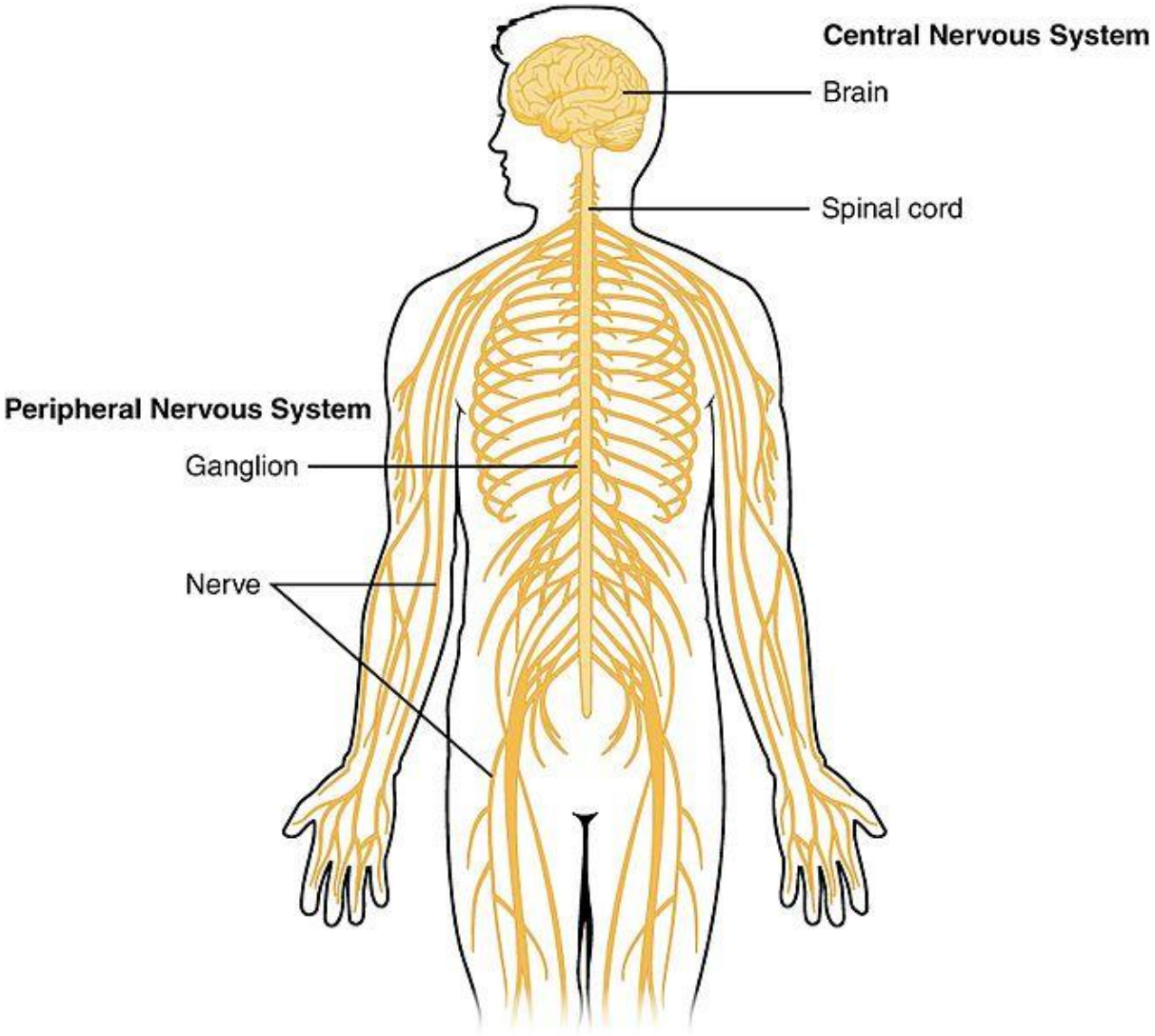


Fig. 3. **Central nervous system and Peripheral nervous system**

Protective covering of Brain

Central nervous system is protected by (i) **Bony covering** (ii) **Meninges** (iii) a **protective fluid.** Apart from that brain is also protected from harmful substances of blood from **blood brain barrier**.

(i) **Bony covering** Brain is protected by bony **cranium**, commonly called as **brain box**. The vertebral foramina of all the vertebrae are placed one above the otherto form a tubular vertebral canal, surrounded by vertebrae. Mspinal cord runs through this vertebral column and remain protected by vertebrae.

The skull consists of 22 bones, which are broadly divided into facial bones (14) and cranial bones (08). The cranial bones are joined together by immovable joints to form cranial cavity, which encloses and protects the brain.

(ii) **Meninges** Meninges are connective tissue covering which is the second level protection for CNS. Cranial meninges cover brain and spinal meninges cover spinal cord.

The three parts of meninges are similar in both cranial and spinal meninges. The three meninges are the (a) outer **duramater** (b) middle **arachnoid mater** and (c) innermost **piamater**. These three connective membranes lie outside the CNS organs and inside cranium and vertebral column.

(a) Duramater It is the outermost and toughest layer, made up of fibrous connective tissue. It is two layered where it surrounds the brain and single layered in spinal cord. At several places, the duramater extends inwards to form partitions in cranial cavity. These flat partitions known as dural septa which limit excessive movements of brain within the cranial cavity.

(b) Arachnoid cavity: The middle meninx, the arachnoid mater forms a loose covering. Below the arachnoid space is present **subarachnoid space.**

(c) Piamater: It is composed of delicate connective tissue and is richly supplied with blood vessels. It clings tightly with brain.

(iii) Cerebrospinal fluid: CSF is found in and around brain and spinal cord. It forms a liquid cushion and provides buoyancy to the brain. It reduces the weight of brain by 97% and protects it from getting crushed. CSF protects the brain and spinal cord from jerks and bolts. It also provides nourishment to the brain.

2b. Organisation of Central Nervous System

The neural system can be broadly divided into central nervous system and **peripheral nervous system**. (Peripheral nervous system is already discussed in Module-1).

The central nervous system consists of **brain** and **spinal cord**. The skull encloses the brain, which is made up of about 10^{11} neurons. Twelve pairs of cranial nerves arise from the base of the brain. Each nerve consists of hundreds to thousands of axons of neurons, bundled together along with connective tissues. Each nerve follows a definite path and performs a single and particular function.

The spinal cord is connected to the brain through **foramen magnum** (a large space present at the lower side of the skull). Spinal cord is encircled by vertebral column. Thirty one pairs of nerves arise from left and right lateral side of spinal cord. Each spinal nerve performs a specific function and serves a particular part.

2c. Parts of Brain

Brain is a soft, pinkish brown structure located safely inside cranium. Brain is made up of neurons and neuroglia.

Structurally brain consists of many parts. Each part performs one or more than one functions. Brain is divided into three parts : (a) **Fore Brain** (b) **Mid Brain** (c) **Hind Brain.** Hollow ventricular chambers are filled with cerebrospinal fluid. Ventricles are spaces in the brain which arise due to expansions of neural tube lumen at embryonal stage.

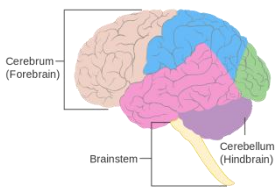
Fore brain It consists of **cerebrum**, **thalamus** and **hypothalamus.** Cerebrum is the most conspicuous part of brain and occupies about 83% of total mass of brain During development, forebrain is forced to take a horse shoe shape and grows posteriorly and laterally and thus it completely grows over **diencephalon** and **midbrain**. Almost the entire surface of cerebral hemispheres is marked by elevations made up of tissues, called **gyri** (singular gyrus) and furrows, called as **sulci** (singular sulcus). Deeper and prominent furrows are called '**fissures**'. Median longitudinal fissure divides cerebral hemispheres. Another transverse fissure separates cerebrum from cerebellum.

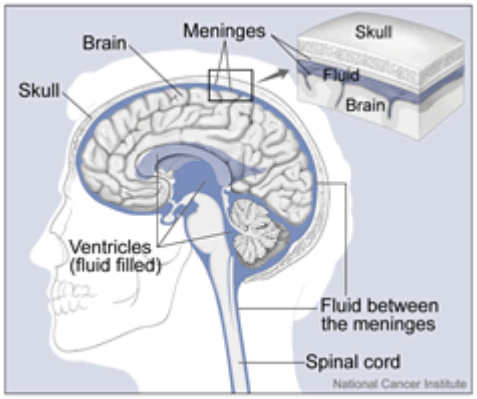
Cerebral hemisphere is divided into five lobes- frontal, parietal, temporal, occipital and insula. The **central sulcus** separates frontal lobe from parietal lobe. Occipital lobe which lies at the posterior part of brain is separated from the parietal lobe by **parietal occipito sulcus**. The **lateral sulcus** separates temporal lobe from the overlying parietal and frontal lobes. The fifth lobe insula lies deeply buried within lateral sulcus and forms a part of it. The insula is surrounded by parts of temporal, parietal and frontal lobes and can not be seen on the surface view.

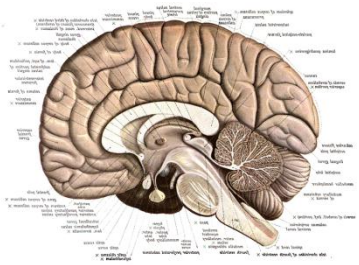
Two cerebral hemispheres are connected by **corpus callosum**, a band of white matter. It consists of several millions axon which maintains homotopic and heterotopic interhemispheric connections. Corpus callosum helps to transfer information between two hemispheres. Severing corpus callosum hampers sharing of information between the right and left hemispheres and result in cognitive development, learning and behavioural changes.

Encircling corpus callosum and upper part of brain stem is present **limbic system.** The lower part of limbic system is located on the floor of diencephalon. Limbic system is called as "emotional brain" as it plays a vital role in the expression of many feelings like pleasure, anger, fear etc. **Amygdala** is a pair of almond shaped set of neurons is located medially deep inside the temporal lobe is structurally belongs to basal ganglia but functionally a part of limbic system. It plays a key role in processing of memory, emotional responses, decision making etc. amygdala has been found to be associated with emotional responses related to fear, anxiety and aggression. It also plays prime role in emotional learning and retention of emotional memories. Damage of both the amygdala in persons results in loss of certain kinds of fear for example, fear of snakes, wild animals or held at gunpoint etc.

Hippocampus is another important constituent of limbic system. There are two hippocampus on either side of brain in vertebrates and human. It is involved in the formation of new memories and is also associated with learning and emotions. The damage of one or both the hippocampus by diseases like Alzhemier's or due to some accidents causes loss of memory and inability to form long term memory.







Each part of cerebral hemisphere has three basic regions (i) Cerebral cortex lying superficially looks grey in fresh brain tissue, so called "**grey matter**".(ii) an internal "**white matter"** mainly constituting myelinated nerve fibres and (iii) **basal nuclei.**

Seated quite deeply in cerebral hemispheres are present three masses of grey matter which are called **nuclei.** These nuclei are collectively called as **basal nuclei**. Main function of basal ganglia is to initiate and terminate movements of the body. Basal ganglia also influence many functions of cerebrum like cognitive, sensory, linguistic etc.

Cerebral cortex This is the region where resides our conscious mind. This region enables us to think, remember, communicate, understand, initiate voluntary movements. This part consists of neuron cell bodies, dendrites and unmyelinated nerve fibres.

In 1906, K. Brodmann mapped cerebral cortex and numbered 52 areas, now known as **Brodmann area.**

Cerebral cortex possesses three functional areas (i) **Motor area** lies in the posterior part of the frontal lobes and it controls voluntary movements. (ii) **Sensory area** is concerned with conscious awarenessof sensation. These areas lie in the parietal, temporal and occipital lobes. (iii) **Association area** communicates with the motor area and sensory area and analyse the sensory inputs with the help of previous experience and memory and help to act.

Each cerebral hemisphere is basically associated with intelligence, the ability to read, write, speak, composing music, making calculations, imagination, storing memories etc. It has been found maximum metabolic activities and blood flow take place in cerebral cortex.

Cerebral hemispheres are used for almost all the human activities. Although structurally both the hemispheres look similar but functionally each of the hemispheres possesses unique

ability of its own. This is known as lateralization. In most of the persons, left hemisphere has greater control over language, mathematics and logic. The right hemisphere is more free spirited. It has more dominant control over spatial skills, artistic and musical skills, intuition etc. usually right dominant cerebral cortex people are usually left handed.

Diencephalon constitutes thalamus, hypothalamus and epithalamus which extend from cerebrum to brain stem. Diencephalon is the central core and remains surrounded by the cerebral hemispheres. It measures about 3 cm. in length.

Thalamus

The thalamus makes up 80% of diencephalon.it remains deeply seated, well hidden inside brain. Thalamus is the main site for relay for most sensory impulses that reach the primary sensory areas of the cerebral cortex from the spinal cord and brain stem. Nerve impulses between different areas of the cerebrum are relayed by thalamus. This activity is of great importance as it maintains consciousness.

Hypothalamus

It is located inner to the thalamus and is comparatively a smaller part of diencephalon. Irrespective of its size it controls a great number of functions. It is one of the major regulator of homeostasis. Some of the important functions are as follows:-

- Hypothalamus controls the activities of pituitary gland by secreting releasing hormones and inhibitory hormones. These hormones respectively activate and inhibit the release of anterior pituitary hormones.
- Hypothalamus along with limbic system controls the emotional and behavioural patterns. They regulate the expression of pleasure, anger, fear etc.
- Hypothalamus regulates circadian rhythm and maintains consciousness.
- Hypothalamus possesses a feeding and thirst centre. It controls the food intake by satiating feeling.

Epithalamus

It is small and most dorsal region of diencephalon. It lies posterior to thalamus. It consists of **Pineal gland.** Pineal glans secretes hormone melanin which induces sleep signal. Thus epithalamus along with hypothalamus regulates sleep wake signal.

Brain stem

It is the part of brain located between diencephalon and spinal cord. Being situated in between cerebrum and spinal cord, brain stem coordinates the functioning between the brain and the rest of the body by communicating information. It is responsible for controlling important body functions like blood pressure, heart rate, breathing, swallowing, consciousness etc.

Brain stem consists of **mid brain, pons** and **medulla oblongata**.

Mid Brain

Mid brain is also called as **mesencephalon** is located between diencephalon and pons. It is quite small and is about 2.5 cm. long. A hollow duct (**cerebral aqueduct**) runs through mid-brain and connects third and fourth ventricle.

Function

It helps in performing important functions in motor activities like eye movement, auditory and visual processing; for example- spatial relationship of the objects in relation to the position of the viewer.

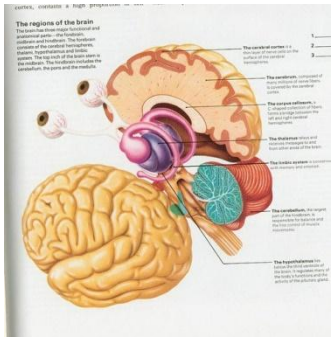


Fig. Section through brain

Hind Brain

Hind brain also known as **rhombencephalon** consists of (i)Pons (ii) Medulla oblongata and (iii) Cerebellum.

(i) Pons

It lies between mid-brain and medulla oblongata. It is located above the medulla and anterior to the cerebellum. It is swollen brain stem region and is about 2.5 cm. long.

Function

In association with medullary respiratory centre, pons helps to maintain normal rhythm of breathing.

(ii) Medulla oblongata

Medulla oblongata or simply medulla is the most inferior part of brain stem. It merges below with spinal cord. It is conical in shape. The cavity of spinal cord extends upward and expands in the medulla to form fourth ventricle.

Functions

Although medulla is very small in size but it controls many important vital functions some of these functions are as follows:-

- Cardiac centre located in medulla adjusts the rate of contraction of heart to meet body's need.

- Respiratory centre controls rate of respiration on negative feedback. In association with pons, it regulates breathing rhythm.
- Medulla oblongata also nregulates sneezing, hiccups, vomiting, coughing and swallowing.

(iii) Cerebellum

(iv) It is located at the top part of brain stem.

Cerebellum

It is cauliflower shaped part of brain located dorsal to pons and medulla and protrudes under occipital lobes. It is bilaterally symmetrical, consisting two cerebellar hemispheres connected by a narrow **vermis**.

Function

- It maintains posture and balance of the body.
- Cerebellum plays a role in cognition and problem solving.

2.d Spinal cord

Origin

Spinal cord develops from the caudal portion of embryonic neural tube.

Spinal cord is about 42 cm. or 17 inches long, 1.8 cm. in width glistening white, tubular structure occupying the axillary position in the body.

Protective covering

Spinal cord extends from the foramen magnum of skull at the level of first and second lumbar vertebrae. It is located within the vertebral canal of vertebral column. The vertebrae provide the main protection to spinal cord, vertebral ligaments, meninges and cerebrospinal fluid.

Meninges

Brain and spinal cord are protected by three connective tissue covering called meninges. Meninges covering spinal cord is called **spinal meninges.** Like cranial meninges spinal meninges also consists of **dura mater**, **arachnoid mater** and **pia mater**. Between dureamater and arachnoid spacean interstitial fluid filled **subdural space** is present.another cushion of fat and connective tissue located inside **epidural space** (a space between vertebral column and duramater) provides additional protection to spinal cord.

Piamater, the innermost meninx is a thin layer closely adhered to the spinal cord. It is richly supplied with blood capilleries, which supply nutrients and oxygen.

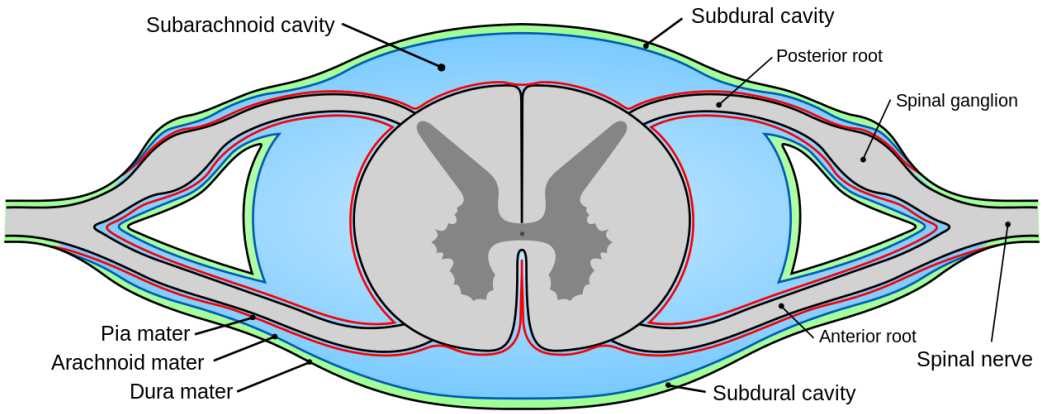


Fig. **Sectional view of Spinal cord**

Anatomy of spinal cord

External anatomy

Spinal cord is roughly cylindrical and slightly flattened anterior posteriorly. During early childhood, vertebral column and spinal cord grow simultaneously At the age of 4-5, the growth of spinal cord stops but the growth of vertebral column continues. As a result, in adults, the spinal cord does not reach the tip of the vertebral column.

Internal anatomy

Cross sectional view of spinal cord shows it to be flattened from front to back with two grooves marking its surface. One of these grooves is deeper and is called **anterior median fissure** and another less shallower is called **posterior median sulcus.** Cross section of spinal cord reveals white matter encircling grey matter occupying the innermost core in the form of 'H' or 'butterfly' shape. White matter basically consists of myelinated axons of neurons. Grey matter mainly consists of dendrites, cell bodies, unmyelinated axons and neuroglia. At the centre of grey matter is present a **central canal**.

The grey matter on each side of the spinal cord is subdivided into regions called 'horns'. The posterior (dorsal) grey horns consist of cell bodies and axons of interneurons and axons of incoming sensory neurons. The anterior(ventral) grey horns contain the cell bodies of somatic motor neurons and some interneuron.

Poliomyelitis virus destroys anterior horn motor neurons. Early symptoms include fever, headache, muscle pain and weakness. Later paralysis occurs and patients may die due to paralysis in respiratory tract.

Reflex action and Reflex arc

Spinal cord along with spinal nerves together controls some of the rapid human responses to sudden environmental changes. When unknowingly we pick up a hot object the muscles grasping the object may suddenly relax and the object is dropped. This sudden response is called **reflex action**.

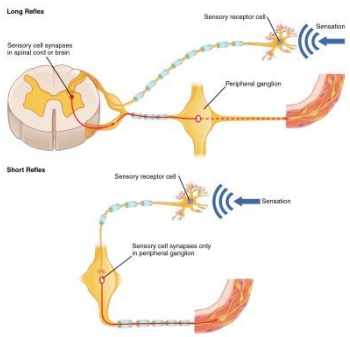


Fig. Reflex Arc

Reflex action is performed through a specific neural pathway called as **reflex arc**. Reflex arc possesses five components. These are (i) **Receptors**- site of stimulus (ii) **Sensory neurons** transfer afferent impulses to central nervous system (iii) **Integration centre** consists of short interneurons which form synapse between sensory neurons and motor neurons. (iv) **Motor neurons** conduct efferent impulses from the integration centre to an effector organ. (v) **Effectors** are muscle fibres or glands which respond to efferent impulses and undergo contraction or secretion respectively.

2.e Functions of Brain and Spinal cord

- Brain controls thought, emotions, behaviour and many basic life activities like maintaining breathing rhythm, blood pressure etc. it stores memory, enables learning, reading, writing, problem solving, analysing, interpretation by observing other's activity. Cerebellum maintains posture and maintains equilibrium. It regulates secretion of hormones.

- Spinal cord collects large amount of information coming to it through peripheral nervous system and transmits to the brain. It also protects the body from sudden environmental changes by responding through reflex action.

Summary

- Central nervous system constitutes brain and spinal cord.
- Brain and spinal cord are protected by several protective covering like bony case, connective tissue layer, cerebrospinal fluid etc.
- Brain is the seat of intelligence, analysis, thought, memory storage, emotions, creativity etc.
- CNS receives responses from sense organs and coordinates the functions of the body.