Nervous system

Group of organs that control and co-ordinate the activities of various parts of the body in response to external and internal stimuli is called Nervous system. This system receives the information from all the parts of body through receptor or sense organs and responses through effector organs. It is divided into three types;

A. **Central Nervous System**
B. **Peripheral Nervous System**
C. **Autonomic Nervous System**
A. **Central Nervous System**

It occupies the central placed of body along the mid-dorsal axis. It includes brain and spinal cord.

I. **Brain**

It is a soft, highly convoluted, semi-spherical and hollow fluid filled mass that lodged in the cranium of skull. It is weighted about 1220 to 1400 grams and consists of 100 billion of neuron. It is made of outer grey matter and inner white matter. The cavities present in the brain are called ventricles that filled up by fluid called cerebrospinal fluid. It is covered by three layers membranes called meninges. Outermost tough and fibrous layer is called Dura matter. Middle thin, delicate and spider webby layer is called Arachnoid membrane and innermost thin, soft and vascular layer is called Pia matter. Space present between dura matter and arachnoid membrane is called Sub-Dural space that fills up with body fluid and Space present between arachnoid membrane and pia matter is called Sub-arachnoid space that fills up with cerebrospinal fluid. This fluid protects the brain from mechanical shocks and infection, maintain the pressure and provides the medium for exchange of materials. Brain is divided into three parts;

1. **Fore brain or Prosencephalon -**
2. **Mid brain or mesencephalon**
3. **Hind brain or rhombencephalon**
1. **Fore brain or Prosencephalon**

It is divided into three parts; **Olfactory lobes, Cerebrum and Diencephalon**.

a. **Olfactory lobes**

A pair of small club shaped structures present at anterior most part of fore brain is known as olfactory lobes, which are fully covered by cerebral hemispheres. Although they are concern for the sense of smell, they are poorly develop and incorporated with cerebrum in human.

b. **Cerebrum**

It is a largest part of the brain and divided into two parts; right and left cerebral hemispheres by a deep median longitudinal groove. These two hemispheres are connected with each other by a thick band of nerve fibers called Corpus callosum. They enclose the cavities known as first and second lateral ventricles (or paracoels). Each cerebral hemisphere has outer highly convoluted appearance due to presence of ridges (gyri) and depression called groove or fissure or sulcus. Each hemisphere is divided into four lobes; frontal, parietal, occipital and temporal lobes by three deep and wide fissures. [The fissure present between frontal and parietal lobes is called central sulcus, the fissure present between frontal and temporal is called lateral sulcus and fissure present between the parietal and occipital is called parieto-occipital sulcus.] Each hemisphere has three functional areas; **sensory, association and motor areas** for coordination, control and respond various activities.

Functions:

- It is main coordinating center of brain and has different areas for control of different motor and sensory activities.
- It is a place in which highly complicated activities like thought, reasoning, memorizing, learning and intelligence etc. are occurred.
- It controls the will, speech and many reflex actions like laughing, weeping and micturition reflex actions etc.
- It interprets various sensation and stimuli like **parietal lobe** responds for heat, cold, pain, touch and taste etc., **Occipital lobe** responds for vision, **temporal lobe** for hearing and **frontal lobe** for association of various sensation and voluntary muscles movement.

c. Diencephalon

It is a posterior small part of fore brain that completely covered by cerebral hemispheres. The cavity present in it is called third ventricle or diacoel [which connected anteriorly with first and second ventricle through small passage called foramen of Monro.] Its dorsal thin wall is called epithalamus. Anterior part of epithalamus is highly vascular and folded called Anterior choroid plexus and posterior part consists of a short pineal stalk with a small rounded pineal body at its tip. Lateral thick walls of diencephalon are called optic thalami or thalami. The ventral wall of diencephalon is called hypothalamus which is composed mainly of neurosecretory cells. The hypothalamus is connected with ventrally present pituitary gland by a stalk called infundibulum. Infront of pituitary gland, optic nerves cross with each other to form ‘X’ shaped, the optic chiasma.

Functions:

- It acts as processing, integrating and relaying center for all sensory information come from different parts of body to corresponding sensory areas of cerebral hemispheres.

- Hypothalamus is coordinating and controlling center for Autonomic Nervous system.
- Hypothalamus is also controlling center of homeostasis functions like osmoregulation, thermoregulation etc. and various aspect of mood and emotions like aggression, rage, fear, pleasure, hunger, thirst, satiety etc.
- Hypothalamus secretes neurohormones and anterior choroid plexus secretes cerebrospinal fluid.

2. Mid brain

It is constricted part that lies in between cerebrum (above) and pons-varolii (below). It encloses a narrow longitudinal passage called Aqueduct of Sylvis or Iter that connects the third ventricle with fourth ventricle. The dorsal part of it consists of four small, solid and rounded structures, the Optic lobes or Corpora quadrigemina. Anterior two lobes are called superior colliculi and posterior two lobes are, the inferior colliculi. Ventral surface of mid brain contains two thick bundles of nerve fibers known as Crura cerebri which connect cerebrum and diencephalon with hind brain and spinal cord.

Functions:

- Superior colliculi control the visual reflex action and Inferior colliculi control the auditory reflex action.
- Crura cerebri transmit the impulses from hind brain and spinal cord to cerebrum and vice versa.

3. Hind brain

It is posterior most part of brain and consists of three parts; **dorsal cerebellum, ventral pons varolii and medulla oblongata.**

a. Cerebellum

It lies just below and posterior to cerebral hemispheres. It has outer highly convoluted appearance. It is divided into three lobes; two lateral cerebellar hemispheres and one median worm like vermis.

Functions: It controls and coordinates the functions of voluntary muscles and also concerns with balance of the body.

b. Pons varollii

It lies just in front of cerebellum, below the mid brain and above the medulla oblongata. It is composed of mainly white matter. It is only present in mammalian brain.

Functions: It acts as bridge to relay the impulses between cerebellum, spinal cord and rest of parts of brain.

c. Medulla oblongata

It is a pyramid shaped posterior most part of brain that lies beneath the pons varolii. It emerges out from cranial cavity through foramen magnum and then connects with spinal cord. It encloses a cavity called fourth ventricle that posteriorly connected with central canal of spinal cord. Its dorsal thin, highly vascular and non-nervous folded wall is called posterior choroid plexus that secretes the cerebrospinal fluid. Its lateral walls are thick and formed by white matter that continues with spinal cord.

Functions:

- It receives and integrates the impulses from spinal cord and send to cerebellum and thalami.
- It contains various centers that regulate the blood pressure, breathing rates, swallowing, salvation, sneezing, vomiting, coughing and other involuntary movements.

[Note: **Brain stem**- mid brain, pons varolli and medulla oblongata are collectively known as brain stem that connects the fore brain with spinal cord.]

II. Spinal cord

It is a long (42-45 cm), hollow, thick-walled nerve tube that present at mid dorsal axis of the body and runs through the neural canal of vertebral column. It starts from posterior part of the medulla oblongata and extends up to the level of second lumbar vertebra. It terminates posteriorly into a non-nervous fibrous tissue (Filum terminalis). It is enlarged in cervical and lumber regions at levels of fore limbs and hind limbs respectively. It encloses a cavity called central canal, communicating anteriorly with fourth ventricle of brain and fills up with cerebrospinal fluid. Its surface is somewhat flattened due to presence of mid dorsal and mid ventral fissures. It is also covered by three layers membranes called meninges. Outermost tough and fibrous layer is called Dura matter. Middle thin, delicate and spider webby layer is called Arachnoid membrane and innermost thin, soft and vascular layer is called Pia matter. Spaces present between these membranes are filled up with cerebrospinal fluid.

Histologically, it is made of outer white matter and inner ‘H’ shaped or butterfly shaped grey matter, surrounding the central canal. The grey matter is extended into either ventro-lateral and dorso-lateral side into two ventral and two dorsal horns. Ventral horn gives ventral root which in turn gives motor nerve and dorsal horn gives dorsal root which receives sensory nerve. Each spinal nerve formed by combination of sensory and motor nerves.

Functions

- It acts as a coordinating center for simple reflex actions like knee jerking and autonomic reflex actions like contraction of the bladder etc.
- It provides a medium for communication between spinal nerves and brain.

B. Peripheral Nervous System

The part of nervous system except brain and spinal cord is called peripheral nervous system. It includes the nerves arise from brain known as cranial nerves and nerves arise from spinal cord called as spinal nerves.

a. Cranial nerves

There are twelve pairs of cranial nerves that emerged from the ventral side of different parts of brain. They are following;

No. of cranial nerve	Name of cranial nerve	Place of Origin	Type of nerve fiber	Organs innervated	Function
I	Olfactory nerve	Olfactory lobe	Sensory	Olfactory epithelium in nose	Smell
II	Optic nerve	Optical lobe of cerebral hemisphere	Sensory	Retina of eye	Vision
III	Oculomotor nerve	Mid brain	Motor	Eyeball muscles, iridial muscles and ciliary muscles	Eye movement and accommodation
IV	Trochlear nerve	Mid brain	Motor	Superior oblique muscle of eyeball	Eye movement
V	Trigeminal nerve: 1. Ophthalmic 2. Maxillary 3. Mandible	Pons varolii	Mixed	Facial skin, muscle of mastication, lacrimal gland, conjunctiva, eyelids, mucous membrane of nose and mouth	Sensation of head and face, chewing movement
VI	Abducens nerve	Medulla oblongata	Motor	External rectus muscle of eyeball	Eyeball movement
VII	Facial nerve	Pons varolii	Mixed	Taste buds, salivary glands, facial and neck muscles	Sense of taste, secretion of saliva and Facial expression
VIII	Auditory nerve 1. Vestibular 2. Cochlear	Cerebellum	Sensory	Sensory cells of semicircular canal and Organ of Corti of cochlea of internal ear	Equilibrium and hearing
IX	Glossopharynx nerve	Medulla oblongata	Mixed	Pharynx, tongue and salivary glands	Taste, sensation, saliva secretion, swallowing
X	Vagus nerve	Medulla oblongata	Mixed	Pharynx, oesophagus, larynx, trachea, thoracic and abdominal viscera	Visceral reflexes like control heartbeat, respiratory rate, vomiting, swallowing etc.
XI	Accessory nerve	Medulla oblongata	Motor	Thoracic and abdominal viscera	Visceral reflexes and movement of head, shoulder, pharynx and larynx
XII	Hypoglossal nerve	Medulla oblongata	Motor	Muscles of tongue	Tongue movement

b. Spinal nerves

The nerves arise from spinal cord are called spinal nerves. There are 31 pairs of spinal; Cervical spinal nerves- 8, Thoracic spinal nerves- 12, Lumbar spinal nerves- 5, Sacral spinal nerves- 5 and Coccygeal spinal nerve- 1. Each spinal nerve arises from dorsal and ventral roots of either lateral halve of spinal cord. The dorsal root receives the sensory or afferent nerve fibers and has ganglion. The ventral root contains motor or efferent nerve fibers. Both the roots united in neural canal, forming single spinal nerve which leaves through intervertebral foramen from each side of vertebral column. Immediately after emergence, spinal nerve divides into three branches; dorsal, visceral and ventral branches. Dorsal branch supplies to skin and muscles of back, ventral branch supplies to lateral and ventral parts of body and visceral branch joins with sympathetic nervous system and supplies to visceral organs.

C. Autonomic Nervous system

It is the part of peripheral nervous system which controlled involuntary activities of body. The activities of autonomic nervous system are controlled by hypothalamus and medulla oblongata of brain. It is divided into types

i. **Sympathetic nervous system**
ii. **Parasympathetic nervous system**

i. Sympathetic nervous system

It includes a pair of long sympathetic nerve cords that are extended from skull to coccyx vertebrae, lying one on either side of vertebral column. Each sympathetic nerve cord bears 22 ganglia in linear series and connected with 15 corresponding spinal nerves through visceral branches in thoracic and lumber region. The sympathetic nerves innervate the visceral organs and glands etc. and their nerve endings release noradrenalin as neuro-transmitter. The stimulation of sympathetic nerves causes the activation of organs for action and they stimulated during danger, stress and excitation like increase the heart beat rate and blood pressure, dilate pupil of eye and bronchi etc.

ii. Parasympathetic nervous system

It is formed by the nerves araise from III, VII, IX and X cranial nerves and from II, III and IV sacral spinal nerves. The parasympathetic ganglia lie close to effector organs and have localized effects. The parasympathetic nerves innervate all the organs supply by the sympathetic nerves and their nerve endings release acetylcholine as neuro-transmitter. The stimulation of parasympathetic nerves calms down the organs and shows inhibitory homeostatic effect like decrease metabolic rate, heart beat rate and blood pressure, constrict the pupil and bronchi etc.

Neuron

1. **Neuron:** Neuron is structural and functional units of nervous system. It is the largest cell of human body and has capability of accumulate and store the electrical charge. Thus, it acts as electric capacitor.

Properties of neuron

- It is capable to undergo into an active state known as state of excitation in response to stimulus.
- It has capability to transmit the excitation from the place of its origin to particular direction along its entire length. This process is called conduction of nerve impulse.

2. **Stimulus:** Sudden change in external or internal environment, which is strong enough to excite the nerve fibers or neuron is called stimulus. It is two types;

i. **Adequate or threshold stimulus:** The stimulus that capable to excite nerve fibers is called adequate stimulus.

ii. **Inadequate or sub threshold stimulus:** The stimulus unable to excite nerve fibers is called inadequate stimulus.

iii. **Summation:** Initiation of nerve impulse or excitation in a neuron due to accumulative effect of series of sub-threshold stimuli that reach in rapid succession is called summation.

3. **Nerve Impulse:** Sum total of physical and chemical disturbance created in a nerve fiber by stimulus which travel along its length is called nerve impulse. Or Wave depolarization of cell membrane of neuron. Or Electro-chemical phenomenon in which flow of ions occurs across length of nerve fiber due to change in permeability of its cell membrane is called nerve impulse.

4. **Neuro-transmitter:** The chemical substance that responsible for transmission of nerve impulse across the synapse is called neurotransmitter. It is two types; noradrenalin and acetylcholine.

Physiology of nerve impulse conduction or Transmission of nerve impulse:
Transmission of nerve impulse consists of two main steps;

1. **Transmission of nerve impulse along the nerve fiber**
2. **Transmission of nerve impulse through synapse**

1. **Transmission of nerve impulse along the nerve fiber:**The transmission of nerve impulse along the nerve fiber consists of three steps;

a. **Polarization stage or Resting state**
b. **Depolarization stage or Action potential state**
c. **Repolarization stage**

a. **Polarization stage or Resting state:** Nerve fibers are bath in extracellular fluid, which contained a large numbers of sodium ions (Na^+ ions), chlorine ions (Cl^- ions), bicarbonate ions (HCO_3^-ions), nutrients, respiratory gases and metabolic wastes etc. While, the intracellular fluid or cytoplasm of nerve fiber contains potassium ions (K^+ ions), Magnesium ions, phosphorus ions and a large numbers of negatively charged protein and organic molecules etc. During resting state, a neuron or nerve fiber does not conduct a nerve impulse. At this state, positively charged Na^+ ions are dominated in extracellular fluid, forming a positive charge outside the plasma membrane, whereas positively charged K^+

ions and a large numbers of negatively charged protein and organic molecules are dominated in intracellular fluid, forming negative charge inside the plasma membrane. This electrochemical difference between outer and inner surface of the plasma membrane of nerve fiber is called membrane potential or resting potential and it is about 70-90 millivolts. During this state, plasma membrane is impermeable to Na^+ ions but permeable to K^+ ions.

b. Depolarization stage: When nerve fiber is excited by stimulus of adequate strength, a disturbance is developed at point of stimulation and suddenly changed the permeability of plasma membrane at that place. The plasma membrane, now, becomes permeable to positively charged Na^+ ions which diffuse rapidly from outside to inside. As a result, inner surface of plasma membrane becomes positively charged whereas outer surface developed negative charged. This reversal of charge than resting potential is called depolarization. This depolarization soon disturbs the adjacent part of plasma membrane and also generates depolarization. Thus, a wave of depolarization, known as nerve impulse or action potential, passes along the length of nerve fiber. The presence of myelin sheath in nerve fiber acts as insulator. Thus, in myelinated area of nerve fiber, depolarization jumps from one node of Ranvier to another. This type of conduction of impulse is called saltatory conduction. Myelin sheath increases the speed of conduction and avoid dispersion of impulse into adjacent fibers.

c. Repolarization: With increase of positively charged Na^+ ions in the intracellular fluid, the plasma membrane becomes impermeable to Na^+ ions but permeable to K^+ ions. Therefore, Na^+ ions are expelled out and K^+ ions are withdrawn inside against the concentration gradient by the active transport method with expenditure of energy is called Na-K pump or Na-K exchange pump or Na-pump. With the help Na-K pump, plasma membrane restores its original polarization state. This is called repolarization. This entire process of repolarization completes in 0.0004 second. This period is called refractory period. During this time nerve fiber cannot stimulate. After that the nerve fiber again ready for carrying another impulse.

2. Transmission of nerve impulse through synapse:

[Note: Structure of Synapse: Synapse is an area of functional contact between the one neuron to another for transmission of nerve impulses or information. It is usually found between the fine terminal branches of axon of one neuron to dendrite of another neuron. It consists of a bulbous expansion in fine terminal branch of axon of one neuron called pre-synaptic knob or bouton, lying close to the membrane of dendrite. The cytoplasm of pre-synaptic knob contains mitochondria, smooth endoplasmic reticulum, microfilaments and numerous synaptic vesicles. Each synaptic vesicle contains neurotransmitter. (There are two types of neurotransmitters; acetylcholine and nor adrenalin.) The membrane of pre-synaptic knob near to synapse is thickened and known as pre-synaptic membrane. The membrane of dendrite near the synapse is

also thickened called post-synaptic membrane. Pre and post-synaptic membranes are separated by a narrow gap called synaptic cleft. The postsynaptic membrane contains numerous numbers of channels and pores, a large number of protein molecules, which act as receptor for neurotransmitter.**]**

When an impulse or depolarization arrives at pre synaptic knob, Calcium ions from synaptic cleft enter into cytoplasm of it and cause the movement of synaptic vesicles to surface of pre synaptic membrane. They get attached and ruptured to release their neurotransmitter into synaptic cleft and then return to cytoplasm to refill again with neurotransmitter. The released neurotransmitter, then binds with protein receptor molecules of post synaptic membrane which change the membrane potential of it and open the channels and pores that allow the Na^+ ions into the dendrite and causes depolarization and generates action potential in post synaptic membrane. In this way impulse transmits from one neuron to another through the synapse. After changing the permeability of post synaptic membrane, neurotransmitter immediately hydrolyzes by enzyme and lost from synaptic cleft.