NERVOUS SYSTEM

The nervous system is a network of **neurons** whose main feature is to generate, modulate and transmit information between all the different parts of the human body. This property enables many important functions of the nervous system, such as regulation of vital body functions (heartbeat, breathing and digestion), sensation and body movements.

The nervous system consists of the highly specialized cells called the neurons. The functions of neurons is to detect and receive information from different sensory organs and then integrate them to determine the mode of response of the living organisms. The nervous system of higher organisms performs three basic functions such as receiving, processing and responding.

The functional unit of the nervous system is the neuron. The neurons have the characteristics of irritability and conductivity.

Function of Nervous system:

1. The stimuli or impulses are carried to CNS from muscles and vice versa.
2. Co-ordinates various organs system.
3. It stimulates and inhibits the activities of muscles, glands and viscera.
4. It helps to maintain the homeostatic condition.

Parts of nervous system:

1. Central nervous system (CNS):

It includes brain and spinal cord.

2. Peripheral nervous system (PNS):

It includes the nerves arising from CNS.

3. Autonomic nervous system (ANS):

It includes nerves and ganglia extending up to visceral organs. It works involuntarily.

Central nervous system (CNS)

1. Brain:

Brain is highly specialized delicate organ located in **skull or cranium**. It is about 1.2 to 1.4 kg. Cranium protects the brain from external injuries. It is composed of some soft nervous tissues covered by three layers known as **meninges**. The meninges are:

a. The outer layer is **duramater** which is just located below the skull. It is formed of highly vascular tough white fibrous tissue. It supports the brain and spinal cord.

b. The middle layer is **arachnoid** that is delicate and thin fibrous covering. It is separated from duramater by **subdural cavity.**

c. The inner layer is **piamater** which is thin, delicate and highly vascular. It is separated from arachnoid membrane by a **subarachnoid space**. The space is filled with spongy connective tissue and **cerebrospinal fluid** (**CSF**).

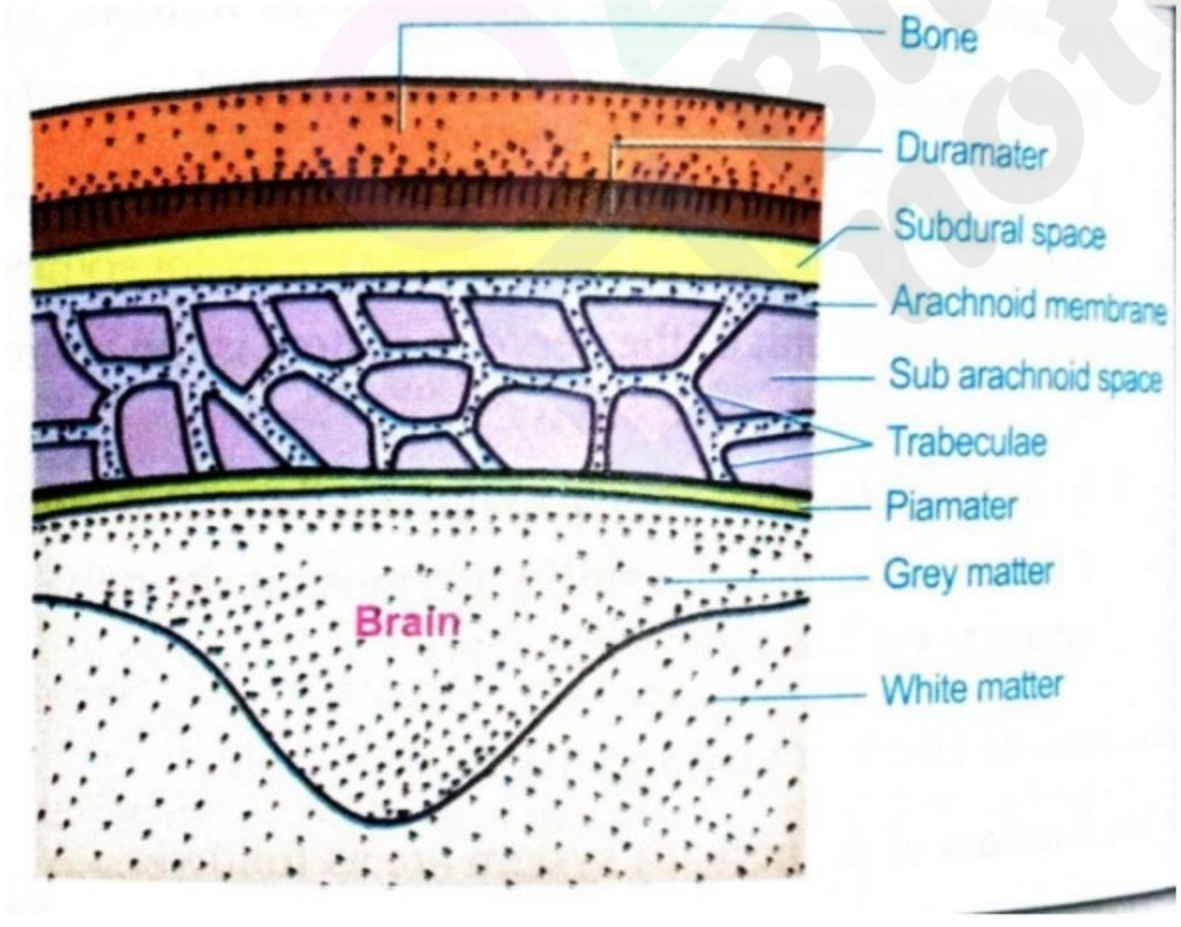


Fig: Brain meninges

Structure of human brain:

Human brain is divided into three parts;

1. **Fore brain** (Prosencephalon)
2. **Mid brain** (Mesocephalon)
3. **Hind-brain** (Rhombencephalon)

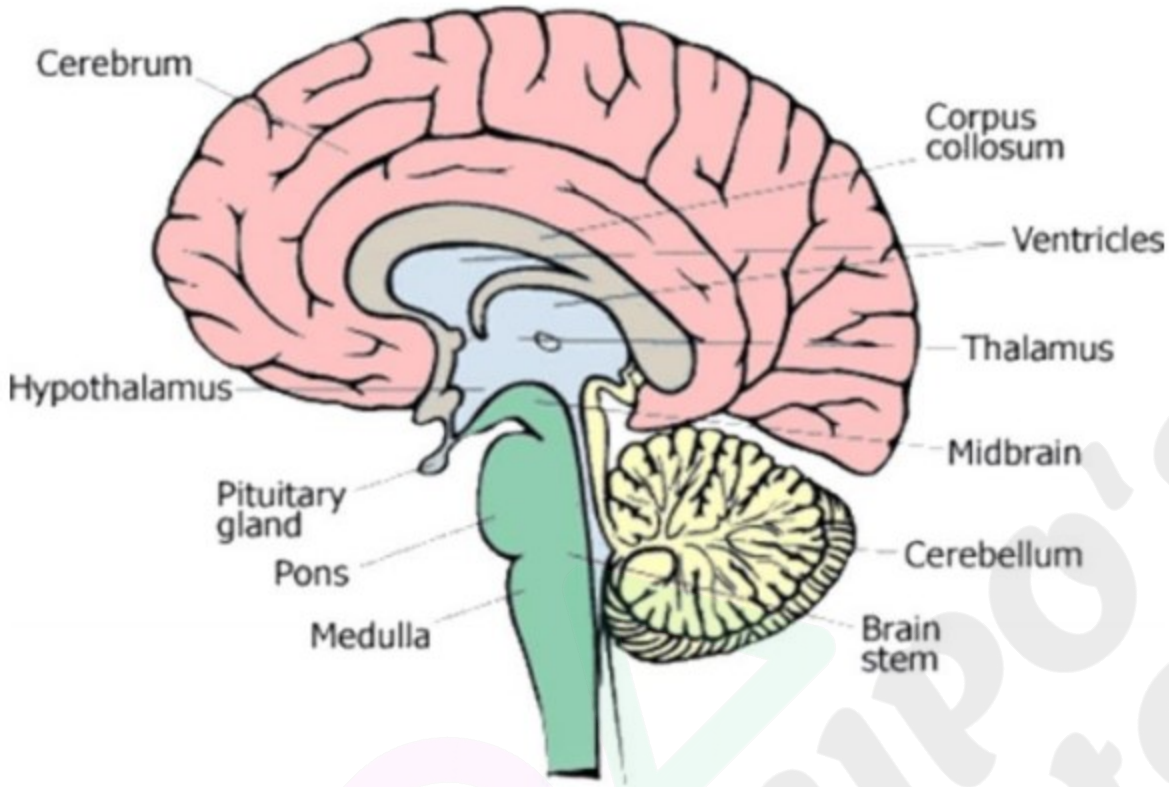


Fig: Parts of human brain

Forebrain:

It is distinguished into 3 parts;

1. **Olfactory lobes:**

It is the anterior part. Each lobe consists of anterior **olfactory bulb** and posterior **olfactory tract**. These parts are fully covered by cerebral hemisphere and ventral view can be seen. It consists of **cavity** called **1st ventricle or rhinocoel**. Olfactory lobes are poorly developed in human. **Function** of olfactory is to receive the sense of smell.

2. **Cerebrum:**

It is more complex and large part of brain. It is divided into left and right **cerebral hemisphere**. Both hemispheres are connected by a broad, curved, thick band of nerve fibers called **corpus callosum**. Its anterior folded part is called **genu** and the posterior curved part called **splenium**. Outer layer of cerebrum is known as **cerebral**

cortex formed of convolutions that greatly increases the surface area. Raised parts are called **gyri** and depressions are called **sulci**. Each cerebral hemispheres can be divided in to- **frontal parietal, temporal and occipital lobes by sulci.**

There are different areas on the cerebrum. These are- **motor** area for movement, **sensory** area for heat, cold, light, pressure, touch etc., **auditory** area for hearing, **visual** area for seeing, **olfactory** area for taste and smell, taste area and speech area. Each hemisphere receives information from opposite side of the body. The cavity of each cerebral hemisphere is called **lateral ventricles.**

Functions-

i. It controls all mental and conscious activities (such as intelligence, memory, reason, will, feelings and emotions).

ii. It is the site of originator of voluntary acts and interpreter of sensations.

iii. It is a control center of many reflex actions.

Different lobes, areas and functions of cerebral hemisphere

Lobes of cerebral hemisphere	Areas present	Functions
Frontal lobe	Motor area	Voluntary motor activities of the muscles
	Speech area	Sensation of memories, judgment, expression of emotions, will power and personality
	Premotor area	- Highest centre for involuntary movement of the muscles - It controls the autonomic nervous system
	Association area	Association between various sensations and movements
Parietal lobe	Sensory area	Sensory perception of pain, touch, heat and cold
Temporal lobe	Auditory area	Hearing, smell and emotion
Occipital lobe	Visual area	Visual sensation

3. Diencephalon:

It lies just below the corpus callosum and above the mid brain. It has three parts; epithalamus, thalamus and hypothalamus.

Epithalamus: It is thin and non-nervous part. Its anterior part is highly vascular and folded to form **anterior choroids plexus** which secrete CSF. There is a **pineal** body behind the choroids plexus. It secrets **melatonin** hormone.

Thalamus: It is the part which consists of optic chaisma (crossing of optic nerves). It is a sensory relay station.

Hypothalamus: It consists of a hypophysis (pituitary gland) attached by stalk called infundibulum. Pituitary gland is a master gland.

The **cavity** behind the lateral ventricle is called **third ventricle**. It is connected with ventricle of cerebrum by **foramen of monro**.

Functions:

i. It serves as relay center for the sensory and motor impulses from spinal cord and brain stem.

ii. It regulates emotions, pleasure, fear and perceptions of heat, cold and pain.

Mid-brain:

It is the brain which connects forebrain with hind brain. It has two parts;

Corpora quadrigemina: These are two pairs of round lobes. The **1st pair** is called **superior colliculi** which is concern with vision and the **2nd pair** is called **inferior colliculi** which is concern with hearing.

Crura cerebri(cerebral peduncles): These are two bundles of fibers which lie on the lower surface of the mid brain. It relay the impulses back and forth between the cerebrum, cerebellum, pons and medulla oblongata.

Hind brain:

It consists of cerebellum, pons varolli and medulla oblongata.

a. **Cerebellum:**

It is also called as **little brain** and is the second largest part of the brain. It lies at the posterior region of the brain. It has three lobes: **two lateral lobes** called **cerebellar hemispheres** made up of grey matter, **one central** part called **vermis** made up of white matter. Internally the cerebellar hemisphere has a branching tree

like white matter called **Arbor Vitae**. The cavity of cerebellum is called fourth ventricle communicating with third ventricle through **Aqueduct of sylvius**.

Functions:

i. It co-ordinate muscular body movement, equilibrium and controls the posture.

ii. It controls reflex action of skeletal muscle activities.

b. Pons varolii (pons =bridge);

It is the characteristics feature of the mammalian brain. It is situated in front of cerebellum and above the medulla oblongata and join medulla oblongata with the mid brain. Its fibre is of white matter. It is known as **middle cerebellar peduncle or brochium point (for regulating breathing).**

It relays impulses from medulla oblongata to the superior part of the brain.

c. Medulla oblongata;

It lies between the pons varolii and the spinal cord. It consists of white matter. It is continuous with the spinal cord. The lower part of it consists of a very thin, non-vascular folded structure called **posterior choroid plexus.**

Functions;

i. It is centre for cardiac, respiratory and vasomotor.

ii. It controls complex activities such as heart action, respiration, sneezing, coughing etc.

Brain Stem:

Mid brain, pons and medulla oblongata collectively forms the brain stem. It connects the fore brain with spinal cord. It is continuous with spinal cord. Death is declared clinically when there is cessation of brain stem function.

Ventricles of Human Brain:

Ventricles are the cavities within the brain filled with cerebrospinal fluid (CSF). It is secreted by anterior and posterior plexuses. There are four ventricles.

i. Right and left lateral ventricles.

ii. Third ventricle (Dioecoel)

iii. Fourth ventricle (Metacoel)

Right and left lateral ventricles:

It lie within the cerebral hemispheres below the corpus callosum. They communicate with third ventricles by **foramen of Monro**.

Third ventricle:

It is situated below the lateral ventricles between two parts of the thalamus. It is communicated with third ventricle by a narrow canal **Iter or cerebral aqueduct.**

Fourth ventricle:

It is a lozenge-shaped cavity situated below and behind the third ventricle, between the cerebellum and pons varolii. It continues below the central canal of spinal cord.

Cerebro-Spinal Fluid (CSF):

It is clear, slightly alkaline and lymph like extracellular fluid. It consists of salts, glucose, water, minerals and small amount of albumin, globulin and few traces of urea and creatinine. It is secreted by anterior and posterior choroid plexus in ventricles of brain, central canal or spinal cord and space around the brain and spinal cord. Total volume of CSF is 150ml.the rate of formation is 20ml/hr. CFS can be obtained by lumbar puncture.

Function of CSF:

- It supports and protects brain and spinal cord.
- It maintains uniform pressure around these delicate structures.
- It acts as a cushion and shock absorber.
- It keeps the brain and spinal cord moist and exchange of substances between CSF and nerve cells.
- It excretes harmful metabolic wastes, drugs and other substances from the brain to the blood.
- It nourishes the nerve cells.
- It also acts as buffer.
- It acts as buoyancy and makes the brain low weight.

2. Spinal cord:

It is a posterior part of CNS which runs mid dorsally within the vertebral column. It is elongated, almost cylindrical part. It extends from the medulla oblongata within vertebral column to the level of second lumber vertebra. It measures about 42 to 45cm long and 2 cm thick. It is surrounded by the same three meninges found in the brain.

Below the 2nd lumbar vertebra, the spinal nerves called **cauda equine or horse's tail** arise from the spinal cord. The spinal cord terminates as the **conus medullaris**.

Internal structure:

Internally, spinal cord is divided into left and right symmetrical halves. The posterior is median sulcus and anterior is median fissure. In the centre there is a central canal surrounded by a butterfly shaped area of grey matter. Around the grey matter there is white matter. Grey matter is an H-shaped part with two dorsal and two ventral horns. Roots of spinal nerve are originated from the horns. There are **31 pairs of spinal nerves** arising from different segments of spinal cords. Each spinal nerve carries both sensory and motor impulses. Each spinal nerve connects with nerve roots.

Dorsal nerve root: It originates from the dorsal horn of grey matter. It consists of only sensory fibers. It bears the dorsal root ganglion containing only sensory cells.

Ventral nerve root: It originates from the ventral horn of grey matter. It is made up of only motor fibers. It does not bear ganglion.

Functions of spinal cord

- It is center of spinal reflex action.
- The stimuli are passed from and to the brain through the spinal cord.

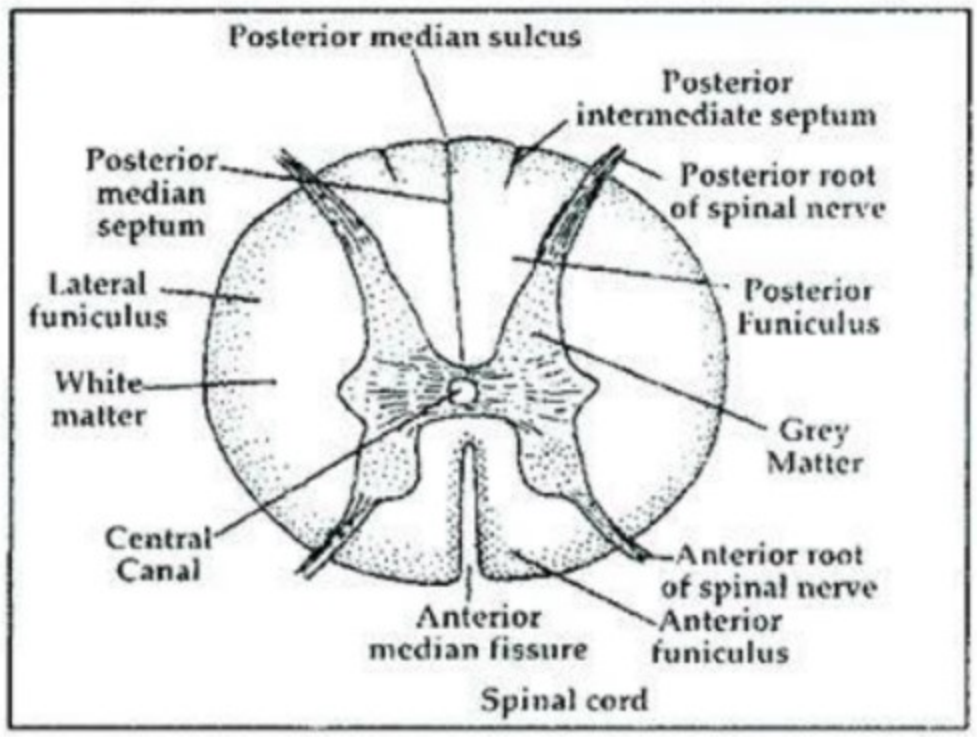


Fig: T.S. of spinal cord

Grey matter and white matter of CNS

The nervous tissue which forms the brain and the spinal cord is of two types i.e. grey and white matter of CNS.

Grey matter: It is grey in colour and consists of cell bodies, dendrites and synapses of neurons. In the brain, the grey matter is situated on the surface while white matter is located deeper.

White matter: It is white in colour and consists of nerve fibres. In the spinal cord white matter is situated on the surface while grey matter is located deeply.

Peripheral Nervous System(PNS)

It consists of;

A. **Cranial nerves**: Those arising from the brain.

B. **Spinal nerves**: those arising from the spinal cord.

Types of Nerve Fibres

1. **On the basis of structures:**

a. **Myelinated or medullated nerve fibres**: These fibre have myelin sheath. These are found in white matter of brain, spinal cord and nerves. These are involved in the conduction of nerve impulses.

b. **Non-myelinated or non- medullated nerve fibres**: These are without myelin sheath. They are found in grey matter of brain and spinal cord. These are involved in the integration of nerve impulses.

2. On the basis of function of nerve impulse:

a. Afferent nerve fibres (sensory):

These conduct nerve impulses from effectors organs to the CNS such as optic nerve.

b. Efferent nerve fibres (motor):

These conduct nerve impulses from CNS to body organs such as occulomotor nerve (for eye movement).

c. Mixed nerve fibres:

These are both sensory and motor in function such as spinal nerves.

3. On the basis of number of their processes

a. Unipolar:

These neurons have only one axon with dendrites. They are found in dorsal root ganglia of spinal nerve.

b. Bipolar:

These neurons have two processes. In which one may be dendrite and other is axon. These are found in the retina of eye.

c. Multipolar:

These neurons have many cell processes. These are found in CNS.

Cranial nerves:

There are 12 pairs of cranial nerves. These arise from ventral side of brain. Their names, types and functions are given below in table.

No.	Cranial nerve	Types of fibre	Organs innervated	Function
I	Olfactory nerve	Sensory	Mucosa in nose	Smell
II	Optic nerve	Sensory	Retina of eye	Vision
III	Occulomoror nerve	Motor	Eye muscles, Ciliary muscles	Eye movement, accommodation
IV	Trochlear nerve	Motor	Superior oblique muscles of eye ball	Eye movement
V	Trigeminal nerve	Mixed	Skin teeth, mucosal membrane of mouth	Sensation of head face
VI	Abducens nerve	Motor	Eyeball muscles	Eyeball movement
VII	Facial nerve	Mixed	Taste buds, salivary glands, facial and neck muscles	Facial expression, saliva secretion, taste
VIII	Auditory nerve	Sensory	Internal ear	Equilibrium Hearing
IX	Glossopharyngeal	Mixed	Pharynx, tongue, salivary glands	Taste, swallowing and saliva secretions
X	Vagus nerve	Mixed	Pharynx to viscera	Visceral reflexes
XI	Spinal accessory	Motor	Thoracic and abdominal viscera	Visceral reflexes, Shoulder movement
XII	Hypoglossal nerve	Motor	Muscles of tongue	Movement

- **Smallest cranial nerves is abducens.**
- **Longest cranial nerve is vagus.**
- **Sensory cranial nerves are I, II, VIII (3 pairs)**
- **Motor cranial nerves are III, IV, VI, XI, XII (5 pairs)**
- **Mixed cranial nerves are V, VII, IX, X (4 pairs)**

Spinal Nerves

There are 31 pairs of spinal nerves in human arising from either side of spinal cord from intervertebral foramina.

These nerves are:

Cervical	8 pairs in neck
Thoracic	12 pairs in thorax

Lumbar		5 pairs in upper abdomen
Sacral		5 pairs in lower abdomen
Coccygeal		1 pair in tail region
Total spinal fibers	=	31pairs

So the spinal formula is --- $C_8\ Th_{12}\ L_5\ S_5\ Co_1$

Each spinal nerve is a mixed nerve. It originates by two roots-Dorsal or sensory or afferent roots and Ventral or motor or efferent root from spinal cord. The two roots join within the neural canal of vertebral column. Each spinal nerve immediately divides into three branches:

- **Ramus dorsalis**:
  It supplies muscles and skin of dorsal side.
- **Ramus ventralis**:
  It supplies muscles and skin of ventral and lateral sides.
- **Ramus comminicans**:
  It joins sympathetic ganglion of ANS.

Autonomic Nervous System (ANS):

Autonomic nervous system controls and co-ordinates the various activities of visceral organs. Hence it is also called **visceral nervous system**. Actually ANS is not **autonomous** or **independent** because it is regulated by higher nerve centre of brain. It consists of two antagonistic (opposite in function) systems-

1. Sympathetic nervous system:

It consists of sympathetic chains, preganglionic fibres, collateral ganglia and postganglionic sympathetic fibres.

i. **Sympathetic chains:**

These are two long lateral chains of sympathetic ganglia present closely one on either side of vertebral column from the cervical region to the coccyx of spinal cord. It is formed of serially interconnected lateral chain of 21 ganglia (3 cervical, 12thoracic, 5 lumbar and 1 sacral) present on vertebral column.

ii. **Preganglionic sympathetic fibres**:

These are short sized axons originated from the grey matter of spinal cord in all

thoracic and lumbar regions.

iii. **Collateral ganglia**:

There are three collateral ganglia-coeliac ganglion, superior mesenteric ganglion and inferior mesenteric ganglion**.** These are located close to the sympathetic chains and join preganglionic fibres and post ganglionic fibres.

iv.Postganglionic sympathetic fibres:

These are long sized axon of neurons originated from collateral ganglia**.** These nerves supply the visceral organs like heart, iris and ciliary muscles, liver, lungs etc.

The sympathetic nerves stimulate the adrenal glands to secrete **adrenaline** or **nor adrenaline**, so these are called **adrenergic nerve fibres**.

2. Parasympathetic nervous system:

It consists of parasympathetic fibres, parasympathetic ganglia and postganglionic parasympathetic fibres.

i. **Preganglionic parasympathetic fibres:**

These are long sized axons of neurons present in midbrain, brain stem and sacral region of spinal cord. Cranial nerves coming from brain are oculomotor (III), facial(VII), glossopharyngeal (IX) and vagus (X). These are emerging from cranium and sacrum form cranio-sacral out flow.

ii. **Parasympathetic ganglia:**

These ganglia are present either close or inside the muscles of visceral organs. These ganglia join the preganglionic fibres and post-ganglionic fibres.

iii .**Postganglionic parasympathetic fibres:**

These are short sized axons of neurons arising from the parasympathetic ganglia and supply smooth muscle and glands or visceral organs. They form a network in the wall of visceral organs called **Aurebach plexus.**

Postganglionic parasympathetic fibres releases a **neurotransmitter** called **acetylcholine** at their nerve endings so these nerves are called **cholinergic nerve fibres.**

Synapse:

Synapse is an area of functional contact between one neuron and another to transfer information. Synapses are usually found between the fine terminal branches of the axon of a neuron and the dendrites or cell body of another.

Structure of synapse:

A typical synapse consists of a bulbous expansion of a nerve terminal called a **pre-synaptic knob** close to the membrane of a dendrite. Cytoplasm of synaptic knob contains mitochondria, smooth endoplasmic reticulum, micro-filaments and numerous **synaptic vesicles**. Each vesicle contains **neurotransmitter** responsible for transmission of nerve impulse across the synapse. The membrane of synaptic knob nearest the synapse is thickened and forms the **post synaptic membrane**. These membranes are separated by a gap, the **synaptic cleft**. The post-synaptic membrane contains large protein molecules which act as receptor sites for neurotransmitter and numerous channels and pores.

The two **neurotransmitters** in vertebrate nervous system are **acetylcholine** (Ach) and **noradrenaline** although other neurotransmitters also exist. Neurons which release acetylcholine neurotransmitters are called **cholinergic** neurons and those releasing noradrenaline are called **adrenergic** neurons.

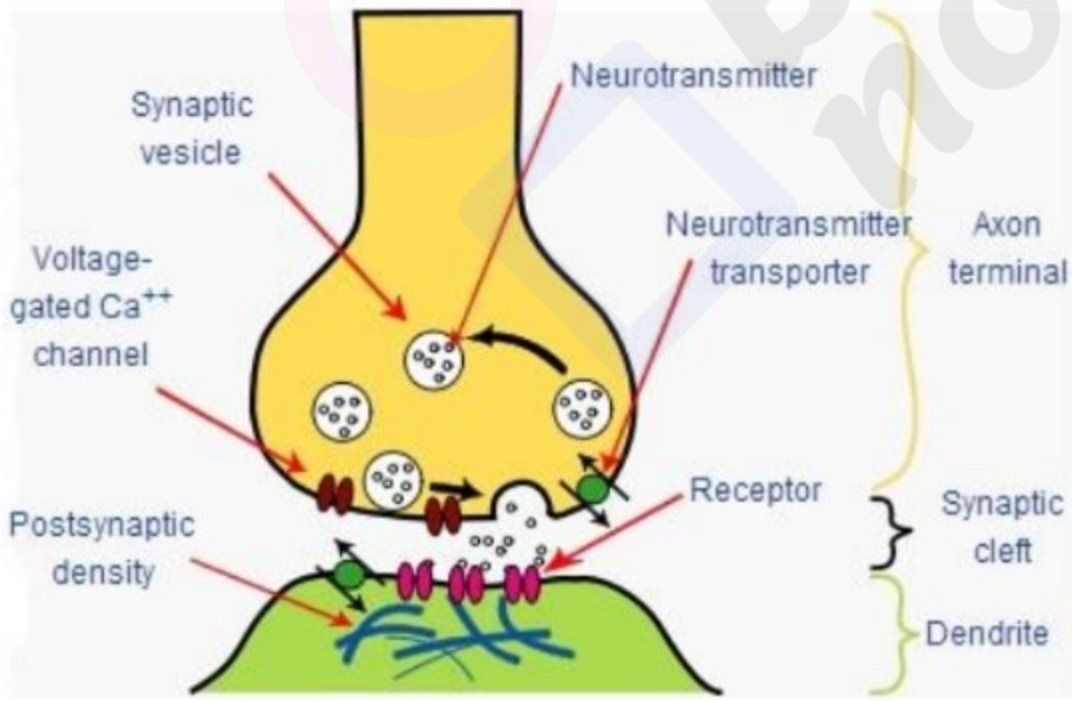


Fig: section of synapse

Stimulus:

Stimulus is a sudden change in the external or internal environment, which excite the nerve or organism or muscle as whole. The stimulus which is capable to just excite given tissue is called threshold stimulus. There are many types of stimuli which can excite the tissue:

a. Mechanical stimuli: These include touch, muscular stress etc.
b. Physical stimuli: These include heat and humidity.
c. Chemical stimuli: The electrical stimuli is able to excite tissue.

Properties of a nerve fibre are:

i. Excitability
ii. Conductivity
iii. Refractory period
iv. Summation
v. All or none rule.

Excitability-When a nerve fibre is stimulated by stimuli of physical, mechanical or chemical means and impulse is formed, it is called excitability.

Conductivity: When the stimulated nerve transmits the impulse in a particular direction is called conductivity.

Refractory period: After excitation or transmission of nerve impulse nerve regain the original state is called refractory period.

Summation: When stimulus applied to a nerve fibre is below the threshold stimulus then it fails to stimulate any response. However, if the same stimulus is continuously applied, stimulation occurs. This is called summation.

All or none rule: When the organism gives response by stimulation, it cannot be increased or response is always maximum. It is called all or none rule.

Nerve impulse:

A nerve impulse is defined as wave of depolarization (wave of reverse polarity) of the membrane of an axon of nerve cell. Nerve impulse is generated in nerve fibre is an electrical phenomenon. Nerve fibres are provided with fluids outside and inside

which are termed as **extracellular fluid (ECF) and intracellular fluid (ICF)** respectively. The extracellular fluid has more **Na** and bicarbonates whereas intracellular fluid contains large amount of **K** along with protein molecules.

The nerve fibres are electrically charged. These are the positively charged cations outside the nerve cell whereas negatively charged anions are inside the nerve cell.

Transmission of nerve impulse:

The best illustrated theory about the nerve impulses **is Ionic theory of nerve impulse** proposed by English neurophysiologists Hodgkin and Huxley in the late 1930s. **This theory states that the electrical events in the nerve fibre are regulated by the differential permeability of the membrane to sodium and potassium ions.**

The transmission of nerve impulse is described in two steps.

A. Transmission of nerve impulse along the nerve fibre.

B. Transmission of nerve impulse across the synapse.

Transmission of nerve impulse along the nerve fibre (axon):

1. **Polarization or resting potential**:

The normal condition of a nerve when there is no conduction of impulse is called **resting potential**. During this, the extracellular fluid has high concentration of Na+ ions and intracellular fluid has high concentration of K+ ions. The outside concentration of Na+ is 10 times more than K+ ions outside the neuron whereas K+ ions is 25 times more than Na+ ions inside the neurons. This makes a difference in charge which is called as **potential difference**. During this Na+ and K+ ion channels are closed. At this state the more amount of negatively charged protein molecules inside and the +vely charged ions outside makes the resting state of polarization.

2. **Depolarization or action potential.**

A nerve impulse can be initiated by mechanical, chemical and physical stimulation. **Sodium channels are opened but potassium channels are closed.** During this a large amount of Na^+ ions flows from outside to inside the neuron. This changes the concentration inside and outside which makes the polarity reversed. It means more positively charged ions are inside and negatively charged ions outside. The membrane with reversed polarity is said to be depolarized.

3. Repolarization.

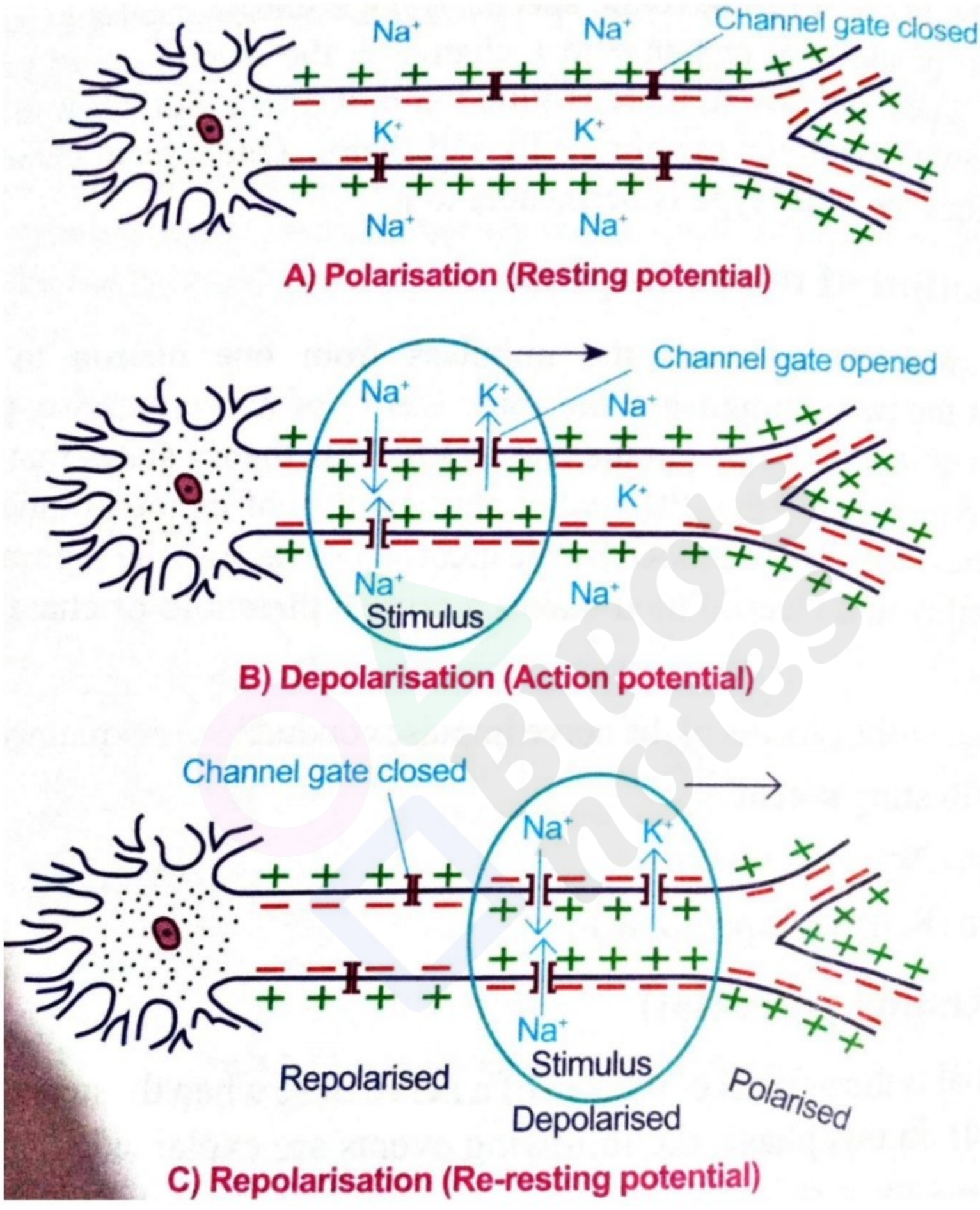
After depolarization, sodium channels are closed and **potassium channel are opened.** K^+ ions diffuse out along their concentration gradient. This start repolarization and resting potential going to reestablish. Similarly the polarity also come back to the original condition i.e. it has the positive charge inside the membrane and negative charge outside the membrane. This process is actually for reestablishing the resting potential. At the same time nerve become less permeable for Na^+ than K^+ .So many K^+ flow out and inside charge become more negative than that it was originally This process is called repolarization. During repolarization the cell returns to its resting potential. The channel gates again remain closed and now the neuron is ready to receive another stimulus.

Sodium- potassium exchange pump:

During resting potential the nerve exchanges the ions across the membrane to maintain a stable potential difference with ionic concentration. The process of drawing in the potassium ion and expelling out the sodium ions against the conc. and electrochemical gradient is known as **Na-K pump.** Na-k pump starts and normal concentrations of Na and K ions are reestablished. Each pump actively transports two K^+ ions into the cell to every three Na^+ ions transported out. The membrane is once again at its resting potential. During this the energy is provided by an enzyme Na+-K+-ATPase in the cell membrane.

Speed of transmission of nerve impulse:

The speed of transmission of nerve impulse through axon is affected by its **diameter and presence of myelin sheath.** The axon has **larger diameter** which has less resistance and increases velocity so there is fast conduction of nerve impulse. The axon is covered by **myelin sheath** and keeps gap at certain interval called **nodes of Ranvier.** This myelinated neurons prevents the ionic change and depolarization along its length which helps in faster transmission of nerve impulse. The depolarization occurs only in the nodes. But if the neuron is non myelinated the depolarization occurs in the whole length decreasing the rate of nerve impulse conduction. Transmission of nerve impulse along medullated nerve fibre is 20 times faster than non medullated fibre. The ionic exchange or depolarization occurs only at nodes because medullary sheath is impermeable to ions. The action potential is conducted from node to node in a jumping manner. This also called **saltatory conduction** of nerve impulses.



Transmission of nerve impulse along nerve fibres.

B. Transmission of nerve impulse across the synapse.

It is explained by Henry in 1936.Following are the steps for the process:

1. When an impulse arrives at the pre-synaptic knob of axon, it depolarizes the pre-synaptic membrane. The voltage gated **calcium channels** are open.

2. Ca^{++}ions pass from the synaptic cleft pass into synaptic knob and cause the movement of synaptic vesicles to the surface of knob. The synaptic vesicles are fused with the presynaptic membrane and get ruptured and discharge their neurotransmitters chemicals acetylcholine in to the synaptic cleft and return to the cytoplasm of synaptic knob to refill neurotransmitters.

3. The neurotransmitter binds with protein receptor molecules in synaptic cleft. This binding action changes the membrane potential of the post synaptic membrane, opening the channels in the membrane and allowing the sodium ions to enter the cell. This causes depolarization. It generates a new action potential in the post synaptic membrane. Thus nerve impulse transferred to the next synapse.

4. The acetylcholine is hydrolyzed by an enzyme **acetyl cholinesterase** into acetic acid and choline in the cleft which are reabsorbed into synaptic knob and resynthesized into acetylcholine using energy from ATP.

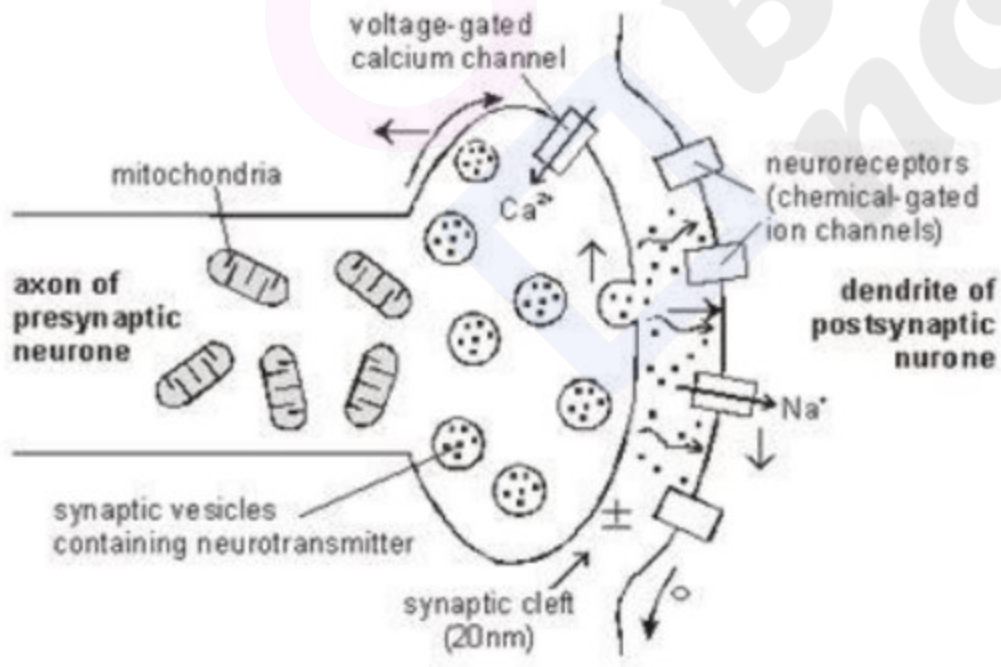


Diagram showing synaptic transmission