# Human Physiology
## (Neural control and Coordination)

## 1. Introduction

All the organs and organ system of our body work together to maintain homeostasis and carry out different process of life.

The process through which two or more organs interact and complement the funcitons of one another is called **co-ordination**. In human beings nervous and endocrine systems jointly coordinate and intergrate all the activities of different organs in synchronised fashion.

Nervous system is responsible for rapid transmission of stimuli and their responses by electro chemical signals which are short lived and very specific while endocrine system is responsible for slow transmission by specific chemicals i.e. hormones those travel through blood stream and act on target organs. The response of these hormones is long lasting and wide spread.

In all multicellular animals above the level of sponges, the system meant to perceive stimuli detected by the receptors, to transmit these to various body parts and to effect responses through effectors, is called *nervous system*. In vertebrates, it is highly specialized and plays at least three vital roles which are following -

**(1) Sensory function –** It senses certain changes (stimuli) both within the body (internal environment) and out side body (external environment).

**(2) Integrative functions –** It analyses the sensory informations, stores some aspects and makes decisions regarding appropriate behaviors.

**(3) Motor functions –** It may responds to stimuli by initiating muscular contractions or glandular secretions.

## 2. Nervous systems in various animals

- The neural system of all animals is composed of highly specialised cells called **neurons** which can detect, receive and transmit different kinds of stimuli.
- The neural organisation is very simple in lower invertebrates. For example, in Hydra it is composed of a network of neurons.
- The neural system is better organised in insects, where a brain is present along with a number of ganglia and neural tissues.
- The vertebrates have a more developed neural system.

## 3. Nerve

### 3.1 Neurons

A neuron is a nerve cell with all its branches. Neuron is derived from neuroblast. It is the structural and functional unit of nervous system. It is the longest cell of the body.

**A. Cyton –** It is also called perikaryon or soma or cell body. Its granular cytoplasm is called neuroplasm which has following structures:

- A large, spherical, centrally located nucleus with single nucleolus.
- Numerous fine threads called neurofibrils for the conduction of nerve impulses.
- A number of small, basophilic granules called **Nissl's granules** formed of rough endoplasmic reticulum and are sites of protein synthesis.

- Neuroplasm has large number of mitochondria to provide high energy for impulse conduction.
- Neuroplasm may have melanophores with melanin pigment and lipochromes with orange or yellow pigment.
- A mature neuron has no centriole, so it cannot divide.
- A "**Barr body**" is often seen abutting against the inner surface of nuclear membrane of cytons in the females. This has been proved to be a transformed '*X*' chromosome.
- Certain neurons having flask-shaped cytons and called **purkinje cells,** occur in the cerebellum of the brain.

**B. Neuron processes –** The processes of neurons, called **neurites,** extend varying distances from the cyton and are of two types – dendrites or dendrons and an axon or axis cylinder (neuraxon).

**(a) Dendron –** These are several short, tapering much branched processes. The dendrites contain neurofibrils, neurotubules, Nissl's granules and mitochondria. They conduct nerve impulse towards the cell body.

**(b) Axon –** This is a single very long, cylindrical process of uniform diameter. It arises from a conical projection, the **axon hillock**, of the cyton. Axon hillock play very important role in gradation of net membrane potential. In cyton summation of different nerve signals occur. Once the signal enters axon it continues till the end of neuron and this phenomenon is called "all or none principal". In axon hillock gradation is done and rate of firing of impulse is determined and is proportional to net membrane potential receive at axon hillock. The axon contains neurofibrils and neurotubules but lacks Nissl's granules. Axon is usually branched only terminally into slender branches called telodendria. The latter have knobbed ends called **endbulbs or axon terminals or buttons or synaptic knobs or end plates.** The synaptic knobs contain mitochondria and secretory vesicles.

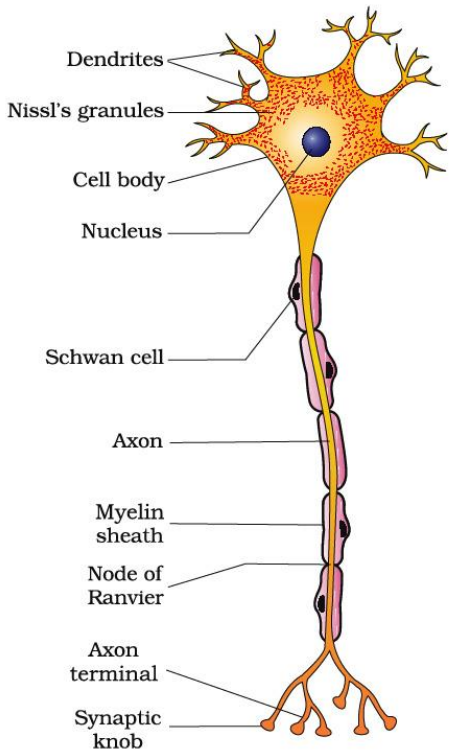



**Figure. Structure of a neuron**

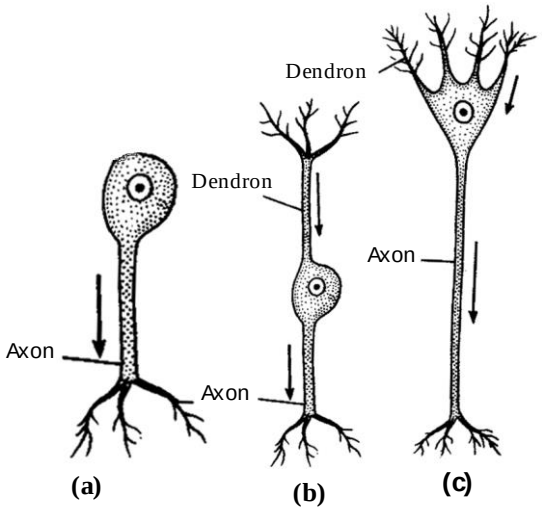
**3.2 Types of neurons –** Neurons are divided into different categories on different basis.

**A. On the basis of functions –** Neurons are divided into three categories:

- **Sensory (afferent) neurons –** These are found in sense organs. Their dendrons receive nerve impulse from the nerve process of the receptor cell while their axon forms synapse with dendron of the next neuron. These may be naked or encapsulated e.g. olfactoreceptors and gustatoreceptors.
- **Internuncial neurons –** These are located in the dorsal horn of the spinal cord. These are called association neurons (when their axon synapses with the dendron of motor neuron of same side) or commissural neuron (when their axon synapses with the dendron of motor neuron of opposite side).
- **Motor (efferent) neurons –** These are always present in the ventral horn of the spinal cord. Their axon ends into the muscle fibres or glands cells. These conduct the nerve impulses to the effector organs which respond to the stimuli.

**B. On the basis of number of nerve processes –** Neurons are of three types –

- **Unipolar neurons:** In these neurons, only one nerve process arises from the cyton which acts as axon but there is no dendron. **These are found only in early embryos.** The unipolar neuron of the adult gives rise to a single nerve process, which immediately divides into a dendron and an axon. Such unipolar neurons are called **pseudo-unipolar neurons.** These are found in the **dorsal root ganglia of spinal nerves** and in the roots of V, IX and X cranial nerves.




**Types of Neurons (a) Unipolar; (b) Bipolar; (c) Multipolar**

- **Bipolar neurons –** In these neurons, the cyton gives rise to two nerve processes out of which one acts as an axon while other acts as a dendron. These are found in the olfactory epithelium of nasal chamber and retina of eye. These may be isopolar or heteropolar (dendrons being irregularly branched). Ganglia of VIII cranial nerve.
- **Multipolar neurons –** In these neurons, the cyton gives rise to several nerve processes out of which one acts as an axon while remaining nerve processes act as dendrons. These are found in the central nervous system and the ganglia of autonomic nervous system of adult.

### 3.3 Nerve fibres

Axon or dendron of a nerve cell covered with one or two sheaths is termed as nerve fibre. The nerve fibres are of two types – medullated or myelinated and non medullated or non myelinated regarding their structure.

**A. Medullated nerve fibres –** A medullated nerve fibre typically consists of a central core, the axis cylinder or neuraxis surrounded by two sheaths: inner thick medullary sheath and outer thin neurilemma.

**(a) Axis cylinder**

- The axis cylinder is simply the axon or dendron of a nerve cell.
- It contains longitudinal neurofibrils and mitochondria in its neuroplasm, called **axoplasm,** limited by cell membrane termed **axolemma.** It is the axolemma that conducts nerve impulses.

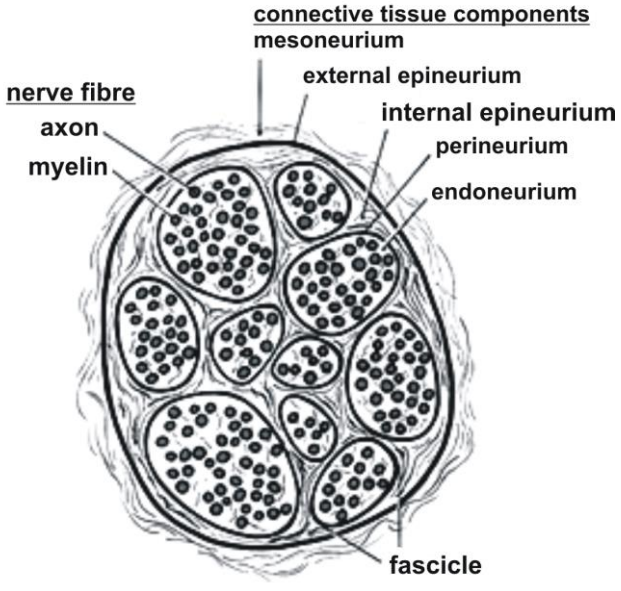
**(b) Medullary sheath**

- The medullary sheath is composed of a shinning, white, fatty substance called myelin.
- This sheath perhaps serves as an insulating layer, preventing loss of energy of the nerve impulse during its passage along the fibre.
- The medullary sheath is continous around the fibres in the central nervous system, but in fibres of the peripheral nerves, it is absent at certain places known as the **Node of Ranvier.** The part of a nerve fibre between two successive nodes is termed the **internode.**

**(c) Neurilemma**

- The neurilemma consists of tubular sheath cells (Schwann's cells) placed end to end. The neurilemma is continuous over the Nodes of Ranvier.
- The function of the Schwann's cells is to produce the myelin sheath around the neuraxis.
- The medullated nerve fibres in the brain and spinal cord lack neurilemma. Instead, they have an incomplete covering of neuroglia cells, which probably produce the myelin sheath.
- Neurilemma present around the peripheral nerve fibres enables them to regenrate after injury.
- Nerve fibres in the brain and spinal cord do not regenrate after injury due to lack of neurilemma.
- The medullated nerve fibres occur in the white matter of the brain and spinal chord and in the cranial and spinal nerves.

**B. Non medullated nerve fibres –** A non medullated nerve fibre consists of an axis cylinder enclosed by neurilemma and connective tissue. These fibres appear grey in colour in the fresh state. The non-medullated nerve fibres occur in the autonomic nerves.




Normal Nerve

### Test your Resonance with concept

**1.** The efferent process of neuron is known as a/an
(1) Axon (2) Dendrite (3) Cyton (4) Neurofibril

**2.** The junction of two nerve fibres is called as
(1) Synapse (2) Junction (3) Connection (4) Neuromuscular junction

**3.** The bundles of nerve fibres are enclosed in a sheath called
(1) Fascicle (2) Endoneurium (3) Epineurium (4) Perineurium

**4.** Bipolar nerve cells and ganglion cells are found in the
(1) Sclerotea (2) Cochlea (3) Retina (4) Cristae

**5.** Largest cell in human body is
(1) Lymph (2) Osteoctyte (3) Neuron (4) Chromatophore

**Answers**

**1.** (1) **2.** (1) **3.** (4) **4.** (3) **5.** (3)

## 4. Biochemical aspect of Nervous Physiology

All parts of a neuron transmit excitations (= impulses), but the transmission is always unidirectional. The dendrites and cytons usually constitute the impulse receiving parts. They receive impulses directly from receptors, or from other adjacent neurons. The axons are specialized as fibres conducting impulses away from the receiving parts. Thus, the reaction or response impulses are always carried to the effectors by axons. That is why, the term '**nerve fibres**' is usually applied to the axons. The latter are 0.1 *mm* to 1 or more (upto 10) *metres* long and about 0.025 *m* thick on an average.

**4.1 Main properties of nervous tissue:** The nervous tissue has two outstanding properties excitability and conductivity.

**A. Excitability/Irritability –** It is the ability of the nerve cells and fibres to enter into an active state called the **state of excitation** in response to a stimulus. Excitation arises at the receptors on account of various stimuli such as light, temperature, chemical, electrical or pressure which constantly act on the organisms.

In terms of membrane potential irritability means change in membrane potential on giving stimules.

**B. Conductivity –** The excitation does not remain at the site of its origin. It is transmitted along nerve fibres. The transmission of excitation in a particular direction is called conductivity.

**4.2. Definition of nerve impulse –** A wave of reversed polarity or depolarization (action potential) moving down an axon is called a nerve impulse.

**4.3 Mechanism of conduction of nerve impulse**

Most accepted mechanism of nerve impulse conduction is ionic theory proposed by **Hodgkin and Huxley.** This theory states that nerve impulse is an electro-chemical even governed by differential permeability of neurilemma to $Na^+$ and $K^+$ which in turn is regulated by the electric field.

**Introduction to membrane potential**

Movement of an ion in living system depends on three factors.

(i) Concentration gradient

(ii) Electric gradient

(iii) Membrane permeability - Ions can move only across protein channels and if the channels are closed cell is said to have low permeability for that particular ion.

In a resting neuron only $K^+$ channels are open and $Na^+$ channles have very low permeability.

Due to $Na^+$ - $K^+$ ATPase pump $Na^+$ concentration is more in ECF and $K^+$ conc. is more in ICF. This cause development of gradient for both of them.

Since membrane is more permeable to $K^+$ ion in resting stage $K^+$ move from ICF to ECF and this is the cause of positive potential outside cells and negative potential in side cells.

At equilibrium $K^+$ channels are open yet $K^+$ do not move along its concentration gradient and this is because opposite working membrane potential which developed due to $K^+$ itself.

The membrane potential of -70 mV developed due to $K^+$ ion and it prevent further efflux of $K^+$ ion.

**A. Transmission of nerve impulse along the nerve fibre**

**(a) Polarization (Resting membrane potential-RMP)**

- In a resting nerve fibre (a nerve fibre that is not conducting an impulse), sodium ions ($Na^+$) and chloride ions ($Cl^-$) predominate in the extracellular fluid, whereas potassium ions ($K^+$) predominate in the intracellular fluid (axoplasm).
- Intracellular fluid also contains large number of negatively charged (anions) protein molecules.
- The concentration of $Na^+$ is about 10 times greater in the ECF then the axoplasm while the concentration of $K^+$ is about 25 times greater in the axoplasm then the ECF.
- As the concentrations of $Na^+$ and $K^+$ are greater in the ECF and axoplasm respectively, they cannot move to apposite sides due to restricted permeability of axolemma for these ions.
- Thus it makes a difference in electrical charges on either side of the membrane. The plasma membrane is electrically positive outside and negative inside.
- It results the potential difference across the axolemma and is known as resting membrane potential.
- This potential averages – 70 *mv* (– 40 to – 90 *mv*) at inner side of axolemma with respect to outer side.
- A higher concentration of cations outside the membrane compared to the concentration of cations inside it. This state of the resting membrane is called **polarised state** and makes its inner side electronegative to its outside.

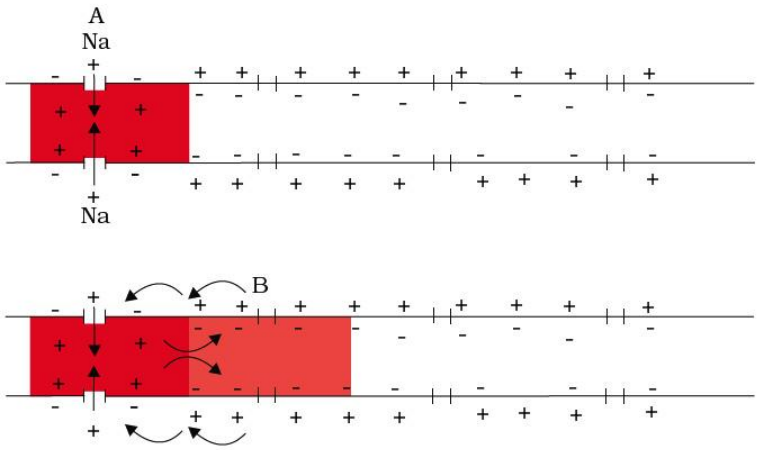



**Figure - Diagrammatic representation of impulse conduction through an axon (at points A and B)**

**B. Depolarization (Action membrane potential or AMP)**

- Depolarization due to $Na^+$ ion.

- When the nerve fibre is stimulated mechanically, electrically, thermally or chemically a disturbance is felt at the point of stimulation which gives rise to a local excitatory state.
- The strength of stimulus must have a threshold value.
- At the point of stimulus permeability of axolemma changes for $Na^+$ ions. Initially few channels for $Na^+$ open. It results the movement of few $Na^+$ inside the axolemma. As few $Na^+$ move to the axolemma, the negative charge inside the axolemma decreases. It results opening of all channels for $Na^+$ in the axolemma. It results an influx of $Na^+$ ions inside the axoplasm causing reversal in the polarity of axolemma.
- The membrane with reversed polarity is said to be depolarized. This wave of depolarization travelling down a nerve fibre is called **action potential**. Infact, the action potential "moves" in the manner of a spark moving along a fuse.
- This "moving" action potential constitutes the **nerve impulse**. The action potential (impulse) is the basic means of communication within the nervous system.

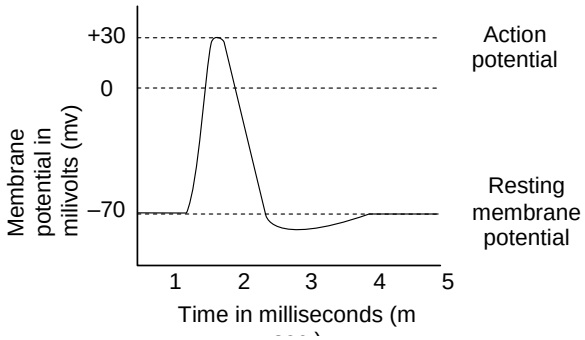
### *Do You Know?*

*When a neuron is not conducting any impulse, i.e., resting, the axonal membrane is comparatively more permeable to potassium ions (K+ ) and nearly impermeable to sodium ions (Na+).*

- The action potential of + 45 *mv* on inner side of axolemma with respect to its outer side is also called **spike potential.**

**C. Repolarization**

- With the increase of sodium ions inside the nerve cell, the axolemma becomes less permeable to sodium ions whereas the permeability of axolemma to potassium ions increases.
- The sodium ions are pumped out of the axoplasm and potassium ions are pumped into the axoplasm until the original polarised state of ionic concentration is achieved.
- Thus this makes the axolemma negative on inside and positive on the outside. This process is called repolarization.




**Record of potential changes**

- The repolarisation of axolemma is carried out by an **active transport** mechanism called sodium potassium pump (also called sodium potassium exchange pump or sodium pump).
- The sodium-potassium pump is a process of expelling out sodium ions and drawing in potassium ions against concentration and electrochemical gradient.
- The entire process of repolarization takes a short time during which the nerve cannot be stimulated again.

- This period is called **refractory period**. During repolarization, as the cell returns to its resting potential, the neuron is ready to receive another stimulus.

## 5. The synapse

The synapse is an area of functional contact between one neuron and another for the purpose of transferring information.

- Synapses are usually found between the axon terminals of one neuron and the dendrites or cell body of another.
- This type of neuron is called axo-dendrite synapse. **Sir Charles Sherrington** (1861-1954) was the first person who used the term 'synapse' to the junctional points between two neurons.

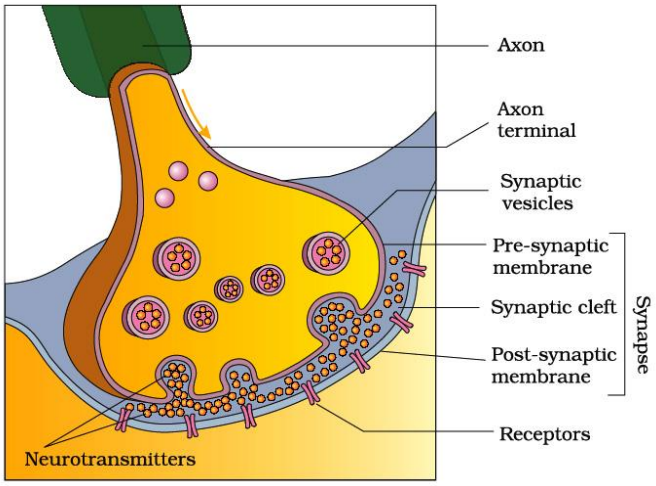



**Diagram showing axon terminal and synapse**

### 5.1 Structure of synapse

- A typical (generalized) synapse consists of a bulbous expansion of a nerve terminal called a pre-synaptic knob lying close to the membrane of a dendrite.
- The cytoplasm of the synaptic knob contains mitochondria, smooth endoplasmic reticulum, microfilaments and numerous synaptic vesciles.
- Each vescile contains neurotransmitter (chemical substance) responsible for the transmission of nerve impulse across the synapse.
- The membrane of the synaptic knob nearest the synapse is thickened and forms the presynaptic membrane.
- The membrane of the dendrite is also thickened and is called the post synaptic membrane.
- These membranes are separated by a gap, the **synaptic cleft.** It is about 200 *Å* across The post synaptic membrane contains large protein molecules which act as receptor sites for neurotransmitter and numerous channels and pores.
- The two main neurotransmitters in vertebrate nervous system are **acetylcholine (ACh) and noradrenaline** although other neurotransmitters also exist.
- Acetylcholine (ACh) was the first neurotransmitter to be isolated and obtained by **Otto Loewi** in 1920 from the endings of parasympathetic neurons of the vagus nerve in frog heart.
- Neurons releasing acetylcholine are called as cholinergic neurons and those releasing noradrenaline are described as adrenergic neurons.

### 5.2 Mechanism of transmission of nerve impulse at a synapse

The process of chemical transmission across synapses was discovered by **Henry Dale** (1936). The physiological importance of synapse for the transmission of nerve impulses was established by **McLennan** in 1963. A brief description of the mechanism of synaptic transmission is given below

- When an impulse arrives at a presynaptic knob, **calcium ions** from the synaptic cleft enter the cytoplasm of the presynaptic knob.
- The calcium ions cause the movement of the synaptic vesicles to the surface of the knob. The synaptic vesicles are fused with the presynaptic membrane and get ruptured (exocytosis) to discharge their contents (neurotransmitter) into the synaptic cleft.
- The synaptic vesicles then return to the cytoplasm of the synaptic knob where they are refilled with neurotransmitter.
- The neurotransmitter of the synaptic cleft binds with protein receptor molecules on the post synaptic membrane. This binding action changes the membrane potential of the postsynaptic membrane.
- The membrane becomes permeable to $Na^+$ which results depolarization and generation of action potential in the post-synaptic membrane. Thus the impulse is transferred to the next neuron.
- Fate of acetylcholine?
- Having produced a change in the permeability of the post-synaptic membrane the neurotransmitter is immediately lost from the synaptic cleft. In the case of cholinergic synapses, acetylcholine (ACh) is hydrolysed by an enzyme **acetylcholinesterase (AChE)** which is present in high concentration at the synapse.
- The products of the hydrolysis are acetate and choline which are reabsorbed into the synaptic knob where they are resynthesized into acetylcholine, using energy from ATP.

## *Key Concepts*

**(1)** Neurotransmitters – As explained in the discussion of synapses, neurotransmitters are chemicals released from a presynaptic neuron that interact with specific receptor sites of a postsynaptic neuron. At least sixty chemicals thought to have the capacity to act as neurotransmitters have been discovered.

| S.No. | Excitatory | Inhibitory |
|---|---|---|
| 1 | Acetylcholine | Gamma amino butyric acid (GABA) |
| 2 | Norepinephrine (NE) | Glycine |
| 3 | Serotonin | |
| 4 | 5-hydroxy tryptamine (5-HT) | |
| 5 | Dopamine | |
| 6 | Histamine | |
| 7 | Glutamate | |
| 8 | Epinephrin | |
| 9 | Gastrin | |
| 10 | Glucagon | |
| 11 | Melatonin | |
| 12 | ADH | |

**(2)** **Synapse, A one-way valve –** The synapse cannot transmit an impulse in the reverse direction as the dendrites cannot secrete a neurotransmitter. Thus, the synapse acts as a one-way valve, allowing the conduct of impulse from axon to dendron only.

**(3) Synaptic delay –** Transmission of an impulse across a synapse is slower than its conduction along a neuron. This is because of the time required for the release of a neurotransmitter, its diffusion through the synaptic cleft, and its action on the postsynaptic membrane. The difference in the rate is called synaptic delay. It amounts to about half a millisecond at body temperature ($37^{o}C$).

**(4) Synaptic fatigue –** Repeated stimulation of the presynaptic knob may deplete the neurotransmitter, and this may fail to stimulate the postsynaptic membrane. This condition of the synapse is termed synaptic fatigue. It lasts for several seconds during which the neurotransmitter is resynthesized. Synaptic fatigue is the only fatigue that affects the nervous tissue. Conduction of the nerve impulse along the neurons is not subject to fatigue.

**(5) "All or None law" (Keith Lucas, 1905) –** When stimulated, the axon membrane (= axolemma) does not respond for a moment due to its resistance or threshold to stimulation. However, when its threshold is broken, the stimulation is conducted through its whole length as a strong impulse. If the stimulation is too weak to break the axon's threshold, impulse is not established, but if the intensity of stimulation is much more than the threshold value, impulse conduction remains normal. Thus, the action potential obeys "all or none law". In other words, impulse conduction is such a triggered phenomenon which, though occurs in a twinkling, like an explosion, but only when it reaches "ignition point" or firing level".

## Test your Resonance with concept

**1.** Which one of the following statement in regard to nerve activity is true?

(1) The synaptic cleft does not prevent direct propagation of action potential from presynaptic neuron to post synaptic cell

(2) Information across the synaptic cleft is transmitted by means of a chemical neurotransmitter in small vesicle

(3) Combination of neurotransmitter with receptor site changes membrane potential without changing membrane potentiality

(4) In tetanus the excitatory impulse to muscles are inhibited leading to lock jaw

**2.** Propagation of action potential is very fast in nerve fibres which have

(1) Large fibre diameter (2) Small fibre diameter

(3) Covering of myelin sheath (4) (1) and (3) both are correct

**3.** The following hormones are neurotransmitters

(1) Acetylcholine and secretin (2) Cholecystokinin and acetylcholine

(3) Adrenalin and acetylcholine (4) Cholecystokinin and adrenalin

**4.** When a neuron is stimulated to generate nerve impulse, the electrical potential on the inside of the nerve membrane changes

(1) From negative to positive and remains positive

(2) From negative to positive and back to negative

(3) From positive to negative and remains negative

(4) From positive to negative and back to positive

**5.** The potential difference in the membrane which is responsible for the conduction of an impulse is brought about by a change in the membrane

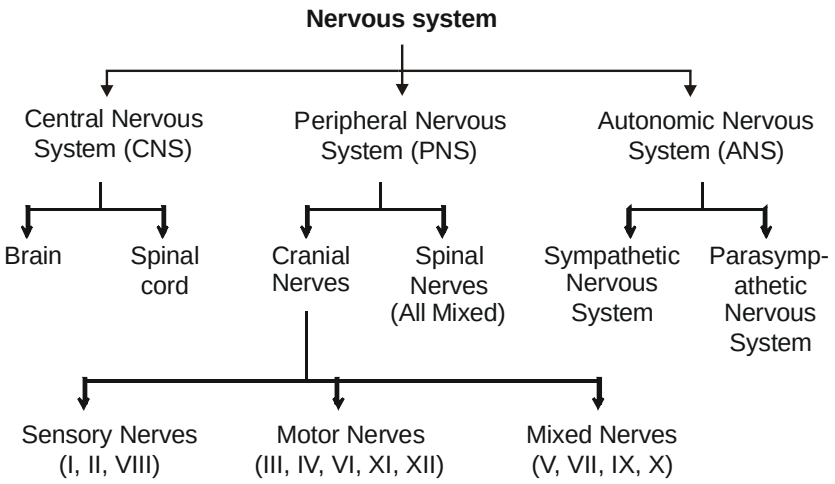
(1) Permeability (2) Structure (3) Anions (4) Concentration

**Answers**

**1.** (2) **2.** (4) **3.** (3) **4.** (2) **5.** (1)

## 6. Parts of Nervous system

Nervous system is divided into three parts –




### 6.1 Central nervous system (CNS)

In all the vertebrates including man, CNS is dorsal, hollow and non-ganglionated while in invertebrates (when present) it is ventral, solid, double and ganglionated. CNS is formed of two parts :

(1) **Brain –** Upper and broader part lying in the head.

(2) **Spinal cord –** Lower, long and narrow part running from beginning of neck to trunk. CNS is covered by 3 meninges and its wall has two type of matter.

### 6.2 Types of matter

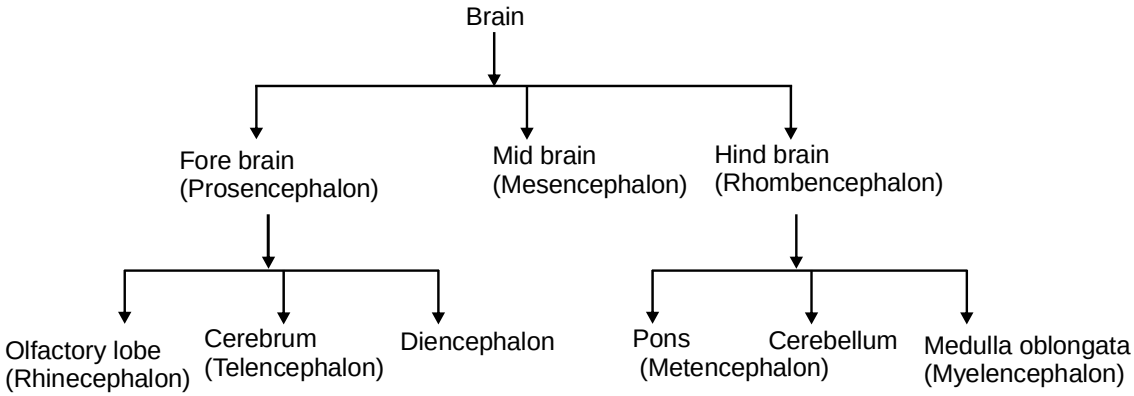
CNS of vertebrates is formed of two types of matter –

(1) **Grey matter –** It is formed of cell-bodies, non-medullated nerve fibres, neuroglea, dendrites of association neurons and motor neurons.

(2) **White matter –** It is formed of medullated nerve fibres or **myelinated axon of motor and sensory neurons,** which appear white due to presence of myelin sheath.

## 7A. Structure of human brain (Encephalon)

It is soft, whitish, large sized and slightly flattened structure located inside the cranial cavity of cranium of the skull. In man, it is about 1200-1400 *gm* in weight and has about 10,000 million neurons. Brain is made up of 3 parts:




**7.1 Fore brain or Prosencephalon –** It forms anterior two-third of brain and is formed of three parts.

**A. Olfactory lobes –** These are one pair, small sized, club-shaped, solid, completely covered by cerebral hemispheres dorsally. Each lobe is differentiated into two parts –

**(a) Olfactory bulb –** Anterior swollen part and

**(b) Olfactory tract –** Posterior and narrow part which ends in olfactory area of temporal lobe of cerebral hemisphere.

**Function –**These control the olfaction.

| **Resonate the Concept** |
|---|
| **(1)** It is normal in frog, rabbit and man.<br>**(2)** It is well developed in dogs. So power of smell is more in dog.<br>**(3)** These are also well developed in dog fish (scoliodon). The name dog fish is on the basis of well developed olfactory lobes. |

**B. Cerebrum**

- Cerebrum is divided into 5 lobes (a) frontal (b) parietal, (c) occipital, (d) temporal and (e) Insula.
- A lobe called insula is hidden as it lies deep in the **sylvian fissure.**
- The cerebral hemisphere are separated from olfactory lobes by **rhinal fissure.**
- The **median fissure** divides the cerebrum into a right and a left cerebral hemisphere.

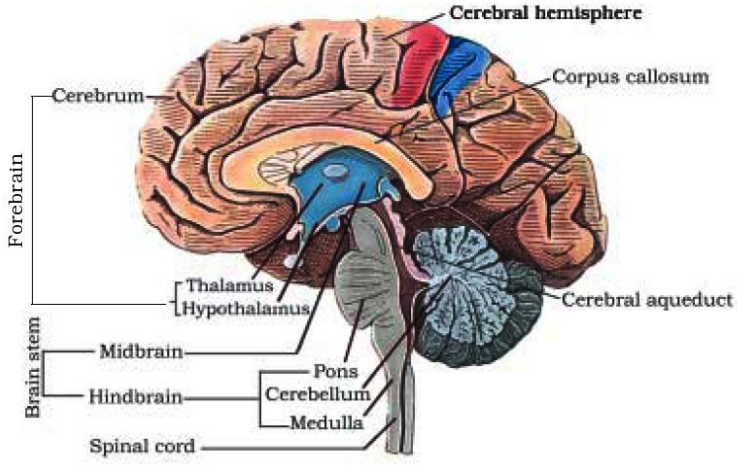



**Diagram showing sagital section of the human brain**

- A few sulci are well developed and form three deep and wide fissures which divide each cerebral hemisphere into four lobes: anterior frontal lobe, middle parietal lobe, posterior occipital lobe and lateral temporal lobe.
- Fissure sulcus lying between the frontal and parietal lobes is central fissure or sulcus. Parieto-occipital fissure lies, that lying between the parietal and occipital lobes. The frontal and parietal lobes from the temporal lobe are demarcated by lateral or Sylvian fissure.
- **Function of Cerebrum –** It is the centre for intelligence, emotion, will power, memory, consciousness, imagination, experience, knowledge, reasoning, voluntary controls, weeping and laughing, micturition and defecation.

**Resonate the Concept**

(1) Each cerebral hemisphere possess a fluid-filled cavity called **lateral ventricle or paracoel.**

(2) Two cerebral hemispheres are interconnected by thick band of transverse nerve fibres of white matter called **corpus callosum.**

(3) The peripheral portion of each cerebral hemisphere is formed of grey matter and is called cerebral cortex, while deeper part is formed of white matter and is called cerebral medulla.

(4) Cerebral cortex is the **highest centre** for many sensations and activities and possess a number of sensory areas. Cerebral cortex is 2-4 mm in thickness.

(5) If cerebrum is removed animal becomes simple reflex animal.

## *Key Concepts*

**(1) Corpus callosum –** It is the unique feature of mammalian brain. It is the band of white neurons present between both cerebral hemisphere and connect them on medial surface.

Below corpus callosum there are two fused band of white fibers called **fornix.** There anterior part is called column and posterior part is called crura. Between column and genu a membrane is called septum lucidum or septum pellicidum. Septum lucidum encloses a space called $V_5$ or Pseudocoel, because it does not possessing CSF.

**(2) Limbic system –** Limbic system present on inner border of cerebrum and floor of diencephalon, It is also called emotional brain or animal brain. Limbic system controlling emotion, animal behaviour like chewing, licking, sniffing, docility, tameness, affection (animals) rage, pain, pleasure, anger, sexual feelings, feer sorrow grooming etc.

**C. Diencephalon**

Diencephaton cavity is called, **III ventricle or diocoel** the thin roof of this cavity is known as the epithalamus, the thick right and left sides as the thalami (sing. thalamus), and floor as the hypothalamus.

**(a) Epithalamus**

- It forms roof of the third ventricle.
- The epithalamus is not composed of nervous tissue. It is composed of piamater only. Hence, it is of relatively little significance as a nerve centre. Its anterior part is vascular and folded. It is called anterior choroid plexus.
- Behind this plexus, the epithalamus gives out a short stalk, the pineal stalk which bears a small, rounded body, the pineal body at its tip and paired right and left habenular nuclei (olfaction or smell).

**(b) Thalamus**

- A pair of mass of grey matter forms the superior part of lateral walls of the third ventricle. It measures 3 cm in length and comprises 80% of diencephalon.
- The thalamus is **principal relay station** for sensory impulses that reach the cerebral cortex from spinal cord, brain stem and cerebellum.
- It also allows crude appreciation of some sensations such as pain, temperature and pressure.
- Certain nuclei in the thalamus relay all sensory input to cerebral cortex. These include –

  (i) Medial geniculate nucleus for hearing.

  (ii) Lateral geniculate nucleus for vision.

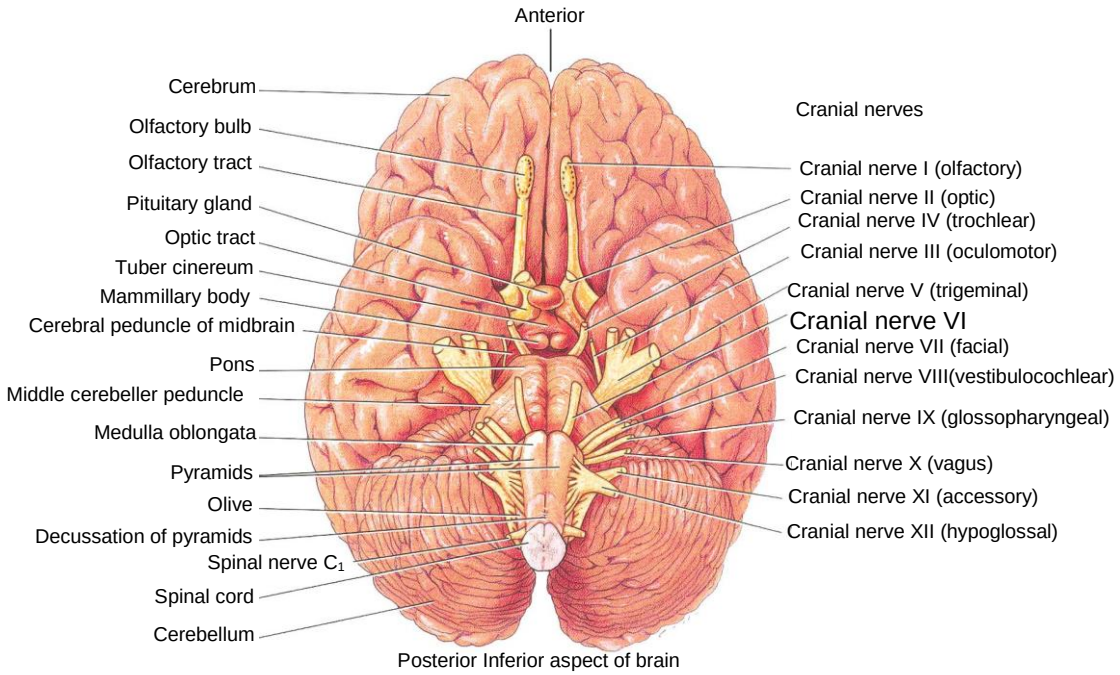
  (iii) Ventral posterior nucleus for taste, touch, pressure, vibration, heat, cold and pain.
- Other nuclei are centers for synapse in somatic motor system. They include -

  (i) Ventral lateral nucleus and ventral anterior nucleus (voluntary motor actions).

  (ii) Anterior nucleus concerns with emotions and memory.

**(c) Hypothalamus**

- The hypothalamus is visible in the ventral view of the brain and forms the floor of diencephalon.
- Hypothalamus also gives a nervous process called infundibulum (forms pars nervosa) which joins a rounded non-nervous pharyngeal outgrowth called hypophysis.
- Both collectively form master gland called pituitary body.
- A stalked outgrowth of infundibulum combines with a pouch-like epithelial outgrowth (Rathke's pouch) of the roof of embryonic mouth (= stomodaeum), forming a pituitary gland or hypophysis. It secretes a number of hormones.
- In front of hypothalamus, there is cross of left and right optic nerves called **optic chiasma.** Behind the hypothalamus, there is one pair of small, rounded, nipple-like bodies called mammillary bodies or corpora mammillares.
- The hypothalamus consists of many masses of grey matter, called hypothalamic nuclei, scattered in the white matter.




**Ventral view of brain**

- In man and some other mammals, most fibres of optic nerves cross, but some fibres do not cross and innervate the eyes of their own respective sides.

- This arrangement enables man and these mammals to have a binocular vision. Rabbits simply have a monocular vision.

| Resonate the Concept |
|---|
| **(1)** Hypothalamus is centre for hunger, thirst, sweating, sleep, fatigue, temperature, anger, pleasure, love, hate and satisfaction. |
| **(2)** It is also centre for releaseing factors for endocrine glands. |
| **(3)** It also controls A.N.S (autonomic nervous system) |
| **(4)** It also functions as the center for regulation of parasympathetic (cranio-sacral) activity. When stimulated, it causes lowering in the rate of heart beat and contraction of the visceral muscles. |

- **Functions of Diencephalon –** It is the centre for:
  (a) *Carbohydrate metabolism*
  (b) *Fat metabolism*
  (c) It relays impulses from posterior region of brain and also to posterior region of brain.
  (d) It secretes neurohormone
  (e) Forms part of pituitary gland
  (f) Secretes cerebrospinal fluid

## *Key Concepts*

**(1) Pineal Gland –** Pineal gland is a pine cone-shaped gland. It is located in the center of brain with which it loses all nerves connection after birth. It is innervated by sympathetic nerves. It has a photosensory role in amphibian and primitive reptiles and is called **'Third eye'**. Pinealocytes secretes melatonin. Mammalian pineal gland does not act as photoreceptor but it produces the hormone called melatonin which is anti FSH and anti LH. It inhibits reproductive function. Melatonin secretion decreases after puberty.

**(2) Cerebrum –** Cerebral cortex is made up of grey matter and differentiated into –

**(a) Sensory** and **associated area** confirms, recognises and evaluates the shape, colour, sound, taste and smell for sensory cells in relation to the objects.

**(b) Broca's area –** Known as sensory speech area or motor speech area. Translate thought into speech. It is located into frontal lobe towards left side. It is associated with language area and also interprete translation of written words into speech. Damage or injury in Broca's area (sensory or motor speech area) may result aphasia (inability to speak), word deafness, word blindness.

| Area | Location | Function |
|---|---|---|
| Premotor area | Frontal lobe | The highest centre for involuntary movements of muscles and ANS. |
| Motor area | Frontal lobe | Controls voluntary movements of the specific muscles |

| | | |
|---|---|---|
| Broca's area | Frontal lobe | Motor speech area (Translation of thought and written words into speech) |
| Somesthetic area | Parietal lobe | Perception of general sensation like pain, touch and temperature |
| Auditory area | Temporal lobe | Hearing (Interprets characteristics of sound such as pitch and rhythm. |
| Olfactory area | Temporal lobe | Sense of smell |
| Wernicke's area | Temporal lobe | Understanding speech written and spoken |
| Gustatory area | Parietal lobe | Sense of taste |
| Visual area | Occipital lobe | Sensation of light |

### 7.2 Midbrain

- The midbrain is located between the thalamus/hypothalamus of the forebrain and pons of the hindbrain.

  It is formed of two parts –

**A. Optic lobes –**These are one pair, large sized lobes present on dorsal side. Each is divided transversely into upper and larger superior coliculus and lower and smaller inferior coliculus. These four optic lobes together called as **optic/corpora quadrigemina** (only in mammals). In frog these are known as bigemina. **Valve of vieussens** joins the optic lobe with cerebellum.

**(a) Superior optic lobe or superior colliculus:** They are concerned with reflex action of eye, head and neck in response to visual stimulus.

**(b) Inferior colliculus –**They are concerned with movement of head and trunk in response to hearing stimulus.

**B. Cerebral peduncle** (crura cerebri) **–**They are the pair of thick bands of longitudinal nerve fibres present on the floor or ventral side of mid brain. This connects upper and lower regions of brain.

**Functions of Mid brain**

**(i)** Pair of anterior optic lobes (which are also known as superior colliculi) is related with vision.

**(ii)** Pair of posterior optic lobe (known as inferior colliculi) is related with audition.

**(iii)** These act as coordination centres between fore and hind brain.

**Resonate the Concept**

**(1)** A canal called the cerebral aqueduct passess through the midbrain.

**(2)** Midbrain and hindbrain together form the **brain stem.**

### 7.3 Hindbrain

- The hindbrain comprises pons, cerebellum and medulla (also called the medulla oblongata).

**A. Cerebellum (sandwiched brain) –** Cerebellum is second largest part of brain lying posterior to medulla and pons and inferior to posterior part of cerebrum. It is butterfly shape in structure. The superficial layer of cerebellum, called cerebellar cortex, consist of gray matter. Deep to gray matter

are white matter tree called **'Arbor vitae' or tree of life.** Cerebellum has very convoluted surface in order to provide additional space for many more neurons.

- **Functions of Cerebellum**

**(i)** It is centre for co-ordination of muscular movement.

**(ii)** It is primary centre for balance, equilibrium and orientation.

**Note:** Poorly developed in frog but well developed in mammals.

**B. Medulla oblongata –** Medulla oblongata is the hindest and posterior most part of brain. Its cavity is known as **IVth ventricle (metacoel)** which is continuous with central canal of spinal cord through formen magnum. It has a pair of lateral foramina of Luschka and a median foramen magendie. Cerebrospinal fluid comes in contact through these apertures from internal cavity of the brain to outer fluid of meninges. Medulla contain nuclei for origin of **5 pairs of cranial nerves, VIII, IX, X, XI and XII**

- **Funcitons of Medulla oblongata – It contains centre for** –

(i) Heart beats

(ii) Respiration

(iii) Digestion

(iv) Blood pressure

(v) Gut peristalsis

(vi) Swallowing of food

(vii) Secretion of gland

(viii) Involuntory function – e.g. vomiting, coughing vasoconstriction, vasodilater, sneezing, hiccouping.

(ix) It control urination, defecation.

(x) The cardiovascular center – regulate rate and force of heart beats.

(xi) Medullary rhythmicity area – adjust basic rhythms of respiration.

**C. Pons Varolii –** An oval mass, of white mater called the pons varolii, lies above the medulla oblongata. It consists mainly of nerve fibres which interconnect as bridge connecting spinal cord with brain and parts of brain with each other. Pons also with pneumotaxic area and apneustic area. Together with medullary rhythmicity area, they help control respiration.

**Resonate the Concept**

- **Salient or mammalian features of human brain:** The salient or mammalian features in the human brain are –

  (1) Relatively small with solid olfactory lobes.

  (2) Very large cerebral hemispheres divided into lobes, highly folded surface and cerebral cortex of gray matter.

  (3) Corpus callosum, interconnecting cerebral hemispheres.

  (4) Very small pineal body.

  (5) A pair of mammillary bodies joined to hypothalamus.

  (6) Relatively small and solid optic lobes, divided into 4 sub lobes (corpora quadrigemina).

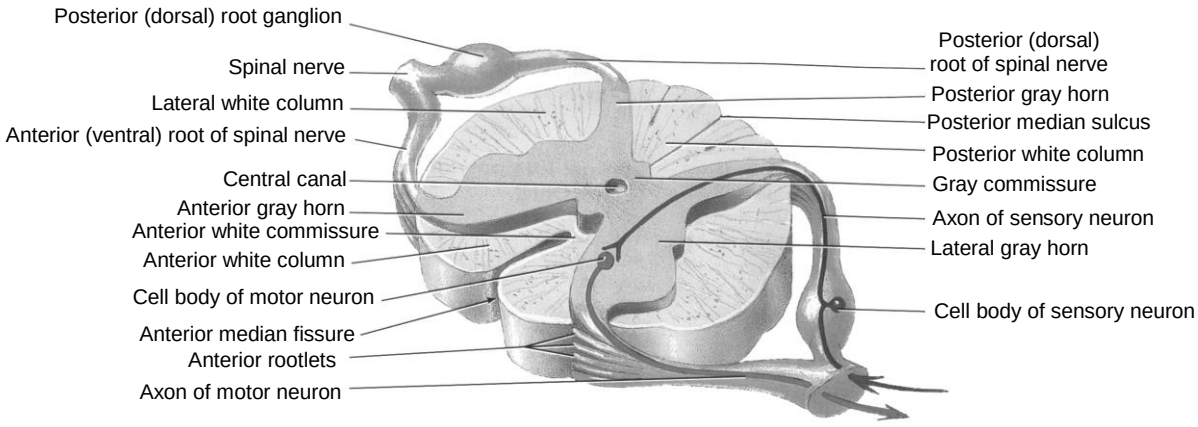
  (7) Large, solid cerebellum with highly folded surface and divided into lobes.

  (8) Pons varolii present anterior to the cerebellum.

## 7B.Spinal cord

It is located in the spinal canal or vertebral canal of vertebral column. It is extended from foramen magnum to II lumber vertebra. In new born infants, it is extended to 3rd or 4th lumber vertebra. Spinal cord is swollen in cervical and lumber region which are called cervical and lumber enlargement. The length of spinal cord ranges from 42 to 45 cm. Its diameter is about 2cm.

- **Structure of spinal cord –** Spinal cord is also covered by duramater, arachnoid and piamater. The outer-part of spinal cord is composed of white matter while inner-part contains gray matter. On the dorsa-lateral and ventro-lateral surface of spinal cord, the gray matter (butter fly like) projects outside and forms one pair dorsal and ventral horns. Dorsal and ventral horns continue in a tube like (bundle of never fibres) structure known as root of dorsal and ventral horns. In root of dorsal and ventral horn, ganglia are present called dorsal and ventral root ganglia respectively. Both roots are combined with each other at the place of intervertebral foramen. Sensory neurons are found in the dorsal root ganglia which is pseudounipolar in nature and near to inter vertebral foramen. Its axon extend and gets embedded into the gray matter of spinal cord. The sensory nerve fibre come from ganglia and make synapse with ventral root neuron. Motor neurons are found in the ventral root. Cyton is found in ventral horn while its dendrons are embedded into gray matter of spinal cord where they make synapse with axon of sensory neuron. Both sensory and motor nerve fibers combindly come out from intervertebral foramen and form spinal nerve.




**T.S. of the thoracic spinal cord of mammal**

## Key Concepts

**(1) Meninges:**

The meninges are connective tissue membranes which surround the brain and spinal cord of CNS. In the fishes, there is only one meninx called meninx primitiva (piamater). In amphibians, reptiles and birds, the brain is covered by two meninges or membranes: inner pia-arachnoid and outer duramater. In mammals, CNS is covered by three meninges or membranes or cranial meninges. Brain meninges are continuous with spinal meninges

- The three layers of cranial meninges in order from superficial to deeper duramater, arachnoid and piamater. Duramater is nonvascular, tough made up of fibrous connective tissue.
- Arachnoid mater made up of reticular connective tissue with collagen and elastin fiber, while innermost vascular piamater (nutritive) is made up of loose aerolar connective tissue.
- Between dura and arachnoid mater sub dural space (no CSF in mammals here) is present. Sub arachnoid space is present between arachnoid and piamater. It is filled with CSF (with CSF in mammals, CSF also found in ventricles and central canal).
- Between duramater and periosteum epidural space is present. An extension of duramater between two cerebral hemispheres called falx cerebri.
- Tentorium is an extension of duramater between cerebrum and cerebellum.

**(2) Cavities or ventricles of the brain**

The ventricles consist of four hollow fluid filled space inside the brain and same duct for connection between these ventricle.

(i) Olfactory lobe: Rhinocoel

(ii) Cerebrum: I and II ventricles or lateral ventricles or paracoel.

(iii) Foramen of monero – I and II ventricles communicating with IIIrd ventricle by foramen of monero.

These are two in human and single in rabbit and frog.

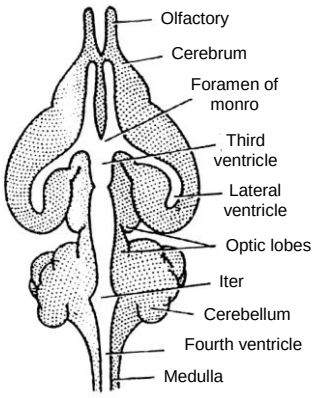
(iv) Diencephalon: Third ventricle or diocoel.

(v) Iter or cerebral aquiduct or aquiduct of sylvius **–** It is very narrow cavity lying between III and IV ventricles.

(vi) Optic lobes: Optocoel

(vii) Cerebellum: Solid.

(viii) Medulla oblongata: IV ventricle or metacoel. Cavities of brain and spinal cord are modified neurocoel.




**Ventricles of brain of rabbit**

They are lined by low columnar ciliated epithelium called **ependyma.**

| Divisions | Subdivisions | Parts | Cavity | Associated strcutures |
|---|---|---|---|---|
| | (1) Telencephalon | Rhinencephalon | I Ventricle (*Rhinocoel*) | Olfactory bulbs, Olfactory tracts, |
| | | | | Olfactory lobes, Palaeocortex on pallium |
| | | Cerebral hemispheres | II or Lateral Ventricles (*Paracoels*) ↓ Formen of Monro | Corpora striata or basal ganglia, |
| | | | | Corpus callosum, Neocortex on pallium, |
| | | | | Paraphysis |
| (I) Prosencephalon (Forebrain) | (2) Diencephalon | Epithalamus (roof) | ↓ III Ventricle (Diocoel) | Habenulae, Pineal apparatus, Parapineal or parietal |
| | | Thalamus (sides) superior | | |
| | | Hypothalamus (floor), Inferior side | | Hypothalamic nuclei, Optic chiasma, Median eminence, Infundibular stalk, Pituitary, Saccus vasculosus, Mamillary bodies, Anterior choroid plexus |
| (II) Mesencephalon (Midbrain) | – | Crura cerebri (floor) | *Iter* or *cerebral aqueduct* | Corpora quadrigemina (superior colliculi, inferior colliculi), Tectum, substantia nigra and red nuclei. |
| (III) Rhombencephalon (Hind brain) | (1) Metencephalon | Cerebellum | | Trapezoid body, Pons |
| | (2) Myelencephalon | Medulla oblongata | IV Ventricle (*Metacoel*) | Restiform bodies, Pyramids |

**(3) Cerebrospinal fluid**

- All the ventricles of brain, central canal of spinal cord are continuous and lined by a columnar, ciliated epithelium, the ependyma.
- These contain lymph-like extracellular fluid called the cerebrospinal fluid (C.S.F.).
- This fluid is secreted by the choroid plexuses by filtration of blood.
- The choroid plexuses consist of loose connective tissue of pia mater covered internally by a simple cuboidal epithelium of secretory (glandular) nature.
- The cerebrospinal fluid slowly flows toward the fourth ventricle by secretion pressure and passes into the spinal cord.
- Some fluid escapes into the subarachnoid spaces via three pores; a median aperture (of magendie) and a paired lateral aperture (of Luschka) in the roof of the fourth ventricle in the medulla.
- From the subarachnoid spaces, the cerebrospinal fluid is transferred to the blood of the venous sinuses.
- Nervous tissue is devoid of lymphatic vessels.
    - The cerebro-spinal fluid (CSF) provides –

(i) Protection to brain from mechanical shocks and physical injury.

(ii) Optimum physiological fluid environment for neural functions *e.g.* conduction of nerve impulses, transport of aminoacids, sugars, $O_2$ etc.

(iii) **'Relief'** mechanism for the increase in intracranial pressure that occurs with each arterial pulse of blood to brain.

(iv) 'Sink' like facility for metabolites of brain.

(v) The blood CSF barrier for selective transport process between blood and CSF.

(vi) Nourishment to CNS.

- The major site of CSF formation is choroid plexus and mid ventricular wall and sub-arachnoid wall also contribute. CSF is devoid of cells, slightly alkaline and is isotonic to plasma. Rate of formation of C.S.F is 20 ml/h (480 ml/day) 20 ml/hour approx, 1/2 litre per day. Total amount present in and around CNS is 80-150 ml, it means there is atleast 3 times renewal of C.S.F. every day. CSF contains glucose, proteins, lactic acid, urea, $Na^+$, $K^+$, $Ca^{2+}$, $Mg^{2+}$, $Cl^-$, $HCO_3^-$ and some WBC.
- Blood brain barrier facilitate maintenance of stable internal environment. Its acts as physiological and pathological barrier.

**(4) Hydrocephalus –** The enlargement of head, a pathological condition characterized by an abnormal accumulation of cerebrospinal fluid resulting headache, vomiting, pain and stiffness of the neck. Infection may be viral, bacterial or both. The most common cause of meningitis is the infection of *Streptococcus pneumoniae, Neisseria meningitidis* and *Haemophilus influenzae*.

**(5) Choroid plexus –** There are three choroid plexus in humans –

(i) **Lateral choroid plexus –** It is in the roof of I and II ventricle.

(ii) **Anterior choroid plexus –** It is in the roof of III ventricle (diacoel).

(iii) **Posterior choroid plexus or pelochoroida –** It is in the roof of IV ventricle.

**(6) Oxygen and glucose requirements of brain –** To control various functions of our body organs brain needs a large and constant oxygen (20% of the body's consumption) and blood glucose (15% of its consumption) supply. Brain deprived of oxygen creats mental confusion and leads to permanent damage within 5 minutes.

## Test your Resonance with concept

**1.** Foramen of Monro is an aperture between
(1) Paracoel & diocoel (2) Diocoel and metacoel
(3) Rhinocoel and diocoel (4) 3rd and 4th ventricle

**2.** The correct sequence of meninges from the outer to the inner side is
(1) Arachnoid – piamater – duramater (2) Arachnoid – duramater – piamater
(3) Piamater – arachnoid – duramater (4) Duramater – arachnoid – piamater

**3.** In which part of the following, the anterior choroid plexus is situated?
(1) Diocoel (2) Metacoel (3) Olfactocoel (4) Optocoel

**4.** Metacoel is the cavity in the
(1) Cerebral hemispheres (2) Diencephalon
(3) Cerebellum (4) Medulla oblongata

**5.** The innermost meninges surrounding the central nervous system in frog and man respectively are
(1) Piamater and piamater (2) Arachnoid and piamater
(3) Piamater and duramater (4) Arachanoid and duramater

**Answers**

**1.** (1) **2.** (4) **3.** (1) **4.** (4) **5.** (1)

# 8. Reflex action

Reflexes are fast predictable, automatic responses to change the environment. First of all Marshal Hall (1833) studied the reflex action. *Best* and *Taylor* defined reflex action "simplest form of irritability associated with the nervous system is reflex actions or a reflex reaction is an immediate involuntary response to a stimulus." The reflex actions are involuntary actions because these are not under the conscious control of the brain. Central nervous system is responsible for the control of reflex action.

**Reflex arc** is formed by the neurons forming the pathway taken by the nerve impulses in reflex action. The simplest reflexes are found in animals involving a single neuron and the following pathway -

### 8.1 Component of reflex action

The whole of the reflex are includes five parts –

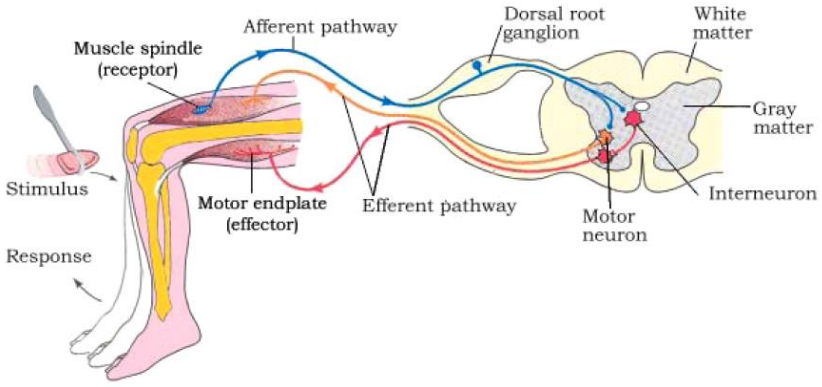
(i) **Receptor organs –** Receptors are windows of the body or guards of the body. These are situated on all, important organs, for example – eyes, nose, ear, tongue, integument etc. These perceive the stimuli from out side the body.

(ii) **Sensory neurons –** These are also termed afferent neurons. These carry stimuli from receptors to spinal cord. These neurons are situated in the ganglion on the dorsal side of spinal cord gray matter or brain stem.

(iii) **Association neurons or Integrating center:** These are also called intermediate neurons or interstitial neurons. These are found in spinal cord. These transfer the impulses from sensory neurons to motor neurons. Association neurons forms monosynaptic and polysynaptic reflex arcs.

(iv) **Motor neurons –** These are situated in the ventral horn of spinal cord. These carry impulses to the effector organs.

(v) **Effector organs –** These are the organs, which react and behave in response to various stimuli, for example – muscles and glands.




**Diagrammatic Presentation of reflex action (showing knee jerk reflex)**

### 8.2 Mechanism of reflex action

- The time taken by a reflex action is too short, for example – in frog it is 0.3 meter per second and in man 5-120 meter per second.
- Whenever, a part of the body is stimulated by any stimulus, for example – pin pricking, then the stimulus is converted into impulse.
- This impulse is perceived by the dendrites of sensory neurons. From here, the stimulus reaches the spinal cord through axonic fibres.

- In the spinal cord, this stimulus passes through synaptic junctions and reaches the intermediate neurons, from where this stimulus reaches the effector organs through motor nerve fibres.
- As soon as the stimulus reaches the effector organs, it is stimulated and that part of the body is immediately withdrawn.
- The whole reflex action takes place so rapidly and quickly that we know it when it is completed.

**8.3 Type of reflexes**

The reflexes are of following types –

**(i) Monosynaptic reflex**

- This is the simplest reflex found in vertebrates.
- The sensory neuron synapses directly with cell body of the motor neuron cell body.
- In this case the reflex action takes place without the involvement of brain.

**(ii) Polysynaptic spinal reflex**

- This has at least two synapses situated within the spinal cord. It involves a third type of neuron also – the internuncial or inter-mediate relay neuron.
- The synapses take place between the sensory neuron and intermediate neuron, and between intermediate neuron and the motor neuron.
- These two reflex arcs allow the body to make automatic, involuntary, homeostatic adjustments, to changes in the external environment, such as the iris pupil reflex and balance during locomotion, and also in the internal environment such as breathing rate and blood pressure.

**(iii) Polysynaptic spinal/brain reflexes**

- In this case the sensory neuron synapses in the spinal cord with a second sensory neuron, which passes to the brain.
- The later sensory neurons are part of the ascending nerve fibre tract and have their origin in pre-intermediate neuron synapse. The brain is capable of identifying this sensory information and stores it for further use. The motor activity may be initiated by the brain anytime and the impulses are transmitted down the motor neurons in descending nerve fibre tract, to synapse directly with spinal motor neurons in the post-intermediate synaptic region.

**(iv) Simple reflex**

- Simple reflex is also known as **unconditioned reflex.**
- It is inborn, unlearned, reflex to a stimulus. Simple reflex is mostly protective in function. Example of simple reflex are
  (a) **Knee jerk** – Tendon of patella tapped, also called patellar reflex.
  (b) **Corneal reflex** (blinking reflex) – closing of eyelids.
  (c) Rapid withdrawal of hand while burned or pricked.
  (d) Quick recovery of balance while falling.
  (e) **Scratch reflex** of frog – in pitched frog with acetic acid.
  (f) Coughing, sneezing and yawning.

**(v) Acquired reflex**

- Acquired reflex is also known as **conditioned reflex.** It is not inborn, but acquired and dependent on past experience, training and learning.
- Demonstration of conditioned reflex was first made by Russian physiologist **Ivan Petrovitch Pavlov** (1846-1936) in hungry dogs. Pavlov rang the bell while feeding dogs, thus associated the unconditioned response with additional stimulus.
- Examples of conditioned reflex are learning of dancing, cycling, swimming, singing,, driving, etc. These actions are under cerebral control during learning.

## 9. Peripheral nervous system

- It is composed of a number of long, thin, whitish threads called nerves extending between central nervous system and body tissues. Each nerve is formed of bundles of nerve fibres, fasciculi, held

together by connective tissue and surrounded by a white fibrous connective tissue sheath called epineurium.

- The nerve fibres are classified into two categories on the basis of presence or absence of myelin (white fatty) sheath.

(1) Medullated or myelinated nerve fibres.

(2) Non-medullated nerve fibres.

On the basis of function, the nerves are of three types

(1) **Sensory nerves**

(i) It contains only sensory nerve fibres.

(ii) It conducts nerve impulses from sense organs to CNS and produce sensation. *e.g.* optic nerve, auditory nerve.

(2) **Motor nerves**

(i) It contains only motor nerve fibres.

(ii) It conducts nerve impulses from CNS to some muscles or glands to control their activities. *e.g.* occulomotor nerve, hypoglossal nerve.

(3) **Mixed nerve**

(i) It contains both sensory and motor nerve fibres.

(ii) It conducts both sensory and motor impulses. *e.g.* all spinal nerves, trigeminal nerve.

On the basis of their origin, nerves are of two types

(1) Cranial or cerebral nerves which either arise from or end into brain.

(2) Spinal nerves which arise from spinal cord.

(4) **Cranial nerves**

(a) 10 pairs of cranial nerves are present in an anamniote (fishes and amphibians).

(b) Number of cranial nerves found in frog is ten pairs (20).

(c) 12 pairs of cranial nervers are present in an amniote (reptiles, birds and mammals).

(d) Number of cranial nerves found in rabbit and man is 12 pairs (24).

(e) The first 10 pairs are common for frog and rabbit. The additional pairs found in rabbit are spinal accessory and hypoglossal.

(f) The smallest cranial nerve is trochlear in human beings, but in other animals smallest cranial nerve is abducens.

(g) The largest cranial nerve is trigeminal in human beings but vagus is largest cranial nerve in all other animals.

(h) Vagus supplies the regions other than head.

(i) The sensory cranial nerves are

| | | | |
|---|---|---|---|
| I | Olfactory | – | Smell |
| II | Optic | – | Vision |
| VIII | Auditory | – | Hearing and equilibrium |

(j) The motor cranial nerves are : III, IV, VI, XI and XII.

(k) Extraocular muscle nerves are : III, IV and VI.

(l) The mixed cranial nerves are : V, VII, IX and X (4 pairs).

(m) Number of cranial nerves in snake (Amniota) 10 pairs.

## *Key Concepts*

| | Name | Nature | Origin | Distribution | Function |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| (1) | Olfactory Nerves | Sensory | Olfactory lobe | Sensory epithelium of olfactory sacs | Receive stimuli from the sensory epithelium of olfactory sac and carry them to olfactory lobes |
| (2) | Optic nerves | Sensory | In retina of eye | Lateral geniculate nuclei of thalamus | Stimulus of light is carried to optic occipital lobe of cerebral cortex. |
| (3) | Occulomotor nerves | Motor | Crura cerebri (mid brain) | Eye ball muscles like superior rectus, medial rectus, inferior rectus and inferior oblique. except superior oblique muscle and external rectus | Movement of eye lids and eye ball. |
| (4) | Trochlear nerves | Motor | From in between the optic lobes and cerebellum | Superior oblique muscle of eye ball | Movement of eye ball |
| (5) | Trigeminal nerves | Mixed | From the gassarion galglia situated on the lateral side of pons | — | — |
| | (i) Ophthalmic nerve | Sensory | ,, | Skin of lips, upper eye lid, lacrimal, gland | |
| | (ii) Maxillary | Sensory | ,, | Upper lip, skin of nose, lower eye lid. Upper teeth. | Carry the stimuli from these organs to brain |
| | (iii) Mandibular nerve | Mixed | ,, | Lower lip and skin of jaw | Carry the stimuli from these organs to brain |
| (6) | Abducens nerves | Motor | Pons | Eye muscles external rectus | Movement of eye ball |
| (7) | Facial nerves | Mixed | Pons | — | — |
| | (i) Palatinus | Sensory | — | In the roof of mouth cavity | Carry the impulses from roof of mouth cavity |
| | (ii) Hyomandibular | Motor | — | Muscles of low jaw, muscles of neck and pinna (external ear) | Carry the impulses from brain muslces of lower jaws, neck and pinna. |
| | (iii) Chordotympani | Mixed | — | In salivary glands and taste buds | Receives the stimuli from the taste buds and carry the stimulus to salivary gland. |
| (8) | Auditory nerves | Sensory | Medulla, pons | — | — |
| | (i) Vestibular nerve | ,, | — | Semicircular canals, saccule, utricle. | Receives impulses from the internal ear and carry to brain for equilibrium |
| | (ii) Cochlear nerve | ,, | — | Cochlea | Impulses associate with hearing. |
| (9) | Glossopharyngeal nerve | Mixed | In medulla | Taste buds present in tongue and muslces of oesphagus | Secretion of saliva, taste muscle sense (proprioception) |

| | | | | | |
|---|---|---|---|---|---|
| (10) | Vagus nerve | Mixed | Arising from medulla, 9th and 10th cranial nerves unites to form vagus nerve but become separate and divide into branches | — | — |
| | (i) Superior laryngeal nerve | Motor | — | Glottis, trachea, lung muscle | (1) Smooth muscles contraction and relaxation.<br>(2) Secretion of digestive juice.<br>(3) Muscle sense (proprioception) |
| | (ii) Recurrent laryngeal nerve | Motor | — | Glottis, trachea, lungmuscle. | (4) Sensation of visceral organs. |
| | (iii) Cardiac nerve | Motor | — | Heart Muscles | From brain to heart muscles |
| | (iv) Pneumogastric | Motor | — | In the abdominal cavity, in stomach and lungs. | Carry impulse from these organs to brain and from brain to muscles of these organs. |
| | (v) Depresser nerve | Motor | — | Diaphragm | Carry the impulse to diaphragm |
| (11) | Spinal accessory | Motor | Medulla | Muscles of neck and shoulders, voluntary muscles of pharynx, larynx, and soft palate. | Swallowing movements, movement of head. |
| (12) | Hypoglossal nerve | Motor | Medulla | Muscles of tongue and neck | Movement of tongue during speech, and swallowing, proprioception (Muscle sense). |

- **Spinal nerves –** Spinal nerves arise from gray matter of spinal cord. There are 31 pairs of spinal nerves in man (37 pairs in rabbit). All spinal nerves are mixed. The spinal nerves in man are divided into 5 groups.

| | | | | |
|---|---|---|---|---|
| (1) Cervical (C) | → | 8 pairs | — | in Neck region |
| (2) Thoracic (T) | → | 12 pairs | — | in thoracic region |
| (3) Lumbar (L) | → | 05 pairs | — | upper part of abdomen |
| (4) Sacral (S) | → | 05 pairs | — | lower part of abdomen |
| (5) Coccygeal (Coc) | → | 01 pair | — | represent the tail nerves |
| Total | = | 31 pairs | | |

- Number of spinal nerves in frog is 10 pairs.
- Spinal nerve formula can be written as – $C_8$, $T_{12}$, $L_5$, $S_5$, $Coc_1$

## 10. Autonomic nervous system

- Autonomic nervous system was discovered by Langley.
- Autonomic nervous system (ANS) automatically regulates the activities of smooth muscles, cardiac muscles and glands.
- This co-ordination is involuntary. Autonomic nervous system usually operates without conscious control.
- Autonomic nervous system is entirely motor. All autonomic axons are efferent fibres.
- Autonomic nervous system is regulated by centres in brain like cerebral cortex, hypothalamus and medulla oblongata.
- Autonomic fibres release chemical transmitters at synapse. On the basis of the transmitter produced, these fibres may be classified as cholinergic or adrenergic.
- Cholinergic fibres release acetylcholine. Adrenergic fibres produce norepinephrine (noradrenaline), also called sympathetin.

**Nature of autonomic control –**The autonomic nervous system regulates and co-ordinates such vital involuntary activities like heart beat, breathing, maintenance of the composition of body fluids (= homeostasis) and body temperature, gut peristalsis, secretion of glands, etc. Autonomic nervous system consists of two divisions –

**(1) Sympathetic ANS** (Thoracolumbar out flow)

(i) Thoraco lumber out flow (spinal segments $T_1$– $L_2$)

(ii) Preganglionic nerve fibres are small.

(iii) Post ganglionic nerve fibres are long.

(iv) Preganglionic nerve fibre secretes acetyl choline.

(v) Postganglionic nerve fibre secretes **sympathatin**. (*nor-epinephrine*)

(vi) It shows sympathy (generally increases the function).

(vii) Expenditure of energy takes place.

(viii) It increase defence system of body against adverse condition.

(ix) It is active in conditions of stress, pain, fear and anger.

(x) **Horner's syndrome** results from the damage of sympathetic trunk of one side.

(xi) A patient of Horner's syndrome exhibits lack of sweating (on affected side), sunken eyes and constricted pupil.

**(2) Parasympathatic ANS** (Cranio-sacral out flow)

(i) ANS Cranio sacral outflow (cranial-III, VII, IX, X Nerves)-(sacral-II, III, IV Nerves)

(ii) Preganglionic nerve fibres are long.

(iii) Postganglionic nerve fibres are small.

(iv) Secrete acetylcholine only.

(v) It provide relaxation, comfort, pleasure, at the time of rest.

(vi) Restoration and conservation of energy takes place.

(vii) Collateral ganglia present in sympathetic nervous system.

| S.No. | Name | Sympathetic | Parasympathetic |
|---|---|---|---|

| | | | |
|---|---|---|---|
| **1** | Secretion | Acetyl choline and Sympathiatin | Acetyl choline only |
| **2** | Blood pressure | Increase | Decrease |
| **3** | Blood vessel to skin | Constrict | Dilate |
| **4** | Blood vessel to heart | Dilate | Constrict |
| **5** | Blood vessel to lung and muscle | Dilate | Constrict |
| 6 | Pupil | Dilate | Constrict |
| 7 | Lacrymal gland | Stimulate | Inhibits |
| 8 | Heart beat | Increase | Decrease |
| 9 | Adrenal secretion | Stimulate | Inhibit |
| 10 | Breathing and BMR | Increase | Decrease |
| 11 | Nostrils | Dilate | Constrict |
| 12 | Urinary bladder | Relax | Constrict |
| 13 | Iris | Constrict | Dilate |
| 14 | Salivary gland | Decrease | Increase |
| 15 | Digestive gland | Decrease | Increase |
| 16 | Gut peristalsis | Decrease | Increase |
| 17 | Ejaculation | Increase | Decrease |
| 18 | Bile | Decrease | Increase |
| 19 | Renin (kidney) | Increase | Decrease |
| 20 | Bronchi | Dilate | Constrict |

- Cutting of sympathetic or parasympathetic nerve to heart will not stop functioning of heart. Heart will beat but without any nervous control.
- Autonomic nervous system functions rapidly to alter visceral functions (3-5 seconds).
- It is activated mainly by centers located in spinal cord, brain stem and hypothalamus. Limbic cortex also influences its function often this system function via visceral reflexes *i.e.* sensory signal $\rightarrow$ enter autonomic ganglia $\rightarrow$ spinal cord $\rightarrow$ brain stem $\rightarrow$ or hypothalamus can elicit reflex responses back to visceral organs to control their activities.

### Test your Resonance with concept

**1.** In man which one of the following cranial nerve is associated with the sense of body balance?
(1) VI (2) VII (3) VIII (4) IX

**2.** Purely motor nerve is
(1) Optic (2) Abducens (3) Opthalamic (4) Palatinus

**3.** Which is a wrong relation?
(1) Conditioned reflex – *Hodgkins*
(2) Blood circulation –*W. Harvey*
(3) DNA double helix model – *Watson* and *Crick*
(4) Father of microbiology–Louis Pasteur

**4.** Spot out the parasympathetic effect
(1) Increasing blood pressure (2) Dialating pupil
(3) Secretion of digestive juice (4) Increasing cardiac output

**5.** Autonomic nervous system is
(1) Paired chain ganglia (2) Brain and spinal cord
(3) Sense organs (4) Cerebral hemispheres

**Answers**
**1.** (3) **2.** (2) **3.** (1) **4.** (3) **5.** (1)

# Sensory Organ

## 11.Introduction

How are environmental changes detected? In its broadest context, sensation is the conscious or unconscious awareness of external or internal stimuli. Cells which are specialised to receive stimulations are called receptors.

The sensory system consists of simple to complex structures called sensory receptors. An animal responds to a stimulus in a four-step process – sensory transduction, transmission, Integration and Response.

## 12.Eye

Human have binocular vision. The eye can discriminate colour, appraise length, width and depth visually and form true inverted image.

### 12.1 Structure of Eye

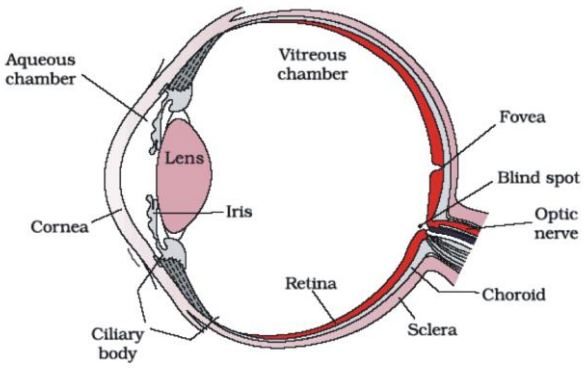



**Diagram showing parts of an eye**

The eyes are two in number and lodged in orbits (bony socket) of skull. The eye is a hollow, spherical organ, about 2.5 cm in diameter and about 6 to 8 gram in weight. It has two parts –

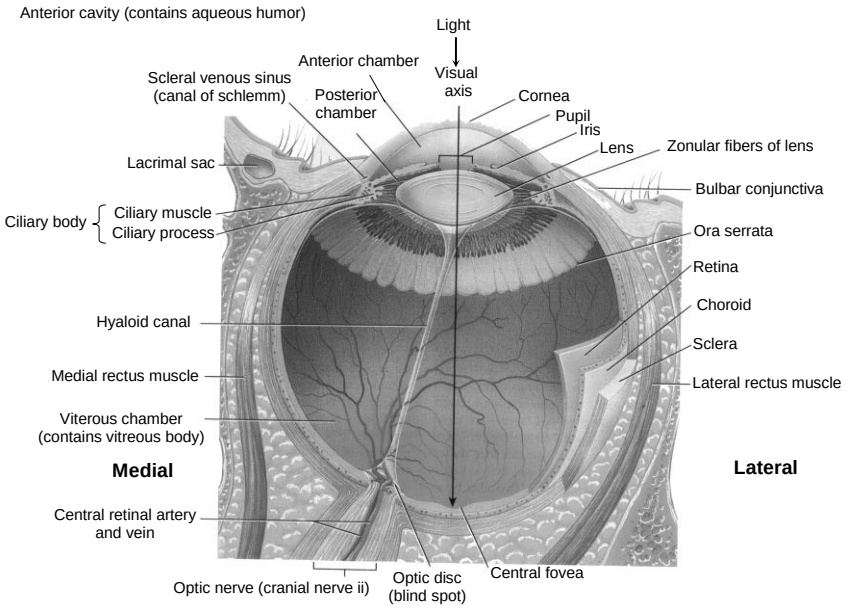
**(1) Protective devices –** Eye has four protective various.

(i) **Eye brows –** The outwardly directed hair of the eyebrows carry the sweat and rain drops trickling down the forehead to the sides to prevent their falling into the eyes.

(ii) **Eye lids (Palpebrae) –** In man two eyelids are present. Only upper eyelid is movable. They are regularly open and close at short intervals to clean the cornea. This is called blinking. In frog out of two, upper eyelid is immovable and lower eyelid is movable. Nictitating membrane is present in frog which protect eye in water. Movement of nictitating membrane takes place by **retractor bulbi**. It becomes folded by **levator bulbi**.

A nonfunctional vestigeal nictitating membrane, called **plica semilunaris,** occurs in human eyes. It remains permanently retracted at the inner angle of each eye.

(iii) **Eye lashes –** The eyelids bear at the free edge a row of stiff hair, the eye lashes. These check the entry of dust particles, tiny insects and rain drops into the eyes.




**Superior view of transverse section of right eyeball**

(iv) **Eye glands**

(a) **Meibomian gland –** The eye-lids bear at the free edge a row of meibomian gland that is **modified sebaceous gland.** (Acts as a lubricant).

(b) **Lacrimal gland or Tear gland –** It lies in the upper outer part of the eye orbit and secretes a slightly saline, watery fluid that contains a antibacterial enzyme called **lysozyme.** This secretion moistens the surface of the eyeball. The excess of this secretion passes through nasolacrimal duct. It is modified sweat gland.

(c) **Harderian gland –** Some aquatic mammals (whale) possess harderian gland which lubricate nictitating membrane. It is also found in frog and birds.

(d) **Glands of zeis (zis) –** These are modified sebaceous gland, found at base of hair follicle of eye lashes, pour lubricating fluid in hair follicle. Infection of these glands is **stye.**

(e) **Glands of Moll –** It is modified sweat gland and open into the follicles of eyelashes. In human meibomian, lachrymal, Moll's glands, and zeis glands are present.

(v) **Connective tissue –** A layer of fatty connective tissue surrounds the eyeball. It serves as a soft shockproof pad.

**(2) Eye ball –** Eye ball is made up of 3 coats or tunic.

(i) **Sclerotic layer (Fibrous tunica) –** Outer most and opaque, fibrous and non-vascular layer easily seen as white of the eye. It is a coat of dense connective tissue made up of collagen fibers and fibroblasts. Sclera covers entire eye ball except cornea, gives shape to eye ball. Sclera in frog is cartilaginous.

(a) **Cornea –** In the centre, sclerotic layer it merges with the transparent round window called cornea.

(b) **Conjunctiva –** The cornea and exposed part of sclera is covered externally by a thin, transparent membrane, the conjunctiva.

(ii) **Choroid layer (Vascular tunica) –** Also known as uvea middle. it is vascular layer which supplies nutrients to the eyes. It is distinguished into three parts choroid, ciliary body and iris.

(a) **Choroid –** It is highly vascular posterior portion of vascular tunic. The choroid occurs in the main part of eye ball adhered to the sclerotic. (The pigment is reddish in rabbit and black, brown or bluish in man).

(b) **Ciliary body –** Ciliary body is vascular and pigmented like choroid. It is made up of ciliary processes and ciliary muscles (only circular type). The ciliary body is hidden by iris. The ciliary body **helps in accommodation** by altering the focus of eye from object or the shape of lens near or far vision.

(c) **Iris –** Beyond the ciliary body, the vascular tunic sharply turns inwards, forming a circular, shelf-like diaphragm called iris. The colour of the iris is responsible for colour of eye e.g., brown, black, blue or green. In **albinos,** iris is deficient of pigments.

**Lens –**

- Lens is colourless, transparent and fibrous crystaline structure made up of protein ($\alpha$ and $\beta$ crystalline protein) and enclosed in lens membrane.
- It is ectodermal in origin. Lens is lodged in eye ball by suspansory ligament of ciliary body.
- Suspansory ligaments are known as **"Zonula of Zinn".** In man lens is biconvex while in frog it is elliptical (subspherical).
- Lens divide the eye ball in 2 chamber outer aqueous chamber (partially divided into a large anterior and a smaller posterior chamber) filled with **aqueous humor** (watery) formed by ciliary body and inner vitreous chamber filled with **vitreous jelly (or Wharton's jelly)** containing 99% water, some salt a little mucoprotein (vitrein) and hyaluronic acid.

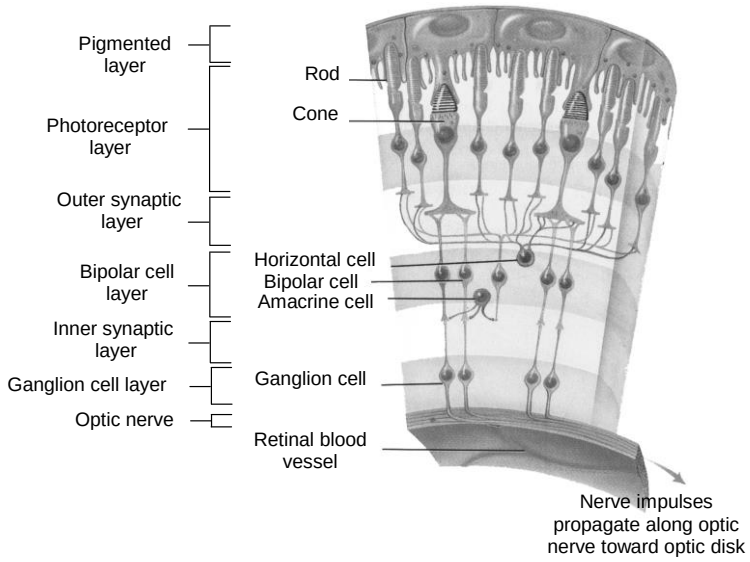
(iii) **Retina (Neurosensory tunica) –** It is innermost, thin and transparent, purplish red due to the present of the eye pigment rhodopsin (in rods) or visual purple which was extracted by **Kuhne** (1876) and named 'Schpurpur' (Visual purple). Made up of 4 distinct layer –

(a) Cuboidal pigmented epithelium (towards choroid).

(b) Layer of rods and cones.

(c) Layer of bipolar neurons.

(d) Layer of ganglia (Towards vitreous chamber innermost).




**Microscopic structure of the retina**

**Area centralis of retina**

- A little part of retina that lies upon the optical axis is called area centralis. Here, the retina is very thin and contains only cone cells filled with a yellow pigment.
- Hence, this part is called **yellow spot or maculla lutea.**
- In man (Rabbits) and other mammals, but not in frogs, this area has a small shallow dispression called **fovea centralis**
- The latter is the most sensitive part of an eye, i.e. the area of most acute vision. It is also claimed that the cone cells in fovea centralis are placed somewhat obliquely. So that these can form magnified images of object.

**Blind spot (Optic disc)**

- At this point, the optic nerve turns towards the outer side, pierces through the whole thickness of the wall of eyeball, forming an optic foramen and runs to the brain.
- Obviously, the region of optic foramen has no retina.
- It therefore, does not take part in image formation and is called blind spot.

**Ora seratta –** The function retina terminates anteriorly along an irregular border, the ora seratta.

**12.2 Working of eye**

(i) **Mechanism of light perception –** The human eye has two functional parts – Dioptric or Focussing part and Receptor part.

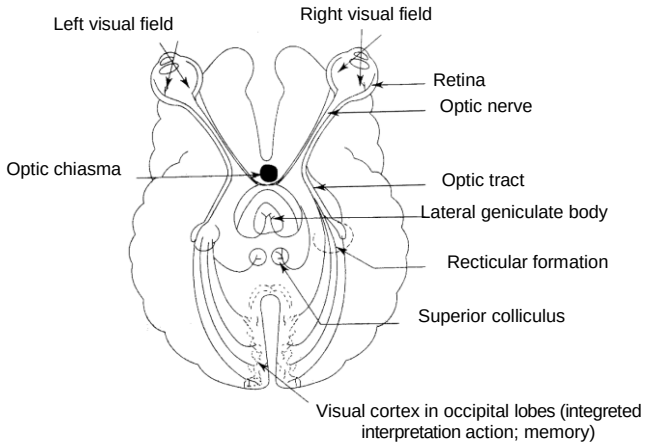
(a) **Focussing part –** It consists of conjunctiva, cornea, aqueous humour lens and vitreous humour. These part are transparent and act as lenses. They refract the light rays passing through the eye to bring them to a focus on the retina. Maximum refraction is caused by the cornea, which places the image approximately on the retina. The lens effects fine adjustment and brings the image into a sharp focus.

(b) **Receptor part –** It comprises the retina. The image formed on the retina is inverted and smaller. It converts the energy of specific wave lengths of light into action potential in nerve fibre.

(ii) **Pathway of sensory impulses from eye to brain –** The nerve impulses generated in the retina of the eye in response to light follow a definitive path and terminates in visual cortex in each optic lobe which act as primary visual center.

### 12.3 Biochemistry of eye

The receptor cells of eye are called photoreceptor or visual cells. They are of two types – Rod cells and Cone




**Pathway of sensory impulses from eye to brain**

**(a) Rod cells**

- The rod cells contain a purplish pigment called **visual purple or rhodopsin.**
- They function in dim light and at night.
- They produce poorly defined images. Bright light splits rhodopsin into a lipoprotein scotopsin and a carotenoid pigment retinal (retinine) a process called bleaching.
- The spiliting of rhodopsin depolarizes the rod cell and it releases a neurotransmitter, passing the nerve impulse via bipolar neuron and ganglion cells to the optic nerve.
- In the dark, rhodopsin is resynthesized from scotopsin and retinal.
- This process is called **'dark adaptation'.** It makes the rods functional.
- It takes sometime for rhodopsin to be reformed.
- This is why on entering a dark room at daytime or on coming out of a well lighted room at night we feel blind for a while, when we go from darkness into bright light, we feel difficulty in seeing properly for a moment till rhodopsin is bleached and cones become functional.

**(b) Cone cells**

- Cones contain **iodopsin** which is visual violet and made up of photopsin + retinal. The 3 types of cones are erythrolobe (775 nm sensitive tored), cyanolabe (430 *nm* sensitive to blue) and chlorolabe (sensitive to green 535 *nm*).
- However, if all the cone, types are simultaneously stimulated by equal amounts of coloured light than sensation for white light is perceived.
- Diurnal animals are adapted to see during day light (Photopic vision) and can perceive colour. In dark, colours are not perceived. Such animals have more cones in their eye than rods.

### 12.4 Accommodation

- Light passes through many refractive surfaces before it is focussed on the retina forming an inverted and true image. The main sites of refraction are cornea $\rightarrow$ aqueous humor $\rightarrow$ iris $\rightarrow$ lens (position can be altered by ciliary body : accommodation) $\rightarrow$ posterior chamber (= vitreous humor) $\rightarrow$ retina ( in fovea).

- The refractive index of the eye varies from 59 diopter (when the lens is at rest) to about 71 diopter (when lens is bulging in maximum accomodation). Cornea contributes maximum in power of eye by converging light when medium changes at its surface.
- The accommodation reflex occurs when the eye changes its focus from a far away object to nearer one.
- The change in strength of the lens provides the physiological basis of accommodation.
- Radial and circular muscle fibres of ciliary muscles play an important role in this as they contract reflexively (parasympathetic control) and increase lens strength.
- The pupil constricts. This facilitates increase in sharpness of image.
- Ageing causes loss of accomodation.

## *Key Concepts*

**(1) Types of vision**

(i) **Binocular Vision –** Man has binocular vision in which both the eyes are focussed on the same object but from slightly different angles. The visual fields of both eyes overlap and the foveae of both are focused on the same object. This provides depth to the images, i.e., gives stereoscopic or 3D effect and enables man to judge distances correctly.

(ii) **Vision in other animals –** Primates and predatory animals, such as owl and cat, have binocular vision. In some animals, such as rabbit, birds, each eye is focussed on a separate object. This is termed monocular vision.

(iii) **Colour vision –** It is the ability of some animals to detect colours in an object. Humans, apes, monkeys, and most fishes, amphibians, reptiles and birdss have strong colour vision. The insects and crayfish also have colour vision. In vertebrates, colour vision results from the activity of cone cells. Most domestic and nocturnal mammals and sharks lack colour vision. They probably see objects in shades of grey (monochrome vision).

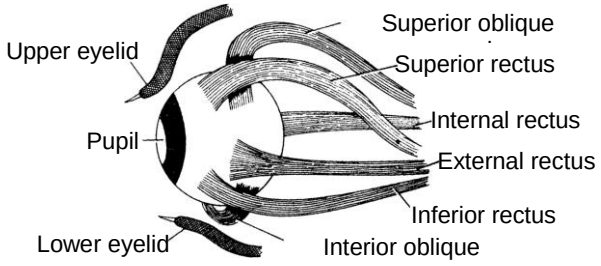
(iv) **Nocturnal and Diurnal vision –** Man has both day vision and night vision as he has both rods and cones in considerable numbers in the retina. Most birds have only day vision as their retina contains mainly cones. Owls have much better night vision than day vision for they possess a large number of rods and few cones in their retina.

**(2) Range of vision –** The visible range of spectrum varies in animals. Bees, ants, spiders and goldfish can see ultraviolet light, which is invisible to man.

**(3) Eye movement –** In eye orbit eyeball remain attached with 6 extrinsic muscles.

Out of six, first four are rectus and last two are oblique muscles.

(1) Anterior rectus or internal ractus
(2) Posterior rectus or External ractus
(3) Inferior rectus
(4) Superior rectus
(5) Inferior oblique muscle
(6) Superior oblique muscle




**Extrinsic muscles of eyeball**

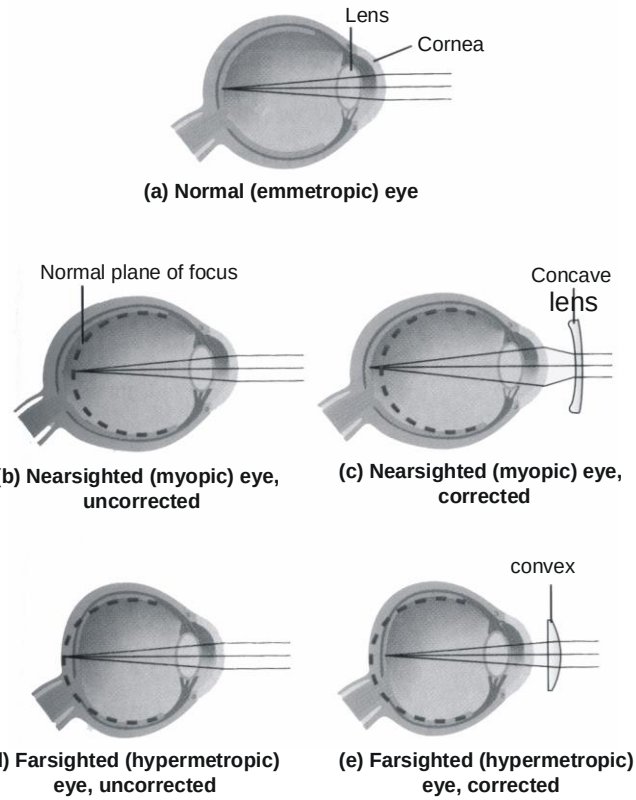
**(4) Eye defects**

(a) **Myopia** (short/near sightedness)

(i) Near object is clear. Far object is not clear.

(ii) Eyeball becomes longer.

(iii) Image is formed before retina. Can be corrected by the use of concave lens.




**Diagrammatic representation of eye defects**

(b) **Hypermetropia** (long/far sightedness)

(i) Far object is clear, near object is not clear.

(ii) Eye ball becomes shorter in anteroposterior direction.

(iii) Image is formed behind the retina.

(iv) Can be corrected by the use of convex lens.

(c) **Astigmatism**

(i) Curvature of cornea become irregular and image is not clearly form.

(ii) Can be corrected by the use of cylindrical lens.

(d) **Cataract**

(i) It is due to defective protein metabolism.

(ii) During this lens or cornea sometime both become opaque.

(iii) Operation is needed.

(e) **Glaucoma**

(i) It is due to increase in intraocular pressure in aqueous chamber.

(ii) Operation is needed at early stage due to blockage of schlemm's canal.

(f) **Trachoma**

(i) It is increase in redness of eye and more secretion of watery fluid.

(ii) It is due to infection of bacteria, Chlamidia trachomatis.

(iii) Due to this follicles may form in conjunctiva.

(g) **Xeropthalmia (dry eye)**

(i) It is due to deficiency of vitamin A. ($A_2$)

(ii) During this conjunctiva or cornea becomes keratinized.

(iii) It may lead to blindness.

(h) **Strabismus (squint)**

(i) In this type eye ball remains in some what in deviated position.

(ii) It is due to the paralysis of extra ocular muscles due to the injury to the fibres of cranial nerves oculomotor, pathetic (trochlear) and/or abducens.

(iii) Operation is needed at early stage.

(iv) Also associated with squint.

(i) **Presbiopia**

(i) During this, power of accommodation of lens decreases due to age factor and defected metabolism.

(ii) Also known as age sightness.

(iii) Can be removed by bifocal lens.

(j) **Photophobia :** No clear image in bright light.

(k) **Emmetropia :** Normal vision.

## Test your Resonance with concept

**1.** Modified sebaceous glands on the eyelid of mammal are known as

(1) Lachrymal gland (2) Meibomian gland (3) Pituitary gland (4) Retinal gland

**2.** The fovea centralis is located in

(1) Blind spot (2) Yellow spot (3) Macula lutea (4) (2) and (3) both

**3.** Iris of an eye is an extension of

(1) Cornea (2) Sclerotic (3) Retina (4) Both choroid and retina

**4.** Acute vision is found in

(1) Vulture (2) Frog (3) Shark (4) Bat

**5.** Rhodopsin (visual purple) of eye will require

(1) Guava (2) Mango (3) Carrot (4) Wheat

**Answers**

**1.** (2) **2.** (4) **3.** (4) **4.** (1) **5.** (3)

# 13. Ear

## 13.1 Phonoreceptor and Mechanism of hearing or auditory sensations and equilibrium

Also known as stato-acuostic organ. It is the receptor for balancing and hearing which is sensitive for gravity and sound waves. It is also sensitive in orientation of body. It is also known as mechano receptor because of it change mechanical energy of sound waves in to action potential.

- **Structure of Ear**

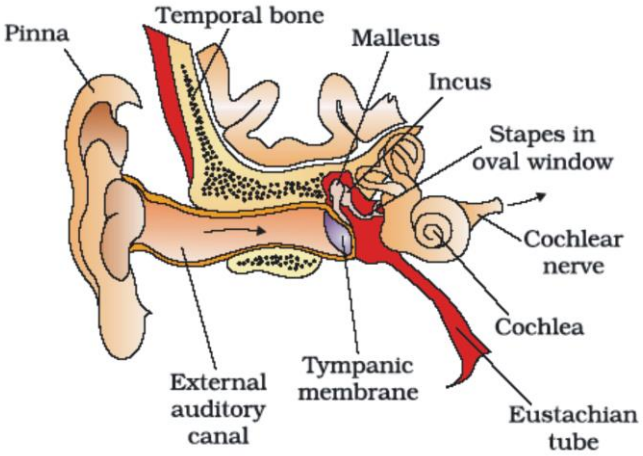
Ear of mammal is divided in to 3 parts –

**(1) External ear –** It is made up of pinna and auditory meatus. Pinna is found in only mammals. Its upper rounded part is helix and lower is ear lobe. It is made up of adipose connective tissue and elastic cartilage and has ear muscles which are vestigeal in case of human beings. Pinna collect the sound waves and drive towards auditory meatus.

Auditory meatus is 25 *mm*. long canal lined by simple columnar epithelia and made up of fibro elastic cartilage. It possesses ceruminus gland which secrete cerumin (ear wax). Cerumin trap the dust particles and microbes.

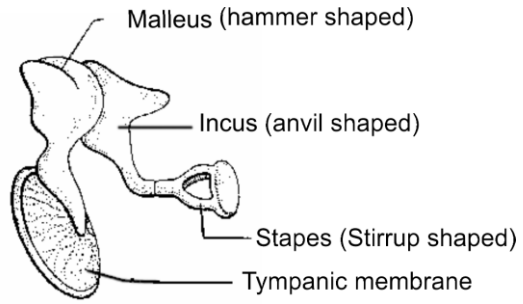
**Tympanic membrane –** It is also called ear drum and present at the junction of auditory meatus and tympanic cavity.

**(2) Middle ear –** The cavity of middle ear is known as tympanic cavity which is enclosed by tympanic bulla bone of skull and filled with air. Middle ear separated from external ear by ear drum and from internal ear by thin bony portion or partition with two openings known as oval and round window.




**Diagrammatic view of ear**

(i) Ear ossicle – A chain of three small, movable bones, the auditory or ear ossicles crosses the tympanic cavity. The outer ossicle is attached to the inner surface of the tympanic membrane.




**Ear ossicles**

| Ear ossicle | Shape | Modification of |
|---|---|---|
| M – Malleus | Hammer shaped | Articular bone of lower jaw. |
| I – Incus | Anvil shaped | Quadrate bone |
| S – Stapes | Stirrup shaped | Hyomandibular of columella |

(ii) **Eustachian tube –** It is made up of elastic cartilage and it connect middle ear to nosopharynx. It maintain equilibrium in and out side of the tympanic membrane. Blocking of eustachian tube impairs hearing due to imperfect vibrations of drum. Eustachian tube is normally closed, it opens during swallowing and yawning.

(iii) **Fenestrae –** Between middle ear and internal ear a thin bony membrane is present which possess two apertures (Windows).

(a) **Fenestra ovalis –** It is upper window, connect middle ear to internal ear and guarded by membrane. End of stapes is fit on the upper window. It is towards vestibule so it is also known as *F. vestibuli.*

(b) **Fenestra rotundus –** It is ventral window, connect middle ear to internal ear and guarded by membrane. It is towards scala tympani so it is also known as *F. Tympani* (also known as *F. cochleae*).

Middle ear act a sound amplifier and increase sound intensity 21 times

Surface area of Tympanum = 51 $mm^2$

Surface area of oval window = 3 $mm^2$

$F_T = F_0$

$\therefore \quad P_T \cdot A_T = P_0 \cdot A_0$

$P_T \cdot 51 = P_0 \cdot 3$

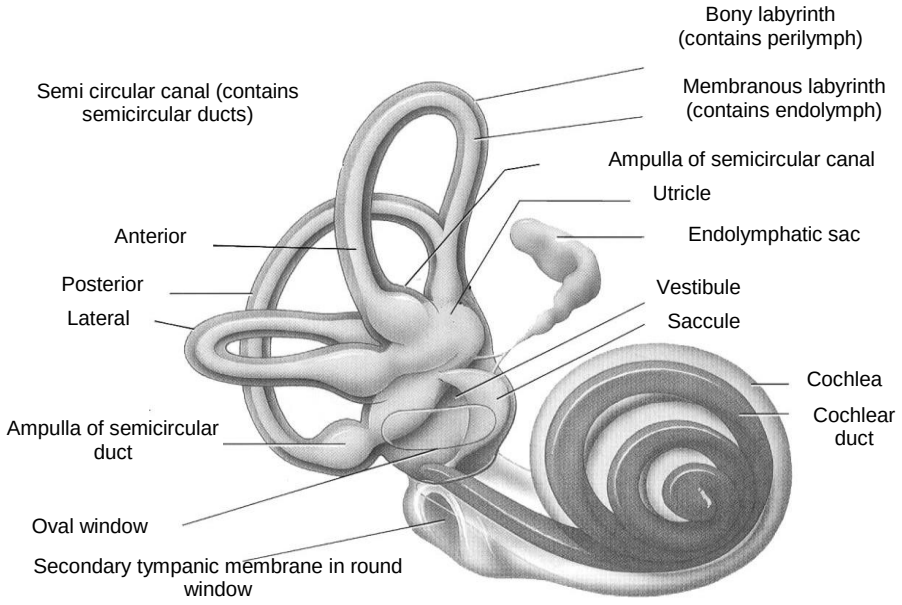
$P_0 = 17\ P_T$

Intensity at oval window increases by 17 times in this way. Bones are solid so they further increase. Intensity 1.3 times.

Total amplification = 1.3 ×17

= 22 times (called as **Impedance matching**)

**(3) Internal ear (Membranous labyrinth) –** Internal ear is also known as membranous labyrinth and enclosed by bony labyrinth. Bony labyrinth is formed by periotic bone or petrous. A cavity is present between membranous labyrinth and bony labyrinth known as perilymphatic space. It is filled with perilymph and endolymph is found in membranous labyrinth. The membranus labyrinth consists of 2 parts – Vestibule and Cochlea.




**Section through the cochlea (Semicircular canals, vestibule and cochlea of the right ear**

(i) **Vestibule –** The vestibule is a central sac like part. It further consists of 2 chambers large – Utriculus (Upper) and smaller – sacculus (lower).

(a) **Semicircular canal –** From utriculus 3 semicircular canals arise these are –

Anterior semicircular canal (Superior)

Posterior semicircular canal (Inferior)

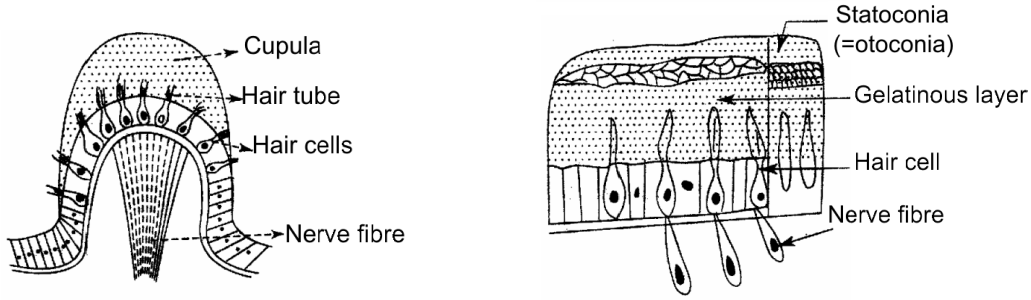
Horizontal semicircular canal (External)

They are perpendicular each other.

**Crus commune –** A common part of anterior and posterior semicircular canal arise from dorsal region of utriculus is known as crus commune.

**Ampulla –** Terminal part of the each semicircular canal is enlarged to form an ampulla.

**Crista:** Each ampulla has a sensory spot called crista ampullaris or simply crista, for equilibrium.




**Crista and macula of ear**

(b) **Sacculus –** It is a lower chamber of vestibule. From the lower part of the sacculus arises a short tube, the ductus reuniens that joins the cochlear duct.

**Ductus endolymphaticus –** It is filled with endolymph and arises from the junction of utriculus and sacculus.

**Macula–** are present in utriculus and sacculus. It is a group of sensory cells. In man (Rabbit) 2 maculas are present. (A crista resembles a macula in structure except that lies on an elevation, the acoustic ridge, its sensory cells have longer "hair", and its gelatinous mass is dome shaped, lacks otoliths and is called cupula.)

| S.No. | Crista | Macula |
|---|---|---|
| 1 | Found in ampulla of semi-circular canal | Found in vestibule i.e. sacculus and utriculus. |
| 2 | Their total number is 3 | Only 2 are present |
| 3 | No otolith | Otolith present |
| 4 | Long auditory hairs | Short auditory hair |
| 5 | Facilitate maintenance of dynamic equilibrium and angular acceleration e.g. rotational movement of head | Help in static equilibrium and linear acceleration e.g. tilting of head or body at rest and rapid forward movement. |

**Otolith:** Also known as otoconia made up of protein and calcium carbonate and present in endolymph.

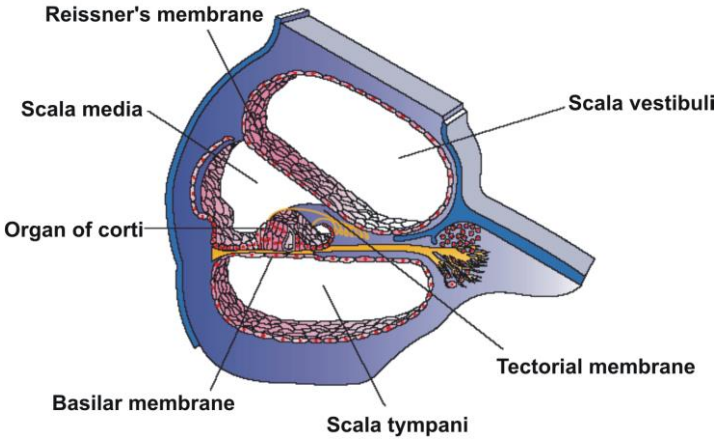
(ii) Cochlear duct and Cochlea – It is a spirally coiled tube (2 – 3 coiling) which is connected to sacculus by a short duct. It is divided into 3 chambers by 2 membranes.

(a) **Scala vestibuli –** Upper chamber filled with – perilymph - connect with middle ear by *F. ovalis*, or oral window.

(b) **Scala media (Real cochlear duct) –** Middle chamber filled with – endolymph.

(c) **Scala tympani –** Lower chamber filled with – perilymph connect with middle ear by *F. Tympani* or round window.

(d) **Reissner's membrane –** Present at the roof of scala media, it saparates S.M. from/and S.V.




**Diagrammatic representation of the sectional view of cochlea**

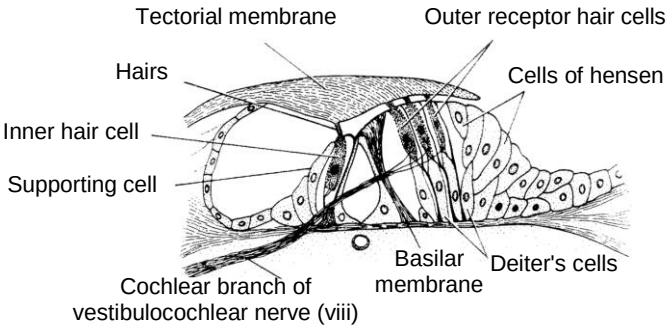
(e) **Basilear membrane –** Present at the base of S.M. It is thicker than Reissner's membrane and it separates S.M. to S.T.

(f) **Modiolus –** A bony core around which bony spiral canal of cochlea make 2 3/4 turns or coils in man.

(g) **Helicotrema –** A aperture present in scala media which connect scala vestibuli to scala tympani is known as helicotrema.

(h) **Tectorial membrane –** Tectorial membrane is a leaf like gelatinous structure present at the dorsal side of organ of corti.

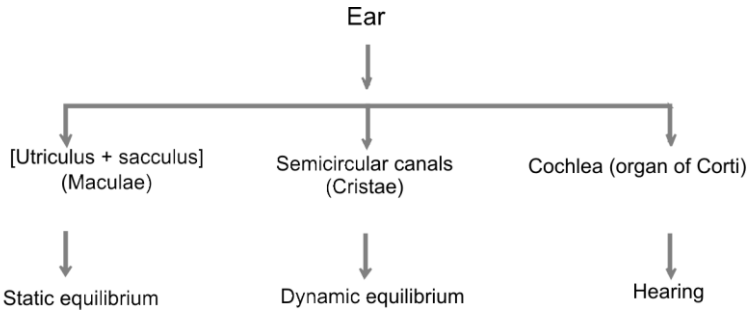
(i) **Organ of corti –** Discovered by Italian anatomist Alfanso-Corti. Also known as ridges of corti which are present in basiler membrane. Organ of Corti contains a variety of cells. They receives nutrients from endolymph. The cells of organ of Corti are following types




**Detailed structure of organ of corti (vertical section)**

### 13.2 Mechanism of sound perception

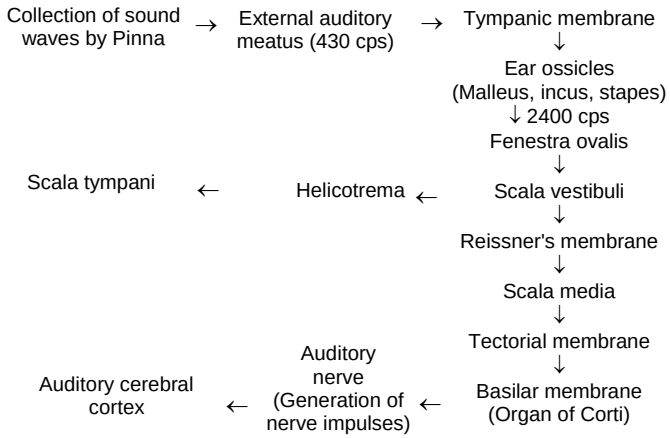
*Vone Beskey* won the Nobel Prize for his work on ear. The mechanism found in ear involve two unrelated functions: Hearings and equilibrium.



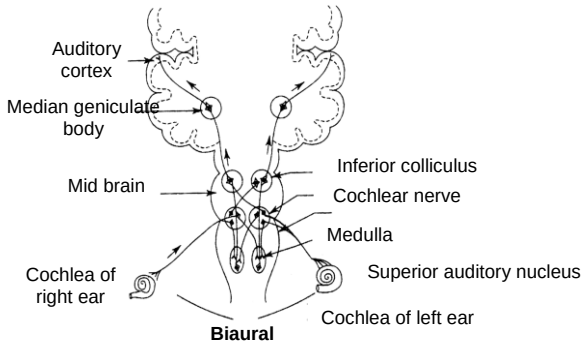

**(a) Hearing**

- The ear not only detects sound but also notes its direction, judges its loudness and determines its pitch (frequency). The sound waves are collect by the pinna and directed inward through the external auditory meatus (frequency of sound is 430 cycles per second).
- Here they strike the tympanic membrane. The latter begins to vibrate at the same frequency as that of the sound waves.
- From the tympanic membrane, the vibrations are transmitted (across the tympanic cavity) by the ear ossicles to the membrane of the fenestra ovalis.
- The force of vibrations is considerably increased in the middle ear by leverage of the ossicles and also by much smaller surface area of the membrane of fenestra ovalis than that of the tympanic membrane. (The frequency of sound is 2400 cycles/sec).
- Increase in frequency is important because the sound wave are transmitted from the air to the fluid medium.
- The membrane of fenestra ovalis transmits the vibrations to the perilymph of the scala vestibuli and via Reissner's membrane to the endolymph of the scala media.
- From here the vibrations are transferred to the basilar membrane and the perilymph in the scala tympani.
- Vibration of the endolymph of the scala media cause the basilar membrane of this chamber to vibrate.

- Vibrations of the basilar membrane make the "sensory hair" of receptor cells in the organ of Corti move in the overlying gelatinous tectorial membrane and get distorted.
- This stimulation causes depolarisation of the receptor cells and initiation of nerve impulse in the fibres of the auditory nerve.
- The nerve impulse travels via relay centers *e.g.* spiral ganglion → cochlear nuclei → superior auditory nuclei → inferior colliculi → auditory cortex of cerebrum (The cerebral cortex interprets the impulses as sound).
- The various steps in the mechanism of hearing




- Human ear can hear a frequency of 500 to 5000 hertz (Hz; 1 Hz = 1 cycle/second). However, it can hear the complete range of frequencies from 20 – 20,000 *Hz* only with intense sound.
- Sound energy is measured in terms of units called decibels (dB). Sounds in our city homes average 40 – 50 *dB*, but street noise averages 70 – 80 *dB*.
- Sounds up to 80 *dB* are considered bearable by man, but higher sound intensity are hazardous, causing nervous stress, irritability, increased blood pressure etc.
- Non stop noise of 90 or more *dB* produces temporary deafness. 160 *dB* sound can cause total deafness by rupturing our ear drum.
- Sound becomes uncomfortable to normal ear at about 120 dB.




**Pathway of sound perception from organ of corti in cochlea to auditory cortex of cerebrum**

**(a) Hearing**

**(b) Equilibrium –** Sound become painful above 140 dB. Exposure to certain antibiotics, such as gentamycin some anticancer drugs, loud sound, loud music, or engine rear of jet planes, vacuum cleaners, damages hair cells of cochlea.

**(i) Static equilibrium and linear acceleration**

- Maculae detect changes in the position of head with respect to gravity (static equilibrium) and in the movement in one direction (linear acceleration).
- With a change in the position of the body, the otoliths, being heavier than the endolymph, press upon the sensory hair of the maculae.
- This stimulates the sensory cells which initiate nerve impulse in the fibres of the auditory nerve.
- The macula of utricle responds to vertical movements of the head and the macula of saccule responds to the lateral (sideways) movements of the head.
- Due to rapid forward movement, the otoliths, because of having greater inertia than the surrounding endolymph, lag behind and press back the sensory hair, stimulating the sensory cells to generate nerve impulses.

**(ii) Dynamic equilibrium**

- Cristae detect rotational movements of the head (angular acceleration).
- When the head is turned, the endolymph in the semicircular ducts, due to its inertia, does not move as fast as the head and the sensory cells of the cristae, but continues to move after the head stops moving.
- Due to this difference in the rate of movement, the sensory hair of the cristae are swept through the endolymph and bend.
- This disturbance stimulates the sensory cells and sets up action potential in the fibres of the auditory nerve which transmits it to the brain.
- Since the three semicircular ducts are arranged in three different planes, a movement of the head in any direction will stimulate the sensory cells of at least one crista.

## Test your Resonance with concept

**1.** The site from which the nerve impulse for hearing originates
(1) Ear ossicles (2) Cochlea (3) Auditory nerve (4) Tympanum

**2.** The sense of equilibrium by ear is the function of
(1) Sensory cells of the organ of corti (2) Sensory cristae of the ampulla
(3) Tectorial membrane of cochlea (4) Basilar membrane of cochlea

**3.** Loudness of sound is discriminated by
(1) Intensity of movement of basilar fibres of cochlea
(2) Vibration of semicircular canals
(3) Vibration of endolymphatic sac (4) Vibration of tympanic bulla

**4.** Columella auris is a modified
(1) Articular (2) Sphenthmoid (3) Hyomandibular (4) Quadrate

**5.** A person going upto 10,000 feet high in a hot air balloon may develop severe pain in the ear due to
(1) Blocked eustachian tube
(2) Rupture of fenestra rotundus
(3) Endolymph getting into semicircular canals
(4) Fear of great height

**Answers**

**1.** (2) **2.** (2) **3.** (1) **4.** (3) **5.** (2)