NEURAL CONTROL AND COORDINATION

- The neural system is the control system of the body which consists of highly specialized cells called **neurons.**
- The neural system of higher animals performs three basic functions :
  - **Receiving** sensory input from internal and external environment by sensory nerves to the CNS.
  - **Processing** the input information in the CNS.
  - **Responding** to the stimuli by transmitting motor commands from the CNS to determine the response of the body parts or cells.

HUMAN NEURAL SYSTEM

- The human neural system is divided into two parts : the central neural system (CNS) and the peripheral neural system (PNS).
- The **CNS includes the brain and the spinal cord** and is the site of information processing and control. The **PNS comprises of all the nerves of the body associated with the CNS** (brain and spinal cord).
- The nerve fibres of the PNS are of two types : **afferent fibres** and **efferent fibres.** The afferent nerve fibres transmit impulses from tissues/organs to the CNS and the efferent fibres transmit regulatory impulses from the CNS to the concerned peripheral tissues/organs.
- The PNS is divided into two divisions called somatic neural system and autonomic neural system. The **somatic neural system** relays impulses from the CNS to skeletal muscles while the autonomic neural system transmits impulses from the CNS to the involuntary organs and smooth muscles of the body. The **autonomic neural system** is further classified into sympathetic neural system and parasympathetic neural system.

NEURON

- A neuron (nerve cell) is a **structural** and **functional** unit of the neural system.
- Neurons with longer processes (projections) are the longest cells in the body. Fully formed neurons never divide and remain in interphase throughout life. Shortly after birth, new neurons do not develop.
- A neuron is a microscopic structure composed of three major parts, namely, **cell body, dendrites** and **axon.**

Cell body (cyton or soma)

- Like a typical cell, a neuron consists of cytoplasm, nucleus and cell membrane.
- It has abundant cytoplasm, called **neuroplasm** and a relatively large spherical central **nucleus** with a distinct **nucleolus.** The cytoplasm has mitochondria, Golgi apparatus, rough endoplasmic reticulum, ribosomes, lysosomes, fat globules, pigment granules, **neurofibrils, neurotubules** and **Nissl's granules.** Presence of neurofibrils and Nissl's granules is characteristic to all neurons. Neurofibrils play a role in the **transmission of impulses.**

Dendrites (Dendrons)

- Dendrites are usually shorter, tapering and much branched processes. They may be one to several.
- They conduct nerve impulse towards the cell body and are called **afferent processes** (= receiving processes).

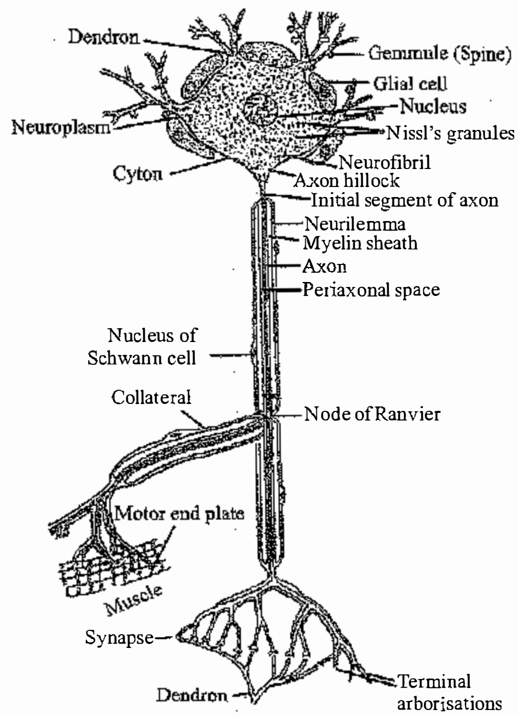


Fig.: Parts of a neuron

Axon

- Axon is a single, usually very long process of uniform thickness. The part of cyton from where the axon arises is called **axon hillock.** It is the most sensitive part of neuron. The axon contains neurofibrils and neurotubules but does not have Nissl's granules, Golgi complex, ribosomes, pigment granules, fat globules etc. The cell membrane of the axon is called **axolemma** and its cytoplasm is known as **axoplasm.**
- The axon ends in a group of branches, the **terminal arborisations (= axon terminals** or **telodendria).**
- When terminal arborisations of the axon meet the dendrites of another neuron to form a synapse, they form **synaptic knobs (= end plates).** The synaptic knobs contain mitochondria and secretory vesicles. The part of the sarcolemma (muscle plasma membrane) that lies beneath the axon terminal/nerve endings, is called **motor end plate.** The axon conducts nerve impulses away from the cell body, therefore, called an **efferent process.**
- There are two types of nerve fibres namely **myelinated** and **non-myelinated.**
- The **myelinated nerve fibres** are enveloped with Schwann cells, which form a myelin sheath around the axon. The gaps between two adjacent myelin sheaths are called **nodes of Ranvier.** Myelinated nerve fibres are found in spinal and

cranial nerves. Non-myelinated nerve fibre is enclosed by a **Schwann cell** that does not form a myelin sheath around the axon, and is commonly found in autonomous and the somatic neural systems.

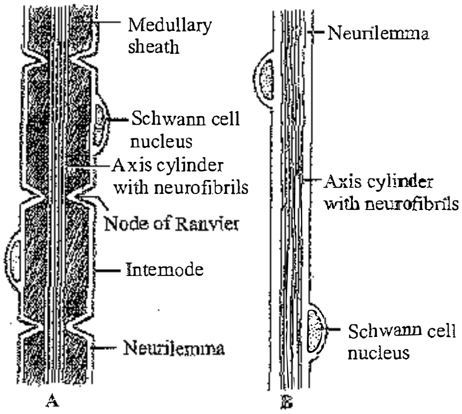


Fig.: A. Medullated nerve fibre; B. Non-medullated nerve fibre

GENERATION AND CONDUCTION OF NERVE IMPULSE

- The ionic gradients across the resting membrane are maintained by the active transport of ions by the **sodium-potassium** pump which transports $3Na^+$ outwards for $2K^+$ into the cell.
- As a result, the outer surface of the axonal membrane possesses a positive charge while its inner surface becomes negatively charged and therefore is **polarised.**
- The electrical potential difference across the resting plasma membrane is called as the **resting potential (–70 mV).**
- When a stimulus of adequate strength **(threshold stimulus)** is applied to a polarised membrane, the permeability of the membrane to Na^+ ions is greatly increased at the point of stimulation.
- Since there are more Na^+ ions entering than leaving, the electrical potential of the membrane changes from –70 mV towards zero. At 0 mV the membrane is said to be **depolarised.** This leads to the positive charge inside and negative charge outside.
- While the resting potential is determined largely by K^+ ions, the action potential is determined largely by Na^+ ions.
- Action potential is another name of **nerve impulse.** The stimulated, negatively charged point on the outside of the membrane sends out an electrical current to the positive point (still polarised) adjacent to it. This local current causes the adjacent inner part of the membrane to reverse its potential from –70mV to +30 mV. The reversal repeats itself over and over until the nerve impulse is conducted through the length of the neuron.
- With the increase of sodium ions inside the nerve fibre, the membrane becomes less permeable to sodium ions and more permeable to potassium ions. Na^+ influx stops and K^+ outflow begins until the original resting state of ionic concentration is achieved. Thus, the resting potential is restored which is called **repolarisation** of the membrane.
- Infact, until repolarisation occurs, neurons cannot conduct another impulse. The time taken for this restoration is called **refractory period.** The refractory period is very short, being only about one millisecond (1/1000 of a second). Thus a nerve fibre can transmit about 1000 impulses per second.
- When an impulse travels along a myelinated neuron, depolarisation occurs only at the nodes. It leaps over the myelin sheath from one node to the next. This process, is called **saltatory conduction.**
- Saltatory conduction accounts for the greater speed of an impulse travelling along a myelinated neuron than along a non-myelinated one. It is upto 50 times faster than the non-myelinated nerve fibre.

SYNAPSE

- Synapse is the junction between two neurons, across which the impulse passes from one neuron to the next.
- A synapse is formed by the membranes of a **pre-synaptic neuron** and a **post-synaptic neuron,** which may or may not be separated by a gap called **synaptic cleft.**
- There are mainly two types of synapses– electrical and chemical.
  - At **electrical synapse** there is continuity between the pre-synaptic and post-synaptic neurons. The continuity is provided by the **gap junctions** between the two neurons.In electrical synapse there is minimal synaptic delay because of the **direct flow** of electrical current from one neuron to the other through gap junctions. Thus, impulse transmission across an electrical synapse is always faster than that across a chemical synapse. It is found in the cardiac muscle fibres, smooth muscle fibres of intestine and the epithelial cells of lens.
  - At a **chemical synapse,** when an impulse arrives at a pre-synaptic knob, calcium ions from the synaptic cleft enter the cytoplasm of the pre-synaptic knob. The calcium ions cause the movement of **synaptic vesicles** to the surface of the knob. The synaptic vesicles are fused with the presynaptic membrane and get ruptured to discharge their content (neurotransmitters) into the synaptic cleft.

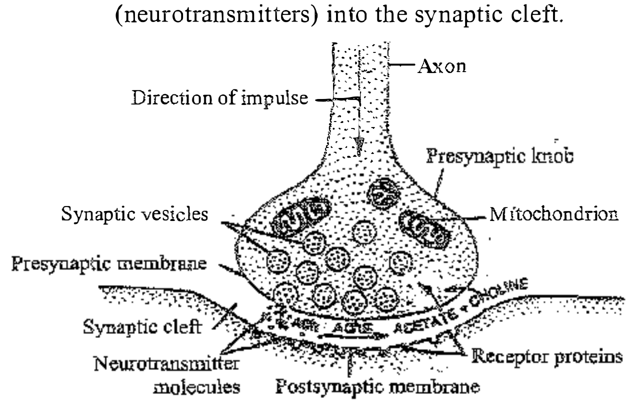


Fig.: Transmission of nerve impulse at a chemical synapse.

- 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, opening channels in the membrane and allowing **sodium ions to enter the cell.** This causes the depolarisation and generation of action potential in the post-synaptic membrane. Thus, the impulse is transferred to the next neuron.

CENTRAL NEURAL SYSTEM

- It comprises of the brain and spinal cord.

BRAIN

- The brain is the central information processing organ of our body. Brain lies in the cranium of the skull. Brain and spinal cord are surrounded connective tissue membranes called as **meninges.** There are 3 meninges in humans; an outer layer called, **dura mater,** a very thin middle layer called **arachnoid** mater and an inner layer called **pia mater.**
- Human brain is divided into three parts-forebrain (**prosencephalon**), midbrain (**mesencephalon**) and hindbrain (**rhombencephalon**).

Forebrain

- It consists of olfactory lobes, cerebrum and diencephalon.
- **Cerebrum** is the largest and most complex of all parts of human brain. A deep cleft divides the cerebrum longitudinally into two halves, which are termed as the left and right **cerebral hemispheres.** The hemispheres are connected by a tract of nerve fibres called **corpus callosum.**

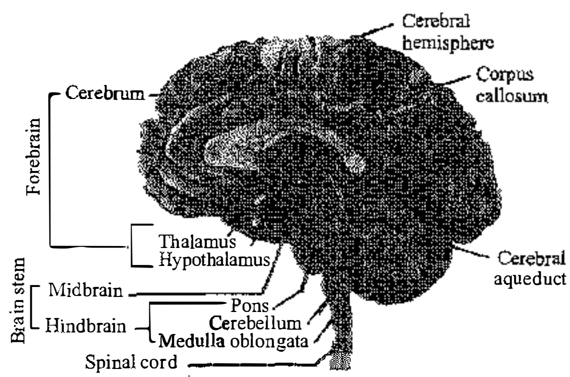


Fig.: Diagram showing sagittal section of the human brain

- The left part of cerebrum controls the functions of right parts of the body while right part of cerebrum commands functions of left side of the body.
- The interior of each cerebral hemisphere contains a **lateral ventricle** (= **paracoel,** first and second ventricles) filled with cerebrospinal fluid. The two ventricles open into third ventricle by a common aperture called **foramen monro.** Cerebrum consists of two parts– cerebral cortex and cerebral medulla.
- The outer layer of the cerebrum is called the cortex which comprises of many folds (usually elevated part) **gyri** and depression called **sulci.**
- Each cerebral hemisphere of the cerebrum is divided into four lobes: frontal, parietal, temporal and occipital lobes.

Table : Important areas present in the four lobes of cerebral hemisphere

Lobes	Area	Function
Frontal lobe	(i) Motor area	Controls voluntary mov-ements of the muscles
	(ii) Premotor area	The highest centre for involuntary movements of muscles and autonomic neural system
	(iii) Broca's area (Motor speech area)	Speech
Parietal lobe	(i) Somaesthetic area	Perceptions of general sensations like pain, touch, temperature and pressure, etc.
	(ii) Gustatory area	Sense of taste
	(iii) Sensory speech area	Speech
Temporal lobe	(i) Olfactory area	Sense of smell
	(ii) Auditory area	Hearing
	(iii) Wernicke's area	Understanding speech
Occipital lobe	(i) Visual area	Sensation of light

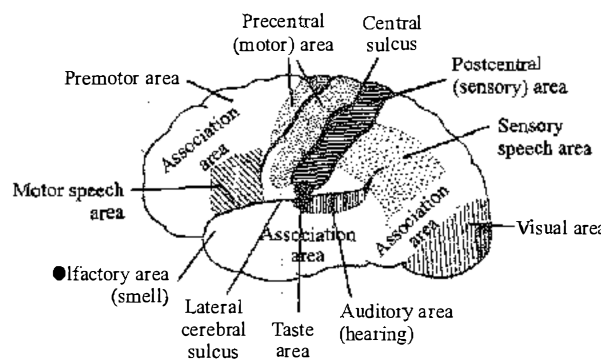


Fig.: A cerebral hemisphere (half of the cerebrum) showing the functional areas

- **Diencephalon** lies between cerebrum and mesencephalon.
- Its cavity is called **third ventricle** or **diocoel.** It contains epithalamus, thalamus and hypothalamus.
- **Epithalamus** is non-nervous part which is fused with piamater to form **anterior choroid plexus.** Behind it lies **pineal body** which is **endocrine in function** and secretes a hormone named **melatonin.** Epithalamus forms the roof of third ventricle.
- **Thalamus** forms the lateral walls of the third ventricle and directs sensory impulses from the lower parts of the brain and spinal cord to appropriate parts of the cerebrum. Just beneath the thalamus, hypothalamus forms the floor and the part of the lateral walls of the third ventricle.
- **Hypothalamus** links nervous system to endocrine system (*via* **hypothalamus - hypophyseal axis**) and exercises a regulatory control on the functioning of endocrine glands by secreting neurohormones.

- It contains higher centres of autonomic nervous system controlling **hunger, thirst, sleep, fatigue, emotions, satisfaction, anger, pleasure, sexual behaviour, etc.**

Midbrain

- It is located between the thalamus/hypothalamus of the forebrain and pons of the hindbrain. A canal called the **cerebral aqueduct** passess through the midbrain. The dorsal portion of the midbrain consists mainly of four round swellings (lobes) called **corpora quadrigemina.** Corpora quadrigemina are equivalent to optic lobes of lower animals.

Hindbrain

- Hindbrain consists of cerebellum, medulla oblongata and pons varolii.
- **Cerebellum** is the largest part of the hind brain consisting of two hemispheres, cerebellar hemispheres and a small median vermis. It is the centre for the maintenance of **posture** and **equilibrium** of the body and for the muscle tone. All activities of cerebellum are involuntary. They may, however, involve learning in early stages. Cerebellum is essential for controlling rapid muscular activities (*e.g.*, running, typing, talking).
- The surface of cerebellum is also highly grooved. The grey matter of cerebellum is called **cerebellar cortex.** A cross section of the hemispheres shows a branching tree-like arrangement of grey and white matter called the **arbor vitae ("tree of life").**
- **Medulla oblongata,** encloses a cavity called **fourth ventricle.** The medulla contains centres for controlling the functions of important organs, *e.g.*, cardiac centre (heart), respiratory centre, vasomotor centre (for regulating diameter of blood vessels) and reflex centres (for swallowing, vomiting, peristalsis, secretions and activity of alimentary canal, salivation, coughing, etc.).
- **Pons varolii** is situated in front of the cerebellum below the mid brain and above the medulla oblongata. It carries impulses from one hemisphere of the cerebellum to another. Functionally, the pons is concerned with maintenance of normal rhythm of respiration. It has got two respiratory centres - the **pneumotaxic centre** and **apneustic centre.**
- The mid brain, pons varolii and medulla oblongata are collectively called the **brain stem,** connecting the fore brain and spinal cord.

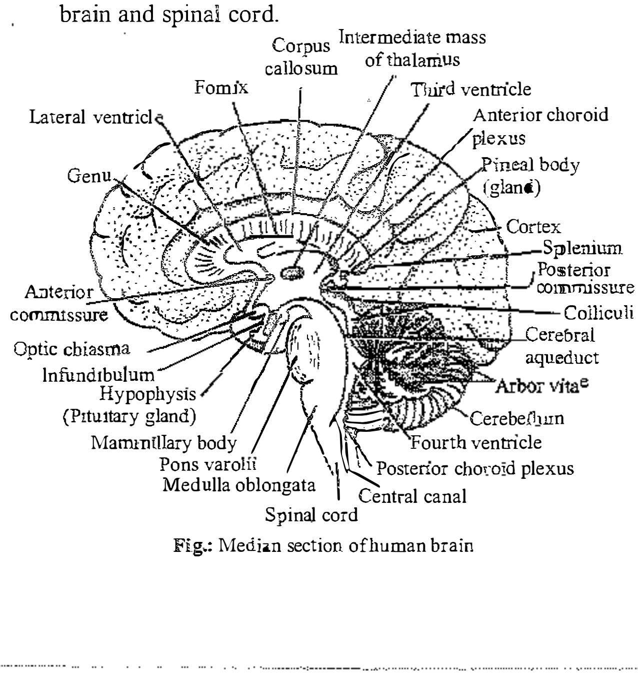


Fig.: Median section of human brain

SPINAL CORD

- The spinal cord is a tubular bundle of neural tissue that extends from the brain (medulla oblongata). In an adult the spinal cord is from **42 to 45 centimeters long.** Its diameter varies at different levels, being enlarged in the cervical and lumbar regions. It begins in the atlas and tapers to a point, **conus medullaris,** in the first or second lumbar vertebra.
- The spinal cord is formed of two types of nervous tissue: grey matter and white matter.
- The **grey matter** is internal, *i.e.*, surrounds the central canal. It has the form of letter H in cross-section (also called butterfly-shaped). The arms of H are called **posterior** and **anterior grey columns.**
- The regions of grey matter projecting towards the back of the body are called the **dorsal horns,** whereas those oriented towards the front are the **ventral horns.**
- The grey matter is surrounded by **white matter,** which consists of groups of myelinated axons.
- The spinal nerves tracts are divisible into two, **ascending** (conducting sensory impulses towards brain) and **descending** (conducting motor impulses from brain).
- **Spinal cord conducts impulses to and from the brain** and controls most of the **reflex activities.**

PERIPHERAL NEURAL SYSTEM

- The nerve running outside brain and spinal cord constitute peripheral neural system. These nerves are of two types: **cranial nerves** (nerves orginating from brain) and **spinal nerves** (nerves originating from spinal cord).

Cranial nerves

- There are **12 pairs** of cranial nerves, 10 pairs originate from the brain stem. They are numbered **I to XII in Roman numerals.**

Spinal nerves

- Spinal nerves are **31 pairs** of spinal nerves arising from either side of the spinal cord. **Each spinal nerve is a mixed nerve,** containing both sensory and motor nerve fibres running between the spinal cord and peripheral tissues.
- The nerve originates from **dorsal** (posterior) and **ventral** (anterior) **nerve roots.** The dorsal root has only sensory nerve fibres and ventral root has only motor nerve fibres.
- Spinal nerves are classified into 5 groups – 8 pairs of **cervical nerves;** 12 pairs of **thoracic nerves;** 5 pairs of **lumbar nerves;** 5 pairs of **sacral nerves,** and one pair of **coccygeal.**

REFLEX ACTION

- Reflex action is an immediate involuntary action of any organ or part of the body in response to a particular stimulus. Reflex action was discovered by **Marshall Hall (1833).** The nervous pathway taken by nerve impulses in a reflex action is called **reflex** arc.

Mechanism of reflex action

- For a reflex action five things are normally essential: **receptor, sensory nerve fibres** (afferent pathway), a

Table : Cranial nerves

	Name	Origin	Distribution	Nature	Functions
I.	**Olfactory**	Olfactory epithelium in nasal cavity	Olfactory lobe or bulb	Sensory	Smell
II.	**Optic**	Retina of eye	Optic lobe of midbrain	Sensory	Sight (Retina of eye)
III.	**Oculomotor**	Floor of midbrain	Eye, 4 muscles of eyeball	Motor	Movements of eye-ball, iris, lens, eyelid and constriction of pupil.
IV.	**Trochlear** (Pathetic)	Floor of midbrain	Superior oblique muscles of eyeball	Motor	Rotation of eyeball
	Trochlear is the only cranial nerve that exits the posterior side of the brain stem and is the thinnest and smallest cranial nerve.				
V.	**Trigeminal** divided into three:	Ventral surface of pons varolii		Mixed	
	(i) **Ophthalmic**		Lacrimal glands, conjunctiva of eye, skin of forehead, eyelids etc.	Sensory	Skin sensations
	(ii) **Maxillary**		Cheeks, upper gums, upper teeth and lower eyelids.	Sensory	Sensations
	(iii)**Mandibular**		Teeth and gums of lower jaw, pinna of the ear, lower lip and tongue	Mixed	Sensations, tongue movements, mastication
	Trigeminal (mandibular) is the largest cranial nerve.				
VI.	**Abducens**	Pons varolii	External rectus muscle of eyeball	Motor	Rotation of eyeball
VII.	**Facial** (bearing geniculate ganglion)	Lower part of pons varolii	Anterior 2/3 tongue (taste buds), muscles of face, neck and salivary gland	Mixed	Taste, facial expression, chewing, movement of neck
VIII.	**Auditory** (also called vestibulo-cochlear) It is formed by two branches				
	(i) **Vestibular nerve**	Vestibular part of the membranous labyrinth	Lateral side of pons varolii	Sensory	Equilibrium
	(ii) **Cochlear nerve**	Cochlear part of the membranous labyrinth	Lateral side of pons varolii	Sensory	Hearing
IX.	**Glossopharyngeal**	Lateral side of medulla	Parotid salivary gland, Posterior 1/3rd of tongue, mucous membrane and muscles of pharynx	Mixed	Taste and touch, movements (swallowing) of pharynx, salivation
X.	**Vagus** (pneumogastric) (i) Superior laryngeal (ii) Recurrent laryngeal (iii) Cardiac (iv) Pneumogastric (v) Depressor	Lateral side and floor of medulla	Muscles of pharynx, vocal cords, lungs, heart, oesophagus, stomach, intestine	Mixed	Sound production, respiratory reflexes, peristaltic intestine movements,speech, swallowing, secretion of gastric glands, inhibition of heart beat
	Vagus is the longest cranial nerve. It has maximum branches and also called wandering nerve.				
XI.	**Spinal accessory nerves**	Lateral side of medulla oblongata	Muscles of pharynx, larynx, vocal cords, neck, shoulder	Motor	Movement of muscles of pharynx, larynx, neck, shoulder
XII.	**Hypoglossal**	Ventral side of medulla oblongata	Muscles of tongue	Motor	Movements of tongue

part of the **central neural system**, **motor nerve fibres** (efferent pathway) and **effector organ** such as muscles and glands.

- Reflexes are categorized into two : unconditioned and conditioned reflex. Unconditioned reflex is inborn, unlearned response to a stimulus or any change in the environment. Whereas, conditioned reflexes are not inborn but are acquired on past experience training or learning. It was first demonstrated by **I.P. Pavlov**.

Table: Differences between unconditioned reflexes and conditioned reflexes

	Unconditioned reflexes	Conditioned reflexes
1.	They are inborn reflexes and transmitted through heredity.	They are acquired after birth. It means they are adopted during the course of life time.
2.	Learning does not form the basis of unconditioned reflexes.	Learning forms the basis of conditioned reflexes.
3.	Breast feeding and swallowing in newly born babies and blinking of eyes are examples of these reflexes.	Withdrawal of limb when it is touched by hot things and typing, riding a bicycle, knitting, etc. are examples of these reflexes.

SENSORY RECEPTORS

- Sensory receptors enable us to detect changes in our own body and objects and events in the world around us. Some receptors are simple and primitive type such as unspecialised sensory neuron whose terminal end is capable of detecting stimuli. For example, olfactory cells. The most complex sensory receptors consist of numerous sense cells, sensory neurons and associated accessory structures. For example, eye and ear.

EYE

- The organ of sight are a pair of eyes in human. The eyes are situated in deep protective bony cavities, called the **orbits or eye sockets** of the skull. Eye consists of tissues present in three concentric layers :
  - Outermost fibrous layer consists of **sclera** and **cornea.**
  - Middle vascular layer (also called uvea) consists of **choroid, ciliary body** and **iris.**
  - Inner most nervous layer consists of **retina.**

Fibrous layer

- **Sclera,** an opaque outer most covering, maintains the shape of the eyeball and protects all the inner layers of the eye.
- **Cornea** is a thin transparent, front part of sclera which **lacks blood vessels** but is rich in nerve endings.
- Cornea allows the light to pass into the eye. The cornea also serves as a filter, screening out some of most damaging ultraviolet (UV) wavelength in sunlight.
- **Conjunctiva** is a thin transparent layer present over the cornea and is continuous with the skin over the eye. It protects the cornea and also secretes oils and mucous that moisten and lubricate the eye.

Vascular layer

- **Choroid** is a pigmented layer present beneath the sclera. It contains numerous blood vessels and nourishes the retina. The choroid layer is thin over the posterior two-thirds of the eye ball, but it becomes thick in the anterior part to form the ciliary body.
- **Ciliary body** holds the lens in position, stretching and relaxation of this changes the focal length of the lens for accommodation.
- **Iris** forms a pigmented circle of muscular diaphragm attached to the ciliary body in front of the lens.Its pigment **gives eye its colour.** The movement of iris controls the size of pupil.

Nervous layer

- The inner layer is the **retina** and it contains three layers of cells (from inside to outside)– ganglion cells, bipolar cells and photoreceptor cells. The photoreceptors or visual cells are of two types: **rod cells** and **cone cells,** named after their shapes. Both have light-sensitive pigments. The **daylight (photopic)** vision and colour vision are functions of cones and the **twilight (scotopic)** vision is the function of the rods.
- Optic nerve contains the fibres of the sensory neurons and leaves the eye ball from the back side. The point of departure of optic nerve through the retina does not have any rod or cones and thus produce a **blind spot** or **optic disc.** At the posterior pole of the eye lateral to the blind spot, there is a yellowish pigmented spot called **macula lutea** with a central pit called the **fovea.** The fovea is a thinned-out portion of the retina where only the cones are densely packed. **It is the point where the visual acuity (resolution) is the greatest.**
- The light rays in visible wavelength, focussed on the retina through the cornea and lens, generate potentials (impulses) in rods and cones. The human eye is composed of **opsin** (a protein) and **retinal** (an aldehyde of vitamin A).

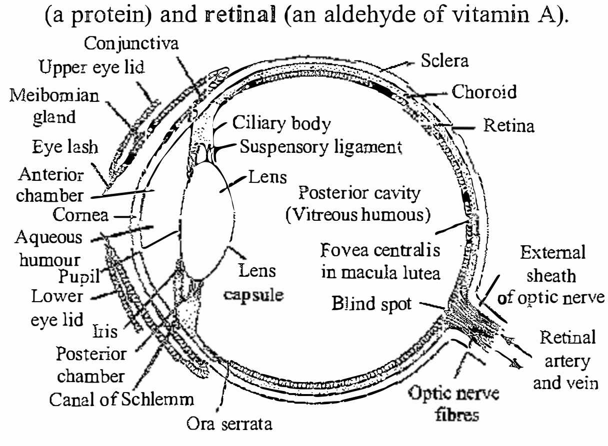


Fig.: V. S. Human eye.

Mechanism of vision

- Light induces dissociation of the **retinal** from opsin resulting in changes in the structure of the opsin. This causes membrane permeability changes. As a result, potential differences are generated in the photoreceptor cells. This produces a **signal** that generates **action potentials** in the ganglion cells. These action potentials (impulses) are transmitted by the optic nerves to the visual cortex area of the brain.

Light induces → Dissociation of Retinal from opsin → Membrane becomes permeable → Potential Differences → Action potential (AP) generates → AP transmitted by optic nerves to visual cortexin brain

Bleaching and regeneration of rhodopsin

The functioning of the pigment rhodopsin for clear vision is as follows:

- Light splits rhodopsin (visual purple) into a pigment retinene (= retinal) an aldehyde derivative of vitamin A and a protein scotopsin (opsin). The process of splitting is called **bleaching.**

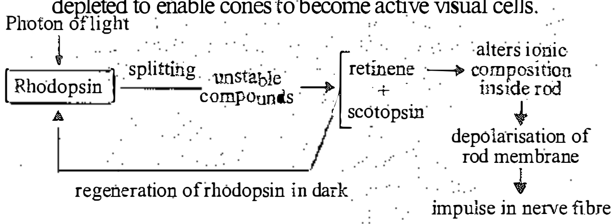
  In light :

  Rhodopsin $\xrightarrow{\text{Bleaching}}$ Retinene + Scotopsin + Energy + Nerve impulse

  In darkness :

  Retinene + Scotopsin + Energy from ATP → Rhodopsin

- Resynthesis of rhodopsin takes some time, so when we go suddenly from bright light into darkness or semi-darkness we can see things only after a few minutes. It is due to reappearence of rhodopsin. Similarly, when we go from darkness into bright light we remain blind for a few minutes till rhodopsin is depleted to enable cones to become active visual cells.



Flow chart : Bleaching and regeneration of rhodopsin

EAR

- The ears perform two sensory functions, hearing and maintenance of body balance. Anatomically, the ear can be divided into three major sections called the **outer ear,** the **middle ear** and the **inner ear.**
- Outer ear comprises two parts, **pinna** and **external auditory canal.** Pinna is an oval, somewhat funnel-shaped skin covered flap of elastic cartilage and muscles. It collects sound waves and directs them into the external auditory canal. External auditory canal is an S-shaped tube leading inward from the pinna. The outer region of the canal bears hair that serve to keep out the dust particles. Its inner region has coiled, tubular, apocrine **ceruminous** or **wax glands,** which lubricate and protect the lining of the meatus.
- Middle ear is an **air filled cavity** in the temporal bone that opens *via* the auditory (Eustachian) tube into the nasopharynx. It includes **tympanic membrane** (or ear drum) and **ear ossicles.** The tympanic membrane is composed of connective tissues covered with skin outside and with mucus membrane inside.
- Middle ear contains flexible chain of three small bones called **ear ossicles**—the **malleus,** the **incus** and the **stapes.** The malleus is attached to the tympanic membrane on one side and to the incus on the other side. The incus in turn is connected with the stapes, which is attached to the oval membrane covering the oval window of the inner ear.
- The **function of the ossicles is to transmit and amplify sound waves** across the tympanic cavity from the tympanic membrane to the oval window. The ossicles are connected in such a way as to act as a lever system to increase the force of the vibration from the ear drum.
- Inner ear is a delicate, irregular organ called **membranous labyrinth.** It is surrounded by an almost similarly shaped bony labyrinth. The membranous labyrinth is joined to the bony labyrinth at certain points, but its greater part is separated from the bony labyrinth by a narrow **perilymphatic space.** This space contains a watery fluid called **perilymph.** The membranous labyrinth is filled with another fluid called **endolymph.**
- The coiled portion of the labyrinth is called **cochlea.** It is the main hearing organ. Internally it consists of three fluid-filled chambers or canals. The middle chamber called **scala media** is the most important canal or channel of the cochlea. It bears an upper membrane, the **Reissner's membrane,** and lower membrane, **basilar membrane.** On the basilar membrane a sensory ridge, the **organ of Corti** is present. Organ of Corti consists of **hair cells** (phonoreceptors), which bear 'hair' at the free surface and have synaptic contacts with the dendrites of neurons at the bases. The tips of 'hair' are embedded in a thin elastic membrane called **tectorial membrane.**

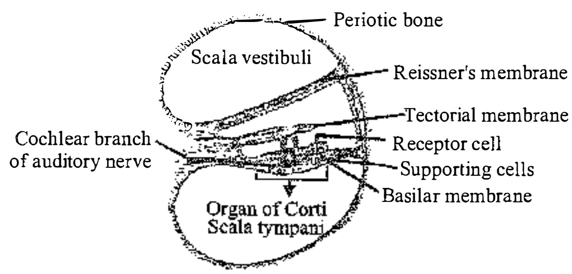


Fig.:T. S. Cochlea.

- The inner ear also contains a complex system called **vestibular apparatus.** The vestibular apparatus is responsible for maintenance of balance of the body and posture.

Mechanism of hearing

- The outer ear receives sound waves and directs them to the tympanic membrane. The tympanic membrane vibrates in response to the sound waves and these vibrations are transmitted through the **ear ossicles** to the oval window. The vibrations are passed through the oval window on to the fluid of the cochlea, where they generate waves in the lymph which **induces ripple in the basilar membrane.** These movements of the basilar membrane bend the hair cells, pressing them against the tectorial membrane. As a result, **nerve impulses are generated** that are transmitted by the auditory nerves to the **auditory cortex of the brain.**

Outer ear receives sound → Tympanic membrane vibrates → Ear ossicles transmits it to oval window → Potential Differences → Basilar membrane vibrates that result in bending of hair cells → Nerve impulses are generated

CONCEPT MAP

Human Neural System

Neural system performs three basic functions receiving, processing and responding.

[illegible]

- Structural and functional unit of the neural system.
- Three major parts; **cell body** (consists of neuroplasm, cell organelles, Nissl's granules and a neurofibrils), **dendrites** (branched processes that conduct nerve impulse towards the cell body), **axon** (thread-like part that carries the nerve impulse away from the cell body).

Sensory receptors

Eye

- Organs of sight
- It consists of three layers; outermost fibrous layer (**sclera** and **cornea**), middle vascular layer (**choroid, ciliary body** and **iris**) and innermost nervous layer (**retina**).

Ear

- Hearing and maintenance of body balance.
- Outer ear comprises of **pinna** and **external auditory canal.**
- Middle ear is an air filled cavity having **tympanic membrane** and **ear ossicles.** The function of ossicles is to transmit and amplify sound waves.
- Inner ear is a delicate, irregular organ called **membranous labyrinth.** It comprises main hearing organ, **cochlea** and contains **vestibular apparatus** which is responsible for maintenance of the body balance.

Central Nervous System (CNS)

Brain

- Central information processing organ

Fore brain

- **Prosencephalon**, consists of olfactory lobes, cerebrum and diencephalon.
- The largest and complex **cerebrum** is divided into two cerebral hemisphere. Each one contain frontal, parietal, temporal and occipital lobes.
- **Diencephalon** contains epithalamus, thalamus and hypothalamus.

Mid brain

- Dorsal portion contains four lobes of **corpora quadrigemina** which is equivalent to optic lobes of lower animals.

Hind brain

- **Cerebellum** maintains posture and equilibrium and controls muscular activities.
- **Medulla oblongata** is cardiac centre, respiratory centre, vasomotor centre and reflex centre.
- **Pons varolii** has respiratory centre **pneumotaxic** and **apneustic centre.**

Spinal cord

- It conducts impulses to the brain and controls most of the reflex activities.

Peripheral Nervous System

- Nerves outside the brain and spinal cord.

Cranial nerves

- 12 pairs; 10 pairs from brain stem

Spinal nerves

- 31 pairs of spinal nerves; cervical nerves (8), thoracic nerves (12), lumbar nerves (5), sacral nerves (5) and coccygeal (1).