

21. Neural Control and Coordination

POINTS TO REMEMBER :

HUMAN NEURAL SYSTEM :

- The human neural system divided into two parts –
 - o **The central nervous system (CNS)**
 - o **The peripheral nervous system (PNS)**

- The CNS includes the **brain** and **spinal cord** and is the site of information processing and control.
- The PNS comprises all nerves of the body associated with CNS.
 - o **Cranial nerves:** nerves arises from the brain (12 pairs)
 - o **Spinal nerves:** nerves arises from the spinal cord (33 pairs)

- The nerve fibres (Cranial and spinal nerves) are of two types –
 - o Afferent fibres: transmits impulses from the tissues to the CNS
 - o Efferent fibres: transmits impulses from the CNS to the tissues.

- The PNS is divided into two divisions –
 - o **Somatic neural system.**
 - o **Autonomic neural system.**
 - **Sympathetic neural system.**
 - **Parasympathetic neural system.**

- The somatic neural system relays impulses from the CNS to skeletal muscles.
- The autonomic neural system transmits impulses from the CNS to the involuntary organs and smooth muscles of the body.

NEURON AS STRUCTURAL AND FUNCTIONAL UNIT OF NERVOUS SYSTEM :

- A neuron composed of three major parts –
 - o **Cell body**
 - o **Dendrites**
 - o **Axon**

- The cell body contains cytoplasm with typical cell organelles and specific granular body called **Nissl's granules**.
- Short fibres which profusely branched projects out of cell body called **dendrites**.
- The axon is a long fibre, branched at the end.
- Each branch terminates as a bulb-like structure called **synaptic knob**.

- Based on the number of axon and dendrites the neurons are of following types –
 - **Multipolar**: one axon and several dendrites - found in cerebral cortex.
 - **Bipolar**: one axon and one dendrite - found in retina of eye.
 - **Unipolar**: cell body with one axon only – found in embryonic stage.
- The axon may be **myelinated** or **non-myelinated**.
- The myelinated nerve fibres are enveloped with **Schwann cells**, which form myelin sheath around the axon. The gaps between two adjacent myelin sheath are called **Nodes of Ranvier**.
- Cranial and spinal nerves are myelinated.
- Autonomic and somatic neural fibres are non-myelinated.

GENERATION AND CONDUCTION OF NERVE IMPULSE :

Polarized membrane/Resting Potential :

- In resting phase when neuron is not conducting an impulse, the axonal membrane is called polarized. This is due to difference in concentration of ions across the axonal membrane.
- At Rest :
 - Axoplasm inside the axon contains high conc. of K^+ and low conc. of Na^+ .
 - The fluid outside the axon contains low conc. of K^+ and high conc. of Na^+ .
- As a result the outer surface of axonal membrane is positively charged and inner surface is negatively charged. The electric potential difference across the resting plasma membrane is called **resting potential**.

Action Potential :

- When a nerve fibre is stimulated, the permeability of membrane to Na^+ is greatly increased at the point of stimulus (rapid influx of Na^+) and hence polarity of membrane is reversed and now membrane is said to be **depolarized**.
- The electric potential difference across the plasma membrane at that site is called action potential, which in fact termed as nerve impulse.
- Depolarization is very rapid, so that conduction of nerve impulse along the entire length of axon occurs in fractions of second.
- Depolarization is followed by the increase in permeability of K^+ to the membrane leads to change in polarization i.e. +ve charge outside and -ve charge inside. It is called **repolarization**.
- Regain of resting potential takes place due to action of Na^+/K^+ ATPase enzyme which transports three Na^+ inside and two K^+ inside with expense of one ATP. It continues till the resting potential becomes -70 mv.

Transmission of impulses through synapse :

- The functional junction between two neurons is called **synapse**.
- 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 two types of synapses:
 - **Electrical synapse**: pre and post synaptic membrane with close proximity without any synaptic cleft.
 - **Chemical synapse**: the pre and post synaptic membrane is separated by a fluid filled synaptic cleft.

Conduction of impulse in chemical synapse :

- The axon terminals contains vesicles filled with chemicals called **neurotransmitters**.
- When the action potential arrives at the axon terminals, it stimulates the movement of synaptic vesicles towards the membrane.
- Synaptic vesicle fused with the pre-synaptic membrane and releases the neurotransmitter into the synaptic cleft.
- The neurotransmitter binds with the receptors located on the post-synaptic membrane.
- Activation of receptors on post-synaptic membrane makes it permeable to Na⁺ and generates action potential as it done by stimulus.
- The new potential developed may be either excitatory or inhibitory depends on the nature of the **neurotransmitter**.

CENTRAL NERVOUS SYSTEM :

- Brain is the central control and command system in neural coordination.
- The human brain is well protected by the skull.
- Inside the skull the brain is covered by **cranial meninges**.
- **Meninges consists of following layers –**
 - **Outer layer – dura mater.**
 - **Middle layer – thin arachnoid.**
 - **Inner layer – pia mater remain close contact with the brain.**
- The human brain is divided into three major parts –
 - **Fore brain.**
 - **Cerebrum.**
 - **Thalamus.**
 - **Hypothalamus.**
 - **Mid brain.**
 - **Hind brain.**
 - **Pons.**
 - **Cerebellum**
 - **Medulla oblongata.**

Fore brain :

- Cerebrum is the major part of the fore brain.
- Deep median fissure divides the cerebrum into two equal **cerebral hemisphere**.
- The hemispheres are connected by tract of nerve fibres called **corpus callosum**.
- The thin layers of cells covers the cerebral hemispheres called cerebral cortex and are thrown into prominent folds.
- The cerebral cortex is referred as the grey matter.
- The cerebral cortex differentiated into –
 - **Motor areas** – sends information to the body
 - **Sensory areas** – receives information from the body
 - **Association area**-neither sensory nor motor (co-ordinates the information)

- Interior of the brain is called **white matter** due to myelin sheath of tract of nerve fibres.
- The cerebrum is wraps around a structure called **thalamus**, which is a major coordinating centre for sensory and motor signaling.
- At the base of the thalamus is the **hypothalamus**.
- The hypothalamus have following functions –
 - o Control body temperature.
 - o Urge for eating and drinking.
 - o Neurosensory cells secrete different hormones.
- The inner part of the cerebral hemispheres and a group of associated deep structures like **amygdala, hippocampus**etc. forms complex structure called the **limbic lobe** or **limbic system**.
- Along with the hypothalamus it is involved in the regulation of sexual behaviour, expression of emotional reactions (excitement, pleasure, rage and fear) and motivation.

Mid brain:

- The mid brain is located between the thalamus and pons of the hind brain.
- A canal called cerebral aqueduct passes through the mid brain.
- The dorsal part of the mid brain consists of four swelling called **corpora quadrigemina**.

Hind brain:

- Comprises pons, cerebellum and medulla oblongata.
- Pons consists of fibre tracts that interconnect different regions of the brain.
- Cerebellum has very convoluted surface in order to provide the additional space for many more neuron.
- Medulla of the brain is continued as spinal cord.
- Medulla contains centers which control respiration, cardiovascular reflexes and gastric secretion.

REFLEX ACTION AND REFLEX ARC :

- Sudden spontaneous, involuntary reaction to a stimulus without involvement of brain is called **reflex action**.
- Some examples of such actions are –
 - o Sudden withdrawal of the body part which comes in contact with objects that are extremely hot, cold, pointed.
- **Reflex arc:** sensory organ → sensory neuron → spinal cord → motor neuron → effector organ.

SENSORY RECEPTION AND PROCESSING :

Eye :

- Eye is the sensory organ of **vision**.
- Our paired eyes are located in sockets of the skull called **orbit**.
- Eye consists of three layer –
- **Sclera: tunica fibrosa.**
 - o External layer composed of dense connective tissue.
 - o It is the only complete layer of the eye.
 - o The anterior portion of this layer is transparent and called cornea.

- **Choroid: tunica vascularis.**

- It is the middle layer of the eye.
- It is well vascularized and looks bluish color.
- Posterior two third parts is thin.
- Anterior part is thick and form **ciliary body**.
- The ciliary body itself continues forward to form a pigmented and opaque structure called **iris** (the visible coloured portion of the eye).
- Iris contains a central aperture called **pupil**.
- The diameter of pupil is regulated by the muscle of iris.

- **Retina or tunica nervosa.**

- It is the innermost layer of the eye.
- It consists of three layer of cells – from inside to outside
 - Ganglion cells
 - Bipolar cells
 - Photoreceptor cells.
- There are two types of **photoreceptor cells** namely **rods** and **cones**.
- Cones contain photopigment called **iodopsin**.
- Cones responsible for daylight (**photopic**) vision and color vision.
- Rods contain photopigment called **rhodopsin** or visual purple, which contain a derivative of Vitamin-A.
- Rods responsible for twilight (**scotopic**) vision.
- The optic nerves leave the eye and the retinal blood vessel enters it at a point where rods and cones are absent hence called **blind spot**.
- At the posterior pole of the eye lateral to blind spot there is a yellowish pigmented spot called **macula lutea**.
- Macula lutea with highly concentrated cones, where the vision is sharpest (high resolution vision)
- In the centre of macula lutea there is a central pit called **fovea centralis**, a tightly packed array of specialized **photosensor-receptor cells**. It prevents the entry of high intensity light by closing the eye by reflex action.

- The **lens** composed of crystalline protein, is suspended behind the pupil by a **suspensory ligament** attached to the ciliary body.
- The lens and suspensory ligament divide the cavity of the eye ball into two chambers.
- Chamber in front of lens called **aqueous chamber** filled with **aqueous humor**.
- Chamber behind the lens is called **vitreous chamber** filled with transparent gel called **vitreous humor**.

Mechanism of vision :

- The light rays in visible spectrum focused on the retina through the cornea and lens generate potentials (impulses) in rods and cones.
- Photosensitive pigments composed of **opsin** (a protein) and **retinal** (an aldehyde of vitamin-A).
- Light induces dissociation of the retinal from opsin resulting changes in structure of opsin.
- This causes change in membrane permeability. As a result, potential differences are generated in the photoreceptor cells.
- This produces a signal that generates action potential in the ganglion cells through bipolar cells.

- These action potentials transmitted by optic nerves to the visual cortex area of brain where the neural impulses are analyzed and the image formed on the retina is recognized.

THE EAR :

- The ear performs two sensory function, hearing and maintenance of body balance.
- Anatomically, the ear can be divided into three major section –
 - Outer ear or external ear.
 - Middle ear.
 - Internal ear or inner ear

External ear :

- Outer ear consists of the **pinna** and **external auditory meatus** (canal).
- Pinna collects the vibration in the air which produces sound.
- Auditory meatus extends upto the tympanic membrane (the ear drum).
- Tympanic membrane is made of connective tissue covered with skin.

Middle ear :

- Middle ear contains three ear ossicles called **Malleus** (hammer), **Incus** (anvil) and **stapes** (stirrup).
- The Malleus is attached to the tympanic membrane and the stapes is attached to the oval window of the cochlea.
- The ear ossicles amplify the sound waves comes from the tympanic membrane.
- A **Eustachian tube** connects the middle ear cavity with the pharynx.
- Eustachian tube helps in equalizing the pressures on either sides of the ear drum.

Internal ear :

- The fluid filled internal ear is called **labyrinth** consists of two parts, the bony and membranous labyrinth.
- The bony labyrinth is a series of channels, inside these channels lies the membranous labyrinth, which is surrounded by a fluid called **perilymph**.
- The membranous labyrinth is filled by a fluid called **endolymph**.
- The labyrinth consists of two portions –
 - The coiled portion called **cochlea**.
 - The complex above the cochlea called **vestibular apparatus**.

Cochlea:

- The coiled portion of the labyrinth is called cochlea.
- The membrane constituting cochlea are-
 - The reissner's membrane
 - The basilar membrane.
- Reissner's and basilar membrane divide the surrounding perilymph into an upper **scala vestibuli** and lower **scala tympani**.
- The space within cochlea called **scala media** is filled with **endolymph**.
- At the base of the cochlea, the scala vestibule ends at the **oval window (fenestra ovalis)**, while scala tympani terminate at the **round window (fenestra rotundus)** which opens into the middle ear.

- The **organ of corti** is a structure located on the basilar membrane which contains **hair cells** that act as auditory receptors.
- The basal end of hair cells is in close contact with the afferent nerve fibres.
- Hair cells contain stereo cilia projected from the apical part of each hair cell.
- Hair cells covered by a thin elastic membrane called **tectorial membrane**.

Vestibular apparatus:

- Vestibular apparatus located above the cochlea.
- Vestibular apparatus consists of –
 - o Three **semi-circular canals**
 - o **Otolith organ** consisting **saccul**e and **utricle**.
- Each semicircular canal lies in a different plane at right angles to each other.
- Membranous semi-circular canals are suspended in the perilymph of bony canal.
- The base of canals is swollen and is called **ampulla**, which contain a projecting ridge called **crista ampullaris** with hair cells.
- The saccul and utricle contain a projecting ridge called **macula**.
- Crista and macula are the specific receptors of the vestibular apparatus responsible for maintenance of balance of the body and posture.

Mechanism of hearing:

- The external ear receives sound waves and directs them to the ear drum.
- Sound waves are amplified by the ear ossicles and send it to the oval window in the middle ear.
- The vibration of the oval window creates waves in the perilymph of scala vestibuli.
- The waves in perilymph induce a ripple in the basilar membrane.
- Movements of the basilar membrane bend the hair cells, pressing them against the tectorial membrane.
- As a result nerve impulses are generated in the associated afferent neuron.
- These impulses are transported to the auditory cortex of the brain where the impulses are analysed and the sound is recognized.