

## CHAPTER

# 7

# Nervous System and Sense Organs

## NERVOUS SYSTEM

- Neurology is the study of nervous system including receptors.
- Embryonic origin of nervous system takes place from ectoderm.
- Nervous system is found only in animals and remains absent in plants.
- Nervous system is made up of nerve cells or **neurons**.
- A nervous system is a network of neurons which are specialized for transmitting informations from sensory receptors to neurons, between neurons and from neurons to effectors, such as muscles and glands.
- The nervous system consists of three main parts—**Central Nervous System, Peripheral Nervous System and Autonomic Nervous System.**

### Central Nervous System (CNS)

- It is the site of information processing within the nervous system. It is divided into **brain and spinal cord.**

### Human Brain

- Human brain is the widest and anterior most part of central nervous system. Human brain lies in the cranium of skull. The weight of human brain is about 1440 g.
- Cranium or brain box protects brain from external injuries.
- The brain is wrapped by three protective membranous coverings called **meninges**. These are :
  - (i) **Outermost duramater** Which is a tough fibrous tissue and serves as protective layer. It lies in the cranial cavity.
  - (ii) **Middle arachnoid mater** It is a thin non-vascular porous membrane.
  - (iii) **Innermost piamater** It is a thin transparent, pigmented and vascular membrane which adheres to the brain.
- Between the duramater and the arachnoid mater is a fluid filled space known as **sub-dural space** and the fluid filled space between the piamater and arachnoid mater is known as **sub-arachnoid space.**
- The sub-dural and sub-arachnoid spaces are filled with cerebrospinal fluid which is slightly alkaline, clear fluid, formed by **choroid plexus**. It provides nutrition to the brain.
- **Meningitis** is infection in meninges which results in headache, vomiting, pain etc.

### Brain matter

– The substances of brain are differentiated into :

- (i) **Gray matter** It forms the outer layer and consists of cell bodies (cytons) of neurons and **non-medullated or non-myelinated** axons of the neurons.
  - (ii) **White matter** It lies inside the gray matter. It is consisted of cell bodies and medullated or myelinated axons (fibres) of neurons.
- **Cerebrum** is the largest and most prominent part of the brain and covers all other parts of the brain.
  - Cerebrum is divided into right and left **cerebral hemispheres** by a median fissure which are connected by a single thick bundle of nerve fibre called **corpus callosum**.
  - Outer surface of cerebrum is formed by a thin layer of tissues, called **cerebral cortex**.
  - The cerebral cortex of each hemisphere is divided obliquely into four sections by deep groves. These are—**frontal lobe, parietal lobe, temporal lobe and occipital lobe.**

- **Frontal lobe** contains **motor area** for voluntary activities, **promotor area** for involuntary activities and **associary area** for association between sensation and movements.
- **Parietal lobe** contains **somaesthesia area** for general sensation.
- **Temporal lobe** is concerned with hearing and reading.
- **Occipital lobe** contains visual area for visual sensation
- **Broca's area** is related with speech while **Wernick's area** of brain is related with understanding speech.
- **Diencephalon** has three main parts **epithalamus**, **thalamus** and **hypothalamus**.
- **Hypothalamus** deals with water balance in the body, behavioural patterns of sex, sleep, stress, emotions etc. It also regulates pituitary hormones and metabolism of fat, carbohydrate and water.
- **Mid brain** is concerned with visual analysis, and auditory functions.
- The optic lobes are 4 solid lobes lying behind the diencephalon. Which are collectively constitute the **corpora quadrigemina**.
- Cerebellum controls coordination of accurate movements and balancing.
- **Medulla oblongata** is long connecting part of brain to spinal cord. It deals with control of heart beats, blood vessels, breathing, salivary secretion and most of reflex and involuntary (uncontrolled) movements.
- The cavity of medulla oblongata is called **metacoel**.
- The **pons** (pons varolli) is largely a region through which nerve tract pass on their ways from one brain centre to another.
- There are four cavities within brain called **Cerebral ventricles**.

Table 7.1 Ventricles of Brain

| Ventricles    | Position                  |
|---------------|---------------------------|
| Ventricle-I   | Right cerebral hemisphere |
| Ventricle-II  | Left cerebral hemisphere  |
| Ventricle-III | Diencephalon              |
| Ventricle-IV  | Hind brain                |

- **Olfactory lobes** are well developed in dog. That is why, power of smell is more in dog.
- **Parkinson's disease** is a defect of brain.

Table 7.2 Important Functions of Brain

|                             |   |
|-----------------------------|---|
| <b>Forebrain</b>            |   |
| Olfactory region            | Smell   |
| Cerebrum                    | Thinking, intelligence, memory, ability to learn from experience, will power, skilled work, reasoning, knowledge, conscious, speech   |
| Control                     | Laughing, weeping, micturition (passing of urine), defecation, voluntary forced breathing, voluntary muscular coordination  |
| Diencephalon (sensation of) | Heat, cold and pain, control centre of autonomic nervous system, control hunger, thirst, sweating, sleeping and sex   |
| Hypothalamus                | Regulate body temperature so 'thermostat' of the body. Appetite and satiety control emotions like love, anger, pleasure and satisfaction. Control metabolism of carbohydrate, fat and water |
| <b>Midbrain</b>             |   |
|                             | Reflex centre of visual and auditory Sensation  |
| <b>Hindbrain</b>            |   |
| Cerebellum                  | Involuntary muscular coordination<br>Maintain posture, orientation and equilibrium of the body  |
| Medulla oblongata           | Regulate heart rate, involuntary breathing, respiratory centre, blood pressure (vasoconstriction and vasodilation) gut peristalsis, food swallowing, vomiting gland secretion.              |

## Spinal Cord

- It is long cord like structure at the back, centrally located and well protected by bony vertebral column.
- It gives out 31 pairs of spinal nerves in man.
- It deals with impulses to and from the brain and is the centre for reflex actions.
- The cavity of spinal cord is known as **central canal** or **neurocoel**.
- Neurocoel is lined with ciliated **ependymal epithelium**.

## Electroencephalogram (EEG)

- **Electroencephalography** (EEG) is the graphical recording of rhythmic electrical changes, which take place in cerebral cortex.
- Through EEG, we can depict working and defects of different parts of the brain.

- **Berger** in 1929 was first to record EEG.
- Electroencephalic record in normal human subjects consists of four different types of rhythmic waves :
  - (i) **Alpha ( $\alpha$ ) waves** : During resting stage.
  - (ii) **Beta ( $\beta$ ) waves** : During mental exercise.
  - (iii) **Theta ( $\theta$ ) waves** : During child birth and stress.
  - (iv) **Delta ( $\delta$ ) waves** : During sleeping, brain disorder and in faults.

## = Peripheral Nervous System (PNS)

- The peripheral nervous system is so named because, it consists of all nervous structures that are "outside of" or peripheral to the central nervous system.
- Peripheral nervous system is made up of cranial nerves and spinal nerves.

### Cranial Nerves

- These conduct sensory information from specialized receptors to the brain. There are **12 pairs** of cranial nerves in man and rabbit.
- In anamniotes, **10 pairs** of cranial nerves are present eg, frog.

Table 7.3 Cranial Nerves of Man

| Name of cranial nerve | Type    | Innervation                 | Function   |
|-----------------------|---------|-----------------------------|--|
| Olfactory             | Sensory | From nose                   | Smell  |
| Optic                 | Sensory | Retina                      | Vision   |
| Oculomotor            | Motor   | Muscles of eye wall         | Eye movement <i>Movement of eyeball</i>            |
| Trochlear             | Motor   | Muscles of eye ball         | Eye movement <i>Rotational movement of eyeball</i> |
| Trigeminal            | Mixed   | Face and teeth              | Sensation  |
| Abducens              | Motor   | Muscles of eye ball         | Eye movements                                      |
| Facial                | Mixed   | Salivary gland, <b>Face</b> | Secretion of saliva and taste                      |
| Auditory              | Sensory | Ear                         | Equilibrium and hearing                            |
| Glossopharyngeal      | Mixed   | Pharynx and salivary gland  | Secretion of saliva and sensation of taste         |
| Vagus                 | Mixed   | Chest, abdomen and heart    | Visceral affects                                   |
| Accessory             | Motor   | Shoulder muscles            | Visceral reflex                                    |
| Hypoglossal           | Motor   | Tongue                      | Movement of tongue                                 |

### Spinal Nerves

- These nerves come out from spinal cord (gray matter).
- **Frog** has 10 pairs of spinal nerves.
- **Rabbit** has 37 pairs of spinal nerves.
- **Man** has 31 pairs of spinal nerves. These are :
 

|           |   |                                  |
|-----------|---|----------------------------------|
| Cervical  | — | 8 pairs in neck                  |
| Thoracic  | — | 12 pairs in thorax               |
| Lumbar    | — | 5 pairs in upper part of abdomen |
| Sacral    | — | 5 pairs in lower part of abdomen |
| Coccygeal | — | Tail nerve                       |
- All the spinal nerves are **mixed nerves**.

## = Reflex Action

- Reflex action is controlled by **spinal cord**.
- Reflex actions are of two types-simple and acquired reflex action.

### Simple Reflex Action

- It is unconditional, inborn, unlearned reflex to a stimulus, **Examples** : Blinking of the eye, when an object comes near to our eyes suddenly; rapid withdrawal of hand while burned; sneezing, coughing, yawning, knee-jerk reflex etc.
- Reflex actions are quick and fast.
- They follow the shortest route for quick response.
- These are mostly protective in function.

### Acquired Reflex Action

- It is also called as conditioned reflex and dependent on past experience, training and learning.
- First demonstrated by **Ivan Petrovitch Pavlov** in hungry dog. **Examples** : Learning of dancing, cycling, swimming, singing and driving etc.
- These are under cerebral control during learning.

### Autonomic Nervous System (ANS)

Autonomic nervous system was discovered by **Langley** and **Gaskell** and the term ANS was coined by **Langley**.

- It is entirely motor and operates without conscious control.
- Autonomic nervous system consists of two divisions.
  - (a) Sympathetic nervous system
  - (b) Parasympathetic nervous system
- Sympathetic nervous system increases defence system of body against adverse conditions. It is active in stress condition eg, pain, fear and anger.
- Parasympathetic nervous system provides relaxation, comfort, pleasure at the time of rest. It helps in the restoration and conservation of energy.

**Table 7.4** Effects of Sympathetic and Parasympathetic Nervous Systems on Various Organs/Physiological Processes

| Affected organ/Physiological function     | Sympathetic nervous system                                      | Parasympathetic nervous system                                     |
|---|---|--|
| Secretion of sweat by sweat glands        | Stimulates  | Inhibits   |
| Blood vessels and blood pressure          | Constricts blood vessels and increase blood pressure            | Dilates blood vessels and decreases blood pressure                 |
| Ejaculation of semen                      | Stimulates  | Stimulates external genitalia and increases sex urge               |
| Adrenal secretion                         | Stimulates  | Inhibits   |
| Urinary bladder                           | Relaxes   | Constricts   |
| Pupils                                    | Dilates   | Constricts   |
| Secretion of lacrimal gland               | Stimulates  | Inhibits   |
| Secretion of salivary and digestive gland | Inhibits  | Stimulates   |
| Heart beat                                | Accelerates   | Retards  |
| Lungs, bronchi and trachea                | Dilates   | Constricts   |
| Anal sphincters                           | Contracts   | Relaxes  |
| Blood sugar level                         | Increases   | Decreases  |
| Secretion of glucagon/insulin             | Increases secretion of glucagon and decreases insulin secretion | Decreases secretion of glucagon and increases secretion of insulin |
| Gastro-intestinal tract                   | Slow gastric movement.  | Accelerates  |

### Conduction of Nerve Impulses

- Conduction of nerve impulse is an **electro-chemical process**.
- Membrane of a non-conducting neuron is positive on the outside and negative inside. This difference in charge is called as **resting potential** and the membrane is said to be **polarized**.
- To maintain resting potential, **sodium-potassium metabolic pump** operates.
- The stimulus may be **mechanical, electrical or chemical**.
- When a stimulus is applied, sodium-potassium pump stops operating. Sodium ions rush inside and potassium ions rush outside. Hence, the nerve fibre is said to be in **action potential** and it is **depolarized**.
- The resting potential inside the membrane is about  $-70$  mV.
- The action potential inside the membrane is about  $+30$  mV.
- The mineral necessary for nerve conduction is **sodium**.
- In white fibres (medullated) impulse jumps from node to node, it is called **saltatory propagation**, which increases the speed of nerve impulse.

**Table 7.5** Divisions and Structures of the Nervous System

| Division/Structure              | Description and location   | Function  |
|---------------------------------|--|---|
| Central Nervous System (CNS)    | Brain within the cranium and the spinal cord within the vertebral canal  | Responds to nerve impulses (sensations) from sensory nerves; body control center  |
| Peripheral Nervous System (PNS) | Composed of sensory, motor, or mixed nerves  | Conveys impulses to and from CNS  |
| Autonomic Nervous System (ANS)  | Composed of specific structures of CNS and nerves of PNS; divided into sympathetic and parasympathetic divisions | Exerts involuntary (autonomic) control of vital body functions including heart rate, respiratory rate, blood pressure, digestion, body temperature, digestion, body temperature, and so forth |
| Brain                           | Composed of gray and white matter within the cranium   | Serves as control center for nervous system   |
| Spinal cord                     | Composed of gray and white matter within the vertebral canal of the spinal column                                | Conveys messages (impulses) to and from brain, reflex center  |
| Neuron                          | Cell within nervous tissue   | Responds to stimuli and conveys nerve impulses  |
| Sensory (afferent) Neuron       | Component of a sensory or a mixed nerve within PNS   | Transmits impulses from sensory receptor to CNS   |
| Motor (efferent) neuron         | Component of a motor or a mixed nerve within PNS   | Transmits impulses from CNS to effector organs (muscles or glands)  |
| Neuroglium                      | Cell within nervous tissue   | Supports neurons  |
| Nerve                           | Bundle of nerve fibres within PNS  | Conveys impulses  |
| Tract                           | Bundle of nerve fibres within CNS  | Interconnects structures of CNS; conveys impulses   |
| Ganglion                        | Cluster of cell bodies of neurons within PNS   | Serves as control center for a bundle of neurons  |
| Nucleus                         | Cluster of cell bodies of neurons within white matter of CNS   | Serves as control center for a bundle of neurons  |
| Nerve plexus                    | Network of nerves within PNS   | Provides overlapping innervation (nerve supply) to certain body regions   |

## Transmission of Impulse Across Synapse

- The junction between two neurons is called **synapse**.
- **Synaptic knob** contains numerous **synaptic vesicles** filled with a chemical transmitter substance **acetylcholine**.
- Arrival of an impulse at the synaptic knob causes the acetylcholine to be discharged into **synaptic cleft**.
- The time required for the impulse to cross a synapse is called **synaptic delay**.
- **Synaptic delay** is about 0.5 milli second.
- Acetylcholine is an **excitatory neurotransmitter**.
- An **inhibitory transmitter** is one that is released by an inhibitory neuron. It can inhibit an impulse at a synapse.

**Table 7.6** Some Common Neurotransmitters

| Excitatory          | Inhibitory                      |
|---------------------|---------------------------------|
| Acetylcholine       | Gamma Amino Butyric Acid (GABA) |
| Norepinephrine (NE) | Glycine                         |
| Serotonin           |                                 |
| Dopamine            |                                 |
| Histamine           |                                 |

## Nerve Cell or Neuron

- **Neuron** is the unit of nervous system and is the longest cell in the human body.
- There is no cell division in neuron after birth of a child. Therefore, nerve cells have **least power of regeneration**.
- A neuron consists of three distinct portions *ie*, **cell body** (cyton), **dendrites** and **axon**.

### The cell body or Cyton

- It comprises a spherical and relatively large nucleus with a prominent nucleolus.
- Numerous, **granular endoplasmic reticulum**, a large reticular Golgi complex, numerous mitochondria, lysosomes, ribosomes, neurofilaments, microtubules, Vesicles, Nissl's bodies and inclusions are found in the cytoplasm of cell body.
- Nissl's granules are consisted of **nucleoproteins** and thus, are associated with synthesis of protein.

### Dendrons

- These are small processes coming out from cell body and branches to form **dendrites**.
- The cytoplasm of the dendrites contain Nissl's bodies.
- Dendrons are specialized to receive impulses from sensory cells or from axons of other neurons. Thus, these are also called **afferent processes**.

### Axon

- An axon is a single long extension coming out from **axon hillock**. Some branches come out from axon are called **collaterals** because they come off from the axon at right angle *ie*, laterally.
- A large number of branches, come out from each axon are called **telodendria**.
- Each branch ends in a round structure called **button**.
- Axon carries impulse away from the cyton so, it is called **efferent process**.
- A long axon, covered by a sheath is called as **nerve fibre**. This outer thin sheath is formed by Schwann cells and is called as **neurilemma sheath** or **sheath of the Schwann cells**.
- Each Schwann cell has a nucleus and a small amount of protoplasm.
- Neurilemma is the myelin or medullary sheath, formed by a fatty substance called **myelin** which contains phospholipids, cholesterol and other similar substances.
- The myelin sheath is interrupted at some places, these are called **node of Ranvier**.

### Classification of Neurons

#### (a) Unpolarized or Non-polar neurons

- Each neuron contains numerous undifferentiated axons and dendrites. They do not found in vertebrates, while common in invertebrates *eg*, *Hydra* and other cnidarians.

#### (b) Unipolar neurons

- These have only one axon which divides into two ends.
- These are found in embryos of invertebrates as well as vertebrates.

#### (c) Bipolar neurons

- These have a single axon and a dendron on opposite poles of a cyton
- These are found in olfactory epithelium, cochlear ganglia and retina of eyes.

#### (d) Multipolar neurons

- These have one axon and many dendrons.
- Most neurons of vertebrates are multipolar neurons.
- On the basis of functions, neurons can be classified into three kinds—**motor, sensory and mixed neurons**.
  - (i) **Motor** Conducts messages from central nervous system to effector organs.
  - (ii) **Sensory** Conducts information from sensory organs to central nervous system.
  - (iii) **Mixed** Works both as sensory and as motor neuron.

## SENSORY ORGANS

- Sensory organs are also called **receptors**. Receptors respond to stimuli (external and internal).
- Receptors of vision, hearing and smell receive stimuli from a distance, hence, called "**teloreceptors**".

Table 7.7 Types of Receptors

| General senses     |   |                  |
|--------------------|---|------------------|
| Temperature        | — | Thermoreceptors  |
| Touch              | — | Tangoreceptors   |
| Heat               | — | Caloreceptors    |
| Cold               | — | Frigidoreceptors |
| Pain               | — | Algesireceptors  |
| Currents of water  | — | Rheoreceptors    |
| Muscle position    | — | Proprioceptors   |
| Hunger, thirst etc | — | Interoceptors    |
| Special senses     |   |                  |
| Vision             | — | Photoreceptors   |
| Hearing            | — | Phonoreceptors   |
| Smell              | — | Olfactoreceptors |
| Taste              | — | Gustatoreceptors |

### • Thermoreceptors

- (i) Ampullae of Lorenzini — Scoliodon (fishes)
- (ii) Organ of Ruffini — Caloreceptor-Heat
- (iii) End bulb of Krause — Frigidoreceptor-cold

### • Tangoreceptors

- (i) Merkel's discs (corpuscles)
- (ii) Meissner's corpuscles
- (iii) Pacinian corpuscles

## = Organs For Special Senses

### Eyes

- Eyes are sense organs for vision having photoreceptors, which convert the energy of specific wavelength of light into action potentials of nerve fibres.
- Eye located in bony cavity, orbit.
- Each eye is a hollow spherical organ often called **eye ball**.
- The wall of eye ball has 3 concentric layers-**sclera, choroid** and **retina**.

#### (a) Sclera

- Outer layer is made up of white fibrous tissue and have transparent cornea.
- Cornea is covered by thin and transparent membrane called **conjunctiva**.

#### (b) Choroid

- Iris has a small aperture in the centre called **pupil**.
- A transparent watery fluid called aqueous humour fills the space between the lens and cornea.

#### (c) Retina

- It is the innermost light sensitive layer.
- It is made up of 2 types of cells-photoreceptors **rods** and **cone cells**.
- **Rods** contain a purple coloured photosensitive pigment rhodopsin (formed from vit.-A) and are sensitive even in dim light and dark.
- **Cones** have a violet coloured photosensitive pigment **iodopsin** and are sensitive to bright light and colour perception.

### Disorders of Eyes

#### (a) Myopia

- Far object is not clear.
- Eye ball become longer.
- Image is formed before retina.
- It can be removed by **concave lens**.

#### (b) Presbiopia

- During this power of accomodation of lens decreases due to age factor and defected metabolism.
- It can be removed by bifocal lens.

#### (c) Hypermetropia

- Near object is not clear.
- Eye ball become short.
- Image is formed behind the retina.
- It can be removed by convex lens.

#### (d) Astigmatism

- Curvature of cornea becomes irregular and image is not clearly form.
- It can be removed by cylindrical lens.

#### (e) Cataract

- It is due to defective protein metabolism. During this lens or cornea (sometime both) become opaque.
- It is also known as **Safaid motia**.

#### (f) Glaucoma

- It is due to increase in intra-ocular pressure in aqueous chamber.
- Operation is needed at early stage due to blockage of Schlemm's canal.
- It is also called **Kala motia**.

(g) *Conjunctivitis*

- It is also called "Pink eye", because conjunctiva turns red.
- The inflammation of conjunctiva results by bacterial infection (*Pneumococci* or *Staphylococci*).

**Ears**

- Ears are the statoacoustic organs meant for both **balancing** and **hearing**.
- Ear consists of three parts-external, middle and internal ear.

(a) *External ear*

- It consists of an ear lobe or pinna and an external auditory canal.
- It collects and directs sound waves into the external auditory canal.

(b) *Middle ear*

- Middle ear has 3 small bones, called ear or auditory ossicles. These are hammer-shaped **malleus**, anvil-shaped **incus** and stirrup-like **stapes**.

(c) *Internal ear*

- It consists of a **bony labyrinth** and a **membranous labyrinth**.
- The bony labyrinth has 3 bony semicircular canals, a bony cavity called **vestibule** and a coiled bony tube called **cochlea** and is filled with **perilymph**.
- Three chambers in cochlea are **scala vestibuli**, **scala media** and **scala tympani**.
- Scala media contains the organs of hearing named **organ of Corti**.

**Nose**

- Receptors for smell occur in a modified form of pseudostratified epithelium covering a part of the nasal mucosa. It is called olfactory epithelium .
- The olfactory receptor cells function as chemoreceptors. They are stimulated by specific chemical substances and produce impulse of smell.
- Continuous smelling of an odour make the receptor cells immune to that odour and the receptor cells fail to respond to the sensation.
- **Jacobson's organ** is concerned with smell.
- Jacobson's organ is well developed in **snakes** and **lizards**.
- Jacobson's organs are less developed in birds and mammals.
- **Nasal bone** is found in the region of Jacobson's organ.

**Tongue**

- Tongue is a **gustatoreceptor** or receptor for taste.
- Taste buds are the organs for taste sensation.
- Taste buds are present on the papillae of mucous membrane on the surface of tongue.
- The human tongue bears about 10,000 taste buds.
- A taste bud has taste receptor cells which act as chemoreceptors.
- The anterior part of the tongue is most sensitive to **sweet taste**, back to the **bitter** and sides to **salty and sour**.
- The taste of chillies is a sensation of burning pain of the pain receptors of the tongue.

**Skin Receptors**

- The skin has the following receptors :

- |                            |                         |                             |
|----------------------------|-------------------------|-----------------------------|
| (i) Free nerve endings     | (ii) Root hair plexus   | (iii) Meissner's corpuscles |
| (iv) Merkel's discs        | (v) Pacinian corpuscles | (vi) Ruffini's corpuscles   |
| (vii) Krause's corpuscles. |                         |                             |