9 The Nervous System

Syllabus : *Nervous system : Structure of Neuron; central, autonomous and peripheral nervous system (in brief); brain and spinal cord; reflex action and how it differs from voluntary reflex.*
Sense organs — Eye and ear : Eye defects and corrective measures (myopia, hypermetropia, presbiopia, astigmatism and cataract).

Scope of syllabus : Various parts of the external structure of the brain and its parts (Medulla Oblongata, Cerebrum, Cerebellum, Thalamus, Hypothalamus) and their functions; reference should be made to the distribution of white and gray matter internally. Diagrammatic explanation of the reflex arc, showing the pathway from receptor to effector, differences between natural and acquired reflex should be taught. Structure and function of the Eye and Ear and their various parts. The external and V.S. of the eye must be taught with a brief idea of stereoscopic vision. The course of perception of sound in human ear. Role of ear in maintaining balance.

Every organism must somehow become aware of what is going on around it and accordingly perform actions for its survival. Apart from actions which provide adjustments to the external environment, there are so many activities going on inside our body of which we are unaware. All such actions have to be properly timed and coordinated. Such **coordination** occurs by two agencies — the **nervous system** and the **hormonal system**. The nervous system is dealt here in chapter 9 and the hormonal system in the next chapter 10. In **section 9 A** of this chapter, you will read about the central and peripheral nervous system and in **section 9 B**, about the sense organs.

9 A. THE BRAIN, THE SPINAL CORD AND THE PERIPHERAL NERVOUS SYSTEM

9.1 NEED OF NERVOUS SYSTEM

The nervous system in our body performs the following major functions :

1. **Keeps us informed** about the outside world through the sense organs.
2. Enables us to **remember**, to **think** and to **reason** out.
3. **Controls and harmonises all voluntary muscular activities**, e.g., running or even, holding this book in your hand while you are reading it.
4. **Regulates involuntary activities** such as breathing or the beating of the heart, without our thinking about them.

9.2 NEURON (or NERVE CELL) : THE UNIT OF THE NERVOUS SYSTEM

Our nervous system consists of brain, spinal cord, sense receptors and a whole lot of nerves. The brain and spinal cord are made up of neurons or nerve cells. So, let us first learn about these cells, the **neurons**.

9.2.1 Structure of the neuron (Fig. 9.1 A)

The three main parts of a neuron are the **cell body, dendrites** and **axon** :

(i) **The cell body (Perikaryon or Cyton)** (*peri* : surrounding, *karyon* : nucleus)

- It contains a well–defined nucleus, surrounded by granular cytoplasm.
- It has all the cell organelles like other cells, only centrosome is absent because nerve cells have lost the ability to divide.

(ii) **Dendrites** (*dendron* : tree/branch)

- These are branched cytoplasmic projections of the cell body. They conduct nerve impulses to the cyton.

(iii) **Axon**

- It is a long process from the cell body.
- It varies in size from a few millimetres to even more than one metre in length.
- In most neurons, the axon is surrounded by a white insulating sheath known as myelin (or medullary) sheath which is covered by an outermost thin sheath called (**neurolemma**).
- The myelin sheath shows gaps throughout the length, which are called **Nodes of Ranvier.**
- Some axons may have side branches called collaterals.
- The end portions of the axons have swollen ends like "bulbs", which store certain chemicals called neurotransmitters.
- Axon terminals are closely placed near the dendrites of another one or more neurons but are not connected (Fig 9.1 B). Such gaps in between are called **synaptic clefts** (*syn* : together, *apse* : gap/window).

Some basic terms in nervous activity

Stimulus : *an agent or a sudden change of the external or internal environment that results in a change in an organism or any of its body parts.*

Response : *the change in an organism resulting due to stimulus.*

Impulse : *a wave of irritability (electrical disturbance that sweeps over the nerve cell)*

Receptors : *the specialised epithelial cells which, on receiving the stimulus, set up waves of impulses towards the central nervous system.*

Effectors : *muscles or glands which, on receiving the impulse from the brain or spinal cord, contract or secrete substances.*

The generalised structure of a neuron is shown in Fig. 9.1 A.

Transmission of the nerve impulse. In the normal (resting) condition, the outer side of the nerve fibre carries positive (+) charge. This is called **polarised** state. This polarisation is due to more Na^+ ions outside the axon membrane (Fig. 9.2 A).

On stimulation (mechanical, electrical, chemical or heat, *etc.*), the axon membrane at that spot becomes more permeable to Na^+ ions which move inwards and cause loss of polarisation **(depolarisation)**. This is known as the **excited region**.

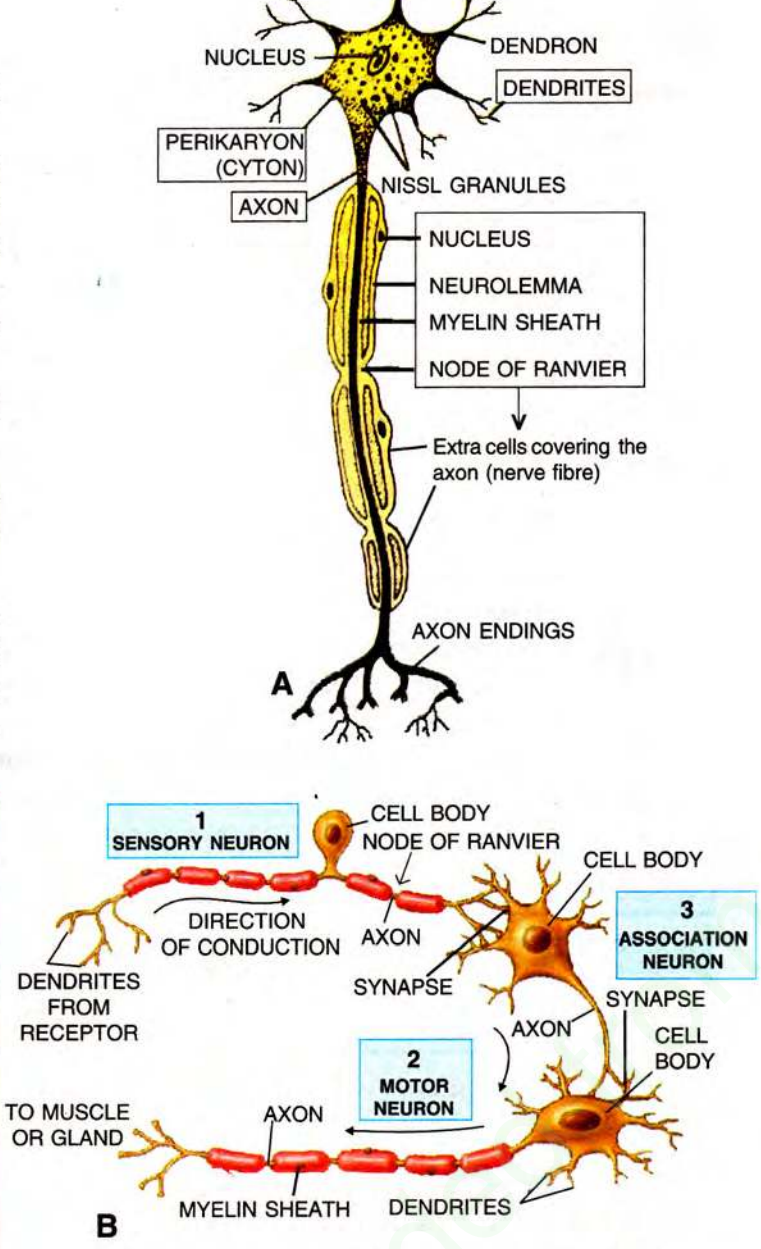


Fig. 9.1 : A–Generalised structure of a nerve cell. B–Three types of neurons (sensory, motor and association), synapse between them and the direction of transmission of nerve impulse

The point of depolarisation becomes a stimulus for the next neighbouring area of the membrane which in turn becomes depolarised (Fig. 9.2 C).

Meanwhile, the previous area becomes **repolarised** due to active transport of Na^+ ions again to the outside (Fig. 9.2 C). This transport is achieved by what is called **"sodium pump"** using energy through ATP.

Conduction of nerve impulse is a wave of depolarisation followed by repolarisation.

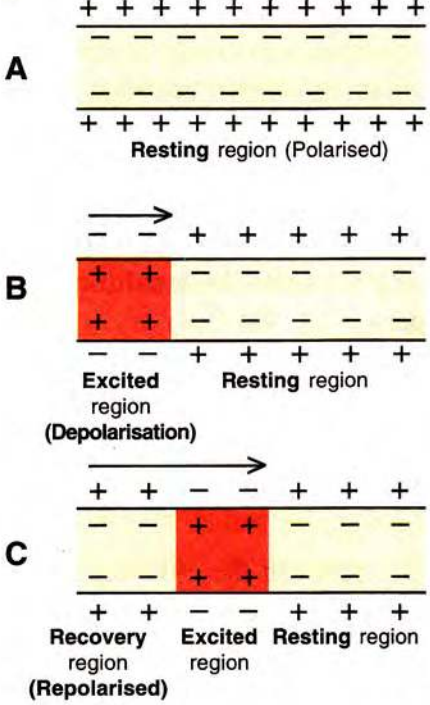


Fig. 9.2 : Conduction of nerve impulse through a nerve fibre

Do not compare conduction of nerve impulse in a nerve fibre with the flow of electricity through an electric wire. In the latter, the electrons actually do move along the wire whereas neither any substance nor any electrons or the ions move along the nerve fibre.

Speed of nerve impulse & speed of electricity

Electricity is conducted through a wire at a speed of about 150,000 km per second, but the nerve impulse travels at a maximum speed of about 100 metres per second only.

9.2.2 Synapse

Synapse is the ***point of contact between the terminal branches of the axon of a neuron with the dendrites of another neuron separated by a fine gap*** (Fig. 9.1B). Here, the nerve impulse "jumps" into the next neuron. This is a chemical process. As the impulse reaches the terminal end of an axon, a chemical **acetylcholine** is released. This chemical sets a new impulse in the dendrites of the adjacent (next) neuron. The chemical is soon broken down by an enzyme to make the synapse ready for the next transmission.

9.2.3 Types of neurons (Fig. 9.1 B)

1. **Sensory neurons** convey the impulse from the receptor (sense organ) to the main nervous system (the brain or spinal cord).
2. **Motor neurons** carry the impulse from the main nervous system to an effector (muscle or gland).
3. **Association (connecting) neurons** are located in the brain and spinal cord, which interconnect the sensory and motor neurons.

9.3 NERVES

Nerve is a bundle of nerve fibres (axons) of separate neurons, enclosed in a tubular sheath.

Nerves are the thread-like white structures which emerge from the brain and spinal cord and branch out to almost all parts of the body. A nerve (Fig. 9.3) may be compared to an underground electric cable containing numerous conducting wires, each insulated from the other. The myelin sheath of the axon acts like an insulation and prevents mixing of impulses in the adjacent axons.

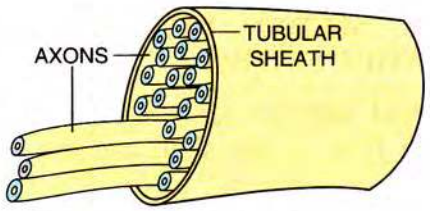


Fig. 9.3 : A nerve, formed of a bundle of axons.

9.3.1. Three kinds of nerves are as follows:

1. **Sensory nerves** contain only sensory fibres bringing impulses from the receptors (sense organs) to the brain or spinal cord.

   Example: Optic nerve arising from the eye and ending in the brain.

2. **Motor nerves** contain only motor fibres carrying impulses from the brain or spinal cord to effector organs (muscles or glands) to bring them into action.

   Example: a nerve arising from the brain and supplying the muscles of the eyeball for rotating the eye.

3. **Mixed nerves** are those, that contain both sensory and motor fibres.

   Example : a spinal nerve.

Ganglia (*sing*. ganglion) are the aggregates of the nerve cells (cell bodies) from which the nerve fibres may arise or enter into.

PROGRESS CHECK

1. Write one word for each of the following:
   (i) The structural and functional unit of nervous system .....
   (ii) Wave of electrical disturbance that sweeps over the nerve cell. .....
   (iii) Long thread-like part of the nerve cell. .....
   (iv) Point of contact between two nerve cells. .....
   (v) A bundle of axons enclosed in a tubular sheath. .....
   (vi) The kind of nerve carrying impulses from the brain to a gland or muscle. .....
2. Categorise the following under stimulus and response.
   (i) Withdrawal of hand on touching a hot plate .....
   (ii) Seeing a green light turning into red at a road crossing before applying the brakes .....
   (iii) Pain in the eye if something falls into it. .....

9.4 TWO MAJOR DIVISIONS OF THE NERVOUS SYSTEM

1. **Central nervous system (CNS)** includes the **brain** lying in the skull and the **spinal cord** contained within the vertebral column.
2. **Peripheral nervous system (PNS)** includes the nerves that emerge from and enter into the brain and spinal cord.

The PNS consists of two subdivisions :

A. **Somatic nervous system** (SNS). Conveys information to skeletal (voluntary) muscles.

B. **Autonomic nervous system (ANS)** includes a pair of chains of ganglia and nerves which control the involuntary actions of many internal organs (smooth muscles, heart muscles and glands).

9.4.1. The brain

In proportion to the size of the body, the human brain is the largest among all animals.

The brain is a very delicate organ well protected inside the **brain box** (cranium) **of the skull**.

Bulk : The adult brain weighs about 1.35 kg and constitutes about 2% of the total body weight.

It is 80% water and consumes more than 25% (one-fourth) of the total oxygen taken into the body.

Coverings (Meninges) : The brain is protected by 3 membranous coverings called **meninges** (*meninx* : membrane) which continue backwards on the spinal cord.

(i) **Dura mater** — the outermost tough fibrous membrane (*dura* : tough, *mater* : mother).

(ii) **Arachnoid** — the thin delicate middle layer giving a web-like cushion (*arachne* : spider).

(iii) **Pia mater** — the innermost highly vascular membrane, richly supplied with blood (*pia*: tender).

(**Meningitis** is the inflammation of the meninges).

The space between the covering membranes is filled with a watery fluid — **cerebrospinal fluid** which acts like a cushion to protect the brain from shocks. The same fluid also fills the central spaces (ventricles) of the brain and the central canal of the spinal cord.

Parts of the Brain :

The brain has three main parts visible externally, (1) **cerebrum**, (2) **cerebellum** and (3) **medulla oblongata**.

1. CEREBRUM (*cerebrum* : brain)

The cerebrum is the largest portion of the brain.

- It is divided into two (right and left) halves called **cerebral hemispheres** (Fig. 9.4). Their outer surface is highly convoluted with ridges and grooves.
- Each cerebral hemisphere is hollow internally and the walls have two regions – an outer (cortex) and an inner portion (medulla).

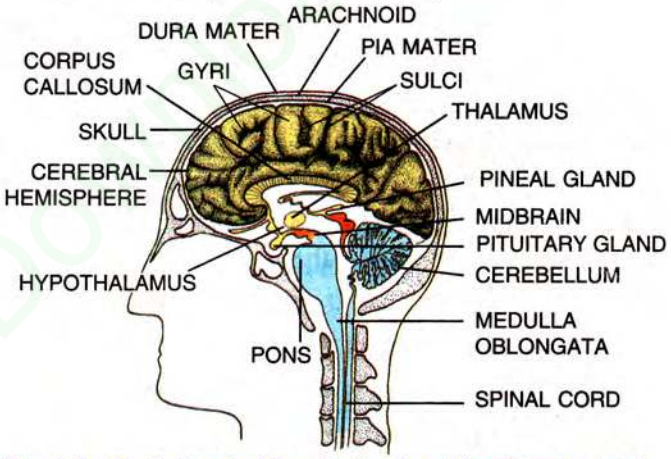


Fig. 9.4 : Brain located inside the head (sectional view)

- The outer portion (*cortex*) of the cerebrum contains cell bodies of the neurons and, being grayish in colour, is called the **gray matter**.
- It is the layer of gray matter which is folded to form the convolutions. The folds are called **gyri** and the grooves are called **sulci** (creases). Such a system increases surface area to accommodate more nerve cells.
- It is believed that the higher number of convolutions in the human brain is due to the larger number of brain (nerve) cells and hence greater intelligence.
- The inner portion of the cerebrum consists of **"white matter"** which mainly contains the axons (nerve fibres) of the neurons.
- **Corpus callosum** ("hard body") is a sheet of fibres connecting the two cerebral hemispheres (Fig. 9.4 & 9.6). Its function is to transfer information from one hemisphere to the other.

The highly developed cortex (gray matter) enables us to **think, reason out, invent, plan** and **memorise**. Overall, the cerebrum is the seat of intelligence, consciousness and will-power. It controls all voluntary actions. Figure 9.5 shows some major functions associated with the different areas of the brain.

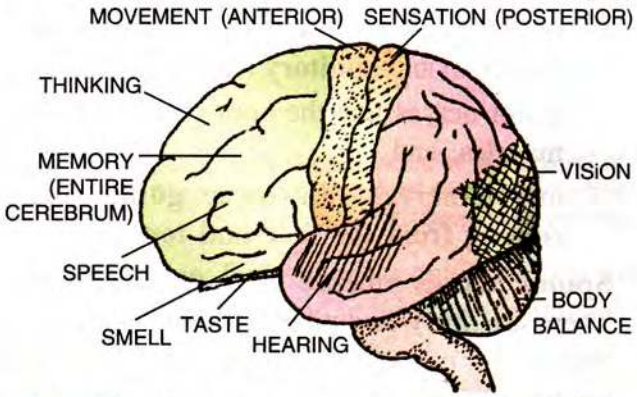


Fig. 9.5 Major functions of the different areas of the brain

What is generally called the **subconscious** or **unconscious mind** is also located in the cerebrum. Many past experiences are covered up by more recent impressions which dominate conscious activity. ***In dreams or when hypnotised and skilfully questioned, past experiences may be recalled.***

2. CEREBELLUM ("little brain")

The cerebellum is a much smaller area of the brain located just at the base and under the large cerebrum. It has no convolutions, but has numerous furrows. This also has an outer cortex made of gray matter. Centrally, it has white matter which, in a median section, appears like a branching tree (Fig. 9.6).

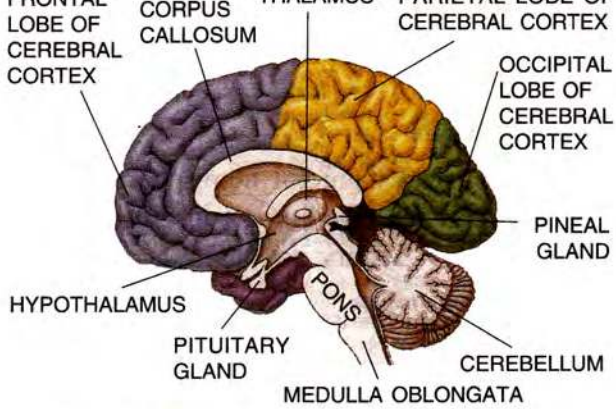


Fig. 9.6 : Brain in median (sagittal) section

The main function of the cerebellum is to **maintain 'balance' of the body** and **coordinate muscular activity**. The impulse for performing a muscular act, originates in the cerebrum and not in the cerebellum. *For example*, if you stand up and walk, the impulse for this activity arises in the cerebrum (conscious part). The act of walking involves coordinated working of many muscles. Proper coordination and timing of their contraction and relaxation is the responsibility of the cerebellum.

An alcoholic person when drunk generally walks clumsily. The cerebellum, due to the effect of alcohol, is unable to coordinate muscular movements properly.

3. MEDULLA OBLONGATA

The medulla oblongata is the lowest portion of the brain located at the base of the skull. It is roughly triangular and is continued behind as the spinal cord. Its function is to **control the activities of the internal organs**, *for example*, peristaltic movement of the alimentary canal, movement of breathing, beating of the heart and many **other involuntary actions**. Injury to the medulla generally results in death.

Three Primary Regions of the Brain

All parts taken together, the brain may be said to consist of three primary regions —**forebrain,**

each region and their principal functions are as follows:

1. FOREBRAIN

(1) **Cerebrum** (cerebral hemispheres) (seat of intelligence, memory, consciousness, will power, voluntary actions).

(2) **Diencephalon**

(a) Thalamus (relays pain and pressure impulses to cerebrum).

(b) Hypothalamus (controls the body temperature and pituitary).

2. MIDBRAIN

A small tubular part (Reflexes involving eyes and ears).

3. HINDBRAIN

(1) **Cerebellum** (***coordinates muscular activity***, balance of the body),

(2) **Pons.** It is located in the centre of the brain below the cerebellum. It carries impulses from one hemisphere of the cerebellum to the other hemisphere and coordinates muscular movements on both the sides of the body.

(3) **Medulla oblongata** (controls activities of internal organs, heart beat, breathing, *etc.*).

9.4.2 The Spinal Cord

The spinal cord extends from the medulla of the brain down almost the whole length of the backbone to end at the second lumbar vertebra and lies within the neural canal of the vertebrae. Figure 9.7 B shows the internal structure of the spinal cord in a cross section. Here the arrangement of white and the gray matter is reversed from that in the brain. The **gray matter** containing the cell bodies of **motor** (efferent) and **association** neurons lies on the inner side and the **white matter** on the outer side. The white matter contains axons running longitudinally to and from the brain and even crossing from one side to the other. There is a small **central canal** in the centre which runs the entire length and is continuous with the cavities of the brain. It is also filled with cerebrospinal fluid which acts as a shock proof cushion and forms a medium for the exchange of food materials, waste products, and respiratory gases with neurons.

Externally, the spinal cord is covered by the same three membranes *dura mater, arachnoid* and *pia mater* in continuation with those of the brain.

FUNCTIONS OF THE SPINAL CORD

The spinal cord is concerned with the followng three functions :

(i) Reflexes below the neck.

(ii) Conducts sensory impulses from the skin and muscles to the brain, and

(iii) Conducts motor responses from the brain to muscles of the trunk and limbs.

9.5 PERIPHERAL NERVOUS SYSTEM

The peripheral nervous system (PNS) includes the nerves which carry impulses to and from the central nervous system. It is divided into **somatic nervous system** and **autonomic nervous system**.

9.5.1 Somatic Nervous System

This consists of two sets of nerves :

(1) **Cranial nerves** and

(2) **Spinal nerves**

1. **Cranial nerves** emerge from the brain. There are ***twelve*** pairs of cranial nerves, some of which are :
   - sensory like the **olfactory** (for nose) the **optic** (for eyes) and **auditory** (for ears),
   - motor nerves like the ones going **to the eye muscles**, and
   - mixed nerves like those **going to** and **coming from the face and tongue**.
2. **Spinal nerves** emerge from the spinal cord. There are ***thirty-one*** pairs : –8 pairs in the neck region, 12 pairs in the thorax, 5 pairs in the lumbar region, 5 pairs in the sacral and 1 pair in the coccygeal region.

A typical spinal nerve originates from the spinal cord by means of two roots–a dorsal root and a ventral root (Fig. 9.7 A & B). Each dorsal root has an ovoid dorsal ganglion. **Every spinal nerve is a mixed nerve having both sensory and motor fibres.** At the junction of the two roots, the sensory and the motor fibres separate out – the sensory fibres continue in the dorsal root and the motor fibres into

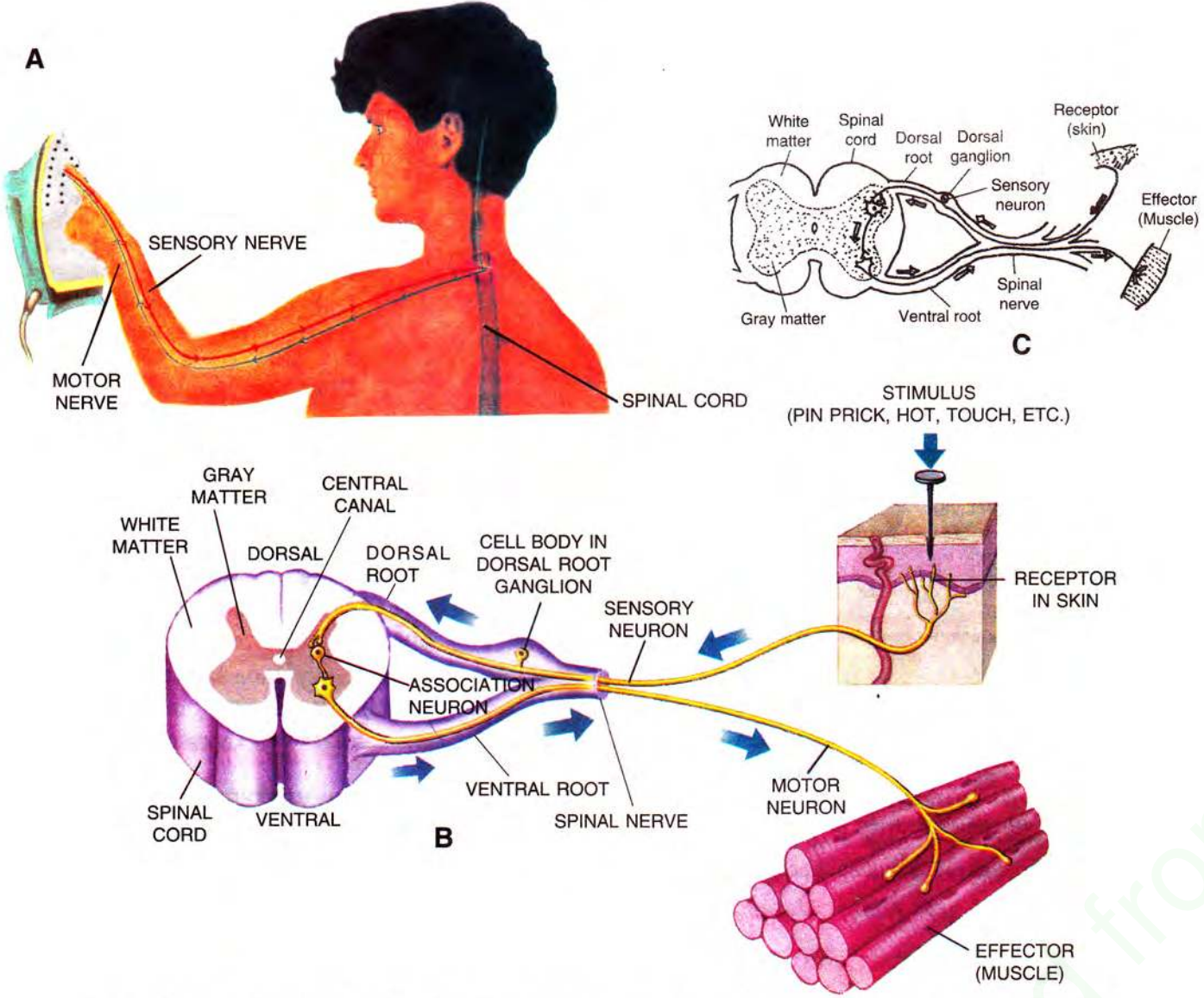


Fig. 9.7 : A–A simple reflex of withdrawal of hand on touching a hot iron, brought out by spinal cord
B–Diagrammatic sketch of the internal structure of spinal cord and nervous pathway in spinal reflex
C–Simplified scheme of the same spinal reflex action

the ventral root. Both the roots enter the gray matter of the spinal cord and end in the corresponding dorsal and ventral projecting "horns" of the gray matter.

9.5.2 Autonomic Nervous System

The autonomic nervous system (ANS) consists of a pair of chains of nerves and ganglia on either side of the backbone. This system controls the involuntary actions of the internal organs. There are two parts of the autonomic nervous system — 1. **Sympathetic** and 2. **Parasympathetic** (Fig. 9.8).

Nerves of **sympathetic system** arise from the spinal cord between the neck and the waist region. The **parasympathetic system** is located at two places, one anteriorly in the head and neck and the other posteriorly in sacral region.

These two parts are in general, opposite to each other in action (see Table 9.1).

The sympathetic nervous system is stimulated by the hormone **adrenaline** secreted by the adrenal gland, located on kidneys.

REMEMBER

Sympathetic nervous system prepares the body **for violent action against abnormal conditions.**
The **parasympathetic nervous system** is more concerned with **re-establishing normal conditions** after the violent act is over.

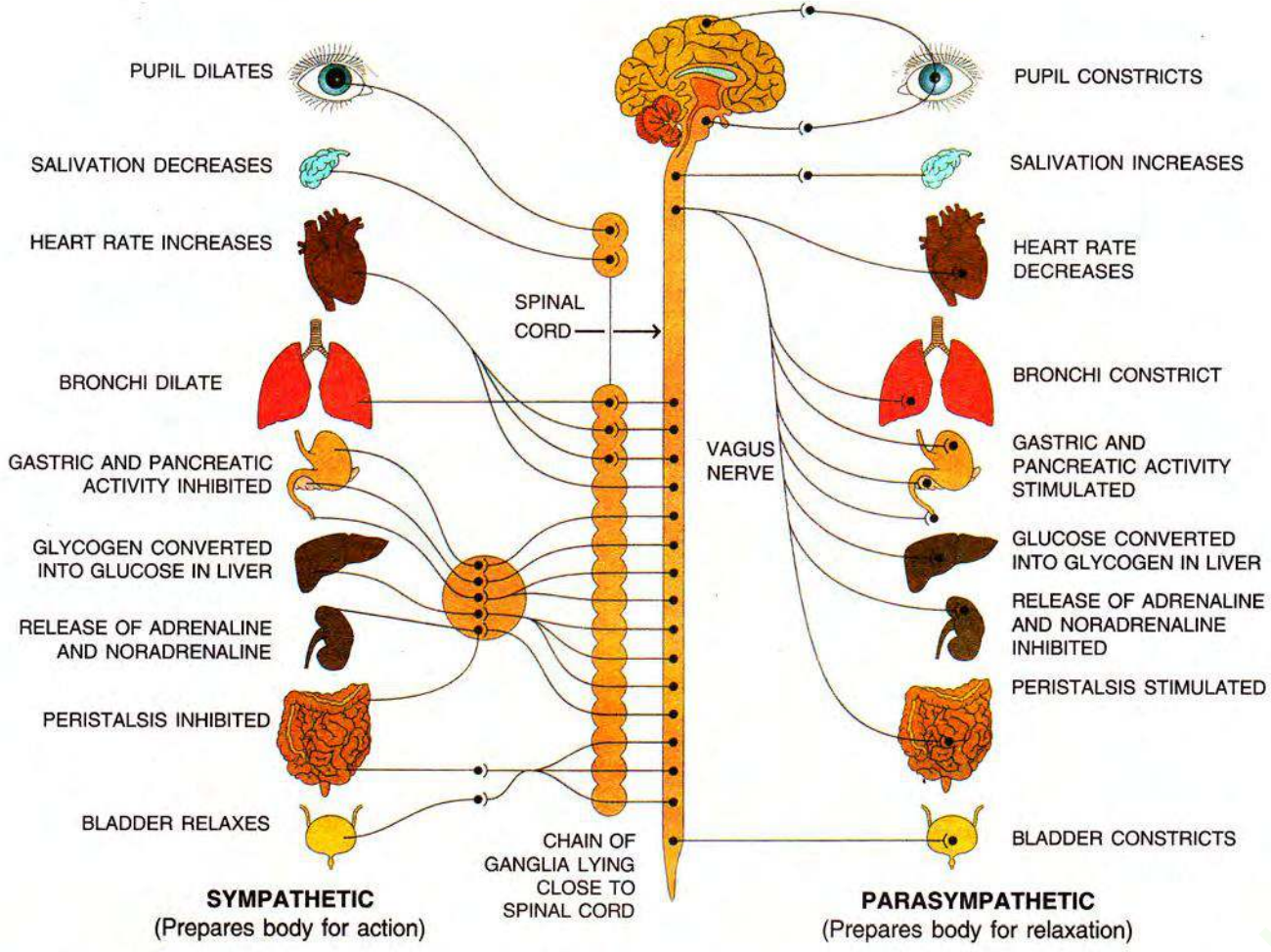


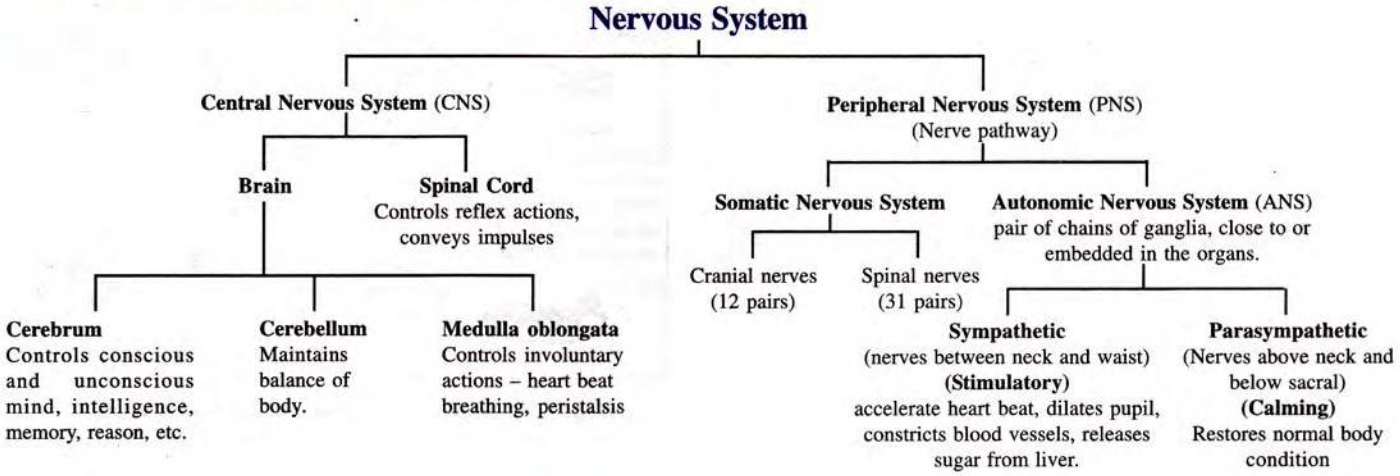
Fig. 9.8 : Autonomic nervous system showing the opposing effects of its two parts – sympathetic and parasympathetic

Table 9.1 : Effects of the two parts of autonomic nervous system (ANS)

S.No.	Organs	Sympathetic system	Parasympathetic system
1.	**Heart**	**accelerates** heart beat	**retards** heart beat
2.	**Blood vessels**	constricts all blood vessels except coronary vessels which are **dilated**	dilates all blood vessels except coronary vessels which are **constricted**
3.	**Lungs**	**dilates** bronchi and bronchioles	**constricts** bronchi and bronchioles
4.	**Intestines**	peristalsis **decreased**	peristalsis **increased**
5.	**Urinary bladder**	sphincter **contraction**, muscle relaxed	sphincter **relaxation**, muscle contraction (feeling to urinate)
6.	**Pupil of eye**	**dilation**	**constriction**
7.	**Salivary glands**	**inhibits** secretion of saliva (dryness of mouth)	**stimulates** secretion of saliva
8.	**Lacrimal (tear) glands**	**stimulates** secretion	**inhibits** secretion
9.	**Arrector (or erector) pili (hair) muscles of skin**	**stimulates** contraction (hairs raised)	**relaxes** (hairs flattened)
10.	**Body (as a whole)**	prepares body **for action**	prepares body **for relaxation**.

Can you make out the opposite actions of the two parts of ANS.

COMPONENTS OF NERVOUS SYSTEM AT A GLANCE



Emotions and autonomic nervous system

Autonomic nervous system is strongly influenced by emotions such as **grief, anger, fear, sexual stimulation**, *etc*. High blood pressure, stomach ulcers and some other troubles may arise due to long continued emotional stress.

9.6 REFLEXES (Involuntary actions)

There are two types of actions which occur in our body : *Voluntary* (performed consciously) and *Involuntary* (performed unconsciously). Examples :

1. Voluntary actions

- You wish to watch some programme on TV and you switch it on and press the remote for a particular channel.
- You pick up an apple and eat it.
- To know the time, you raise your arm and look at the watch on your wrist.

2. Involuntary actions (occurring unknowingly) (also called *Reflexes*)

Reflex action

Reflex action is an automatic, quick and involuntary action in the body brought about by a stimulus.

- Some particle falls into your eye and there is immediate **flushing of tears** to wash out the particle (glandular secretion).
- **Instantaneous withdrawal of hand** when it accidentally touches a hot iron (muscular movement).
- **Shivering** when it is too cold (muscular contractions) or sweating when too hot (glandular secretion).
- **Dilation of the eye pupil** to look in the dark and vice versa (muscular movement).
- **Pushing along of the swallowed food** through the food canal (muscular movement).
- **Non-stop beating of the heart** (muscular movement)

All involuntary actions or reflexes are initiated by some kind of sensory stimulation resulting in either a muscular action or a glandular secretion.

Table 9.2 : Differences between reflexes and voluntary actions

Reflexes (Involuntary actions)	Voluntary actions
1. Initiated by some **stimulus** (touch, pain, pressure, heat, light, etc.)	1. Initiated by a **willing thought**.
2. Mainly **self protective** due to environment.	2. Fulfilment of a **desired goal**.
3. Commands originate mostly in the **spinal cord** and **autonomic nervous system** and a few in the **brain** as well.	3. Commands originate in **brain**.
4. Involve **muscles** and **glands.**	4. Involves only **muscles**.

Stimulus : A stimulus is any agent or an environmental change which initiates a response in the body.

The stimuli can be of several types : ***physical*** (mechanical – touch, prick, pressure, *etc.*), ***chemical, radiant*** (light), ***thermal*** (heat or cold), or ***electrical***.

TYPES OF REFLEXES

Reflexes are of two types (1) **natural (inborn) reflexes** and (2) **conditioned (acquired) reflexes.**

1. **Natural (inborn) reflex** is one in which no previous experience or learning is required. These reflexes are inborn, *i.e.* inherited from the parents. Example :
   - Blinking, coughing, sneezing : these are **protective**.
   - Salivation, swallowing, peristalsis : provide **functional efficiency**.
2. **Conditioned (or acquired) reflex** is one which develops during lifetime due to experience or learning. For example, what you experience simply at the sight or by the smell of a **familiar** tasty food resulting in watering (salivation) of your mouth. This means that if you have not eaten that food earlier, the response would not occur.

Salivation can occur as a natural reflex also. Saliva starts flowing down when you chew or eat food. But in the above example of salivation, the sight or the smell of food was enough for the response. There, your brain actually remembered the taste of the food and worked in an unconscious way. Such **conditioned reflexes** are not inborn and are thus also called **acquired reflexes**.

A conditioned reflex is an involuntary, spontaneous automatic response brought about due to a previously learned experience.

Pavlov's experiment on a dog (Fig. 9.9).

A classic example of developing a conditioned reflex is that of Pavlov's experiment on a dog. This famous Russian biologist noted that under normal conditions, no animal will secrete saliva in response to the ringing of a bell or to any other sound. But when a bell was repeatedly sounded simultaneously with the presentation of food during an adequate period of training, the dog salivated at the sound of the bell even when there was no food at that time. In other words, **a stimulus which previously had no relation with the organism's salivary response, now elicits a response in that gland.**

Here the condition (stimulus) is the sound (not the sight of the food) and the reflex is salivation.

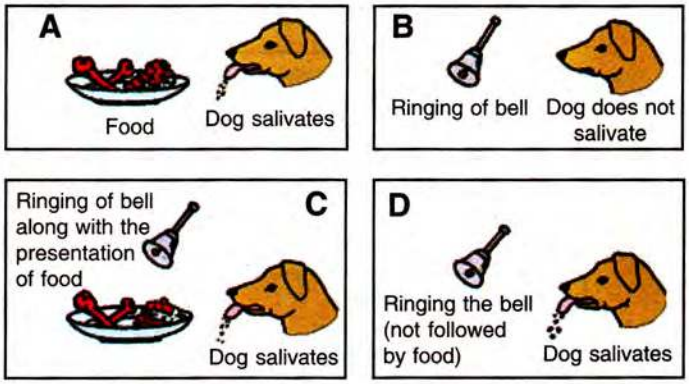


Fig. 9.9 : Pavlov's experiment to demonstrate a conditioned reflex

The dog runs away!

If a dog at a distance sees you simply kneeling down (as if you are picking up a stone), the dog runs away. This is a very commonly observed conditioned reflex found in dogs.

Wild animals in a circus are trained to do many strange acts. These are largely through conditioned reflexes.

SOME COMMON REFLEXES IN HUMANS

A. Natural (inborn) Reflexes

- **Knee-jerk** in which the leg is involuntarily extended as a result of a sharp tap below the knee-cap in a relaxed leg rested on the other leg while sitting.
- Quick **closing of the eyelids** when an object suddenly approaches the eye or when a strong beam of light is flashed across.
- **Withdrawal of the hand** or any part of the body when suddenly pricked.
- **Peristaltic reflexes:** Chyme (food) is propelled through the small intestine by peristaltic waves. When a portion of the intestine becomes distended with chyme, the *stretching* of the intestinal wall becomes a *stimulus* and its contraction pushing the food along is the *response*.
- **Coughing reflex** when the food swallowed enters the wind pipe.
- **Sneezing reflex** when any irritant enters the nose.

Most of the daily habits and acts are conditioned reflexes.

- Seeing the teacher entering the classroom, **you stand up**.
- You **tie your shoe-laces** while talking and not knowing whether you are first putting the right lace over the left or vice versa.
- **Playing on a musical instrument.**
- **Using keys** of the key-board while working on the computer.
- **Giving a hand signal** to your right automatically, when you are turning your cycle or car to the right.
- **Applying brakes** in your vehicle (car or bicycle), if someone suddenly comes in front.

Now you can better differentiate between a simple and an acquired reflex as follows:

Natural (Simple) Reflex	Conditioned (Acquired) Reflex
1. Inborn (inherited) requiring no previous experience.	1. Developed by experience or learning.
2. Directly related to the stimulus	2. Brought about by a condition totally different from the direct initial stimulus.
3. Similar in all humans (or similar among all individuals of any one species)	3. Differs in different individuals, subject to learning and experience

Nervous pathways in reflexes

A reflex action must be quick to have value. Therefore, the pathway for receiving and sending information must be short. In a simple reflex, impulses are not conducted up and down the spinal cord, but leave at the same level at which they enter (Fig. 9.7). This may involve two neurons or three neurons. When it involves two neurons, these are : a dorsal ***sensory neuron*** located in the dorsal root and a ventral ***motor neuron*** located in the ventral part of the gray matter of the spinal cord with its fibre in the ***ventral root***. The impulse from the sense receptor is received through the sensory (afferent meaning carrying towards) fibres of the dorsal root of the spinal nerve, and as it reaches the motor neuron in the spinal cord, a response impulse is immediately nerve to the effector muscle (or organ) to react.

Sometimes, a third neuron (called ***intermediate*** or ***connecting*** or ***association neuron*** or ***relay neuron***) is included in the reflex arc lying between the sensory fibre and the motor neuron inside the spinal cord as is shown in Fig. 9.7B. After the instant response, the sensation is also carried to the brain via the interconnecting longitudinal nerve fibres (ascending neurons) in the spinal cord.

Complex reflex action

Complex reflex action involves neurons at different levels of the spinal cord. While walking in the dark on a road, if you happen to step on a coiled piece of rope, you suddenly jump aside with the fear of a suspected snake. Virtually, all the skeletal muscles are involved in this reflex.

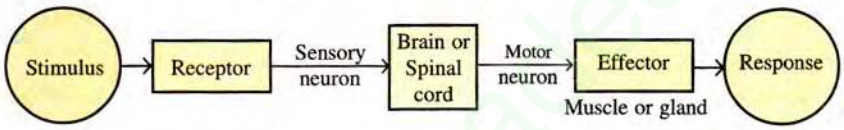
PATH OF REFLEX ARC

A reflex arc may be represented as follows :

Stimulus → receptor in the sense organ → afferent (sensory) nerve fibre → CNS (spinal cord/brain) → efferent (motor) nerve fibre → muscle (to contract)/ gland (to secrete).

The term "reflex" comes from the Latin word "reflexus" meaning reflected or directed back. Can you make out wherefrom the impulses are reflected back in a reflex ?

The above path can be expressed schematically as follows :



The various terms/components in it are explained below :

- **Reflex arc** – is the shortest route that can be taken by an impulse from a receptor to an effector.
- **Receptor** – The specialised epithelial cells in contact with the terminal endings of the nerve cells which respond to stimulus and convert it into an impulse in a sensory neuron.
- **Sensory neuron** – The neuron in the spinal cord that receives nerve impulses through its axon/terminal endings which are in contact with a receptor cell.

- **CNS** (Central nervous system – Spinal cord/brain) – It is a region in the spinal cord/brain where incoming sensory impulse generates an outgoing motor impulse. In the centre, there may be an association neuron between sensory and motor neuron.
- **Motor neuron** – It carries impulse generated by the association neuron in the CNS to the effector organ (muscle or gland).
- **Effector** – It is an organ (muscle or gland) that responds to motor nerve impulse.

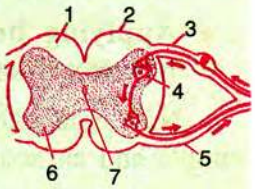
REMEMBER

All reflexes are *involuntary* (not under the control of will) but *all involuntary actions are not reflexes.*

Certain voluntary actions by *consciously repeating them* with specific stimuli can become involuntary, and such actions are called *conditioned reflexes.*

PROGRESS CHECK

1. Fill in the blanks by choosing the correct alternative given for each.
   (i) Brain and spinal cord are the parts of ..... nervous system (central/peripheral/autonomous)
   (ii) ..... is the largest part of the brain. (Cerebellum/cerebrum/medulla oblongata).
   (iii) White matter consists mainly of ..... (axons/dendrites/cytons)
   (iv) The part of the brain concerned with body balance is ..... (cerebrum, cerebellum, medulla oblongata).
2. Given below are a few common reflexes in humans. Write against each the kind of reflex it is (**simple** or **conditioned**).
   (i) Knee-jerk .....
   (ii) Watering of mouth on seeing a favourite dish .....
   (iii) Tying of shoe laces while talking. .....
   (iv) Closing of eyelids if a strong beam of light is flashed across .....
3. Given alongside is a partial diagrammatic representation of a certain phenomenon pertaining to the nervous system.



   (i) Name the parts numbered 1-7
   (ii) What phenomenon does the diagram represent ? .....
   (iii) Name the parts not shown in the diagram that should be included to complete the pathway of the phenomenon. .....

REVIEW QUESTIONS

A. MULTIPLE CHOICE TYPE

(Select the most appropriate option in each case).

1. The insulating sheath covering the neural axon is called
(a) plasmalemma (b) neurolemma
(c) dura mater (d) pia mater

2. Which one of the following pairs of brain part and its function is **not** correctly matched?
(a) cerebrum — memory
(b) cerebellum — balance of body
(c) Medulla oblongata — controls activities of internal organs
(d) Pons — consciousness

3. A mixed nerve is one which
(a) carries sensations from 2 or more different sense organs.
(b) contains both sensory and motor fibres.
(c) has a common root but branches into two or more nerves to different organs.
(d) has two or more roots from different parts of brain.

B. VERY SHORT ANSWER TYPE

1. **Name** the following :
   (a) The fluid that is present inside and outside the brain.
   (b) The junction between two nerve cells.
   (c) The part of the brain which is concerned with memory.
   (d) The part of the human brain which controls body temperature.
2. **Note** the **relationship** between the first two words and **suggest** the suitable word/words for the fourth place.
   (a) Stimulus : Receptor :: Impulse : .....
   (b) Cerebrum : Diencephalon :: Cerebellum: .....
   (c) Receptor : Sensory nerve :: Motor nerve: .....
3. **Complete** the following statements by choosing the **correct alternative** from the choices given in brackets :

cell bodies of (motor/sensory/intermediate) neurons.

(b) Cerebellum is the part of the brain which is responsible for
   (i) conducting reflexes in the body
   (ii) maintaining posture and equilibrium
   (iii) controlling thinking, memory & reasoning.

(c) Reflex action is controlled by
   (i) brain (ii) spinal cord
   (iii) autonomic (iv) peripheral nervous system.

C. SHORT ANSWER TYPE

1. **Mention**, where in the human body are the following located and state their main functions :
   (a) Corpus callosum
   (b) Central canal

2. **State** whether the following statements are ***true*** (T) or ***false*** (F).
   (a) The main component of the white matter of the brain is perikaryon. (T/F)
   (b) The arachnoid layer fits closely inside the pia mater. (T/F)
   (c) A double chain of ganglia, one on each side of the nerve cord belongs to the spinal cord. (T/F)
   (d) Dura mater is the outermost layer of the meninges. (T/F)

3. **Differentiate** between following pairs with reference to the aspect in brackets.
   (a) Cerebrum and cerebellum (function).
   (b) Sympathetic nervous system and para-sympathetic nervous system (overall effect on body).
   (c) Sensory nerve and motor nerve (direction of impulse carried).
   (d) Medulla oblongata & Cerebellum (function).
   (e) Cerebrum and spinal cord (arrangement of cytons and axons of neurons).

4. Given below are two structures, **write** their special **functional activity**.
   (a) Cerebellum and .....
   (b) Myelin sheath and .....

5. **State** the functions of the following :
   (a) Synapse (b) Association neuron
   (c) Medullary sheath (d) Medulla oblongata
   (e) Cerebellum (f) Cerebrospinal fluid.

6. **Explain** the following terms :
   (a) Motor nerve .....
   (c) Conditioned reflex .....
   (d) Association neuron .....
   (e) Gray matter .....

7. **Rearrange** the following in correct sequence pertaining to what is given within brackets at the end.
   (a) Effector — Sensory neuron — Receptor — Motor neuron — Stimulus — Central nervous system — Response (**Reflex arc**)
   (b) Repolarisation — Depolarisation — Resting (polarised) (during **conduction of nerve impulse** through a nerve fibre)
   (c) Axon endings — Nucleus — Dendrites — Axon — Perikaryon — Dendron (**Neuron structure**)
   (d) Diencephalon — Cerebellum — Medulla oblongata — Pons — Cerebrum — mid brain (**sequence of parts** of human brain).

D. LONG ANSWER TYPE

1. (a) **What** is meant by reflex action?
   (b) **State** whether the following are simple reflexes, conditioned reflexes or neither of the two.
      (i) Sneezing .....
      (ii) Blushing .....
      (iii) Contraction of eye pupil .....
      (iv) Lifting up a book .....
      (v) Knitting without looking .....
      (vi) Sudden application of brakes of the cycle on sighting an obstacle in front .....

2. **What** are the **advantages** of having a nervous system?

3. **Why** is the spinal cord and the brain referred to as the central nervous system?

4. **What** is the **difference** between reflex action and voluntary action?

5. **Draw** a labelled diagram of a myelinated neuron.

6. During a street fight between two individuals, mention the effects on the following organs by the autonomous nervous system, in the table given below: (one has been done for you as an example).

Organ	Sympathetic System	Parasympathetic System
e.g. Lungs	Dilates bronchi and bronchioles	Constricts bronchi and bronchioles
(1) Heart		
(2) Pupil of the eye		
(3) Salivary gland		

E. STRUCTURED/APPLICATION/SKILL TYPE

1. Two hungry boys (A and B) enter a restaurant and find a table decorated as follows :

Boy B starts salivating but not A. Explain the reason for this difference.

2. Given below are a few situations. What effective change will occur in the organ/body part mentioned and which part (sympathetic or parasympathetic) of the autonomic nervous system brings it about ?

Situation	Organ / Body part	Change/Action	Part of autonomic nervous system involved
1. You have entered a dark room	Eye	.....	.....
2. Your body is consuming lot of glucose while running a race	Liver	.....	.....
3. You are chewing a tasty food	Salivary gland	.....	.....
4. You are running a race	Adrenal gland	.....	.....
5. You are retiring to bed for sleep	Heart	.....	.....
6. You are shivering in intense cold	Body hairs	.....	.....

3. Given below is the partially incomplete scheme of the components of peripheral nervous system. Fill up the blanks numbered (1)–(8) :

Peripheral Nervous System (PNS)

(Carries impulses to and from .....(1).....)

Somatic Nervous System

Cranial nerves (.....(3)..... pairs)

.....(4)..... nerves (.....(5)..... pairs)

.....(2)..... **Nervous System** (ANS)

pair of chains of ganglia, close to or embedded in the organs.

Sympathetic

(nerves between neck and waist)

accelerate heart beat, ...(6).....

pupil, ...(7)..... blood vessels,

releases sugar from .....(8).....

Parasympathetic

(Nerves above neck and below sacral)

Restores normal body condition

9.7 THE SENSE ORGANS

The sense organs enable us to be aware of the conditions of the environment.

The major sense organs in our body are the **eyes, ears, tongue, nose** and **skin** which are sensitive to light, sound, taste, smell and touch respectively. In addition, there are also the senses of **balance, body movements, hunger** and **thirst, pain,** etc. The actual sensation is perceived by the sensory cells located in these organs — such cells are categorised as receptors.

RECEPTORS

Receptor is any specialised tissue or cell sensitive to a specific stimulus.

(i) **Mechanoreceptors –** are receptors for touch, pressure of skin due to mechanical change.

(ii) **Chemoreceptors –** receptors of taste of the tongue and smell of the nose due to chemical influences.

(iii) **Photoreceptors –** are rods and cones of the retina of eye due to light.

(iv) **Thermoreceptors –** are heat and cold receptors in the skin, due to change in temperature.

(v) **Phonoreceptors –** receptors for sound/hearing.

9.7.1 The Eyes

Orbits : The two eyes are located in deep sockets or **orbits** on the front side of the head. Each eye is in the form of a ball and can be rotated with the help of six muscles.

Eyelids : The upper and the lower movable **eyelids** protect the outer (front) surface of the eyes and can shut out light. Each eyelid carries outwardly curved **eyelashes** which prevent falling of larger particles into the eye.

Eyebrows are virtually not a part of the eye, yet these are also protective; they prevent the rain drops or the trickling perspiration from getting into the eyes.

Tear glands (lacrimal glands) (Fig. 9.10) are located at the upper sideward portion of the orbit. Six to twelve ducts of the gland pour the secretion over the front surface.

- The movements of the eyelids (blinking) spread the liquid which mainly serves as a **lubricant**.

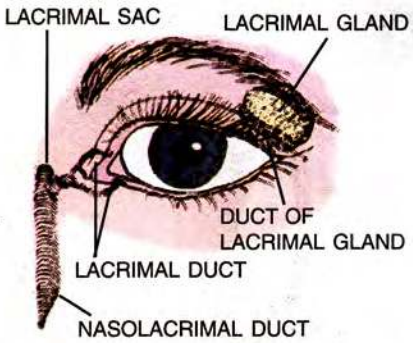


Fig. 9.10 : Lacrimal (tear) apparatus of the human eye

- The tears also keep the front surface of the eye clean by **washing away dust particles.**
- They also have an antiseptic property due to the enzyme **lysozyme** which **kills the germs.**

The tear ducts drain off the liquid into a sac lying at the inner angle of the eye. A nasolacrimal duct conducts the secretion into the nasal cavity. All of us have sometimes experienced that medicines dropped in the eyes come into the nose and even into the throat. This happens through the above-mentioned duct. Due to irritation or in certain **emotional states**, the tear glands pour out a lot of liquid which "waters the eyes" or overflows as "tears". You may shed tears both in grief and in extreme joy.

FUNCTIONS OF TEARS

1. Lubricate the surface of the eye
2. Wash away dust particles
3. Help in killing germs
4. Communicate emotions

The **conjunctiva** is a thin membrane covering the entire front part of the eye (Fig 9.11). It is continuous with the inner lining of the eyelids. Over the cornea, it is reduced to a single layer of ***transparent epithelium***. You must have often heard of a very common eye disease "**conjunctivitis**" in which this outermost layer turns red due to a viral infection.

The bony orbit socket, eyebrows, tear glands and conjunctiva serve for eye protection in their own ways.

STRUCTURE OF THE EYEBALL (Fig. 9.11)

The wall of the eyeball is composed of three concentric layers : (1) outer **sclerotic**, (2) middle **choroid**, and (3) inner **retina**.

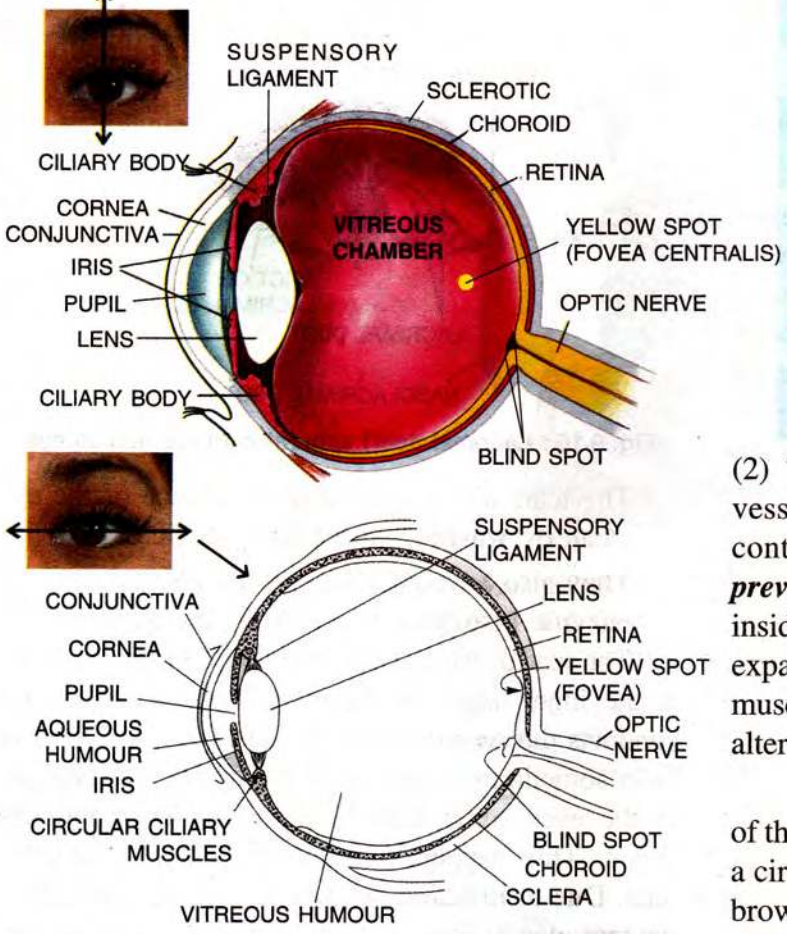


Fig. 9.11 : (Upper)–Right half of the left eye (V.S.), colour contrasted, (Lower)– Horizontal section of the eye. In simple black and white for practising to draw

(1) The **sclerotic layer** (or **sclera**) is made of tough fibrous tissue and is white in colour. The white portion on the front of the eye is the sclerotic layer, itself visible through the conjunctiva. It bulges out and becomes transparent in the front region where it covers the coloured part of the eye; this part is called the **cornea**.

Sometimes, the cornea of certain patient turns opaque (white) and non-functional. In such cases, the defective cornea can be replaced by a healthy cornea from a donated eye.

Donation of eye

Cornea remains alive up to nearly 40 hours after the death of a person. If donated, the eye can be removed soon (within about 4 hours) after death. It is stored in an eye bank at a very low temperature in a suitable medium such as blood plasma or certain other sterile (germ-free) liquid medium. For grafting, the cornea part is taken out from the eye and is fixed in place of the defective cornea and the vision is restored.

And now – up to three from one. According to a report, AIIMS (New Delhi) has developed the technique of slicing the cornea into 2-3 layers that can be grafted on as many defective eyes.

(2) The **choroid layer** is richly supplied with blood vessels for providing nourishment to the eye. It contains a dark black pigment (melanin) which ***prevents light rays from reflecting*** and scattering inside the eye. In the front of the eye, the choroid expands to form the ***ciliary body*** (containing circular muscles). The smooth muscles in the ciliary body alter the shape of the lens.

The ***iris*** (Latin **iris :** rainbow) is also an extension of the choroid, partially covering the lens and leaving a circular opening in the centre, the **pupil**. The blue, brown or black colour of the eye refers to the colour of the iris. **["PUPIL" name has been derived from the Latin word "*pupa*" meaning "doll", which in this context refers to the tiny image of oneself seen reflected in another's eye].** The iris contains radial muscles to widen and circular muscles to constrict the pupil. **This adjustment of the size of the pupil regulates the amount of light entering the eye**. You can easily observe this by throwing a torch light into the eyes while looking in a mirror. In dim or dark light, the pupil is dilated, while in bright light, it is constricted (Fig. 9.14). The pattern and arrangement of the iris muscles is unique for every individual and therefore these are also a source of an individual's identification (see p. 133).

Table 9.2 : Comparison of rods and cones

Rods	Cones
1. **More** numerous.	1. **Less** numerous
2. Mostly at the **periphery of retina**.	2. Mostly located in the **centre of retina**.
3. Very sensitive to **low levels of illumination**.	3. Only stimulated by **bright light**.
4. **One type** of rods only, stimulated by most wavelengths of visible light except red.	4. **Three types** of cone, each selectively responsive to different wavelengths, therefore, allowing colour perception.
5. **Rapid regeneration of** light-sensitive **pigment**, therefore, can perceive flicker well.	5. **Slower regeneration of** light-sensitive **pigment**, therefore, less responsive to flicker.

(3) The **retina** of the innermost layer is sensitive to light. It contains two types of sense cells called **rods** and **cones**.

- The **rod** cells (inner ends rod-like) are sensitive to dim light but do not respond to colour. They contain the pigment ***rhodopsin*** or ***visual purple***. The rod cells are distributed almost throughout the retina.
- The **cones** (inner ends conical) are sensitive to bright light and are responsible for colour vision. They contain the pigment ***iodopsin***. The cone cells are mostly confined to the yellow spot.

YELLOW SPOT – The area of best vision

The distribution of rods and cones is not uniform. A particular spot called the **macula lutea** (**macula** : pit; **luteum :** yellow) or simply **yellow spot** or **fovea centralis** lies at the back of the eye almost at the centre on the horizontal axis of the eyeball. This spot contains the ***maximum number of sensory cells*** and particularly the cones. As a result, this is the region of brightest vision and also of the colour vision. The rest of the retina has fewer cones and more rods.

Yellow spot is the place of best vision of the normal eye. This is the reason why you move your eyes from word to word as you read a line through a printed page.

BLIND SPOT – The area of no vision

Lateral to the yellow spot on the nasal side is the blind spot. There are no sensory cells here and, therefore, this is the point of no vision. This is the point at which the nerve fibres from all the sensory cells of the retina converge and bundle together to leave the eyeball in the form of the optic nerve.

EXPERIENCE YOUR OWN BLIND SPOT

Look at the drawing below (Fig. 9.12). Close your right eye and hold the page at an arm's length and look at the circle with your left eye. You can see both the circle and the square from this distance. Now bring the page slowly towards yourself with the left eye still fixed on the circle. When the drawing is about 15cm away from the eye, the square disappears.

Repeat this experiment with the left eye closed and the right eye focused on the square. As you bring the drawing closer this time, the circle will disappear.

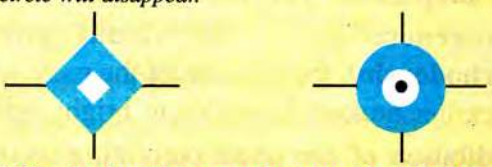


Fig. 9.12 : A chart for experiencing the blind spot

LENS

The lens is a transparent biconvex crystalline body located just behind the pupil. It contains transparent **lens fibres** (long thin cells which have lost their nuclei). The lens is collectively held in position by fibres called the **suspensory ligament**, which attaches it to the **ciliary body**. The ciliary body lies at the junction of the choroid and the iris, and is itself a part of the choroid. The ciliary body contains muscles which on contraction and relaxation, change the shape of the lens (being somewhat elastic) for viewing objects at different distances.

TWO CHAMBERS OF THE EYE — AQUEOUS AND VITREOUS CHAMBERS

The lens, together with its suspending structures, divides the inner cavity of the eyeball into two chambers: aqueous chamber in front of the lens and vitreous chamber behind the lens (Fig. 9.11).

(1) **Aqueous chamber** is the front chamber between the lens and the cornea. It is filled with a clear watery liquid called **aqueous humour** (*aqueous* : watery; *humour* : fluid).

- The aqueous humour serves in two ways :
  (i) Keeps the lens moist and protects it from physical shock,
  (ii) It refracts light.

(2) **Vitreous chamber** is the larger cavity of the eyeball behind the lens. It is filled with a transparent jelly-like thicker fluid called **vitreous humour** (*vitreous* : glassy; *humour* : fluid).

- The vitreous humour serves two functions :
  (i) It helps in keeping the shape of the eyeball,
  (ii) It protects the retina and its nerve endings.

HOW DO WE SEE?

The four major steps in seeing an object are as follows:

(1) **Entry of light rays :** Light rays from the object enter the eyes through the transparent structures (conjunctiva, cornea, aqueous humour, lens, vitreous humour).

(2) **Focusing of image :** First, the curvature of the cornea converges the light rays to some extent and the lens converges them further to form an image on the retina. ***The image on the retina is inverted and real.***

(3) **Nerve impulse produced in retina transmitted to brain :** The light energy of the image produces chemical changes in the sensitive cells (rods and cones). These changes generate nerve impulses which travel through the optic nerve and reach the visual area of the cerebrum, where they give the sensation of sight.

(4) **Brain interprets :** Our brain interprets the image in many ways, e.g., it "sees" the objects upright even if the image formed in the eye is inverted.

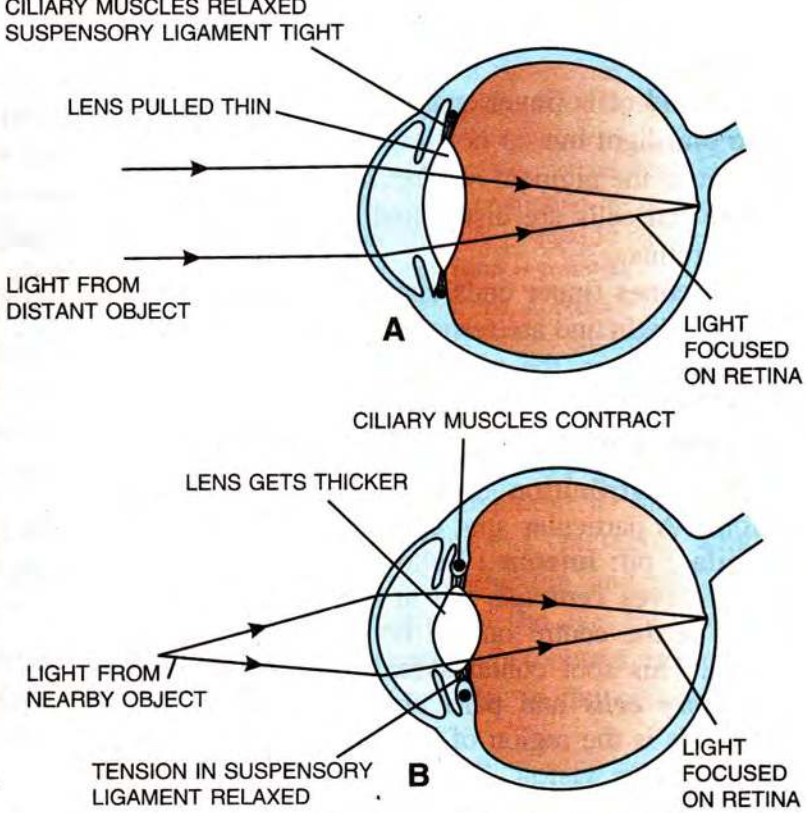
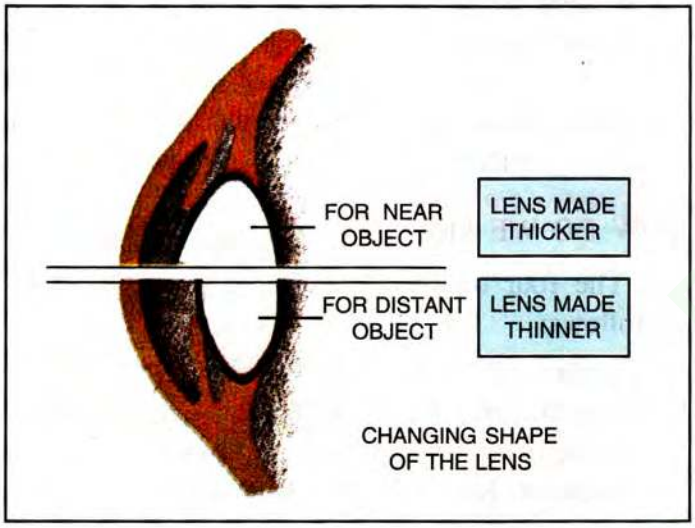


Fig. 9.13 : Accommodation of the eye: A – for distant object; B – for near object

Accommodation (viewing objects in sharp focus). To see an object clearly, its image should be in sharp focus in each eye. The process of focusing the eye to see objects at different distances is called **accommodation**. This is mainly brought about by a change in the curvature of the elastic lens making it thinner or fatter.

- For **distant vision,** the lens is more flattened or thinner.
- For **near vision** (nearer than 6 metres), the lens becomes more convex or rounded. These changes in the shape of the lens is brought about by the ciliary muscles.



In the normal condition (ciliary muscles relaxed), the lens remains stretched by the suspensory ligaments and it is less convex, suited for viewing distant objects (Fig. 9.13A).

When we look at nearby objects, the **ciliary muscles** (which are circular) contract and tend to pull the ciliary body slightly forward. This releases the tension on the suspensory ligament making it loose and the lens, on account of its elasticity, becomes thicker and more rounded or convex (Fig. 9.13.B).

Light and dark adaptation

When you pass from a brightly lighted area to a dark room (such as a cinema hall), you experience difficulty in seeing objects for a short while. Slowly, your vision is improved. This improvement is called **dark adaptation**. This change is due to

(a) regeneration of the **visual purple** (or **rhodopsin**), the pigment of the rods, which was earlier broken down due to bright light, and

(b) **dilation of the pupil** permitting more light to enter the eyes (Fig. 9.14).

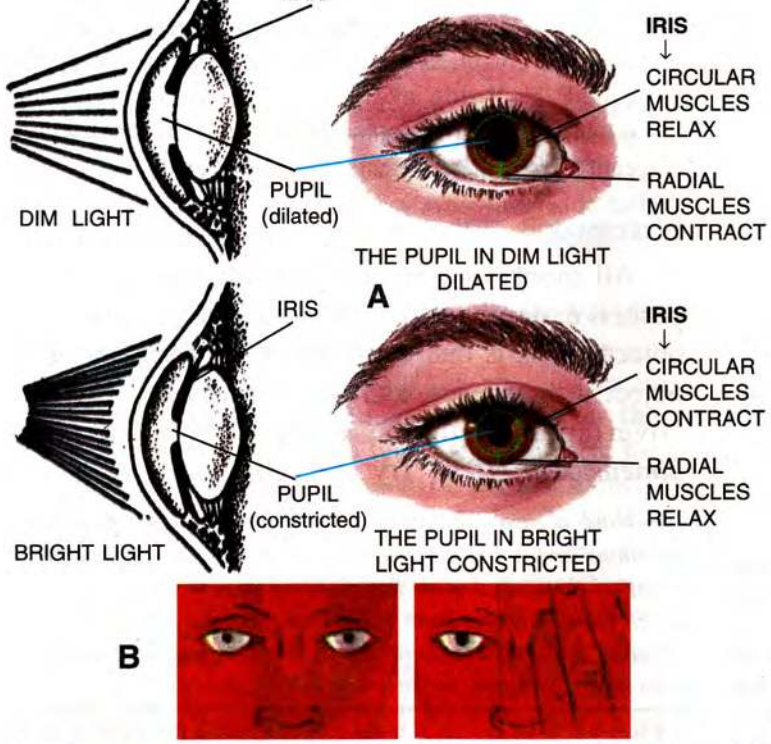


Fig. 9.14 : A–Size of pupil in dim light and bright light. B–One can as well experience the pupil reflex by covering one eye, the pupil of the other eye opens up as a result of reflex linking the two eyes

When a person with dark adapted eyes moves to a brightly lighted area, as in coming out of a cinema hall after the noon show, he experiences a dazzling effect for a short period. After a few seconds, he comes back to normal viewing through **light adaptation**. The adaptation is due to reverse of the previous changes, *i.e.*,

(a) the visual purple of the rods is bleached, reducing their sensitivity, and

(b) the pupil constricts (gets narrower), to reduce the amount of light entering the eyes.

The partial closure of the eyelids in dazzling light also serves the same purpose.

Colour Vision

Colour vision is possible only through cones of the retina which are stimulated only in bright light. You cannot make out the red, violet or purple flowers in a garden on a moonlit night, because then only the rods function and not the cones.

9.7.2 Common Defects of the Eye

1. **Near** or **short-sightedness (Myopia)** is a condition in which the near objects can be seen clearly while the distant objects appear blurred. In it, the image

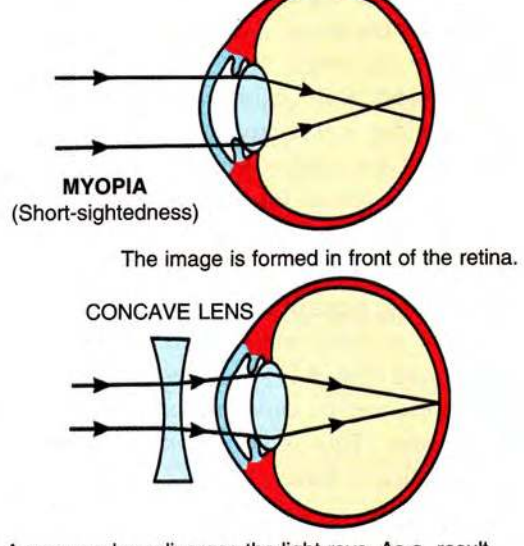


Fig. 9.15 : Short-sightedness (Myopia) and its correction by a CONCAVE LENS

of distant objects is formed **in front** of the retina (Fig. 9.15).

Reasons for myopia : The two possible reasons are (i) the ***eye ball is lengthened from front to back*** OR (ii) the ***lens is too curved*** (even both reasons may occur together).

Correction of myopia : This defect can be corrected by suitable concave (diverging) lens which causes the light rays to diverge before they strike the lens of the eye. Most of your classmates using spectacles may be suffering from myopia (power of glasses used is mentioned in minus "–").

2. **Hyperopia or long-sightedness**

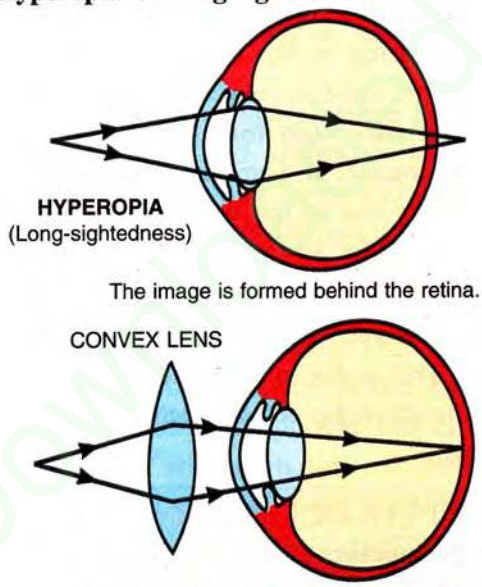


Fig. 9.16 : Long-sightedness (Hyperopia) and its correction by a CONVEX LENS

Hypermetropia) is a condition in which there is a difficulty in seeing near objects. In it, the image of near object falls behind the retina and a convex (converging) lens is required to correct it (Fig. 9.16) (power of the glasses used is mentioned in plus "+"). This defect results on account of either **shortening of the eyeball** from front to back or the **lens is too flat**.

3. **Astigmatism** is a defect in which some parts of the object are seen in focus while others are blurred (Fig. 9.17). It arises due to the uneven curvature of the cornea. This is corrected by cylindrical lenses.

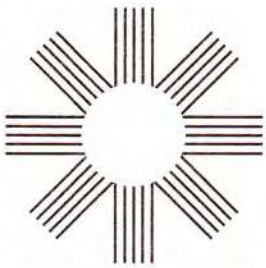


Fig. 9.17 : Do you suffer from astigmatism? Shut one eye and look at this picture. If all the lines appear equally dark, you do not. But if some sets of lines appear dark and those at right-angles to them appear lighter, then you do. Try the same with the other eye

4. **Presbyopia** is a condition affecting older people who cannot see near objects clearly. Their lens loses flexibility resulting in a kind of far-sightedness. This again is corrected by a convex lens.
5. **Cataract** is a condition in which the lens turns opaque and the vision is cut down even to total blindness. It can be corrected by surgically removing the lens, and by using spectacles with highly convex lenses, compensating for the missing lens, or in a newer technique, a small plastic lens is implanted behind or in front of the iris.
6. **Night-blindness** is a condition in which a person feels difficulty in seeing in dim light as during the night. This is due to non-formation of the pigment **visual purple** of the rods. **Only rods function in dim light** and in the absence of the pigment, they cannot function. This is usually due to the **deficiency of vitamin A** which is required for the synthesis of the pigment.
7. **Colour blindness :** Some people by birth cannot discriminate between certain colours such as the red and green. This is due to a genetic defect. The males mostly suffer from this defect, whereas it rarely occurs in females.

ARE YOU COLOUR BLIND ?

Try to read the numbers printed alongside, in the three coloured circles. If you can read these numbers in 1, 2 and 3, you are normal, otherwise colour blind, as *for example in circle* 4.

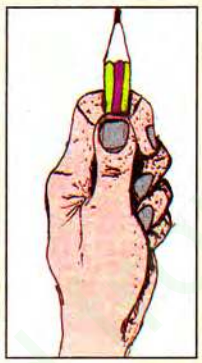
converge leading to what is called **"cross eye"**. An opposite condition appears when they diverge and is called the **"wide eye."** Both conditions may cause double vision or diplopia. Surgery and suitable exercise can correct these defects.

Stereoscopic (binocular) vision.

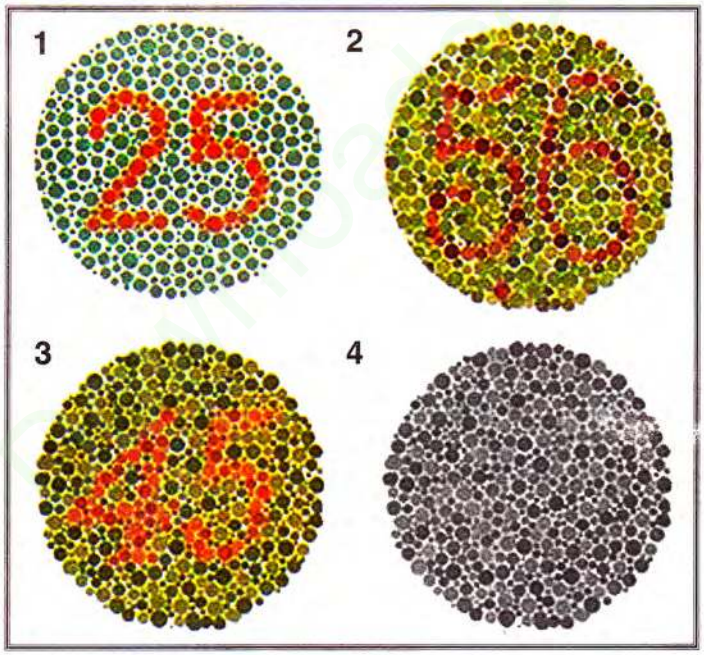
All monkeys/apes and particularly humans can perceive depth or the relative distance of the objects. This is due to simultaneous focusing of an object in both eyes, and their images by a kind of "overlapping" in the brain giving the ***three dimensional effect***. Try one activity :

— *Hold a pencil horizontally with its point facing inward at about* ***arm's length.*** *Close one eye and try to touch the point of the pencil with the point of another pencil in your other hand, starting from a position with the arm at the side of your body. You cannot do it speedily but with both the eyes open, you can do so more easily and quickly.*

Find out which eye is used more. Hold a pencil at arm's length with its point in line with some distant object with both eyes open. First, close one eye and open it and then close the other and open it. With one, the pencil will seem to jump sideways and not with the other. This shows that the other eye was used to line up the pencil and that is the one you use more.



Is it not surprising ? The size of our eyes does not change in our life time as we grow.



If one looks at a bright object for a moment and then closes the eyes, the sensation of light persists for a short period. In the same way, if one looks at a brightly coloured object and then looks at a dark surface, an image of the object in the same colour will persist. This is known as **persistence image** or the **after-image**. It lasts for about one-tenth of a second. This is the principle on which the technique of motion pictures is based.

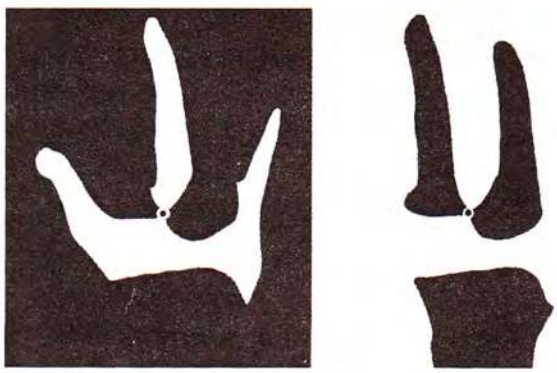
In a movie, pictures are projected on a screen at the rate of about 24 pictures per second, but we cannot see the individual frames on account of the after-images in our eyes. The **life-like continuous movement on the screen is an illusion**. Television too is similar, where the scanning beam of a picture frame of the TV camera moves so rapidly on the viewing screen of the TV set that our eyes cannot keep pace with it. Out of numerous other optical illusions, two are shown at the end of this chapter on p. 133.

Can you now answer ?

You saw a dream — Did the eyes see it ?

Is it the eyes that see or the brain through the eyes ?

EXPERIENCE AN AFTER-IMAGE



Fix your gaze on the spot at the centre of the drawing on the left for half a minute or more. Then look at the spot in the centre of the drawing on the right. Do you visualise a complete hand ?

PROGRESS CHECK

1. State the functions of the following:
   - (i) Eyelids .....
   - (ii) Eyelashes .....
   - (iii) Tears .....
   - (iv) Iris .....
   - (v) Ciliary muscles .....
2. Write in proper sequence the names of all the parts of the human eye through which the light rays coming from an object pass before they form an image on the retina.
3. Name the following :
   - (i) Place of best vision in the retina of the eye .....
   - (ii) Place of no vision in the retina of the eye .....
   - (iii) Kind of retinal cells sensitive to dim light .....
   - (iv) The circular opening enclosed by iris .....
   - (v) The fibres which collectively hold the lens in position .....
   - (vi) Capacity of the eye to focus at different distances .....
   - (vii) The kind of lens required to correct near sightedness .....
   - (viii) The layer of the wall of the eye-ball that corresponds to the black lining of the box of a camera .....
4. Give the reason for the following :
   - (i) Medicines dropped in the eye flow down into the nose .....
   - (ii) A person from bright sunlight outside enters a poorly lit room and feels blinded for a short while.....

9.7.3 The Ear — Senses of Hearing and Balance

The human ear (Fig. 9.18) is concerned with two functions, ***hearing*** and ***body balance***. It has three main divisions : (i) outer ear, (ii) middle ear and (iii) inner ear.

(i) The **outer ear** *consists of the projecting part* **pinna** (also called "auricle") and the passage **auditory canal** leading to the **ear drum** (or **tympanum**).

(ii) The **middle ear** contains three tiny bones — **malleus, incus** and **stapes** or *hammer, anvil* and *stirrup* in popular terms and an **eustachian tube** which connects the cavity of the middle ear with the throat. The three bones are collectively called the **ear ossicles** (*osseus*: bone, *ossicle* : little bone). The handle of the hammer bone is attached to the inner surface of the ear drum. Its opposite end is connected to the anvil which, in turn, is joined to the stirrup. The flat part of the stirrup fits on the so-called **oval window**, a membrane-covered opening leading to the inner ear. A second opening, the **round window**, also covered by a thin membrane, connects the middle and the inner ear.

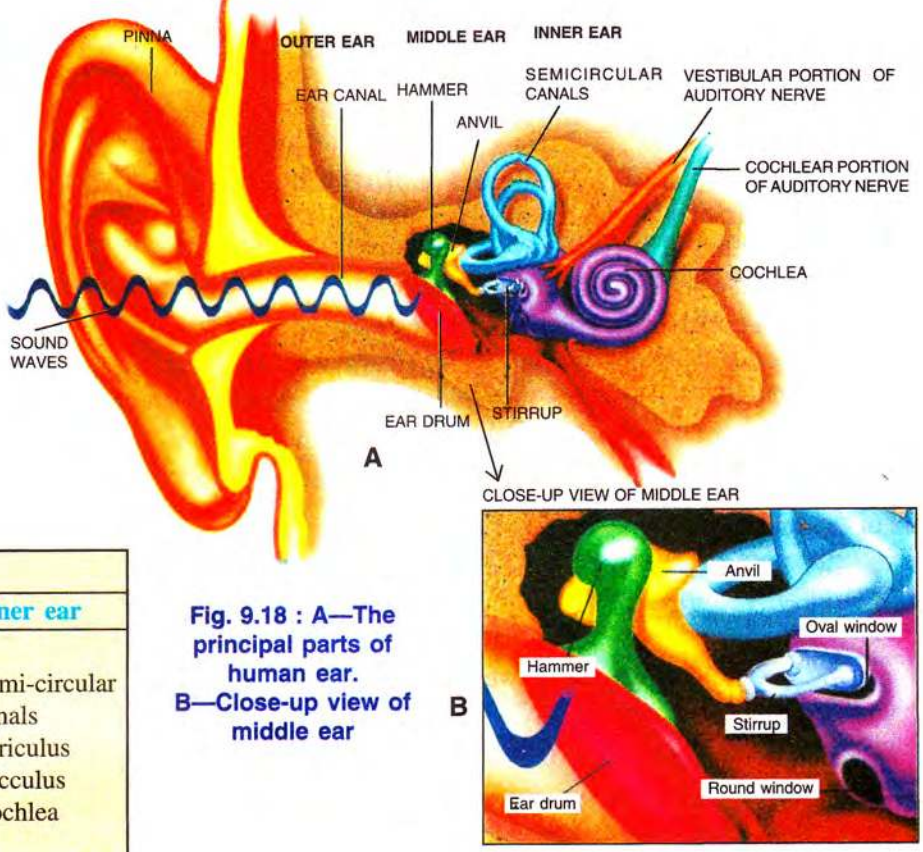


Fig. 9.18 : A—The principal parts of human ear. B—Close-up view of middle ear

PARTS OF EAR		
Outer ear	**Middle ear**	**Inner ear**
– Pinna – Auditory canal – Ear drum	– Ear ossicles • Malleus (hammer) • Incus (anvil) • Stapes (stirrup) – Oval window – Round window – Inner opening of Eustachian tube	– Semi-circular canals – Utriculus – Sacculus – Cochlea

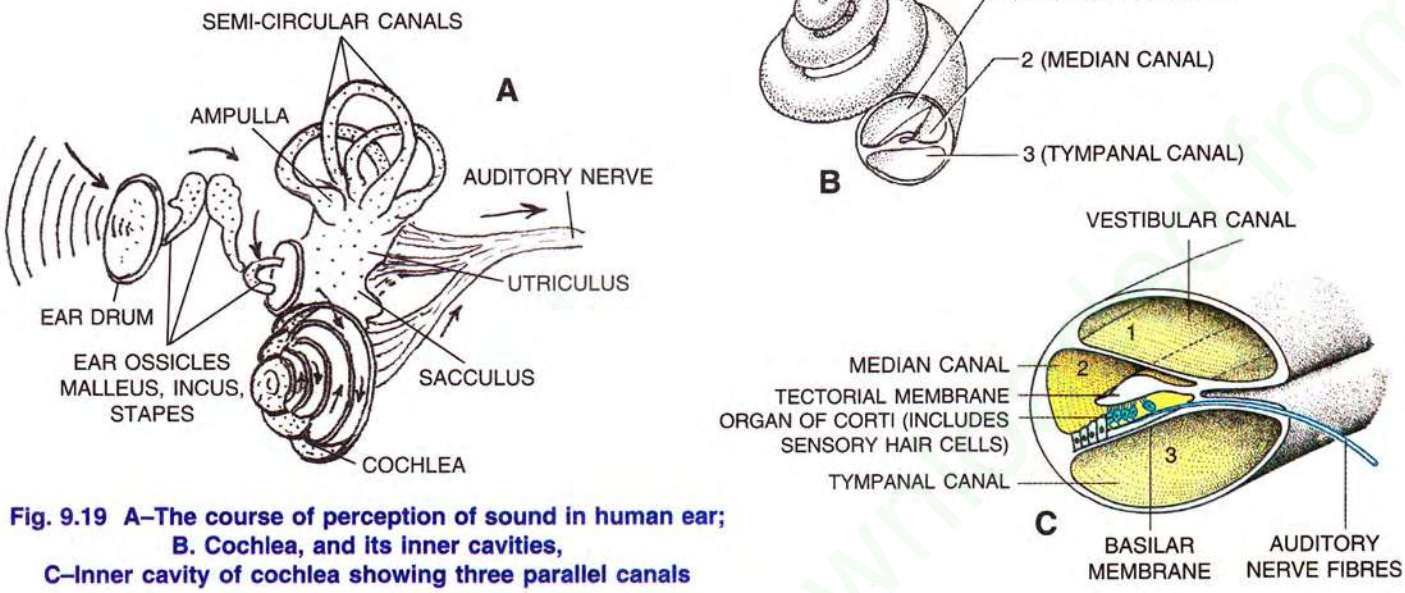


Fig. 9.19 A–The course of perception of sound in human ear; B. Cochlea, and its inner cavities, C–Inner cavity of cochlea showing three parallel canals

(iii) The **inner ear** or **membranous labyrinth** has two main parts — the cochlea and the semicircular canals (Fig. 9.18A). The **cochlea** is spiral-shaped and looks like a snail shell. It has two and a half turns. Its inner winding cavity is divided into three parallel canals separated by membranes (Fig. 9.19C, 1,2,3). The median (cochlear) canal (2) is filled with a fluid called **endolymph** and the other two (1 & 3) with **perilymph**. The middle canal contains areas possessing sensory cells, spiral organ called **organ of Corti** for hearing. The nerve fibres arising from these cells join the auditory nerve. The sensory cells lie on the **basilar membrane**.

The other part of the inner ear is a set of three **semi-circular canals** which are arranged at right angles to each other in three different planes so that one is horizontal and the other two are vertical. One end of each canal is widened to form an ampulla which contains sensory cells for **dynamic balance** while the body is in motion and nerve fibres from them join the auditory nerve.

The short stem joining the bases of semicircular canals to the cochlea shows two parts — a **utriculus** and a **sacculus**. These parts also contain sensory cells for **static balance** when the body is stationary as in standing.

FUNCTIONS OF THE EAR : The internal ear is involved in two sensory functions : **hearing** and **body balance**.

A. HEARING

The pinna collects the sound waves and conducts them through the external auditory canal. They finally strike on the ear drum which is set into vibration.

— The **eustachian tube** equalises the air pressure on either side of the **ear drum allowing it to vibrate freely.**

— **The vibrating ear drum** sets the three ossicles also into vibration.

— The **vibration of the last ossicle** (stirrup) is magnified due to lever-like action of the first two ossicles.

— The vibrating stirrup transmits the vibration to the **membrane of the oval window** which in turn sets the fluid contained in the cochlear canals also into vibration (see arrow marks in Fig. 9.19A).

— The **vibrating movements of the fluid** stimulate the hair-like processes of the **sensory cells of the cochlea** (in spiral organ) and the impulses are transmitted to the brain via the **auditory nerve**.

The different areas of the cochlear canal are suited to sounds of different pitch. Most of the sounds we hear are combinations of vibrations at many different rates of speed, i.e., of different pitches. We cannot pick up vibrations of all rates of speed (frequencies). Our sensory endings can receive only those from 20 to 20,000 Hertz, but the most keenly heard sounds are those at frequencies between 1000 and 4000 Hz. The dogs can perceive sounds of even higher frequencies.

B. BALANCING

As the head is turned in different directions, the fluid inside the semicircular canals is also shaken. The moving fluid in the canals pushes against sensory hair cells sending the nerve impulse through the nerve fibres attached to them, to the brain via the auditory nerve. The sensory cells in the semicircular canals are concerned with **dynamic equilibrium** *i.e.*, **while the body is in motion**. Similar sensory patches are also located in the utriculus and sacculus which register the **static** (positional) **balance** with respect to gravity.

If you spin round and round, the fluid in the semicircular canals continues to spin for a short time even after you stop, and you feel dizzy and at the same time, your eyes perform to-and-fro movements caused due to stimulation of semi-circular canals. Sea-sickness, air-sickness, and car-sickness are often due to these unusual sensations of equilibrium.

9.7.4 The Sense of Taste (Gustation) *(Extra – not specified in syllabus)*

The sense of taste is located in the taste buds of the tongue. A taste bud is an ovoid group of sensory and supporting cells (Fig. 9.20). The sensory cells end in hair-like processes and have nerve fibres extending from their bases. The taste hairs project into the outer taste pore located on the surface of the epithelium. *Substances* in *solution* enter these pores

SENSITIVITY ON DIFFERENT AREAS OF THE TONGUE FOR THE FOUR ELEMENTARY (otherwise in hundreds) TASTES — SWEET, SALT, BITTER AND SOUR

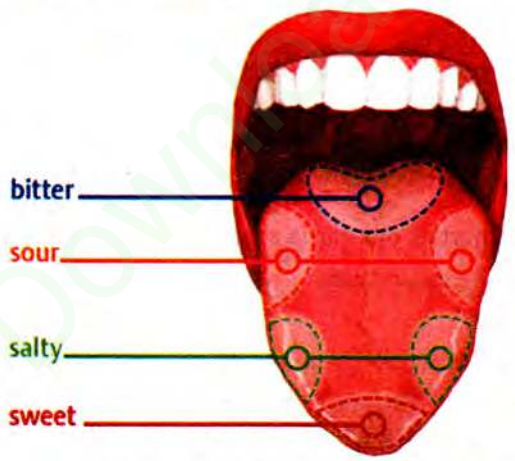


Fig. 9.20 Different taste areas of tongue

and stimulate the sensory hairs. The taste buds are located mainly on the upper surface of the tongue and some are also present on the other areas in the mouth and the throat.

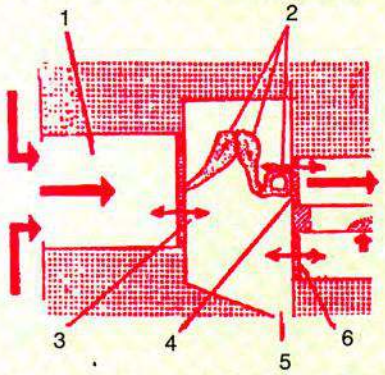
9.7.5 The Sense of Smell *(Extra – not specified in syllabus)*

The sense of smell is located in the delicate epithelial layers of the nasal chamber. The sense cells for smell have hair-like projections which respond to particles dissolved in the mucous secretion of the nose. The impulse from these cells is transmitted to the brain by the olfactory nerve.

FLAVOUR is a combination of taste and smell while eating or sipping. If you hold your nose, you will find that grated apple and grated onion taste alike - slightly sweet. Cold with blocked nose has the same effect and makes food taste/smell/ flavourless.

PROGRESS CHECK

1. Categorise the following parts under (i) external, (ii) middle and (iii) internal ear.
   Ear drum, hammer, pinna, cochlea, anvil, stirrup, eustachian tube, tympanum, oval window, semi-circular canals.
   (i) External ear : .....
   (ii) Middle ear : .....
   (iii) Internal ear : .....
2. State the functions of the following :-
   Semi-circular canals .....
   Cochlea .....
   Auditory nerve .....
3. Name the four fundamental tastes and the areas of the tongue which perceive them.
   .....
4. Given below is a diagrammatic representation of a part of the human ear.
   (i) Name the parts numbered 1-6.
   (ii) Which parts of the ear shown here are complete.



5. Which parts of your hand are most sensitive to touch?
6. Mention if the following statements are **true** (T) or **false** (F) :
   (i) Sense of hunger is located in the tongue. T/F
   (ii) Human ear is concerned with hearing only. T/F
   (iii) Pinna concentrates and directs sound waves towards tympanum. T/F

REVIEW QUESTIONS

A. MULTIPLE CHOICE TYPE

(Select the most appropriate option in each case).

1. Which part of the eye is grafted in a needy patient from a donated eye ?
(a) Conjunctiva (b) Cornea
(c) Choroid (d) Ciliary muscles

2. Which part of our ear is shaped like a snail shell ?
(a) Semi-circular canals (b) Cochlea
(c) Stapes (d) Eustachian tube

3. The three parts of human ear contributing in hearing are –
(a) cochlea, ear ossicles and tympanum
(b) semicircular canals, utriculus and sacculus
(c) eustachian tube, tympanum and utriculus
(d) perilymph, ear ossicles and semicircular canals.

4. The region in the eye where the rods and cones are located is the
(a) retina (b) cornea (c) choroid (d) sclera

B. VERY SHORT ANSWER TYPE

1. **Name** the following :
(a) The photosensitive pigment present in the rods of the retina.
(b) The part which equalises the air pressure in the middle and external ear.
(c) The ear ossicle attached to the tympanum.

(d) The outermost covering layer of the brain.

(e) The tube which connects the cavity of the middle ear with the throat.

(f) The part of the eye responsible for its shape.

(g) The nerves which transmit impulse from ear to the brain.

(h) The photoreceptors found in the retina of the eye.

(i) The eye defect caused due to shortening of the eye ball from front to back.

2. Note the **relationship** between the first two words and suggest the suitable word/words for the fourth place.

(a) Cones : Iodopsim :: Rods : .....

(b) Sound : Ear drum :: Dynamic balance : .....

4. **Which one or more** of the expressions in column II are appropriate for the items listed in column I? **Write** the **correct matching** pairs –

Column I	Column II
(i) The blind spot	(a) colour of the eye
(ii) The yellow spot	(b) shape of the lens
(iii) Ciliary muscle	(c) protective covering of the brain
(iv) Iris	(d) basic unit of brain
(v) Meninges	(e) free of rod cells
	(f) vitreous humour
	(g) centre of the retina
	(h) no sensory cells

Correct matching

(i) : _____ _____

(ii) : _____ _____

(iii) : _____ _____

(iv) : _____ _____

(v) : _____ _____

C. SHORT ANSWER TYPE

1. **Differentiate** between members of each of the following pairs with reference to what is asked in brackets.

(a) Myopia and hyperopia (Cause of the defect)

(b) Rods and cones (Sensitivity)

(c) Semi-circular canal and cochlea (Function)

(d) Rod and cone cells (Pigment contained).

(e) Dynamic balance and static balance (Definition)

2. **State** whether the following statements are ***true*** (T) or ***false*** (F). If false, correct them by changing any one single word in each.

(a) Deafness is caused due to rupturing of the pinna. (T/F)

(b) Semi circular canals are concerned with static (positional) balance. (T/F)

3. **Mention**, **where** in living organisms are the following located and state their main **functions** :

(a) Fovea centralis (b) Organ of Corti

4. **Mention** if the following statements are ***true*** (T) or ***false*** (F). Give reason.

(a) Sometimes medicines dropped into the eyes come into the nose and even throat. (T/F)

(b) Ciliary muscles regulate the size of the pupil. (T/F)

(c) Yellow spot of the retina is the region of colour vision. (T/F)

(d) The auditory nerve is purely for perceiving sound. (T/F)

(e) Malleus, incus and stapes are collectively called the ear ossicles. (T/F)

(f) Flavour and taste are one and the same thing. (T/F)

(g) Short-sightedness and hyperopia are one and the same thing. (T/F)

(h) Blind spot is called so because no image is formed on it. (T/F)

5. Given below are two sets (a) and (b) of five parts in each. **Rewrite** them in correct **sequence**.

(a) Cochlea, tympanum, auditory canal, ear ossicles, oval window.

(b) Conjunctiva, retina, cornea, optic nerve, lens.

6. Given below are certain structures. **Write** against each their special **functional activity**.

(a) Organ of Corti and .....

(b) Olfactory nerve and .....

(c) Retina and .....

(d) Taste bud and .....

7. **Answer** the following :

(a) What is a lacrimal gland?

(b) In what two ways is the yellow spot different from the blind spot?

(c) Name an old-age eye defect. What causes it?

(d) What is meant by power of accommodation of the eye?

(e) Mention the characteristics of the image that falls on the retina of the eye.

8. **What** is meant by optical illusion? Give one example.

9. **Where** are the following located? Briefly mention

(a) Oval window (b) Cochlea

(c) Semicircular canals (d) Utriculus

10. **Name** the four principal tastes and the respective **regions** of the tongue concerned with their perception.

11. **Complete** the following table by filling in the blank spaces.

	Structure	Function
1.	Yellow Spot	.....
2.	.....	Transfers impulse from inner ear to brain
3.	.....	Helps to change the focal length of the eye lens
4.	Spinal cord	.....
5.	Oval window	.....
6.	.....	Dynamic equilibrium

D. LONG ANSWER TYPE

1. **Describe** the mechanism of focusing the image of a distant object in your eye when you raise your head after reading a book.

2. Sometimes you remember a vivid picture of a dream you saw. **What** is the role of your eyes in this experience?

3. By closing the eyes and gently pressing them by your palms, you may see some specks of brilliant light. **How** do you get this **sensation** while there is no light entering your eyes?

4. **Explain the terms** 'adaptation' and 'accommodation' with reference to the eye.

5. You do not enjoy watching a movie from a very short distance from the screen in a cinema hall. **Why**?

6. **Enumerate** the common defects of vision, their causes and the possible methods of correcting them.

7. **Name** the three ear ossicles. **How** do they contribute in the mechanism of hearing?

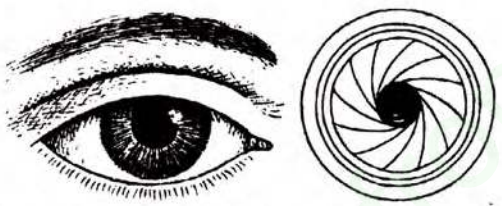
8. **What is meant** by *Power of accommodation* of the eye? **Name** the muscles of the eye responsible for the same. .....

TYPE

1. With reference to the functioning of the eye, answer the questions that follow :
   (a) **What** is meant by power of accommodation of the eye?
   (b) **What** is the shape of the lens during (1) near vision (2) distant vision?
   (c) **Name** the two structures in the eye responsible for bringing about the change in the shape of the lens.
   (d) **Name** the cells of the retina and their respective pigments which get activated (1) in the dark and (2) in the light.

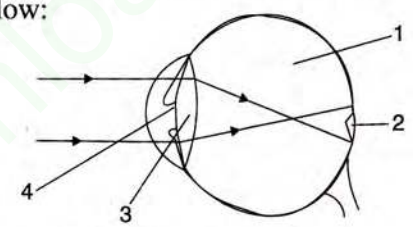
2. With reference to the human ear, answer the questions that follow:
   (a) **Give** the technical term for the structure found in the inner ear.
   (b) **Name** the three small bones present in the middle ear. **What** is the biological term for them collectively?
   (c) **Name** the part of the ear associated with (1) static balance (2) hearing (3) dynamic balance.
   (d) **Name** the nerve, which transmits messages from the ear to the brain.

3. The figure below compares a part of our eye with a part of a photographic camera



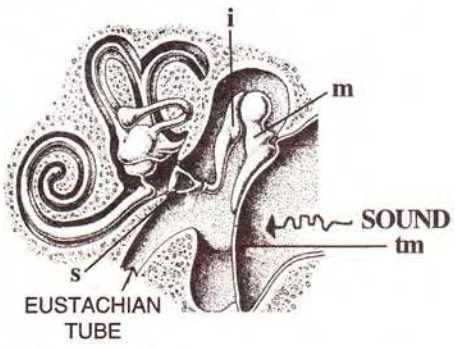
   (a) **Name** the corresponding parts of the eye and the camera shown here that are comparable in function.
   (b) **Explain** the mode of working and the functions of the parts of the eye mentioned above.

4. Given below is a diagram depicting a defect of the human eye. **Study** the same and **answer** the questions that follow:



   (a) **Name** the defect shown in the diagram.
   (b) **Give** two possible **reasons** for *this defect.*
   (c) **Name** the parts labelled 1 to 4.
   (d) **Name** the type of lens used to correct this eye defect.
   (e) **Draw** a labelled diagram to show how the above mentioned defect is rectified using the lens named above.

the skull showing a sense organ :



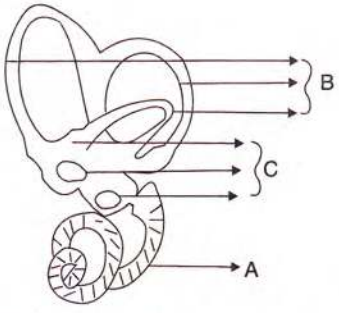
(i) **Name** the sense organ.

(ii) **What** are the parts labelled "m", "i" and "s" ? What do these three parts constitute collectively?

(iii) **What** do you call the part shown in the form of a spiral? What is its **function**?

(iv) **Name** the part labelled "tm"? What is its **function**?

6. Given below is the diagram of a part of the human ear. **Study** the same and **answer** the questions that follow :



Labyrinth of the inner ear.

and Stapes.

(ii) **Name** the parts labelled A, B and C in the diagram.

(iii) **State** the functions of the parts labelled 'A' and 'B'.

(iv) **Name** the audio receptor region present in the part labelled 'A'.

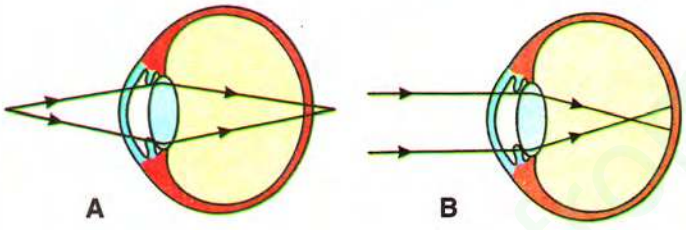
7. **Draw** a labelled diagram of the inner ear. Name the part of the inner ear that is responsible for static balance in human beings.

8. Have a look at the posture of this girl who is reading a book and answer the questions which follow :

(a) **Name** the problem she is facing.

(b) **What** are the two conditions shown in sections A and B of the eye as applicable to her.

(c) **What** kind of reading glasses does she need ?

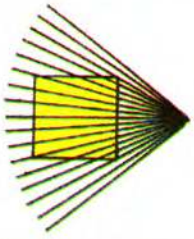


OPTICAL ILLUSIONS

There are dozens of optical illusions which we know, e.g. the life-like movements on a cinema or TV screen.

Two other examples of illusions are given below.

Is it a vase or two human profiles facing each other ? →



← Is there a perfect square or a distorted one?

FOR IDENTIFICATION

Some offices have introduced "Attendance register for looking into camera and pressing a button by fingertip to automatic recording of attendance.