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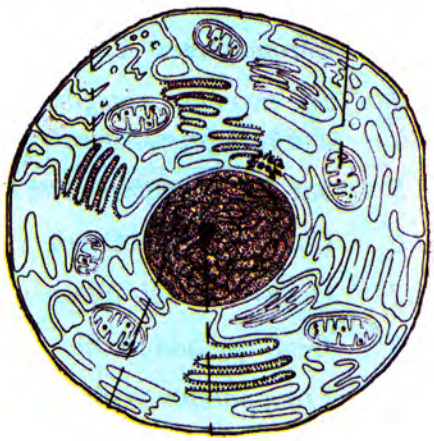

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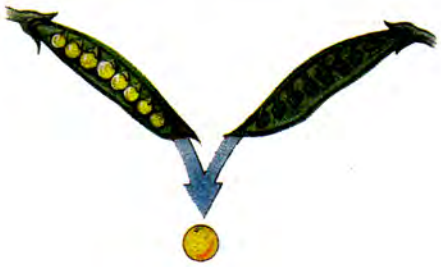

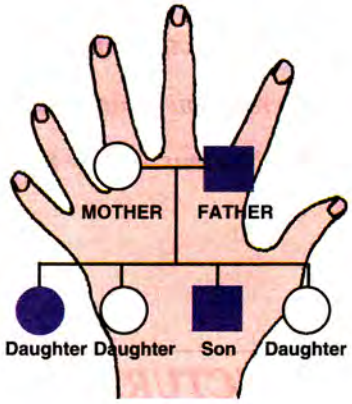

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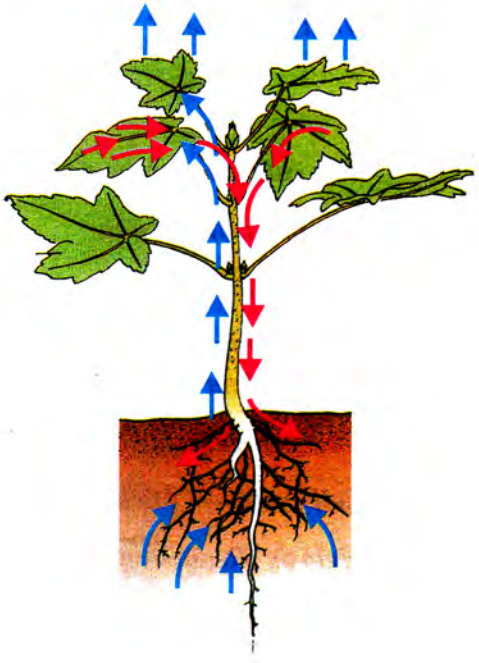

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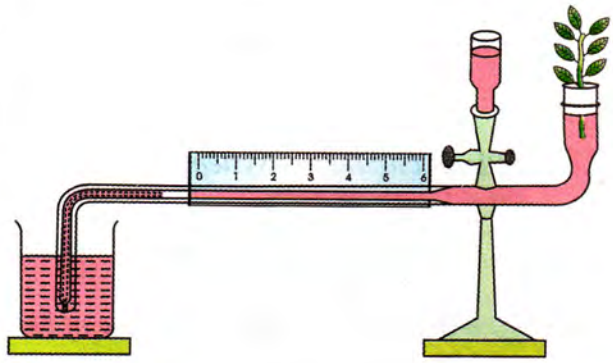

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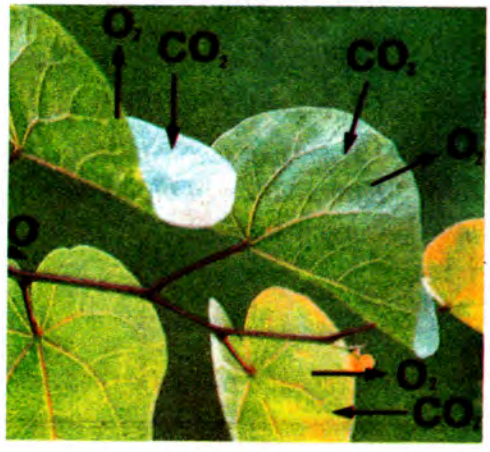

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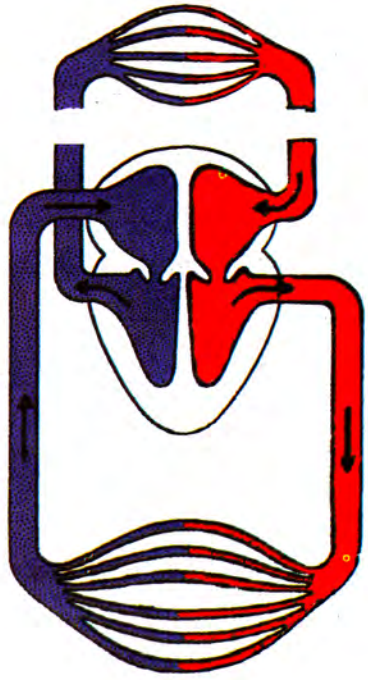

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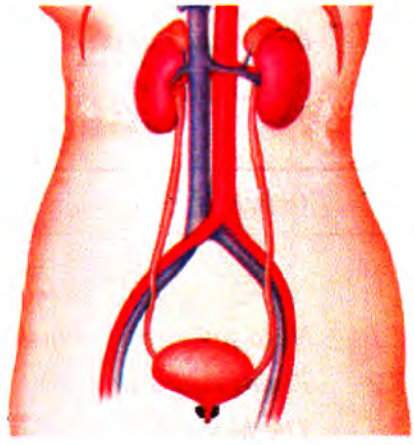

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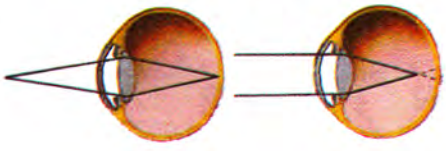

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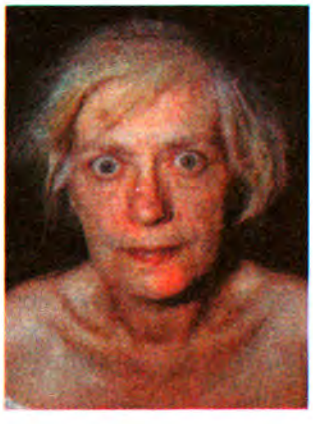

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1 Cell – The Structural and Functional Unit of Life [For Revision Only]

All organisms, including ourselves, are made of microscopic cells. These cells perform activities which contribute to the overall tasks of an individual. It is also to note that every organism starts its life as a single cell. The same cell undergoes repeated divisions to give rise to a large mass of cells. Further, the cells get specialised for various tasks such as those of giving support, producing digestive enzymes and carrying out photosynthesis.

1.1 CELLS – A BASIC STUDY IN BIOLOGY

You have already read about cells in some detail in Class IX. However, it is necessary to refresh your knowledge for a proper understanding of several aspects of biology which specially constitute the Class X syllabus. Some of the main points about cells are as follows :

- All living beings are made up of cells.
- The cell is the structural and functional unit of the body.
- All living beings develop from a pre-existing cell.

1.2 CELLS – HOW NUMEROUS?

Larger an organism, greater the number of cells in its body.

Single-celled : Many small organisms are made up of just one single cell.

Examples : Bacteria, yeast and amoeba.

Few-celled : Some very small organisms are made up of just a few hundred or a few thousand cells.

Examples : Spirogyra, Volvox.

Multi-celled : Most plants and animals we see around are made up of millions and billions of cells.

Examples : Humans, mango.

1.3 CELLS — HOW SMALL?

Cells are very small and can be seen only with a microscope.

- **Smallest** cells are certain bacteria, red blood cells in the human body, etc.
- **Longest** cells are the nerve cells.
- **Largest** cells are the birds' eggs (actually the central yellow sphere). Ostrich egg, before development begins in it, is the largest single cell of the living world today. The white (albumen) of the egg and the egg-shell are extra parts added on the actual egg as it passes down the reproductive tract.

An average-sized adult human constitutes approximately:

- **1000 million million cells in the whole body.**
- **10,000 million nerve cells in the brain cortex.**
- **25 million million red blood cells.**
- **30 thousand million white blood cells.**

1.4 CELL SHAPES

Different shapes of cells are often related to the different functions they perform.

- Human red blood cells are **circular** and **biconcave**, for easy passage through blood capillaries and to transport oxygen.
- White blood cells are **amoeboid** (amoeba-like movement, with pseudopodia) that can squeeze out through capillary walls.
- Nerve cells are **long** to conduct "impulse" from distant parts of the body to the brain and vice-versa.
- Guard cells of stomatal pore in the leaves are **bean-shaped** to open and close it.

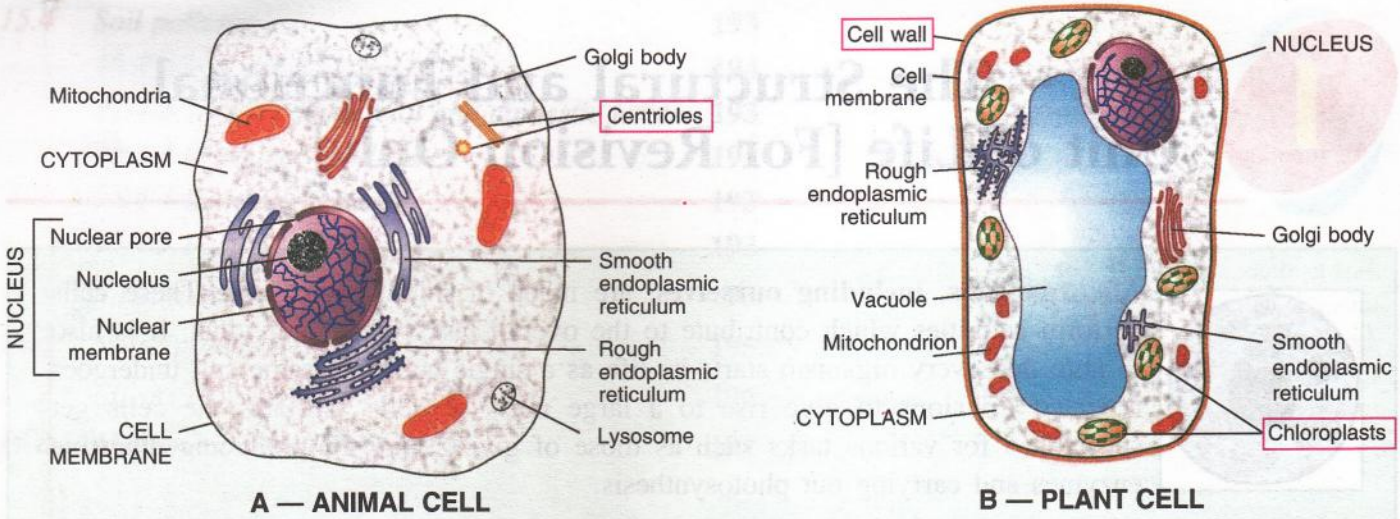


Fig. 1.1 : A generalised animal cell and a generalised plant cell. (Note the parts common to both cells and the parts which are found exclusively in an animal cell or in a plant cell)

1.5 GROSS STRUCTURE OF CELL – THE THREE ESSENTIAL PARTS

1. **Cell membrane** (or **plasma membrane**) encircles the cell.
   - It is a living membrane having fine pores.
   - It is *semi-permeable* (also called selectively permeable or differentially permeable) meaning that it allows only certain substances to pass through while preventing others.

   In the plant cell (Fig. 1.1 B), an additional outermost non-living layer called the **cell wall**, surrounds the cell membrane.
   - The cell wall is mostly made up of **cellulose**.
   - It gives **shape** and **rigidity** to the cell.
   - It is **freely permeable** (allowing substances in solution to enter and leave the cell without hindrance).

2. **Cytoplasm** is the part of the cell inside the cell membrane and outside the nucleus.
   - It is a semiliquid substance.
   - Many chemical reactions catalyzed by enzymes occur in it.
   - It contains several **organelles**, each concerned with some specific function.
   - The part of the cytoplasm other than the organelles (mitochondria, etc.) is called **cytosol,** which constitutes mainly the liquid medium.

3. **Nucleus** is a large somewhat spherical body lying nearly in the centre of the cytoplasm.
   - It is surrounded by a double layered nuclear membrane with nuclear pores (Fig. 1.2).

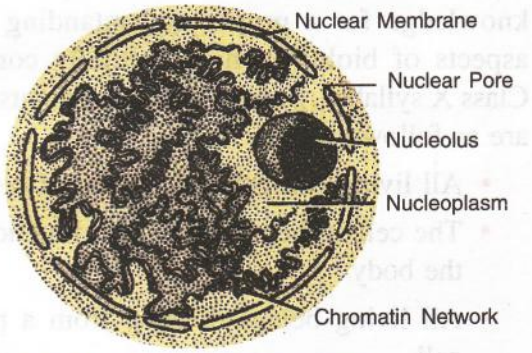


Fig. 1.2 : Structure of nucleus

   - The ground substance of the nucleus is a semi-solid substance (**nucleoplasm**) containing one or more round-shaped **nucleoli** (*sing.* nucleolus).
   - The nucleoplasm contains a network of dark-coloured fibres called **chromatin fibres**. These chromatin fibres condense into short thick **chromosomes** (Fig. 1.3) during cell division.

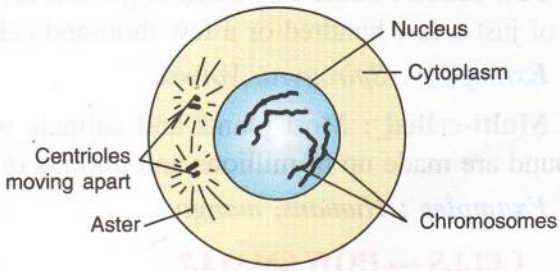


Fig. 1.3 : An early stage of cell division in an animal cell showing two pairs of chromosomes that have condensed from the chromati network, inside the nucleus (diagrammatic). Chromosome number varies from one organism to another.

1.6 FINER STRUCTURE OF CELL – THE ORGANELLES

Organelles are the specialised *membrane-bound* structures in a cell, concerned with definite functions.

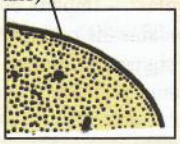
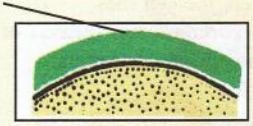
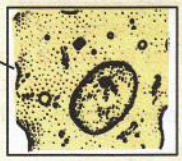
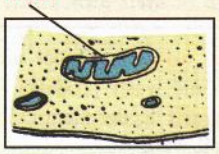
ORGAN and ORGANELLE

Just as there are organs in the body, so are the organelles inside a cell.

Just as each body organ performs one or more special functions, similarly, each organelle has a specific function in a cell.

The living parts of a cell which consist of cytoplasm, nucleus and other living bodies are collectively called **protoplasm** or **protoplast**. The latter term protoplast is more appropriately used for a plant cell after the removal of cell wall. The **living bodies** called organelles are the same in both plant and animal cells except cell wall in plants and centrosome with centrioles in animals. The various organelles are : Nucleus, nucleolus, mitochondria, endoplasmic reticulum, ribosomes, Golgi bodies, lysosomes, chloroplasts, vacuoles, cell membrane.

Table 1.1 Parts of cell and their main characteristics and chief functions

Part of cell	Main characteristics	Chief function(s)
1. **Cell membrane** (also called plasma membrane) 	1. Outermost in animal cells. 2. Lies next to cell wall in plant cells. 3. Very thin, flexible, **living membrane**. 4. Possesses **fine pores**. 5. **Semi-permeable.** 6. Made up of lipoproteins.	1. Separates contents of cell from its surroundings 2. **Regulates the entry** of certain solutes and ions. 3. Maintains shape of the cell (in animal cells).
2. **Cell wall** (Plant cells only) 	1. **Non-living** rigid layer surrounding plasma membrane 2. Mainly composed of **cellulose**. 3. **Freely permeable.**	1. **Gives rigidity and shape** to the plant cell. 2. Allows substances in solution to enter and leave the cell without hindrance. 3. Provides protection.
3. **Cytoplasm** 	1. All the parts together inside the plasma membrane excluding nucleus. 2. Contains a mixture of water and soluble inorganic and organic compounds, and various organelles.	1. Different organelles contained in it perform different functions. 2. All metabolic activities occur in it. 3. Medium of earlier steps of respiration (production of pyruvic acid) (*anaerobic* respiration).
4. **Endoplasmic reticulum** (ER)	1. Irregular network of tubular double membrane. 2. It is continuous with the plasma membrane on the outside and the nuclear membrane on the inside. 3. May be smooth or rough (attached ribosomes).	1. **Supportive framework** for the cell. 2. **Synthesis and transport** of proteins and fat.
5. **Mitochondria** 	1. Various shapes but usually sausage-like. 2. Double walled; inner wall thrown into folds **(cristae)**. 3. Have their own DNA (containing several genes) 4. Also, contain their own ribosomes	1. **Release of energy** from pyruvic acid produced in cytoplasm in the form of ATP. (Seat of cellular aerobic respiration & stores energy). 2. Synthesis of respiratory enzymes.
6. **Golgi apparatus** (In animal cells) (called dictyosomes in plant cells)	1. Stacks of **flattened membrane sacs**. 2. Consists of tubules, vesicles and vacuoles.	1. **Synthesis and secretion of enzymes, hormones,** etc. 2. Formation of acrosome of sperm.

(Contd.)

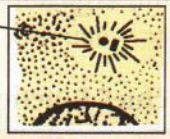
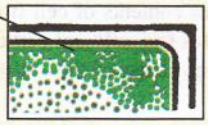
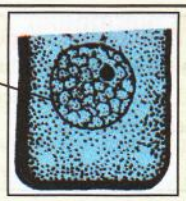
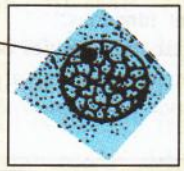
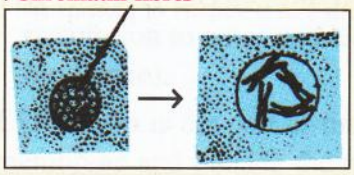
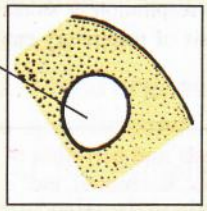
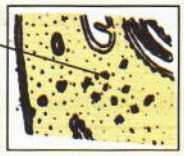
7. **Ribosomes**	1. **Small granules** either scattered in the cytoplasm or attached to the outside of endoplasmic reticulum. 2. **Single walled** dense, spherical bodies composed mainly of RNA.	1. **Protein synthesis.**
8. **Lysosomes**	1. **Membranous sacs** budded off from Golgi body. 2. Contain 40 different types of enzymes.	1. **Intracellular digestion.** 2. **Destroy foreign substances.** 3. When cell is old or injured, these rapidly **destroy organelles** (hence called "suicide bags"). 4. Digest cartilages during formation of bones.
9. **Centrosome** (Animal cells only) 	1. A region surrounding the centrioles, located near nucleus. 2. Contains **one or two centrioles** 3. Centrioles are surrounded by microtubules.	1. **Initiates and regulates cell division.** 2. Forms spindle fibres, with the help of asters.
10. **Plastids** (Plant cells only) 	1. Several kinds, most common ones are **chloroplasts** containing the green pigment chlorophyll. 2. **Double membraned**, proteinaceous matrix, **contain DNA.** 3. Disc-like structures called thylakoids contain **chlorophyll.**	1. **Chloroplast** (green) trap solar energy for photosynthesis, contans the pigment chlorophyll. 2. **Leucoplast** – stores starch. 3. **Chromoplast** – imparts colour to flowers and fruits, contains the pigment Xanthophyll (yellow coloured pigment); Carotene (orange-red pigment). 4. Anthocyanin pigment is dissolved in cytoplasm (blue-violet colour).
11. **Nucleus** 	1. Largest cell organelle. 2. Mostly spherical and dense. 3. Nuclear membrane with pores to allow substances to enter and leave. 4. Contains network of thread-like structures called chromatin fibres which contain DNA.	1. **Regulates cell functions.** 2. If removed, the cell dies. 3. **Contains chromosomes** (bearers of genes that control hereditary characters).
12. **Nucleolus** 	1. One or more round-shaped nucleoli inside the nucleus.	1. Produces ribosomes 2. **Participates in protein synthesis by forming and storing RNA.** 3. Dictates ribosomes to synthesise proteins.
13. **Chromatin fibres** 	1. The network in resting stage of the nucleus condenses into chromosomes during cell division. 2. Made up of **DNA threads.**	1. Chromosomes carry **hereditary information** or the genes.
The next two parts, i.e. vacuoles and granules, are non-living. These are important in their own way.		
14. **Vacuoles** 	1. Clear spaces with water or other substances in solution. 2. Plant cells have larger vacuoles, while the animal cells have fewer and smaller ones. 3. Covered by a covering called **tonoplast.**	1. **Storage of water** and other substances, food, pigments, and waste products. 2. Give **turgidity** to the plant cells by pressing against cell wall.
15. **Granules** 	1. Small particles, crystals or droplets.	1. Starch (in plant cells), glycogen (in animal cells) and fat-containing granules serve as **food for the cell.**

Table 1.2 Differences between Plant and Animal Cells

FEATURE	PLANT CELLS	ANIMAL CELLS
1. Cell wall	A definite *cell wall*, made up of cellulose.	1. No cell wall
2. Centrosome	Absent.	2. Present.
3. Vacuoles	Prominent, one or more.	3. Vacuoles, if any, are small and temporary; concerned with excretion or secretion.
4. Plastids	Usually present.	4. No plastids.
5. Size	Usually larger.	5. Usually smaller.
6. Cytoplasm	Cytoplasm not so dense.	6. Cytoplasm denser and more granular.
7. Arrangment of cytoplasm	Only a thin lining of cytoplasm, mostly pushed to the periphery.	7. Cytoplasm fills almost the entire cell.

1.7 MICROSCOPIC EXAMINATION OF ONION PEEL

Epidermal cells of onion

The epidermal peel from onion is easy to prepare. You can proceed as follows :

Cut the onion bulb into four pieces (quarters) lengthwise (Fig. 1.4).

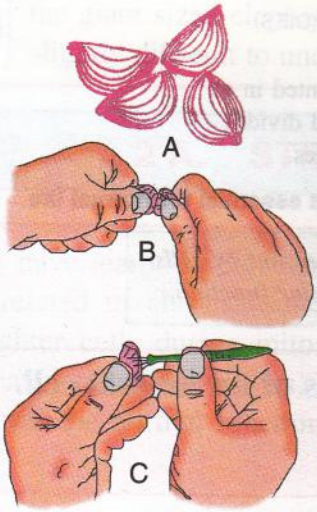


Fig. 1.4 : Preparation of an onion peel

From one of these quarters, remove one thick scale leaf. Take the fleshy scale of onion in your hand and tear it from the inner (concave) side so as to get a thin transparent strip (Fig. 1.4B). Using a pair of forceps, remove this strip (peel) (Fig. 1.4 C) and put it in a watch glass containing water. Cut a square piece of this peel (about 5 × 5 mm) and mount it on a slide in a drop of water as shown in Fig. 1.5. Cover the peel with a coverslip carefully so that the tissue does not get wrinkled. Examine the preparation under a low power microscope. You may as well stain the material with ***iodine*** or ***eosin*** solution, which will ***make the nucleus***

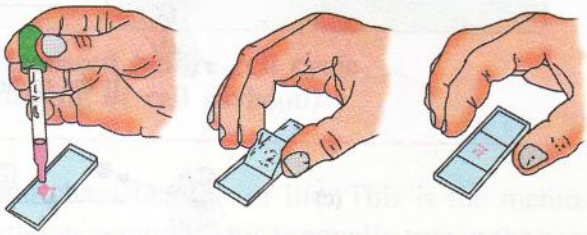


Fig. 1.5 : Preparation of a slide of onion peel

more distinct. More details of the cell structure will be seen under a high power microscope.

The cells of onion peel have a somewhat regular shape, linear or rectangular (Fig. 1.6). Each cell has a prominent cell wall, a nucleus and the cytoplasm encircling one or two large vacuoles. The details are better seen in high power, especially the thick cell wall. Note that the cells are

- firmly bound together and
- the nucleus is placed towards one side, which is usually the case in almost all plant cells.

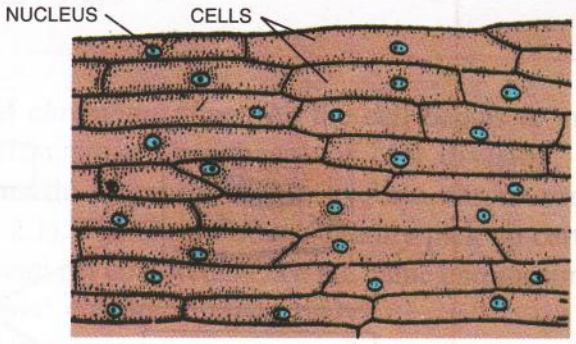


Fig. 1.6 : Cells from a peeling of onion scale leaf as seen under the low power of microscope

1.8 THE NUCLEUS — KEY TO THE LIFE OF A CELL

Although every part of a cell contributes to the life of the cell as a whole, yet the key performer or the

master of each cell is the nucleus. This can be easily understood by an experiment performed on Amoeba, a single cell organism (Fig. 1.7).

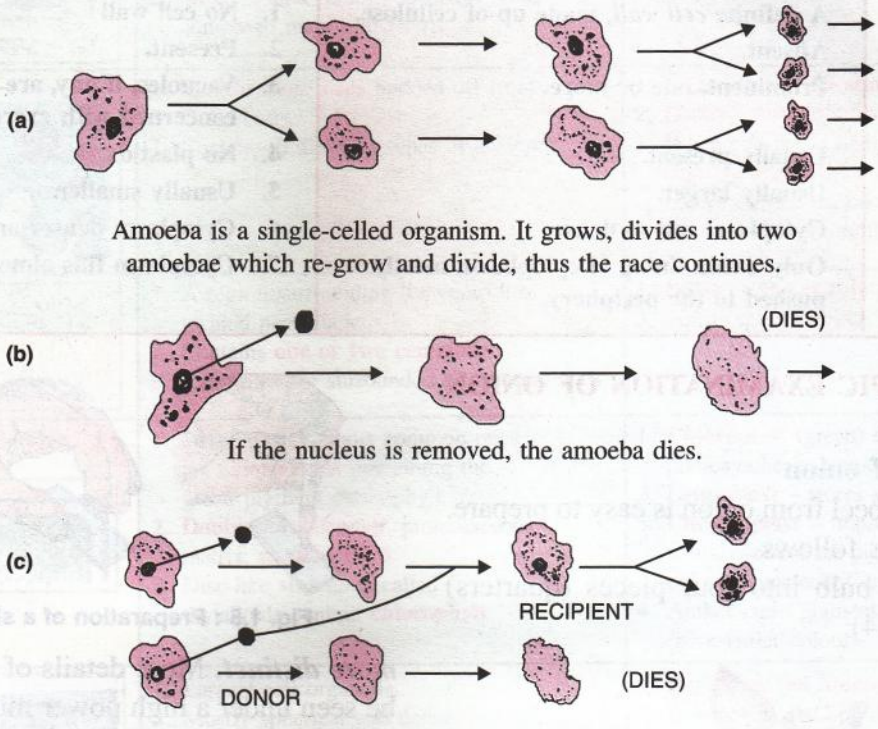
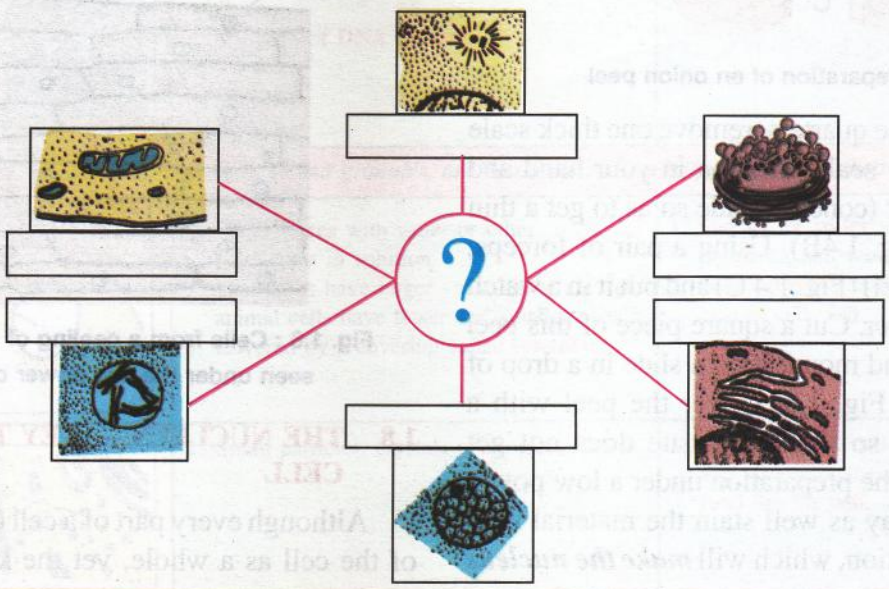


Fig. 1.7 : An experiment on amoeba to show that nucleus is essential for normal life

Every activity of the body of an organism is carried out by cells. But each kind of cell is specialized for a particular function.

Shown below are some of the cell organelles of an animal cell.

Can you identify these ?



2 Structure of Chromosomes, Cell Cycle and Cell Division

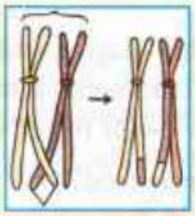
Syllabus : *Cell Cycle and Cell Division. Structure of chromosome.*

Scope of Syllabus : Cell cycle — Interphase (G_1, S, G_2) and M phase

Cell Division : Mitosis and its stages. A basic understanding of Meiosis as a reduction division (stages not required). Significance and major differences between mitotic and meiotic division.

Basic structure of chromosome with elementary understanding of terms such as chromatin, chromatid, gene structure of DNA and centromere.

(Structure of chromosomes has been discussed before cell cycle and cell division for better understanding of cell division)



Cell division is one of the most fundamental characteristics of life. This is the method which enables life to perpetuate generation after generation. This is equally true in the case of the simplest organisms like amoeba as is in the highly complex ones such as ourselves, the giant sized elephants or the tall coconut tree. Some of the details of cell division are slightly difficult to understand, but we have tried to make it as simple as possible. .

2 A. STRUCTURE OF CHROMOSOMES

You have learnt earlier that the most conspicuous events occurring during cell divisions are all related to chromosomes. The duplicated chromosomes get evenly distributed into the daughter cells during mitosis. Thus, all body cells that are the result of a long chain of repeated mitotic divisions, have the same type of chromosomes in the same number. This ensures the normal functioning of the cells and through that, the life of the organism.

2.1 WHAT ARE CHROMOSOMES?

When a normal unstained living cell is observed under a light microscope, its nucleus may not appear to contain any particular thing inside. But when the same cell is stained with suitable dyes, several structures become noticeable in the nucleus. In all probability, you may be looking at a non-dividing stage (interphase) of the cell, although depending upon the part of the body from where the cell has been taken, it may as well show some division stages too.

In the interphase, the nucleus shows a network of very long extremely thin dark-staining fibres called *chromatin fibres*. As the cell begins to enter the first stage (prophase) of cell division, the **chromatin fibres condense** to form chromosomes (Fig. 2.1). The chromosomes readily pick up certain dyes and get coloured, hence the name chromosomes (*chroma:* coloured, *soma* : body).

Chromosomes are the highly condensed coiled chromatin fibres.

2.2 DISCOVERY OF CHROMOSOMES

Chromosomes were first discovered in 1882 by a German Scientist, Walther Fleming. He noticed these in the rapidly dividing cells of the larvae of

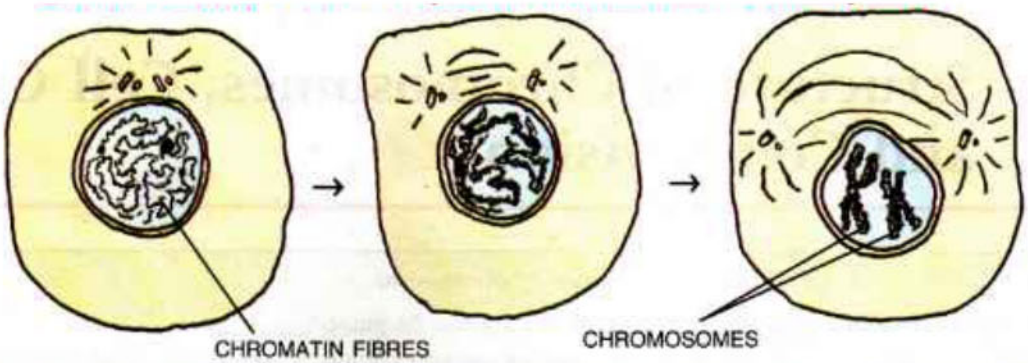


Fig. 2.1 : Condensation of chromatin fibres into chromosomes during mitotic prophase

salamander (an amphibian). The microscope he used was of old type and through it, he saw minute threads that appeared to be dividing lengthwise. Fleming called their division *mitosis* (literally meaning "thread"). Subsequently, with the help of more powerful microscopes and by using special techniques, the chromosomes and their constituents have been studied in great detail.

2.3 STRUCTURE OF CHROMOSOMES

Each chromosome in its condensed form as visible during the start of cell division, consists of two chromatids joined at some point along the length. This point of attachment is called **centromere**, and it appears as a small constricted region (Fig. 2.2). The centromere also serves to attach to the spindle fibre during cell division. Each chromosome's centromere is located at a particular site. As the spindle fibre contracts, the sister chromatids are separated at the centromere, and each is pulled away from the other towards the two poles of the dividing cell (see Fig. 2.9, stages D & E, page 13).

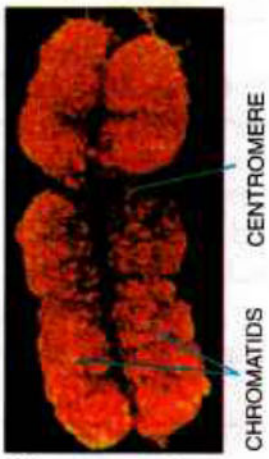


Fig. 2.2 : A human chromosome showing the chromatids and the centromere (constricted part)

After the completion of cell division, the chromatids (now called chromosomes) decondense and revert to their very long and fine thread-like chromatin fibres. There would be as many chromatin fibres inside the nucleus as the number of chromosomes that appear during cell division.

Chromatin : The chromatin material that constitutes the fibre is formed of two substances :

1. **DNA** (deoxyribonucleic acid) — about 40%.
2. **Histones** (a particular type of proteins) — about 60%.

Figure 2.3 given below is a highly diagrammatic representation of the structure of chromatin fibres showing the sequentially enlarged view of the DNA strand.

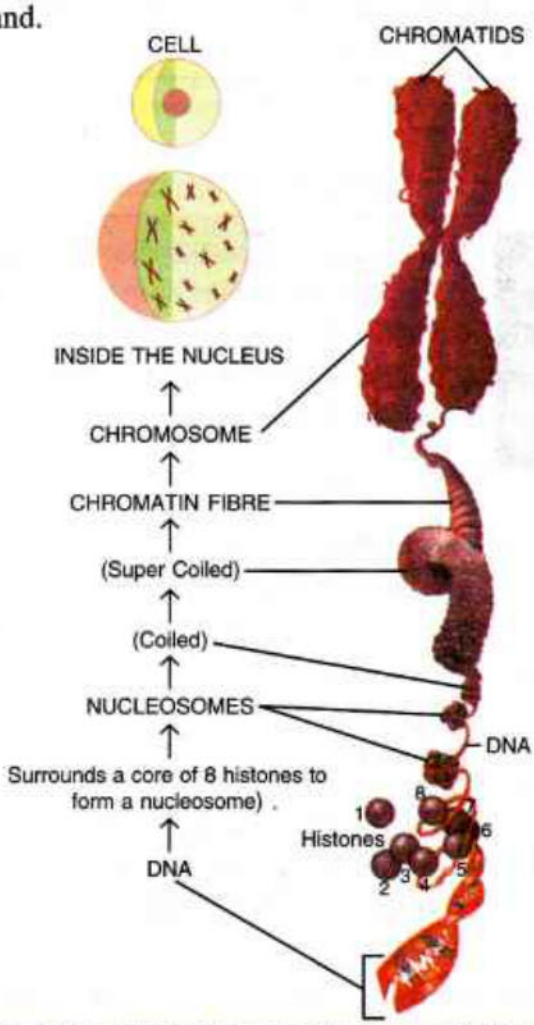


Fig. 2.3 : A highly diagrammatic representation of the structure of a chromosome, the chromatin fibre and DNA

The DNA strand winds around a core of *eight* ***histone*** molecules. This core can be imagined like a football, around which a long rope is wound with one or two loops. Each such complex is called ***nucleosome***.

A single human chromosome may have about a million nucleosomes!

The entire chromatin fibre is coiled and super-coiled something like the coils and supercoils we see in a typical telephone cord (Fig. 2.4).

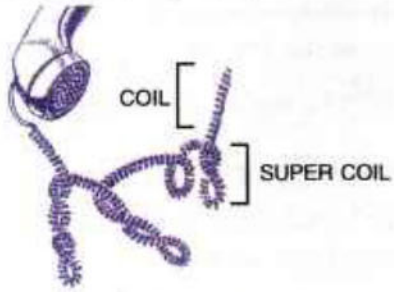


Fig. 2.4 : The concept of coiling and supercoiling as is also found in the chromatin fibre of the chromosomes

Structure of DNA

[The shape of the DNA molecule was studied by Rosalind Franklin in 1953 and the structure was finally worked out by Watson and Crick in the same year.]

The DNA is a very large single molecule, and hence it is described as a **macromolecule**. It is composed of two complementary strands wound around each other in a double helix (Fig. 2.5).

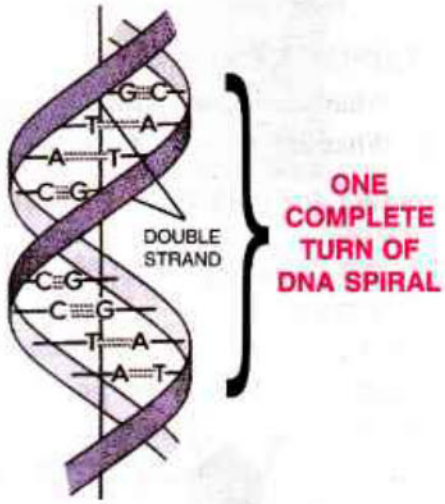


Fig. 2.5 : Schematic diagram of helical structure of DNA

Each single DNA strand is composed of repeating **nucleotides** which are made of three components, ***phosphate***, ***sugar*** (pentose) arranged lengthwise and a **nitrogenous base** attached to the sugar inwards (Fig. 2.6 A) which extends to join (by a hydrogen bond) the complementary **nitrogenous base** from the other strand (Fig. 2.6B). Thus the two strands together make a ladder-like arrangement, with the nitrogenous bases forming the "rungs" of the ladder. The bases are – **Adenine** (A), **Guanine** (G), **Cytosine** (C) and **Thymine** (T). Adenine pairs with Thymine with two hydrogen bonds. Guanine pairs with Cytosine with three hydrogen bonds (Fig. 2.6 reveals the same)

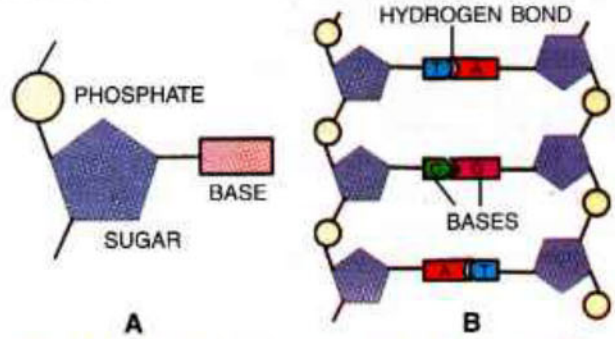


Fig. 2.6 : A – The basic structure of a nucleotide, B – Two parallel strands of a part of DNA

Formation of the new DNA. During the interphase of cell cycle, each DNA molecule (*i.e.* the chromosome) duplicates in readiness for their equitable distribution in the two daughter cells during mitosis. For replication, the DNA double helix opens at one end, making the two strands free to which **new strands begin to form** and the process continues in a sequence for the whole length of the DNA (Fig. 2.7). The entire replication is a

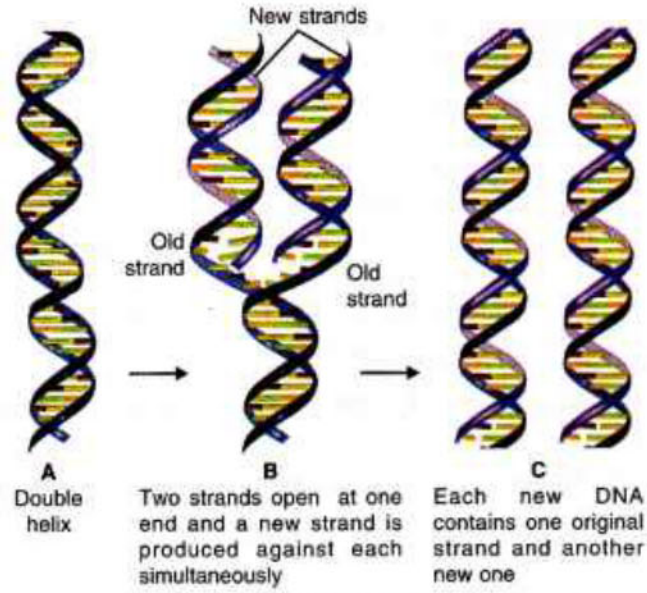


Fig. 2.7 : Replication of DNA

very complicated process which you will study in detail in higher classes.

2.4 WHAT ARE GENES ?

***Genes* are specific sequences of nucleotides on a chromosome, that encode particular proteins which express in the form of some particular feature of the body.**

EXTRA **DNA FINGERPRINTING** **Not in syllabus**

Lots of regions in between genes are just non-functional. Such areas (about 99 percent of the total DNA) show tremendous variations from person to person and help in identification of the individual by what is popularly known as **DNA fingerprinting** but better called **DNA profiling**. DNA fingerprinting is useful in establishing paternity and maternity in criminal cases. Blood or semen stains, hair, or items of clothing found at the site of crime provide biological evidence through DNA fingerprinting.

? PROGRESS CHECK

1. Fill in the blanks :
   (i) Chromatin fibre is made up of DNA and .....
   (ii) The chromatids are attached to each other at .....
   (iii) DNA replicates in the ..... of the cell cycle.
   (iv) Who first discovered the structure of DNA ?
   .....
   .....

REVIEW QUESTIONS

A. MULTIPLE CHOICE TYPE

(Choose the best option out of the four alternatives a, b, c and d)

1. The chromatin material is formed of
   (a) DNA only (b) DNA and Histones
   (c) Histones only (d) Nucleotides
2. The term "chromosomes" literally means
   (a) Inherited bodies (b) Twisted threads
   (c) Coloured bodies (d) Shining threads

B. VERY SHORT ANSWER TYPE

1. **Name** the following :
   (a) The repeating components of each DNA strand lengthwise.
   (b) The complex structure consisting of DNA strand and a core of histones.
   (c) The type of bond which joins the complementary nitrogenous bases.
   (d) The three components of a nucleotide.

C. SHORT ANSWER TYPE

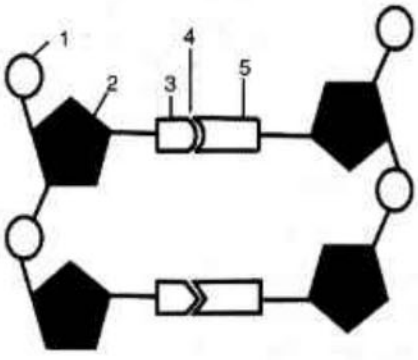
1. **What** is the difference between chromatin fibre and chromosome ?
2. **What** are the rungs of the "DNA ladder" made of?
3. Correct the following statements if there is any mistake.
   (a) The four nitrogenous bases in the DNA are Guanine, Thiamine, Adrenaline and Cytosine.
   (b) Genes are specific sequences of bases on a chromosome.
   (c) A nucleotide is composed of a sulphate, a sugar (pentose) and a nitrogenous base.
   (d) Nucleosomes are groups of cysteine molecules surrounded by DNA strands.
   (e) If there are 46 chromosomes in a cell, there will be 23 chromatin fibres inside the nucleus during interphase.

D. LONG ANSWER TYPE

1. **What** are nucleosomes ?
2. **What** are genes ?

E. STRUCTURED/APPLICATION/SKILL TYPE

1. Given below is a schematic diagram of a portion of DNA.



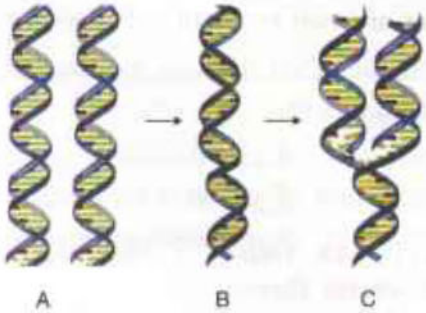
(a) **How many** strands are shown in the diagram?

(b) **How many** nucleotides have been shown in each strand?

(c) **Name** the parts numbered 1, 2, 3, 4 and 5 respectively.

(d) **Name** the DNA unit constituted by the parts 1, 2 and 3 collectively.

2. The three sketches given below (A, B and C) are intended to represent the replication of DNA. **What** should be their correct sequence starting with the first and ending with the last ? .....



2B. CELL DIVISION – NEW CELLS FROM THE EXISTING ONES

2.5 NEW CELLS NEED TO BE PRODUCED

New cells need to be produced for (1) growth, (2) replacement, (3) repair and (4) reproduction.

1. ***For growth :*** Every organism, be it a plant or an animal, begins its life as a single cell (the fertilized egg). This cell divides repeatedly to form a cluster of cells which start shaping for different functions to form tissues and organs. Thus, cell division is essential for ***growth***.

Fig. 2.8 : A 4-day-old human embryo containing 16 cells, resulting from four cell divisions [1 × 2 = 2; 2 × 2 = 4; 4 × 2 = 8; 8 × 2 = 16]. As they multiply, they specialise to form the tissues and organs of the body

2. ***For replacement :*** There is always a wear and tear of cells during the normal body functions. *For example*, 20 million red blood cells in our body are destroyed every minute. These are ***replaced*** by new cells formed through a division of their parent cells in the bone marrow. In plants, the old and dried leaves fall off and new ones grow out.

3. ***For repair :*** Apart from normal wear and tear of the tissues in the body, there may be accidental injuries. One may get cuts in the skin or fractures in the bone. ***Repair*** of such injuries is again through cells which divide, cover up the gaps and join the broken ends.

REMEMBER

In cell divisions for growth, replacement and repair, the number of chromosomes remains the same at each division. The chromosomes duplicate and distribute equally in the daughter cells. This kind of division which occurs in all body cells except in the egg producing oocytes (in ovaries) and sperm producing spermatocytes (in testes), is known as ***mitosis***.

4. ***For reproduction :*** Reproduction is also through the activity of the dividing cells. Amoeba or bacteria just divide to produce two similar independent cells by mitosis. In higher forms, as in humans, or in the banyan tree, special cells in the reproductive organs undergo a special kind of cell division (***meiosis***) to produce sperms and eggs. The sperms and eggs receive only half the number of chromosomes of their parent cells, *i.e.*, one chromosome from each pair. This reduction in chromosome number is very significant.

Look at the following example in humans :

Kind of cells	*Chromosomes*	
	in **MAN**	*in* **WOMAN**
(a) **Body cells**	= 46 (23 pairs) ($2n$)	46 (23 pairs) ($2n$)
(b) **Sex cells** (sperms and eggs) =	23 (single) (n) ↘	23 (single) ↙ (n)
Fertilised egg	(from sperm) 23 + 23 (from egg)	
	New baby = 46 (23 pairs) ($2n$)	

2.6 TYPES OF CELL DIVISION

There are two types of cell division :-

1. ***Mitosis :*** Cell division leading to growth and development.
2. ***Meiosis :*** Cell division leading to the production of gametes (sex cells).

2.6.1 MITOSIS (*mitos* : thread, referring to chromatin thread)

MITOSIS is the cell division in which one parent cell divides into two identical daughter cells.

The most important aspect of mitosis is that **the same normal chromosome number is maintained at each cell division.**

Just before the division of the cell, the nucleus prepares for this change and doubles the quantity of DNA (the chromosome substance). This is the **interphase** (Fig. 2.9), apparently the resting phase, since no change in chromosomes is visible externally, but actually it is quite active in synthesising the DNA.

Phases of mitosis — Karyokinesis

Karyokinesis of mitosis occurs in four main phases although each of these phases merges into the next phase thereby making it a continuous process. The four phases of mitosis are :

(i) **Prophase** (ii) **Metaphase**
(iii) **Anaphase** (iv) **Telophase**

By and large, the four phases of mitosis are similar in both animal and plant cells. However, we are first describing the mitotic stages in an animal cell. Figure 2.2 illustrates these stages in animal and plant cells side by side. Two major differences in the mitosis of plant and animal cells have been listed in Table 2.1.

(i) Prophase (*pro* : first) (Fig 2.9 A & B)

(1) The **chromosomes** have become short and thick and are clearly visible inside the nucleus.

(2) Each chromosome has already duplicated (having made its copy), to form two **chromatids**.

(3) The two sister chromatids remain attached to each other at a small region called **centromere**.

(4) The **centrosome** (in animal cell) splits into two along with **simultaneous duplication of the centrioles** contained in it. The daughter centrioles move apart and occupy opposite "poles" of the cell. Each centriole is surrounded by radiating rays and is termed **aster** (*aster* : star). (The animal cells may have either one or two centrioles).

(5) A number of fibres appear between the two daughter centrioles, which are called the **spindle fibres**.

(6) The **nuclear membrane** and the **nucleolus disappear**.

(7) The duplicated **chromosomes start moving towards the "equator"** of the cell.

[***Note :*** "Poles" mean the extremities of an axis, and "equator" means the middle plane dividing the cell into two similar halves. The naturally occurring cells may be oriented in all possible directions (Figure in Box p. 14)]

(ii) Metaphase (*meta* : after) (Fig. 2.9 C)

The duplicated chromosomes arrange on the equatorial plane. Each chromosome gets attached to a spindle fibre by its centromere.

(iii) Anaphase (*ana* : up, back) (Fig. 2.9 D & E)

The centromere attaching the two chromatids divides and the two sister chromatids of each chromosome separate and are drawn apart towards opposite poles. The drawing action is performed by the contraction of spindle fibres.

(iv) Telophase (*telo* : end) (Fig. 2.9 F)

1. Each chromatid or the daughter chromosome lengthens, becomes thinner and turns into a network of chromatin threads.
2. Nuclear membrane reappears.
3. Nucleolus reappears in each daughter nucleus.

All the contents of the cytoplasm including the mitochondria and also the chloroplasts in plant cell are randomly distributed in the daughter cells during karyokinesis.

Cytokinesis (Division of cytoplasm)

At the end of telophase, a furrow appears in the cell membrane in the middle, which deepens and finally splits the cytoplasm into two, thus producing two new cells (Fig. 2.9).

INTERPHASE (resting phase)

No visible change in chromosomes but active synthesis of DNA

(i) PROPHASE (A and B)

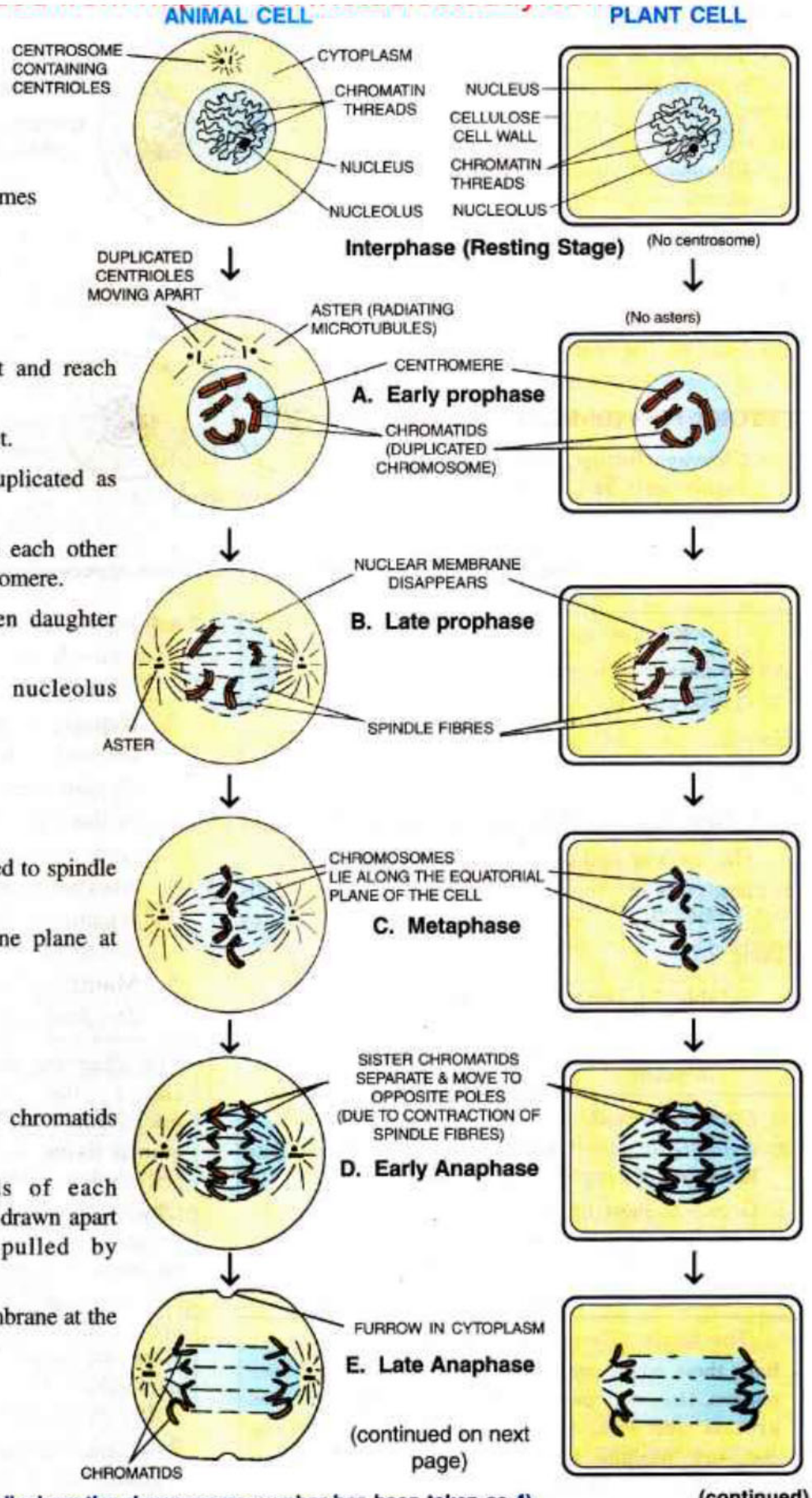
- Centrioles start moving apart and reach opposite poles.
- Chromosomes become distinct.
- Chromosomes are already duplicated as paired chromatids.
- Sister chromatids attached to each other at a small region called centromere.
- Spindle fibres appear between daughter centrioles.
- Nuclear membrane and nucleolus disappear.

(ii) METAPHASE (C)

- Each chromosome gets attached to spindle by its centromere.
- Chromosomes lined up in one plane at equator.

(iii) ANAPHASE (D and E)

- Centromere attaching the two chromatids divides.
- The two sister chromatids of each chromosome separate and are drawn apart towards opposite poles pulled by shortening of spindle fibres.
- A furrow starts in the cell membrane at the middle in animal cell.



(continued on next page)

Fig. 2.9 : Mitosis (in a cell where the chromosome number has been taken as 4)

(continued)

(iv) TELOPHASE (F)

- Two sets of daughter chromosomes reach opposite poles.
- Spindle fibres disappear.
- Chromatids thin out in the form of chromatin fibres.
- Nuclear membrane is formed.
- The cleavage furrow starts deepening in the animal cell.
- Nucleoli reappear.

CYTOKINESIS (Division of cytoplasm)

- Cleavage furrow deepens totally in animal cell and separates the two daughter cells.

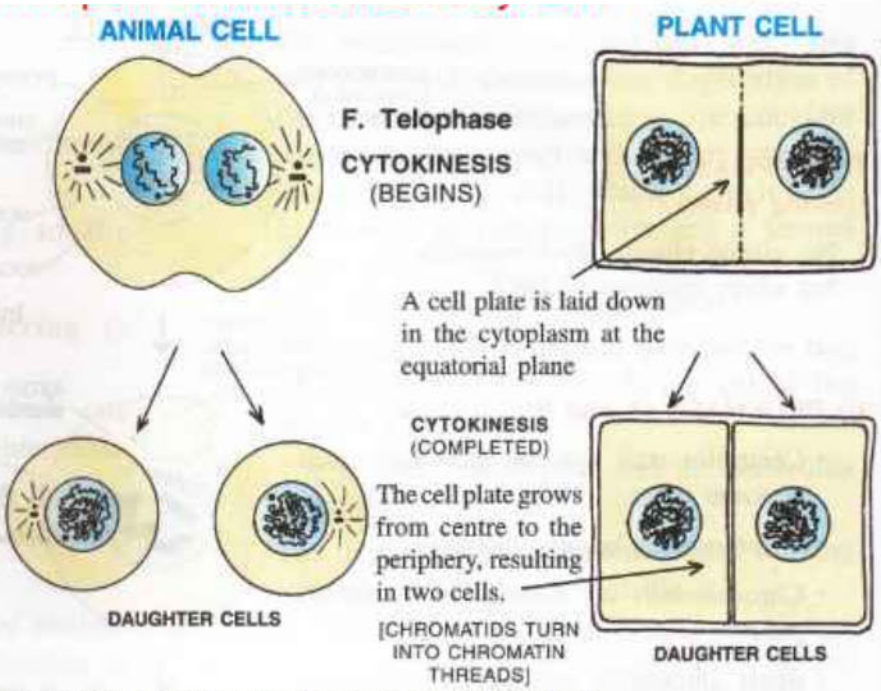


Fig. 2.9 (Continued) : Mitosis (in a cell where chromosome number is 4)

Karyokinesis and Cytokinesis

All the nuclear changes that occur during cell division are collectively termed **karyokinesis** (**karyo** : nucleus)

Karyokinesis is followed by the division of cytoplasm **(cytokinesis)**.

2.6.2 Differences in Mitosis in Animal and Plant cells

The nuclear and chromosomal events of mitosis in plant cells are the same as those in animal cells (Fig. 2.9). But some differences are as follows (Table 2.1) :-

Table 2.1 Differences between mitosis in animal and plant cell

Animals	Plants
1. Asters are formed.	1. Asters are not formed.
2. Cytokinesis **by furrowing** of cytoplasm.	2. Cytokinesis **by cell plate** formation.
3. Occurs in most tissues throughout the body (for growth and replacement.)	3. Occurs mainly at the growing tips (for lengthening) and sides (for increase in girth)

The terms "Parent" and "Daughter" cells !

Both these terms are actually inappropriate for two reasons. One, the "parent" cell loses its identity in the process and two, the "daughter" cells are not necessarily feminine. However, these two expressions are being used conventionally.

2.6.3 Significance of Mitosis

1. **Growth** or increase in the body size due to formation of new cells in the tissues.
2. **Repair** of damaged and wounded tissues by renewal of the lost cells.
3. **Replacement** of the old and dead cells such as the replacement of the blood cells and the epidermal cells of the skin.
4. **Asexual** reproduction in which the unicellular organisms, such as amoeba or the yeast cell, divide into two.
5. Maintains **same chromosome number** in daughter cells.

The diagram alongside shows the sectional microscopic view of an animal tissue undergoing active mitotic cell division. Observe carefully that such naturally occurring cells are oriented in all possible directions, and also they are in different phases. Note the stages of cells numbered 1-6.

1 — Cell in interphase stage

2 — Cell in prophase stage : Advancing condensation of chromatin network into chromosomes.

3 — Cell in metaphase stage : Chromosomes arranged at "equator" (as if seen from the polar end above).

4 — Cell in anaphase stage : Chromosomes start getting pulled to the poles.

5 — Cell in telophase stage : Chromosomes reach the "poles" and nucleus is being formed.

6 — Young cells formed after division.

THE MITOCHONDRIA AND CHLOROPLASTS IN CELL DIVISION

- Both mitochondria and chloroplasts have their **own DNA** (containing certain genes).
- They also contain their own **Ribosomes** which help in producing the particular proteins of these two organelles.
- Both these **divide of their own** by simple fission, just splitting into two and are partitioned between the two daughter cells produced by mitosis.
- Mitochondrial division is also guided by the genes in the nucleus and through the cytoplasmic ribosomes.

HOW OLD ARE SOME OF OUR BODY CELLS ?

- Cells of the **eye lens, nerve cells** of the cerebral cortex and most **muscle cells** last a life time but once dead are not replaced.
- **Skin cells** are replaced every two weeks or so.
- **Red blood cells** last for about 120 days and are replaced.
- **Bone cells** are replaced every 10 years or so in adults.
- **Epithelial cells** lining the gut last only 5 days.
- Average life of **other gut cells** is about 15 years.
- **Liver cells** are replaced every 300–500 days.

2.7 CELL CYCLE — *"Divide, grow and redivide"*

The new cells at the end of mitosis are relatively small, with a full sized nucleus but relatively little cytoplasm. Now, they enter **interphase** during which they prepare for the next cell division and grow to the same size as their mother cell. The interphase itself has *three* phases — (i) **first growth phase,** (ii) **synthesis phase** and (iii) **second growth phase.**

(i) First Growth Phase (G_1) — RNA and proteins are synthesised, the volume of cytoplasm increases. Mitochondria (in all cells) and chloroplasts (in plant cells) divide – these two organelles have their own DNA. In late G_1 phase, all cells must follow one of the two paths. They may *either* withdraw from the cell cycle and enter a resting phase (R) *or* start preparing for the next division by entering the next synthesis phase (S).

(ii) Synthesis Phase (S) – More DNA is synthesised, the chromosomes are duplicated.

(iii) Second Growth Phase (G_2) – This is a shorter growth phase, in which RNA and proteins necessary for cell division continue to be synthesised. Now the cell is ready to start next cell division and thus the cell cycle goes on.

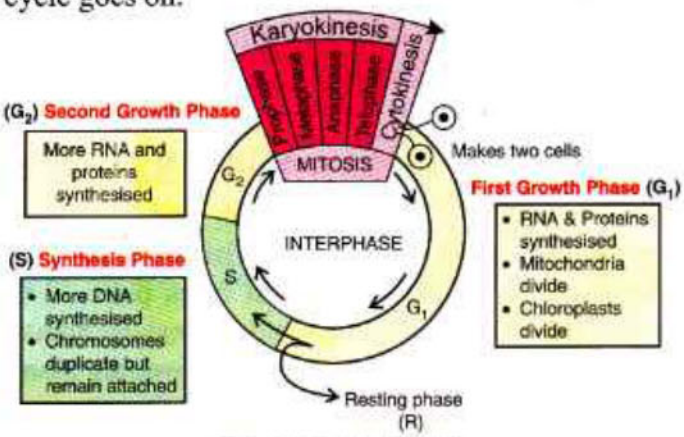


Fig. 2.10 : Cell cycle

Can the cell cycle go on endlessly ?

No. At some places it stops **permanently**, at some places **temporarily** and at others **till it is needed**. There is a regulatory mechanism for cell cycles.

- **Brain** and other **nerve cells**, once formed in the embryo do not divide further. Once dead, they are not replaced.
- **Liver cells** may divide only once every one to two years to replace damaged or destroyed cells.
- **Surface skin** cells are continuously lost and replaced by the underlying cells. A large portion of household dust contains human skin cells. The powdery material that comes off from your skin on scratching or on hard rubbing while bathing contains same dead cells.
- In plants, the cells at the growing points **(meristems)** divide very rapidly and produce new leaves, buds and flowers, etc.

- Specialised **germinal cells** in the ovary and testis in animals and in the ovary and anthers in plants undergo the other type of cell division called meiosis to produce sex cells.
- Uncontrolled non-stop cell cycles may lead to **tumours that may or may not be cancerous.**

Cell production and cell death

- As **children** we grow, because new cells are continously being produced and they outnumber the dying cells.
- When we are **adults**, our cell population stays constant. The number of new cells produced equals the number of cells dying.
- As we grow **old**, the number of new cells produced runs short of those that are dying.

2.8 MEIOSIS (Reduction division producing gametes)

Meiosis is the kind of cell division that produces the sex cells or the gametes. It takes place in the reproductive organs (**testis** and **ovary**) in humans to produce ***sperms*** and ***ova***. In the flowering plants, it takes place in the **anthers** and the **ovary** to produce ***pollen grains*** and ***ovules***.

The most significant aspect of meiosis (*meiosis* : diminution) is that the **number of chromosomes** in the sex cells is halved. *For example*, out of the 23 pairs of chromosomes in humans, only single chromosomes *i.e.* one member of each pair **(haploid)** are passed on to the sex cells. This is essential because when the male and female gametes fuse during fertilisation, the normal double **(diploid)** number of chromosomes (in pairs) is reacquired. The diploid number, as a rule, is expressed as **"2n"** and the haploid number as **"n"**.

Stages in meiosis (Fig. 2.11) [As per scope of syllabus, the **stages of meiosis are not required**]. However, just to know the basic about it, meiosis is completed in two divisions meiosis I and meiosis II, the first is the **reduction division** and the second is **mitotic division** (Fig. 2.11).

EXTRA **NOT IN SYLLABUS**

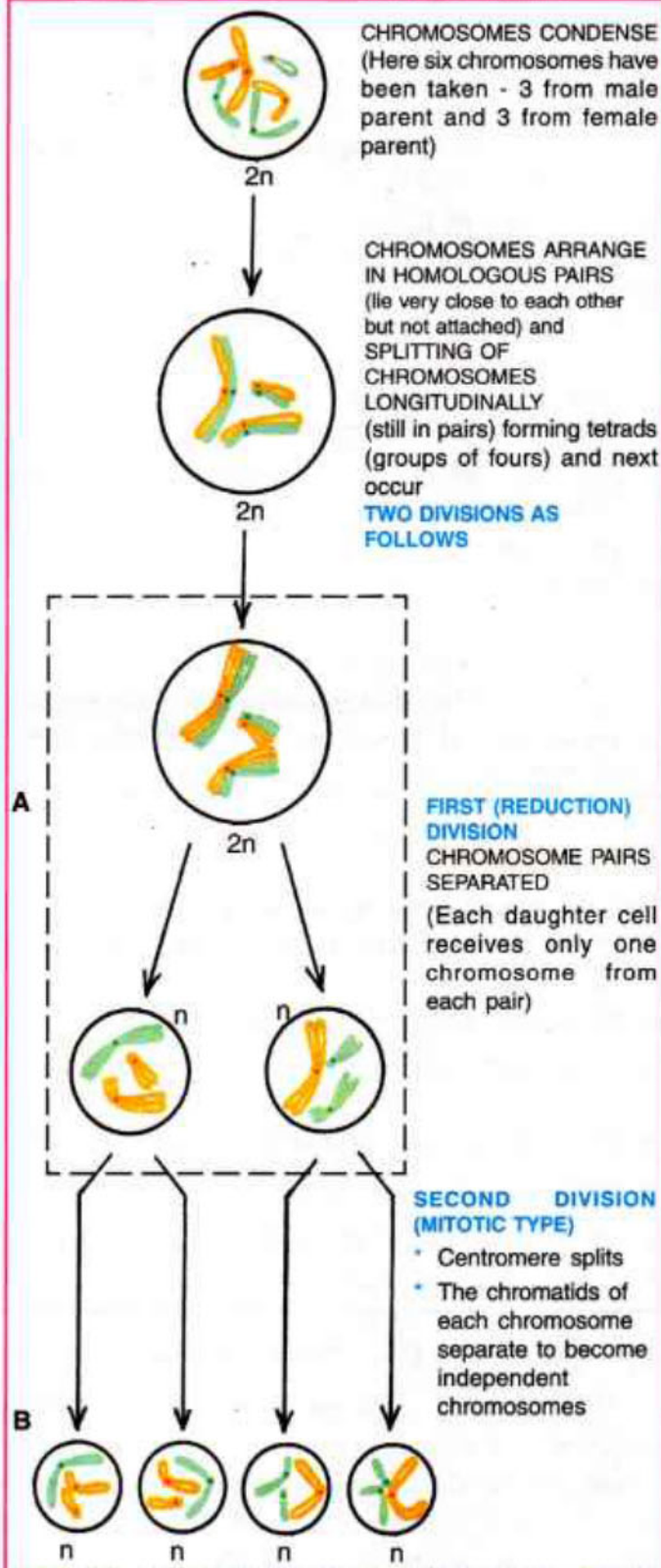


Fig. 2.11 : The behaviour of chromosomes shown during nuclear divisions in meiosis. Chromosome number taken is 6 (=3 pairs). We may imagine that the hollow outlined yellow chromosomes are paternal (having been received from male parent) and the solid green ones maternal (from the female parent).

2.8.1 Significance of Meiosis

1. **Chromosome number is halved** in gametes (sex cells), so that on fertilization, the normal number ($2n$) is restored.
2. It provides for **mixing up of genes** which occurs in two ways :
   (i) **The maternal and paternal chromosomes get mixed up** during the first (reduction) division as they separate from the homologous pairs.
   (ii) **Cross joining.** While the maternal and paternal chromosomes are separating, the chromatid material very often gets exchanged between the two members of a homologous pair (as shown in Fig. 2.12) resulting in genetic recombination.

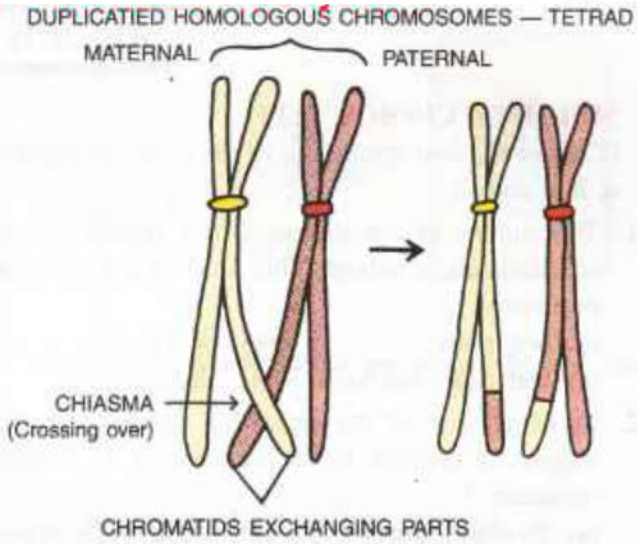


Fig. 2.12 : Crossing over between maternal and paternal chromatids during meiosis to produce a new combination of genes — having split at the chiasma

Both these permutations and combinations provide for the innumerable variations in the progeny. That is how the children of the same parents, howsoever similar, are different from each other in certain respects. The variations often contribute in evolution.

Table 2.2 : Differences between Mitosis and Meiosis

	Mitosis	Meiosis
1. *Where it occurs*	in the **somatic** (body) **cells**.	in **reproductive cells**.
2. *What for*	to provide **for growth and replacement**.	only **for gamete formation**.
3. *When it occurs*	continuously **throughout life**.	only in **reproductively active age**.
4. *Number of daughter cells produced*	**two daughter cells**.	**four daughter cells**.
5. *Number of chromosomes passed on to each daughter cell*	**full set of chromosomes** is passed on to each daughter cell. This is the **diploid** (2n) number of chromosomes.	Only **half the number of chromosomes** is (Only one member from each pair). This is the **haploid** (n) number of chromosomes.
6. *Number of nuclear divisions*	**a single nuclear division** after chromosome duplication.	**two nuclear divisions** after chromosome duplication.
7. *Identity of chromosomes and genes in daughter cell*	**identical**.	**randomly assorted** between the gametes produced. This results in genetic variations.

EXTRA **STEM CELLS** **Not in syllabus**

[Stem cells mean undifferentiated cells which can undergo unlimited divisions and give rise to one or several different types of cells.]

The term **"stem cells"** is very much in the news these days, and specially so in connection with the treatment of certain human diseases. The term **"stem"** though more familiar with respect to plants, has a wider sense meaning **"branch off"**. The plant stem bears unspecialised cells that can differentiate into leaves, flowers, fruits, seeds, *etc.*

In animals, there are embryonic cells which differentiate into different tissues and organs. Embryonic stem cells take different development directions. *For example*, some become nerve stem cells, some become specialised to produce blood cells and so on. These tissue specific stem cells persist throughout life even in adults.

REVIEW QUESTIONS

A. MULTIPLE CHOICE TYPE

(Choose the best option out of the four alternatives a, b, c and d)

1. The number of chromosomes in a certain type of cell division is halved. This kind of cell division occurs in
   (a) only testis (b) only ovary
   (c) both ovary and testis (d) all body cells
2. In which one of the following options the two stages of mitosis have been given in correct sequence ?
   (a) Prophase, anaphase (b) Metaphase, telophase
   (c) Anaphase, telophase (d) Telophase, anaphase
3. Synthesis phase in the cell cycle is called so for the synthesis of more of
   (a) RNA (b) RNA and proteins
   (c) DNA (d) Glucose

B. VERY SHORT ANSWER TYPE

1. Imagine one cell (A) has undergone one mitotic division and another cell (B) has completed its meiotic division. How many cells would the two produce?
   Cell A : .....
   Cell B : .....
2. **Match** the events given in column A with the phase in mitotic cell division in Column B

Column 'A'	Column 'B'
(a) Chromosomes get arranged in a horizontal plane at the equator.	Anaphase
(b) Daughter chromosomes move to the opposite poles of a spindlle.	Prophase
(c) Chromosomes become visible as fine long threads.	Telophase
(d) Chromosomes lose their distinctiveness and gradually become transformed into a chromatin network.	Metaphase

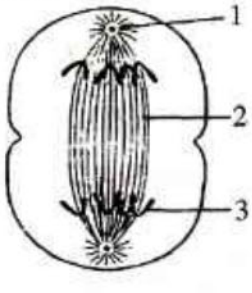
3. Fill in the blanks
   (a) Mitosis occurs in our ..... cells.
   (b) Mitosis produces two daughter cells whereas meiosis produces ..... daughter cells.
   (c) Meiosis occurs only in ..... cells.
   (d) Modern humans have 46 chromosomes. Their sperms and eggs will have ..... chromosomes each.
   (e) During the pairing of chromosomes in meiosis, the ..... chromosomes come to lie side by side.
   (f) The ..... (s) are surrounded by radiating rays and termed as aster.

C. SHORT ANSWER TYPE

1. **State** the difference between :
   (a) Chromosome and chromatid,
   (b) Centrosome and centromere,
   (c) Aster and spindle fibres.
   (d) Haploid and diploid
2. "First meiotic division is the reduction division". **What** does the word 'reduction' refer to in this statement?
3. "Gametes must be produced by meiosis for sexual reproduction". **Why** is it so?
4. Mention whether the following statements are ***true*** **(T)** or ***false*** **(F)**. Give reason in support of your answer.
   (a) As you grow from childhood to adulthood, your skin cells divide only to replace such cells that are lost from the surface. (T/F)
   (b) The unfertilised human egg has half the number of chromosomes of the body cells. (T/F)
   (c) Nuclear membrane in a mitotically dividing cell remains intact up to the metaphase and disappears only in the telophase. (T/F)
   (d) Mitotic cell division can be a mode of reproduction. (T/F)
   (e) Crossing-over between chromatids can occur only between homologous chromosomes. (T/F)

D. STRUCTURED/APPLICATION/SKILL TYPE

1. The diagram below represents a stage during cell division. Study the same and then answer the questions that follow:



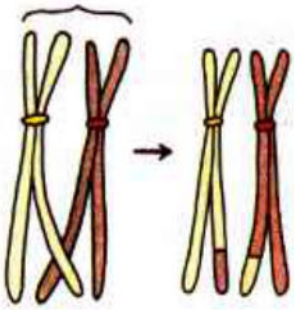
   (a) **Name** the parts labelled 1, 2 and 3.
   (b) **Identify** the above stage and give a reason to support your answer.

(c) **Mention** where in the body this type of cell division occurs.

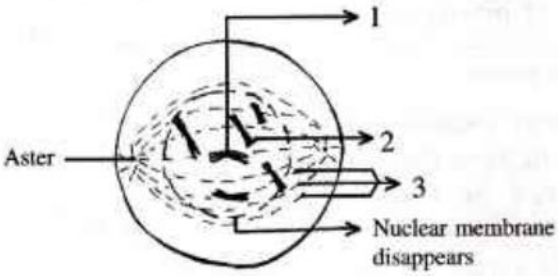
(d) **Name** the stage prior to this stage and draw a diagram to represent the same.

2. **Draw** a labelled diagram to show the metaphase stage of mitosis in an animal cell having '6' chromosomes.

3. The diagram given below represents a certain phenomenon which occurs during meiosis. **Name** and **explain** the phenomenon by using the terms — **homologous chromosomes, chromatids, crossing-over**.



4. Given below is a diagram representing a stage during mitotic cell division in an animal cell. **Examine** it carefully and **answer** the questions which follow.



(a) **Identify** the stage. Give one reason in support of your answer.

(b) **Name** the cell organelle that forms the 'aster'.

(c) **Name** the parts labelled 1, 2 and 3.

(d) **Name** the stage that follows the one shown here. How is that stage identified?

(e) **Mention** two differences between mitosis and meiosis with regard to :

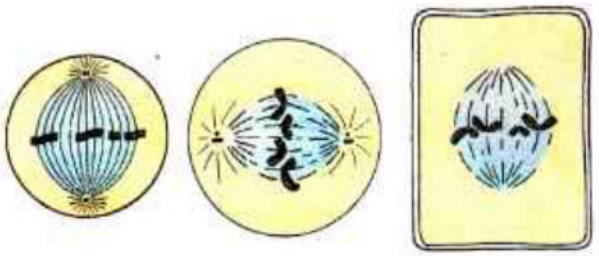
(i) The number of daughter cells produced.

(ii) The chromosome number in the daughter cells.

5. Given ahead are three diagrammatic sketches (A, B and C) of one and the same particular phase during **mitotic type of cell division.**

(a) Identify the phase .....

(b) What is the diploid number of chromosomes shown in them ? .....



A B C

(c) Identify whether these are animal cells or plant cells ?

A .....,

B .....,

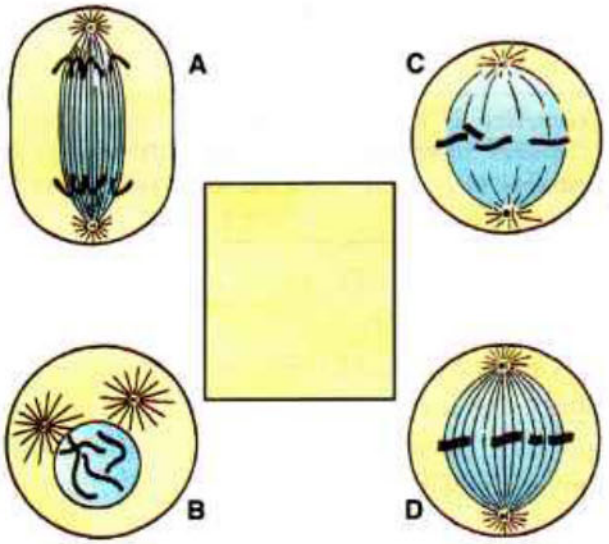
C .....,

(d) Which of these is/are shown in correct direction ? (Tick mark the correct answer).

(i) Only A (ii) Only B

(iii) Only A and C (iv) All the three

6. Shown below are four stages (A, B, C, D) (not in sequence) of a certain kind of cell division.



(a) **Is it** a plant cell or an animal cell? Give two reasons. .....

(b) **Is it** undergoing mitosis or meiosis?

.....

(c) **What** should be the correct sequence of these four stages among themselves?

.....

(d) **Name** the stage that should precede the earliest of these stages.....

(e) **Draw** the stage named above inside the blank space provided.

3 Genetics — Some Basic Fundamentals

Syllabus : *Genetics : Mendel's laws of inheritance and sex-linked inheritance of diseases.*

Scope of Syllabus : Monohybrid cross, dihybrid cross. The following terms to be covered : gene, allele, heterozygous, homozygous, dominant, recessive, mutation, variation, phenotype, genotype. Sex determination in human beings.

Sex-linked inheritance of diseases to include haemophilia and colour blindness (only criss cross inheritance).

Whenever a child is born the family members usually start comparing his appearance as to whom he/she resembles more. All this, although a matter of chance, is governed by certain laws. This chapter presents some fundamentals of Genetics including Mendel's laws of inheritance as envisaged in the syllabus. In order to properly understand Mendel's laws of inheritance (page 29) and the sex-linked inheritance (page 26), it is essential to know beforehand, some basic aspects of genetics. You will learn about the chromosomes, the genes and some very common hereditary traits in humans. You can do several investigatory projects, if desired.

3.1 WHAT IS GENETICS ?

Genetics is the study of transmission of body features (both similarities and differences) from parents to offspring and the laws relating to such transmission.

GREGOR MENDEL — An Austrian Monk and Father of Genetics

Gregor Mendel (1822 – 84) was born in a peasant family. He had his early education in a monastery and later he studied Science and Mathematics at University of Vienna. *He wanted to be a teacher but luck did not favour him, and he failed in the examination of teaching certificate. But what he discovered later as a craze, has made him a* ***"teacher of teachers"***. He had returned to his monastery and spent the rest of his life as an abbot. The monastery had a lovely garden which satisfied his urge to understand some secrets of life regarding the inheritance of certain features in garden pea. His findings are now called Mendel's laws of inheritance.

Mendel — "Father of Genetics"

Two modern applications of genetics

Genetic engineering is the technique in which the ***genetic constitution of an organism*** (bacterium) ***is altered by introducing new genes into its chromosomes***. The genetically modified organism (GMO) thus produced is grown to multiply fast and the gene product is obtained in large quantities. The hormone ***insulin*** was the first such product. The insulin producing gene of mammals has been successfully introduced in certain bacteria which have been made to produce it.

Genetic counselling is yet another practical aspect. Newly married couples are advised to consult a specialist regarding the possibilities of any undesirable trait which their children might inherit. Diseases like ***haemophilia*** (bleeder's disease with a tendency to bleed freely from even a slight wound), ***thalassaemia*** and ***sickle cell anaemia*** with defective haemoglobin are examples of genetic diseases which can be prevented to some extent by proper genetic matching of the prospective parents.

Heredity

The term heredity may be defined as "transmission of genetically based characteristics from parents to offspring."

The term heredity is rather old. For centuries, man has known that many characteristics are inherited in animals (domesticated ones) as well as in humans, and that he could breed varieties of animals and plants with desirable qualities.

Like begets like
It means that young ones look like their parents

- Cats produce cats and not dogs.
- A mango seed germinates into a mango tree.
- Humans give birth only to humans and not to apes.
- Even the curd bacteria which grow in milk undergo hundreds of generations each day, and continue to produce the same type of bacteria and not of any different type.

Like Begets Like and Yet the variations

All organisms —whether animals, plants or microorganisms, produce their **own** kind through reproduction. But the offspring are never identical to their parents; some difference, how-so-ever small it may be, is found in them.

3.2 VARIATIONS IN POPULATION

Human beings as a species share many main characters or traits among themselves which identify the **species** *Homo sapiens*. Yet the various **races** or tribes look different in several features. Even within the same race or tribe, the individual members in the **population** show differences. Further, the smallest unit of population is the **family** and there too, members show differences in body features. *These small differences among individuals are called* ***variations***.

The same is true for animals also. We keep pets, like dog or cat and domesticate animals, like cow or buffalo. There are so many breeds of each one of them and even in the same breed, there are minor differences, and variations among individuals.

CHARACTER AND TRAITS

Any inheritable feature is a **character**. The alternative forms of a character are called **traits**.

INHERITANCE IN HUMANS

We inherit thousands of **characters** from our parents (father and mother) who in turn, had inherited them from their parents. Thus the family members— brothers, sisters, cousins—tend to resemble one another. Here is a list of some such **characters** and their **traits** :-

1. Colour of the eyes—**brown** or **blue**
2. Hair shape—**Curly** or **straight**
3. Eyebrows—**Heavy bushy** or **thin**
4. Hair on the middle joint of fingers — **Growth** or **no growth**
5. Colour vision—**Normal** or **red-green colour blindness**
6. Tongue rolling—**Rolling of tongue** into U-shape when extended out from the mouth or **no rolling**
7. Hand use—**Right-handedness** or **left-handedness**
8. Skin colour—**Albinism** (total absence of pigment in skin) or **normal** (light or dark) pigment.
9. Ear lobe—**Free** or **attached**
10. Lips—**Thick** or **thin**
11. Rh Blood group—**Rh positive** or **Rh negative**.

? *PROGRESS CHECK*

1. Mention if the following statements are ***True*** (T) or ***False*** (F) :
   (i) Genetics and heredity are the same thing. T/F
   (ii) "Like begets like", this applies only to animals. T/F
   (iii) The entire human population shows variations. T/F
2. Which of the following in humans are established genetic traits ? (Tick-mark the correct ones) in the box provided.
   (i) Capacity to be a good cricketer ☐
   (ii) Curly hair ☐
   (iii) Left-handedness ☐
   (iv) Quality of voice ☐
   (v) Red-green colour blindness ☐

3.3 CHROMOSOMES—THE CARRIERS OF HEREDITY

Chromosomes are only visible when a cell nucleus is about to divide. Photographs of the dividing cell nucleus can be taken through a high powered light microscope. These photographs are used for artificially arranging the chromosomes according to their size and shape on a chart (**karyotype**). One such human karyotype is shown below in Fig. 3.1

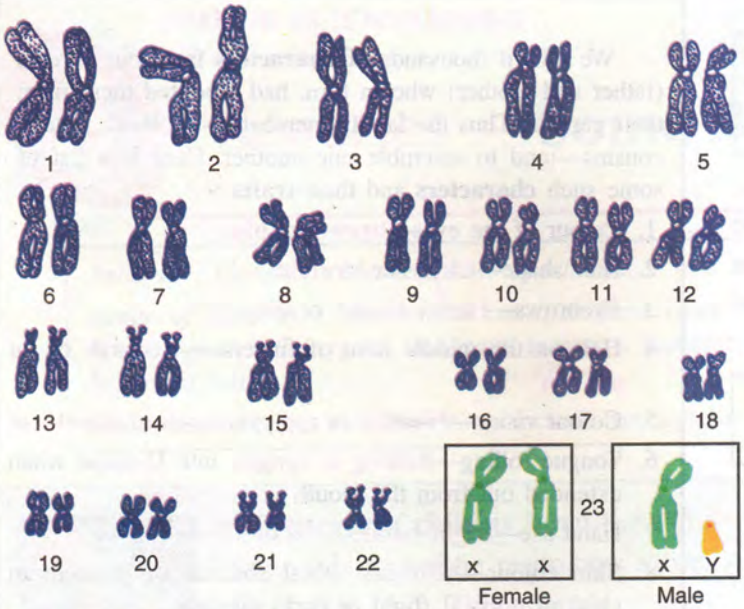


Fig. 3.1 : The human chromosomes arranged in pairs in order of their size and shape (karyotype). Chromosomes become distinctly visible only during cell division. Each chromosome is split into two chromatids joined by a small circular dot-like centromere

Chromosome number

The chromosome number is constant for the individuals of a species, and each body cell has the **same** number. Humans have 46 chromosomes.

Chromosome numbers of some other common animals and plants are as follows :

Ascaris	.....	2
Onion	.....	16
Maize	.....	20
Lion	.....	38
Tiger	.....	38
Domestic cat	.....	38
Mouse	.....	40
Humans	.....	**46**
Gorilla	.....	48
Potato	.....	48
Monkey	.....	54
Dog	.....	78
Chicken	.....	78
Crayfish	.....	200
Some insects	.....	More than 1000

Chromosomes in Homologous Pairs

Once again look at the above list carefully. In each organism, the chromosomes occur in even numbers. This is so because they always occur *in pairs*. Thus in humans, the 46 chromosomes are present in 23 pairs (Fig. 3.1). The two chromosomes of each pair are similar in size and shape and are derived as one each from the two parents. These identical chromosome pairs are called homologous chromosomes.

Homologous chromosomes

A pair of corresponding chromosomes of the same shape and size, one from each parent.

3.4 THE TWO MAIN CATEGORIES — AUTOSOMES AND SEX CHROMOSOMES

In Fig. 3.1, you would notice that each one of the chromosome pairs numbered 1-22, has identical chromosomes and these are categorised as **autosomes**. But the 23rd pair is different and its chromosomes are called **sex chromosomes** which are designated as X and Y. The XX pair with similar partners is found in females whereas the XY pair with dissimilar partners is found in males. The Y chromosome of males is much smaller than the X chromosome (Figs 3.1 & 3.2).

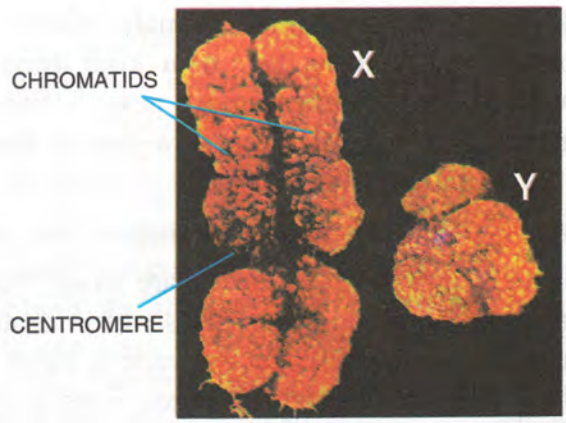


Fig. 3.2 : Two human male sex chromosomes (X and Y) showing the chromatids and centromere in each

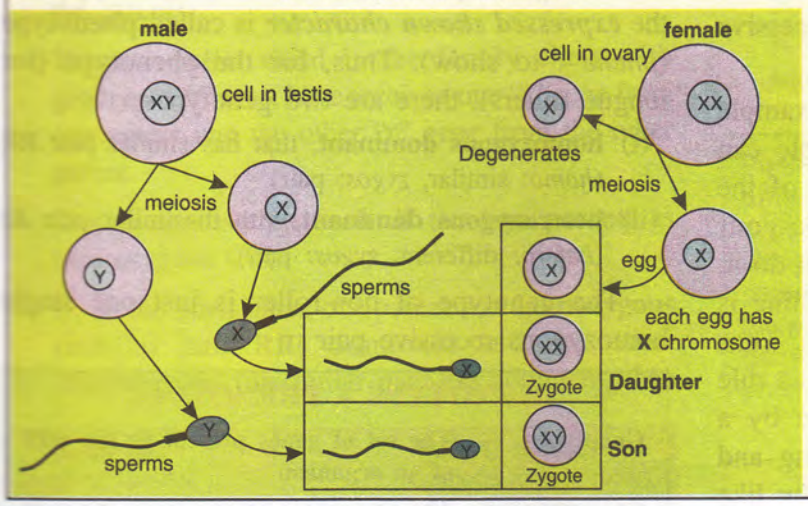
3.5 SEX DETERMINATION — SON OR DAUGHTER

The sex of the child depends upon the kind of sperm that fertilises the egg. The egg contains only one X chromosome, but half of the sperms released into the female are X-bearing and the remaining half are Y-bearing. It is simply a matter of chance as to which category of sperm fuses with the ovum :-

- If the egg (X) is fused by X-bearing sperm, the resulting combination is XX, *i.e.* female type and the child produced is female **(Daughter)**.

Son or Daughter?

(So far only a matter of chance)



All eggs are alike (each with one X-chromosome), but sperms are either with X- or with Y-chromosome (50% of each kind). **Which sperm fertilises the egg determines whether the child will be male or female.**

Successful trials have been reported of isolating the two kinds of sperms and getting the ovum fertilised by the particular kind for the desired sex of the unborn.

– If the egg (X) is fused by Y-bearing sperm, the resulting combination is XY, *i.e.* male constitution and the child produced is a male **(Son)**.

? PROGRESS CHECK

1. Mention the following :
   (i) Total number of **pairs** of chromosomes in each body cell in humans .....
   (ii) Any two animals having **19 pairs** of chromosomes .....
   (iii) Number of **pairs** of autosomes in humans. .....
   .....
2. A certain couple got only four daughters in a row and no son. Does it mean that the husband does not produce Y-bearing sperms? Explain.....

3.6 CHROMOSOMES — CARRIERS OF GENES

All species have a fixed number of chromosomes. However, the characteristics of species including physical appearance, body functions, behaviour, etc., are not simply the outcome of chromosome number, but these are the result of the units called **genes** which the chromosomes carry. The lion and the cat have the same number of chromosomes (38). Yet one is distinct from the other in body size, appearance, colour, behaviour, etc. All such characteristics of an organism are the result of the genes located on the chromosomes.

GENES AND GENOME

- **GENES : Genes are the specific parts (DNA segments) of a chromosome, which determine the hereditary characteristics.**
- **The Number of Genes in Humans : According to the latest findings there are nearly 30,000 genes in humans. Chromosome No. 1 has the largest number of genes (2968) and chromosome Y has the fewest (231).**
- **GENOME is the full complement of DNA (including all genes and the intergenic regions) of an organism.**

3.7 GENES AND THEIR ALLELES

Normally, every gene has two alternative forms for a character producing different effects. These alternative forms are called the **alleles**. *For example*, in the character of tongue rolling (projecting the tongue out of the mouth in the form of a tube), there are two possibilities — *either* **one can roll the tongue** *or* **one cannot**. Thus there are two alleles of this gene — one for rolling and the other for non-rolling.

The year 2009 — Hundredth birthday of the term "gene". The word was coined by geneticist Wilhelm Johanssen in 1909 to simply describe what parents passed to their offspring, the detailed DNA structure came to knowledge much later.

DOMINANT AND RECESSIVE ALLELES

Out of the two alleles of a gene, one is **dominant** (superruling) and the other is **recessive** (subordinate or submissive).

To understand this, again take the same example of **tongue rolling**. A large number of people can roll their tongue into a tube projecting out of the mouth. Try whether you can do it. Ask your classmates to try the same. Most of them can do it, but a few may not. The gene for tongue rolling is located on a particular pair of chromosomes. Thus every individual has a pair of this gene. It is a rule in genetics to represent the dominant gene by a capital letter, so here **"R"** for tongue rolling and the recessive gene by the same but small letter like **"r"** for non-rolling. Thus, a recessive gene is one which, in the presence of the contrasting (dominant) gene, is not expressed.

ALLELES : Alternative forms of a gene, occupying the same position (locus) on homologous chromosomes and affecting the same characteristic but in different ways.

A pair of chromosomes showing four imaginary genes A, B, C, and D. The situations depicted here are:

(i) AA is homozygous (similar) dominant pair,
(ii) bb is homozygous (similar) recessive pair and
(iii) Cc and dD are heterozygous (dissimilar) pairs.

Remember – *The chromosome as a whole can neither be dominant nor recessive.*

3.8 GENOTYPE AND PHENOTYPE

The three situations pertaining to any pair of genes, as for example in tongue rolling, can be as follows :

(i) RR (both **dominant**)
..... TONGUE ROLLER

(ii) Rr (one **dominant**, one recessive)
..... TONGUE ROLLER

(iii) rr (both **recessive**)
..... NON-ROLLER

You can see from the above that the tongue rollers have two kinds of genetic constitutions (RR or Rr) whereas non-rollers have only one genetic constitution (rr).

The ***genetic constitutions*** (pertaining to the kinds of genes possessed) are called **genotype** and the ***expressed shown character*** is called **phenotype** (*phene* : to show). Thus, for the phenotype (for tongue rollers), there are two genotypes:

(i) **homozygous dominant**, that has similar pair RR (*homo*: similar, *zygos*: pair)

(ii) **heterozygous dominant** with dissimilar pair Rr (*hetero:* different, *zygos:* pair)

The genotype of non-roller is just one single homozygous recessive pair rr.

GENOTYPE – PHENOTYPE

Genotype	–	**The set of genes present in the cells of an organism**
Phenotype	–	**The observable characteristic which is genetically controlled.**

3.9 FROM PARENTS TO CHILDREN — TONGUE ROLLING — AN EXAMPLE OF INHERITANCE

Fig. 3.3 illustrates a family chart of two parents and their three children, again illustrating the trait of **tongue rolling**.

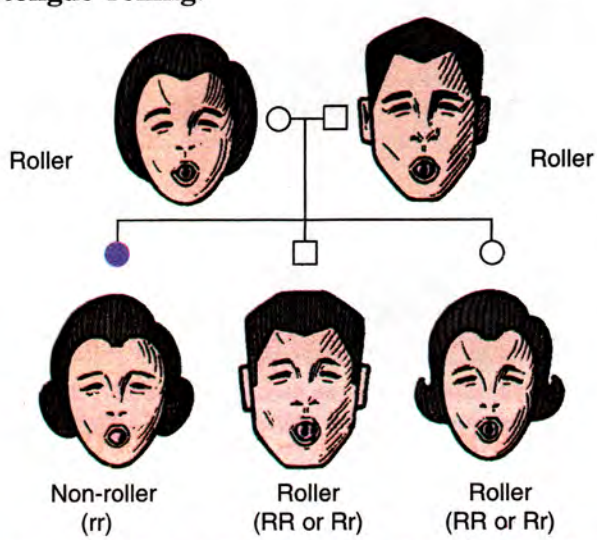


Fig. 3.3 A pedigree (family) chart showing inheritance of the ability to roll the tongue. (Symbols : O = female, □ = male; solid symbol indicates the character being traced)

Observe the following points in the above pedigree (family) chart :

— **Males** are shown by squares and **females** by circles.

— Both father and mother are tongue rollers (**hollow symbols** represent the usual expressed character).

— Of the three children born, two can roll (hollow symbols) and one cannot (**solid symbol**).

— The recessive trait (rr) of non-rolling in one of the children could have come from nowhere else but the parents.

— The non-roller child in the family chart with genotype "rr" must have received one "r" gene from one parent and the other "r" gene from the other parent.

— Conclusion is that each of the two parents is heterozygous (Rr).

— If, on the other hand, one parent was **homozygous** (similar pair RR) dominant and the other **heterozygous** (dissimilar pair Rr) dominant, then every child would have got at least one dominant gene from the homozygous dominant parent through the sex cells. The situation can be schematically explained as given in a Punnett square (Fig. 3.4).

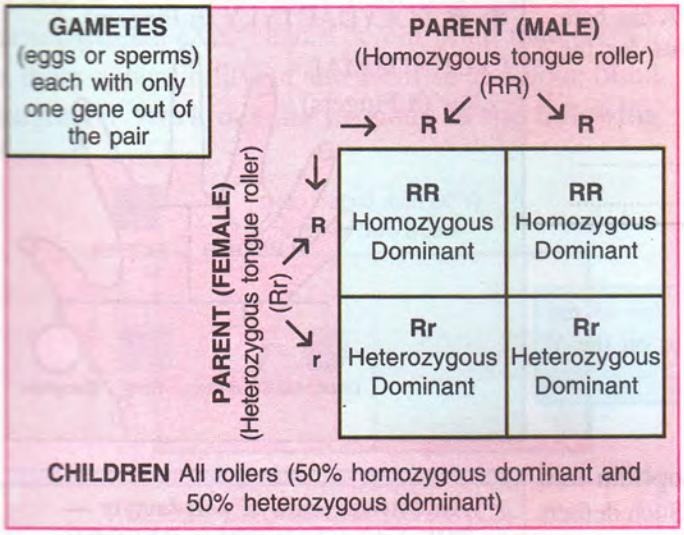


Fig. 3.4 : A possible family where both parents are phenotypically similar (tongue rollers) but genotypically dissimilar (one homozygous dominant and "RR" the other heterozygous "Rr"). All their children will be tongue rollers

Punnett square is a simple diagram in which the different types of gametes (sex cells with the concerned trait) of one (female) parent are placed along one side of the square and those of the other parent (male) are placed along the other side. Then, the possible combinations (genotypes) of the opposite gametes are given in the sub-squares. The resulting phenotypes can be written under the genotypes.

Dominant and recessive forms of some common Hereditary Traits in Humans

Character	Dominant trait	Recessive trait
Eye colour	Brown	Blue
Tongue	Rolling	Non-rolling
Hand	Right-handedness	Left-handedness
Ear lobe	Free	Attached
Lips	Thick	Thin
Rh blood group	Positive	Negative
Colour vision (red-green)	Normal	Colour blind
Cheek	Dimpled	Normal

Some rather uncommon hereditary traits

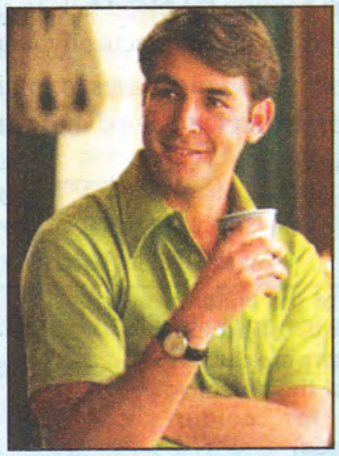
Polydactyly (Extra fingers & toes) = Dominant
Albinism (Total absence of skin pigment) = Recessive
Camptodactyly (Inability to straighten the little finger) = Dominant

SOME BIOLOGY IN DESIGNING THE WRIST WATCHES !

Most people wear the wrist watch on left hand and only *very few* on right hand. Is it ***true*** ?

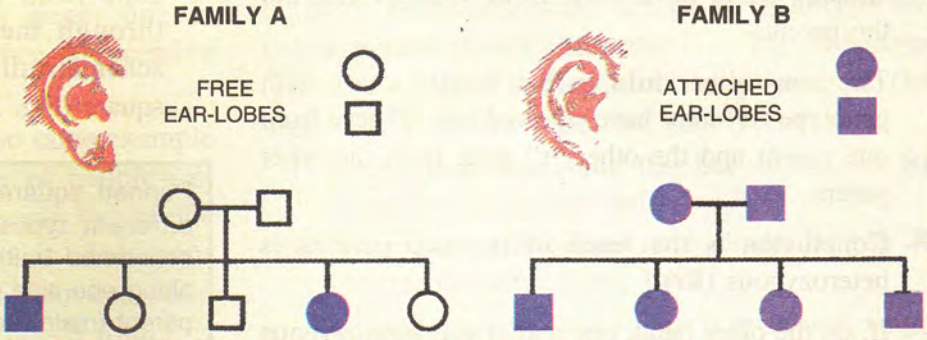
Something to do with human genetics.

(**Hint :** Interpret the position of the knob of the wrist watch and the related human genetic trait).



AN INTERESTING EXERCISE TO TRY

Can you try to explain the inheritance of the character of **Free** or **Attached Ear lobes**. Given alongside are pedigree charts of two families A and B. In family A, both parents have free ear lobes and those of family B, have attached ear lobes (Recollect from previous example what the symbols of circle and square, indicate).



Pedigree charts of two families A & B showing the inheritance of attached ear lobes

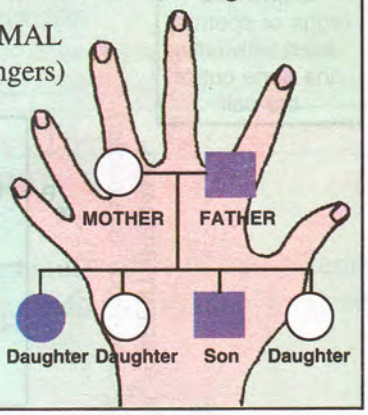
Can you find answers to the following ?

1. Which trait — free ear lobe or the attached ear lobe is dominant ?
2. Family B has all children of one type only whereas family A has both types. Parents in which family A or B, are heterozygous for the character ?
3. What is the difference indicated by
   (i) Squares and circles ? .....
   (ii) Solid symbols and hollow symbols ? .....

Can you describe the situation here too?

● ■ POLYDACTYLY (6 Fingers)

○ □ NORMAL (5 Fingers)



3.10 SEX-LINKED INHERITANCE

Sex-linked inheritance is the appearance of a trait which is due to the presence of an allele exclusively either on the X chromosome or on the Y chromosome.

'X' linked inheritance :

Certain disorders caused due to heredity such as **haemophilia and colour-blindness** are more common in males than in females. Such defects are due to **recessive genes**, which occur on the **'X' chromosome**. (You can check if you are normal or colour blind by reading the numbers given in the three coloured circles on page 126. If you can see them, you are normal otherwise colour blind as in fourth circle).

Haemophilia is a genetic disorder in which the sufferers (homozygous recessive female and the recessive X-bearing male) are at a risk of bleeding to death because the blood fails to clot in them. Rare cases of haemophiliac males do occur but practically, none of haemophiliac females.

The following cases explain the sex-linked (X-chromosome linked) **inheritance of colour-blindness** (or **haemophilia**) **in humans.**

CASE 1

[None of the children is colour-blind but daughters are carriers (XX°) of the defective allele for colour-blindness]

Normal mother (XX) × Colour-blind father (X°Y)

Colour-blind father (X°Y)
Sperms (two types)

Normal mother (XX) Eggs (all similar)	X°	Y
X	XX°	XY
X	XX°	XY

XX° : Daughters - heterozygous dominant, normal vision
XY : Normal sons

An extreme case of polydactyly — THE LATEST WORLD RECORD.

15 Month old **"Akshat"** from *Bareilly, Uttar Pradesh*, with 7 fingers in each hand and 10 toes in each foot (thus 34 digits in all). He was successfully operated at AIIMS, New Delhi in June/July 2011; to remove the extra digits and reshaping a few of them both in hands and feet.

CASE 2

Carrier mother (not colour-blind) (XX°) and (XY) Normal father

Normal father (XY)
Sperms (two types)

Carrier mother (X°X) (not colour-blind) Eggs (two types)	X	Y
X°	X°X Carrier daughter	X°Y Colour-blind son
X	XX Normal daughter	XY Normal son

CASE 3

Think of a possibility of a marriage between carrier woman (XX°) and a colour blind man (X°Y). Is there a possibility of the birth of a colour blind daughter ? **Work out the progeny in the following Punnett square.**

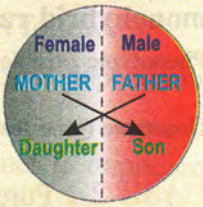
Colour-blind man (X°Y)
sperms (two types)

Carrier woman (X°X) Eggs (two types)		

CRISS-CROSS INHERITANCE

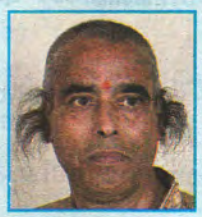
(Mother to Son and Father to daughter)

Inheritance of X-linked genes as in colour blindness and haemophilia is also called **criss-cross inheritance**. This is because the son (male sex) may get it from the otherwise normal but carrier mother (as in case 2) and a colour blind father may pass it on to the daughter making her colour-blind if the mother is a carrier. (Refer to case 3, if you have solved it.)



EXTRA **Not in syllabus**

'Y'-linked inheritance :



The Y–chromosome linked traits (characters) occur in males but not in females. *For example*, traits such as **hypertrichosis of ears** (hair growing out of ears), and **pattern baldness** are found in men only. This is because the dominant genes of such traits are found on 'Y' chromosome which determines the male sex.

? PROGRESS CHECK

1. Approximately, how many genes have been discovered in humans ?
2. Define the following terms :-
   (i) Allele .....
   (ii) Dominant gene .....
   (iii) Genotype .....
   (iv) Phenotype .....
   (v) Heterozygous dominant .....
3. Can there be a heterozygous recessive ? Explain.
   .....
   .....
4. List any four traits in humans which you can easily study just by observing and making family charts.
   (i) .....
   (ii) .....
   (iii) .....
   (iv) .....

3.11 MENDEL'S EXPERIMENTS ON INHERITANCE

The basic principles of genetics were discovered for the first time by Gregor John Mendel in the mid-nineteenth century. Mendel was an Austrian monk and he conducted breeding experiments on garden pea (*Pisum sativum*) out of sheer interest. His findings became a milestone in biology.

Mendel had selected garden pea for three reasons:

1. **Many varieties** were available in **alternative forms** of a character.
2. Varieties were available in **pure forms that bred true**, i.e. produced the same type generation after generation.
3. Peas are **normally self-pollinated** but self-pollination could be prevented by removing corresponding reproductive parts (male part stamens and the female part carpels) of the flower and could as well be **cross-pollinated artificially**.

Mendel took varieties of this plant showing seven pairs of contrasting features as shown ahead in Fig. 3.5.

Mendel crossed pure breeding varieties, first, by taking only one feature at a time **(monohybrid cross)** and then, by taking two features together

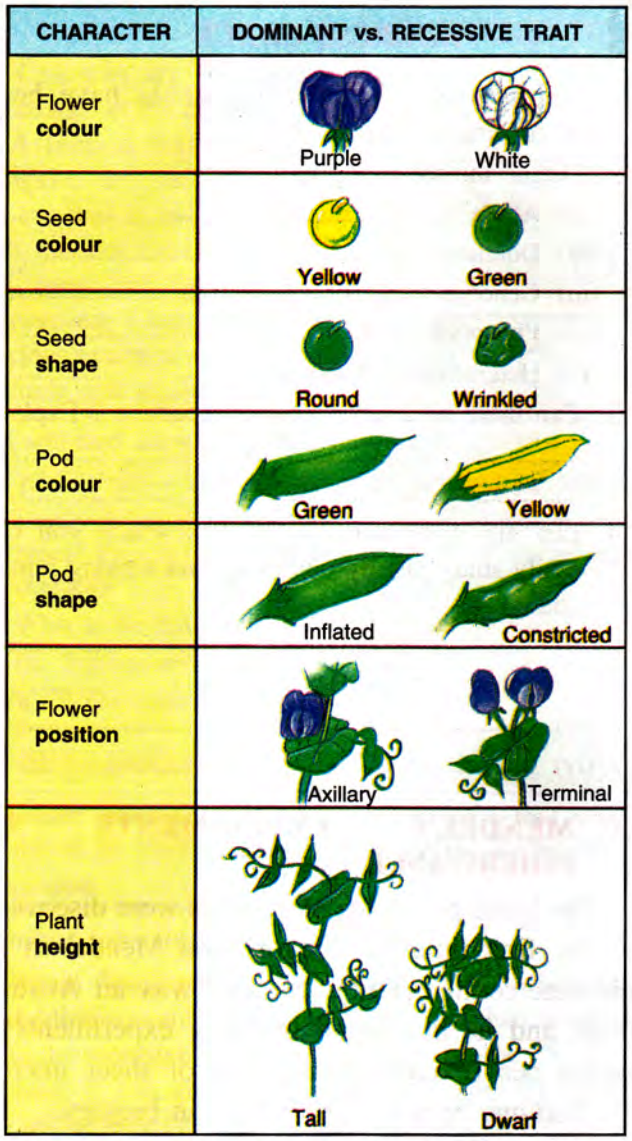


Fig. 3.5 : Seven pairs of contrasting features of garden pea studied by Mendel

(dihybrid cross). He tried with all the seven features and his observations were similar for all.

CASE 1 : One of the monohybrid crosses is shown below in Fig. 3.6. A pure breeding plant bearing **terminal flowers** was cross-pollinated with a pure breeding plant having **axillary flowers** (flowers borne in the axil of leaves).

The resulting seeds after sowing produced all plants with axial flowers only (none bearing terminal flowers). When these hybrid plants (F_1 generation*) were self-pollinated, they produced in F_2 generation plants with axillary flowers and plants with terminal

* F_1= First filial generation. **Filial generation** means a cross between offsprings. The first, second and third generation of the offspring are known as first filial, second filial and the third filial generation and are denoted by the symbols F_1, F_2 and F_3 respectively.

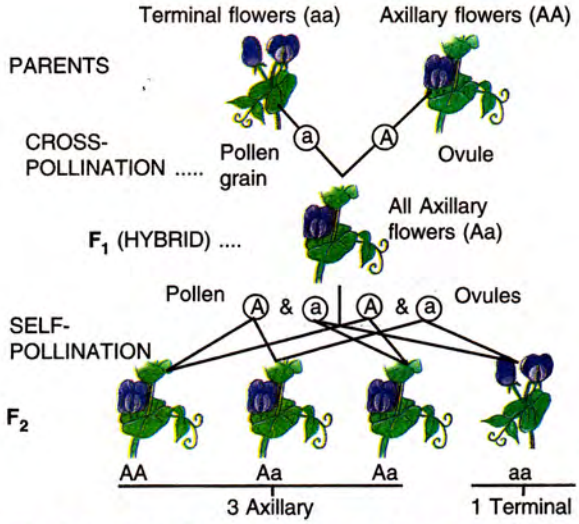


Fig. 3.6 : Crossing of garden pea bearing terminal flowers with pea bearing axillary flowers through two generations (F_1 and F_2)

flowers in the ratio of 3 : 1. These were the visible forms which we call the phenotypes. Out of these, the one with terminal flowers (aa) in subsequent (self-pollinated) generation produced all plants with terminal flowers only. Out of the other remaining three with axillary flowers :

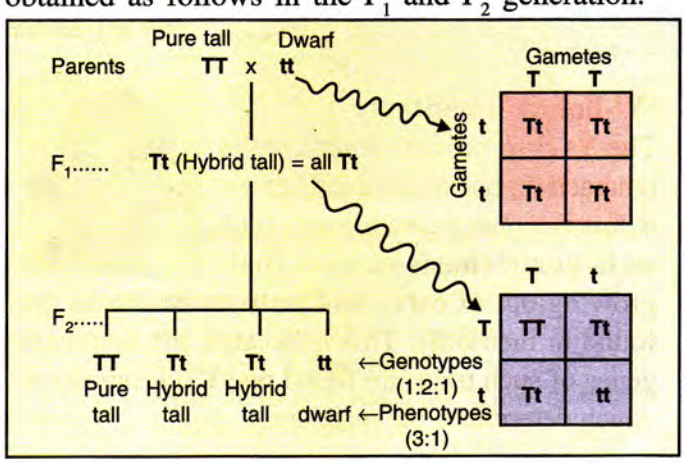
- One (AA) produced all plants with axillary flowers only
- Two (Aa) again produced in the same ratio 3 : 1 as was in F_2 generation.

This kind of ratio obtained by crossing for two ***different traits*** of a ***single character*** is known as **monohybrid ratio**. This consisted of the following:

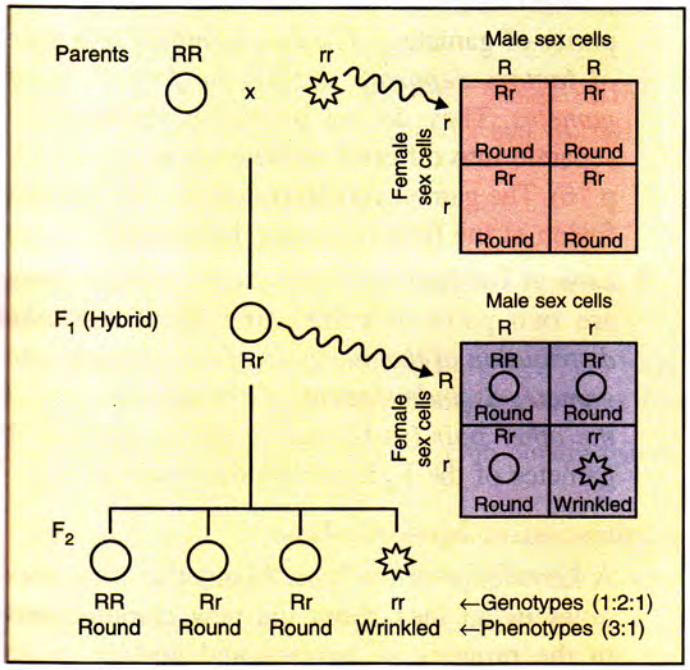
Phenotypic (visible feature) ratio = **3 : 1** (three axillary and one terminal)

Genotypic (gene feature) ratio = **1 : 2 : 1** (one AA, two Aa and one aa)

CASE 2 : Pure **tall** (TT) pea plants were crossed with **dwarf** (tt) plants and the progenies were obtained as follows in the F_1 and F_2 generation.



CASE 3 : Similarly, on crossing the plants grown from pure **round(RR)** seeds with plants grown from pure **wrinkled(rr)** seeds, the results were as given below :



In all the above three cases, the monohybrid ratios are same:

Phenotypic ratio 3 : 1;

Genotypic ratio 1 : 2 : 1

Some of the generalized principles based on the above breeding experiments were as follows :

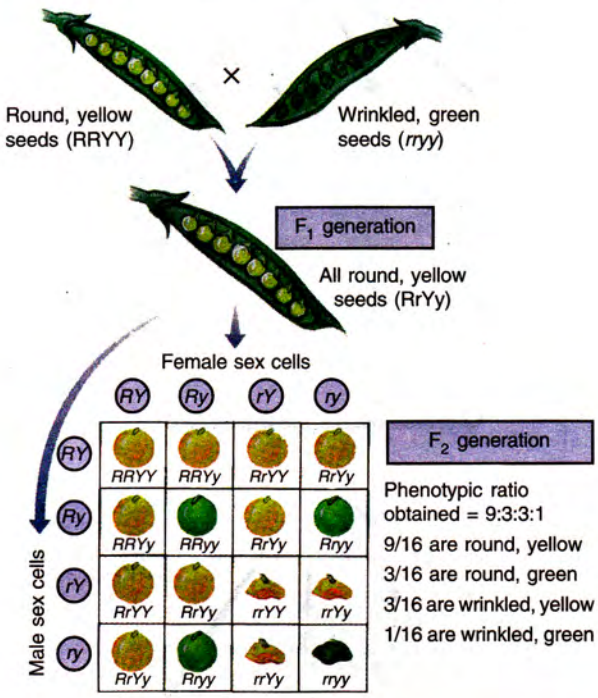
1. Each pair of contrasting characters depends on a pair of genes.
2. Each individual carries such genes in duplicate.
3. An individual produces gametes (sex cells) which have only one member of a pair of genes.
4. Fertilization of the gametes restores the duplicate condition of the genes.
5. Sex cells with respect to the genes they contain, get fertilised at random.

Dihybrid ratio (breeding results with two pairs of contrasting characters).

Mendel tried several combinations. One such combination was the crossing of a variety with **round and yellow** seeds with another variety having **wrinkled and green** seeds.

The ratio is 9 : 3 : 3 : 1.

The above results from parents to $\mathbf{F_1}$ and then to $\mathbf{F_2}$ can be easily understood from the following :



Thus, the two kinds of ratios in the two kinds of hybridisations are as follows :

Monohybrid ratios in F_2 generation

Phenotypic — 3 : 1

Genotypic — 1 : 2 : 1

Dihybrid ratios in F_2 generation

Phenotypic — 9 : 3 : 3 : 1

Genotypic — (very complex)

3.12 MENDEL'S LAWS OF INHERITANCE

Mendel's generalizations of the results of breeding experiments are summarised under three laws:

1. **Law of Dominance.** *Out of a pair of contrasting characters present together, only one is able to express itself while the other remains suppressed.* The one that expresses is the **dominant** character and the one

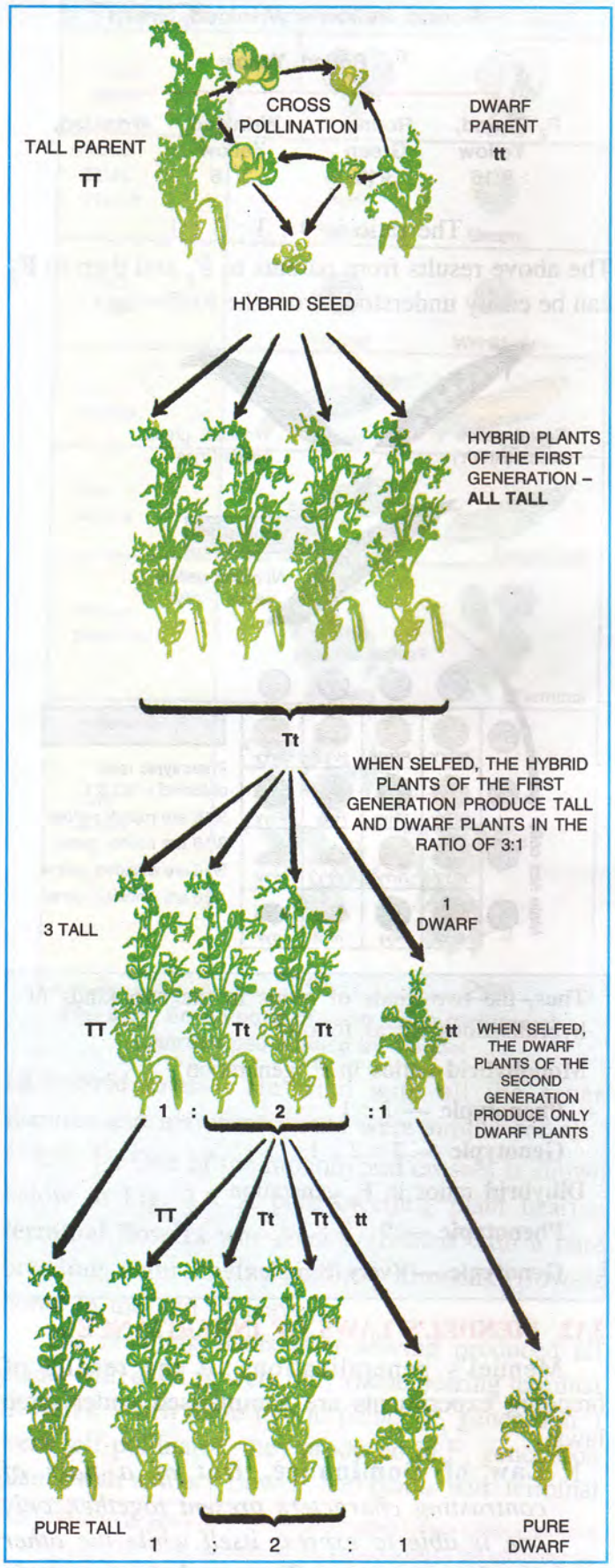


Fig. 3.7 : Diagrammatic representation of Mendel's results obtained by crossing tall plants with dwarfs of garden pea

unexpressed is the **recessive**. The recessive character can express only when the pair consists of both recessives (homozygous recessive).

2. **Law of Segregation** (also called the law of purity of gametes). The *two members of a pair of factors separate during the formation of gametes*. They do not blend but segregate or separate into different gametes (see Fig. 2.11A p.16). The gametes combine together by random fusion at the time of zygote formation.

3 **Law of Independent Assortment**. When there are two pairs of contrasting characters, *the distribution of the members of one pair into the gametes is independent of the distribution of the other pair* (as is seen in the production of gametes of the F_1 hybrid in dihybrid cross).

Application of Mendel's laws

(i) A knowledge of the basic Mendelian principles gives us an idea about the new combinations in the progeny of hybrids and enables us to predict their frequency.

(ii) Such information is of great importance to both plant and animal breeders for producing better breeds.

(iii) New types of plants with new combinations of useful characters can be produced by hybridisation.

3.13 MUTATION

Mutation is a sudden change in one or more genes, or in the number or in the structure of chromosomes.

Mutation alters the hereditary material of an organism's cells and results in change in certain characters or traits. *For example* :

(i) **Sickle cell anaemia.** It is a blood disease caused by a gene mutation. The mutation causes change in the DNA resulting in the production of sickle shaped RBCs.

(ii) **Radioactive radiations** also alter the gene structure and their effects can be seen generation after generation. An atomic explosion which had occurred during World War-II 1945 in Japan (Hiroshima, Nagasaki),

had led to a number of deformities in the body of plants and animals which are still persisting.

PROGRESS CHECK

1. Who discovered for the first time the basic principles of genetics? .....
2. Give the common and scientific names of the organism on which Gregor Mendel had worked.
   Common name .....
   Scientific name .....
3. Define the following terms:
   (i) Monohybrid .....
   (ii) Dihybrid .....
   (iii) Filial generation .....
4. List any four traits in humans which you can easily study just by observing and making family charts.
   (i) ..... (ii) .....
   (iii) ..... (iv) .....

REMEMBER

Monohybrid cross : A cross between two pure breeding different varieties of organism taking the alternative traits of *one* single character. ***Example*** **:** A cross between pure tall (TT) and dwarf (tt) pea plants.

Monohybrid ratio : The kind of ratio obtained in the progeny in F_2 generation, by crossing for *two* different traits of a single character.

Dihybrid cross : A cross between two parents taking into consideration alternative traits of *two* different characters. ***Example*** **:** A cross between tall, purple flower bearing pea plant with dwarf and white flower bearing pea plant.

Dihybrid ratio : The kind of ratio obtained in the progeny in F_2 generation by crossing for contrasting the traits of *two* different characters.

Gene : Basic unit of heredity. It is a specific part (DNA segment) of a chromosome which controls the expression of a character. ***Example*** **:** The gene for free ear lobe in humans.

Allele : The alternative form of a gene occupying the same position on a chromosome and affecting the same characteristic but in two alternative ways. ***Example*** **:** The free and attached ear lobe alleles of the ear lobe character.

Dominant allele : The super-ruling allele of a gene. ***Example*** **:** The allele for tallness of pea plant.

Recessive allele : The suppressed allele of a gene. ***Example*** **:** The allele for dwarfness of pea plant.

Homozygous : The condition in which a pair of chromosomes carries similar alleles of a particular character. ***Example*** **:** A colour blind daughter will have both the X chromosomes with defective alleles.

Heterozygous : The condition in which a pair of chromosomes carries dissimilar alleles for a particular character. ***Example*** **:** A daughter (XX°) from a normal homozygous mother (XX) for colour vision and a colour blind father (X°Y) has one normal and one defective allele.

Genotype : The combination of genes in an organism. ***Example*** **:** TT (homozygous dominant tall), Tt (heterozygous tall) and tt (homozygous recessive dwarf) pea plants.

Phenotype : The expressed character which is genetically controlled. ***Example*** **: Tall** pea plants (genotypes TT or Tt), **dwarf** pea plants (genotype tt).

Variation : Small differences between individuals due to inheritance.

Mutation : Sudden change in one or more genes or in the number and structure of chromosomes in the progeny, which normally may not have existed in the parents, grand parents or even great grandparents. ***Example*** **:** Albinism (total loss of skin pigment).

Homologous chromosomes : A pair of corresponding chromosomes of the same size and shape, one from each parent.

REVIEW QUESTIONS

A. MULTIPLE CHOICE TYPE

(Select the most appropriate option)

1. Which one of the following has the smallest number of chromosomes ?
   (a) Onion (b) Mouse
   (c) Monkey (d) *Ascaris*
2. Which one of the following is the phenotypic monohybrid ratio in F_2 generation ?
   (a) 3 : 1 (b) 1 : 2 : 1
   (c) 2 : 2 (d) 1 : 3

B. VERY SHORT ANSWER TYPE

1. **Match** the terms in column I with their explanations in column II.

Column I (Term)	Column II (Explanation)
a. Genetics	(i) Chromosomes similar in size and shape
b. Autosomes	(ii) The alternative forms of a gene
c. Recessive gene	(iii) Study of laws of inheritance of characters
d. Allele	(iv) A gene that can express only when in a similar pair
e. Homologous chromosomes	(v) Chromosomes other than the pair of sex chromosomes.

2. **Name** two animals which have nineteen pairs of chromosomes.
3. **Name** any two genetic diseases in humans.
4. Which one of the following genotypes is homozygous dominant and which one homozygous recessive in regard to tongue rolling :
   Rr, rr, RR.

C. SHORT ANSWER TYPE

1. **Differentiate** between :
   (a) genotype and phenotype.
   (b) character and trait.
   (c) monohybrid and dihybrid cross (phenotypic ratio).
2. Among lion, tiger and domestic cat, all the three have the same number of 38 chromosomes, yet they have different appearances. **How** do you account for such differences ?
3. **List** any three features of garden pea with their dominant and recessive traits.
4. **Explain** why generally only the male child suffers from colour blindness and not the female?
5. In a certain species of animals, black fur (B) is dominant over brown fur (b). **Show** the possible ratio of genotypes and phenotypes of the offspring of the pure breeding different coloured parents.

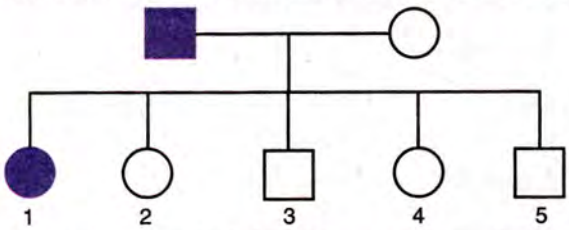
D. LONG ANSWER TYPE

1. **Explain** the following terms :
   (a) Heterozygous (b) Homozygous
   (c) Pedigree chart.
2. **State** the three Mendel's laws of inheritance.
3. Does the sex of the child depend on the father or it is just a matter of chance? **Discuss.**

E. STRUCTURED/APPLICATION AND SKILL TYPE

1. In a certain species of animals, black fur (B) is dominant over brown fur (b). **Predict** the genotype and phenotype of the offspring when both parents are 'Bb' or have heterozygous black fur.
2. Two pairs (A & B) of rabbits were crossed as given below:

   (a) Can you tell which coat colour (black or white) is dominant? .....
   (b) Is the coat colour sex-linked? .....
3. **Make a Punnett square** for finding out the proportion of different genotypes in the progeny of a genetic cross between
   (a) A **pure tall** (TT) pea plant with a **pure dwarf** (tt) pea plant.
   (b) Red flower variety of pea (RR) with white flower variety of pea (rr).
4. A family consists of two parents and their five children and the pedigree chart below shows the inheritance of the trait colour blindness in them.



   (a) Who is colour blind in the parents — the Father or the Mother ?

(b) How many daughters and how many sons have been born in the family ?

(c) What does the child 1 indicate about this trait ?

(d) On which chromosome is the gene of this trait located ?

(e) Name one other trait in humans which follows the similar pattern of inheritance.

"REBIRTH" ? AS "CLAIMED BY THE PARENTS"

As reported in newspapers, can we call it a case of "rebirth" of their son who had died exactly 11 months before, or is it simply **an excellent example of hereditary similarity**?

(Died May 3, 2005)

(Born April 12, 2006)

"HEBRA"

A cross between Horse & Zebra

HEBRA ? 'Eclyse', a zebra-horse crossbreed, in Schloss Holte, Germany. The father of 'Eclyse' was **a horse from Italy** and the mother was a **zebra from the Safari Park**.

Similarly —

Tigon	—	**Tiger × Lioness**
Zorse	—	**Zebra × Horse**
Biffalo	—	**Bison × Buffalo**
Zenkey	—	**Zebra × Donkey**
Liger	—	**Lion × Tigress**
Geep	—	**Goat × Sheep**
Pomato	—	**Potato × Tomato**

A case of one Black and one White twins born to a **mixed race darkish mother** and a **white father** (Reported in Times of India, 24th October, 2006).

- Both are twin sisters, one black and one white.
- Both are dizygotic (fraternal) twins produced from two fertilized eggs.
- One of the **genetic probabilities** leading to this type of inheritance could be as follows.

Skin colour, as we know today, is determined by 3 genes — let us suppose A, B and C.

Mother (Darkish) — A a Bb Cc

Father (Almost white) — aa Bb cc

Two of the several combinations of these genes through the egg and sperm could be as follows :

Darkish (Darker than the mother) — A a BB Cc

White — aa bb cc

4 Absorption by Roots — The Processes Involved

Syllabus:

(i) Absorption by roots; imbibition; diffusion and osmosis; osmotic pressure; root pressure; turgidity and flaccidity; plasmolysis and deplasmolysis, the absorption of water and minerals, active and passive transport (in brief); the importance of root hair.

(ii) The rise of water up to the xylem; a general idea of Cohesive, Adhesive forces and transpirational pull); demonstrated by the use of dyes.

Scope of syllabus : Characteristics of roots, which make them suitable for absorbing water, should be discussed with the process of absorption. Structure of a full-grown root hair should be explained.

Experiments to show the conduction of water through the xylem should be discussed. Mention of the causative forces must be made for better understanding but as per the syllabus.

Plant physiology is the branch of biology which deals with the **life functions** of the plant. It includes the functioning of cells, tissues, organs, organ-systems and the organism as a whole. This chapter deals with some of the most fundamental processes like osmosis, which have tremendous significance in the life of all organisms.

4.1 ABSORPTION BY THE ROOTS

The roots fix the plant in the soil giving it support but the most important and life-supporting function of the roots is to absorb

(A) ***water*** and

(B) ***mineral nutrients*** *from the soil,*

and conduct them into the stem for supply to the leaves, flowers, fruits, etc.

4.2 NEED OF WATER AND MINERALS FOR PLANTS

A. Need of water

Besides being a constituent of protoplasm, water is needed inside the plant body for four purposes : **photosynthesis, transpiration, transportation** and **mechanical stiffness**.

1. ***Photosynthesis :*** Water is used up in the green leaves as a raw material in the synthesis of glucose.
2. ***Transpiration :*** A large quantity of water is passed out as water vapour during transpiration, for cooling in hot weather, for producing a suction force, etc.
3. ***Transportation :*** Transportation of substances in water solution from the roots upward into the shoot (mineral salts) or from leaves to other parts (sugar, etc).
4. ***Mechanical stiffness :*** Water provides turgidity (fully distended condition), which is necessary for the stiffness of plant tissues.

B. Need of mineral nutrients

Mineral nutrients required by the plant are absorbed from the soil by the roots only. Some of these nutrients are absorbed as salts (nitrates, phosphates, sulphates, etc.) and some simply as ions (potassium, calcium, magnesium, chlorine, etc.). These elements are required as constituents of cell and cell organelles as well as in the synthesis of a variety of compounds or enzymes within the cell.

4.3 CHARACTERISTICS OF ROOTS FOR ABSORBING WATER

The ability of the roots to draw water from the soil is dependent on three characteristics : (i) **a huge surface area** provided by rootlets and root hairs, (ii) Root-hairs containing the solution (cell sap) at

a **concentration higher** than that of the surrounding soil water and (iii) Root hairs having **thin walls**.

(i) **Surface area of roots is enormous** (Fig. 4.1).It is a common experience that even a small garden plant such as balsam, when gently uprooted from the soil, shows a thick bunch of rootlets (branch roots).

When carefully examined, each rootlet would show hundreds of root hairs. If all the root hairs of this plant were to be laid end to end, they would cover a length of many kilometres.

Fig. 4.1 : A freshly germinated seed showing the single root with root hairs

A botanist H.J. Dittmer (1937) worked out that a four-month-old rye plant had an aggregate root length of about 600 km. The number of root hairs in it exceeded 14 billion and their estimated total length would even exceed 10,000 km. Thus, altogether, the roots of any plant provide a huge surface area to facilitate the absorption of water.

(ii) **Root-hairs contain cell sap, of a higher concentration than that of the surrounding water**. Root hairs are the extensions of the outer (epidermal) cells of the root. They also contain large vacuoles filled with a sort of solution called cell sap. Some salts are dissolved in it and the cell sap, therefore, usually has a concentration higher than that of the surrounding water. This characteristic is an important requirement to draw in the outside water, i.e. for the occurrence of osmosis, which is described later (page 36).

(iii) **Root-hairs have thin walls**. Like all plant cells, root-hairs also have two outer layers – a cell wall and a cell membrane (Fig. 4.2).

- The cell wall is **thin** and **permeable**. It allows the movement of water molecules and dissolved substances freely in and out of the cell.

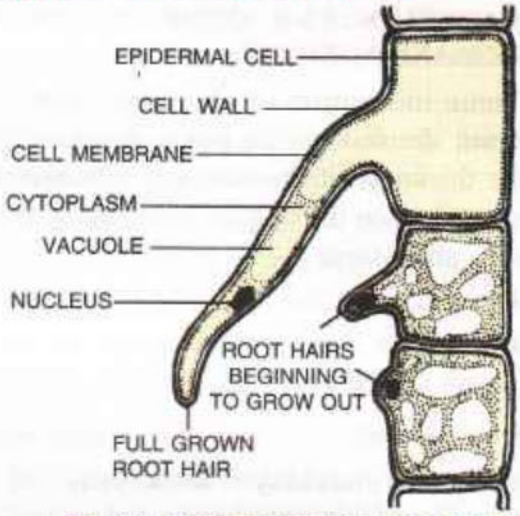


Fig. 4.2 : A single full grown root hair and two more in successive stages of growth from the epidermal cells

- The cell membrane is **very thin**, and **semi-permeable**, which means that it allows water molecules to pass through, but not the larger molecules of the dissolved salts. The secret of the absorption of water from the soil by the roots lies mainly in this characteristic.

? PROGRESS CHECK

1. List the three primary functions of root.
   (i) .....
   (ii) .....
   (iii) .....
2. Mention four purposes for which the plants need water.
   (i) .....
   (ii) .....
   (iii) .....
   (iv) .....
3. Where are the mineral nutrients mostly used in plants?
   .....
4. List three main characteristics of the roots that suit them to draw water from the soil.
   (i) .....
   (ii) .....
   (iii) .....

4.4 ABSORPTION AND CONDUCTION OF WATER AND MINERALS

The entire mechanism of absorbing water and minerals from the soil by the roots, its movement through the thickness of the root and subsequently its upward conduction through the stem, is the result of five main phenomena :

1. Imbibition,
2. Diffusion,
3. Osmosis,
4. Active transport,
5. Turgidity and Flaccidity (Plasmolysis)

4.4.1 Imbibition :

Imbibition is a phenomenon by which the living or dead plant cells absorb water by surface attraction.

Substances which are made up of cellulose or proteins are hydrophilic (strong affinity for water). They imbibe water or moisture and swell up, e.g., dry seeds, wooden doors, swell up on contact with water or on exposure to moist air. Due to imbibitional pressure, seed coat ruptures in case of germinating seeds. It is also an important force in the ascent of sap.

4.4.2 Diffusion

Diffusion is the free movement of molecules of a substance (solute or solvent, gas, liquid) from the region of their higher concentration to the region of their lower concentration when the two are in a *direct* contact.

Diffusion can be easily demonstrated by a simple activity.

Activity. Place a sugar cube or a small tablet of a soluble dye or a crystal of potassium permanganate in a beaker containing water, in one corner (Fig. 4.3). The sugar, the dye, or the potassium permanganate slowly dissolves and spreads in the liquid. Eventually, the molecules of this substance are diffused, or distributed uniformly throughout the water.

In the movement of molecules, there was no obstacle of any kind in the path of the molecules

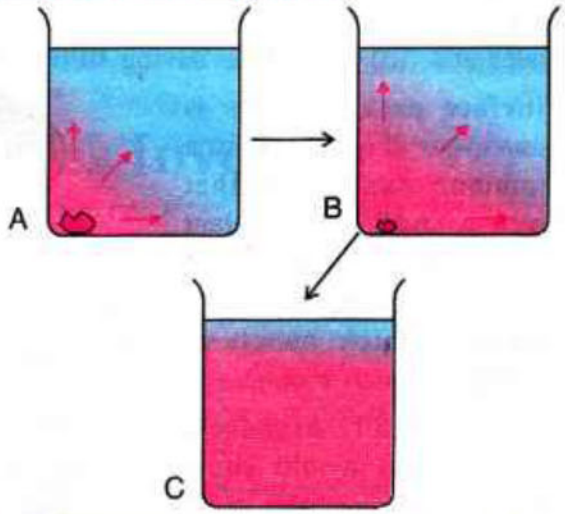


Fig. 4.3 : Diffusion of a soluble dye in water, forming a solution (schematic).
A – Diffusion started,
B – Diffusion progressing,
C – Diffusion completed, making a homogeneous solution; molecules of the solute are evenly distributed in the solvent.

of the dye (solute) and they could move freely in water in all directions.

Let us see how the definition of diffusion applies in this case:

- The molecules of the dye are more crowded (more concentrated) in and near the tablet of the dye.
- These molecules move away farther and farther in the regions where they are fewer or absent (less concentrated).
- This movement continues until the molecules are uniformly distributed. Stirring with a spoon or glass rod hastens the process of uniform diffusion and you get a homogeneous solution much faster.

4.4.3 Osmosis and osmotic pressure

A. OSMOSIS

Osmosis is the movement of water molecules from their region of higher concentration (dilute solution) to their region of lower concentration (concentrated solution) through a semi permeable membrane.

What is most important to note in the above definition is that only the **water molecules move** from their higher concentration (whether in dilute solution, or in pure water) to their (water molecules) lower concentration (in stronger solution or just a solution in relation to pure water).

Inward and Outward Osmosis

With reference to a cell, the osmosis can be either inward or outward depending on the extent of concentration of the solutions surrounding it.

ENDOSMOSIS (*endo* : inward, *osmo* : push/thrust) is the inward diffusion of water through a semi-permeable membrane when the surrounding solution is less concentrated. This tends to swell up the cell.

EXOSMOSIS (*exo*: outward) is the outward diffusion of water through a semi-permeable membrane when the surrounding solution is more concentrated. This tends to cause shrinkage of the cell.

CAN YOU ANSWER IT?

If the concentration of the surrounding solution is the same as that inside the cell, in which direction will the net movement of water molecules be across the cell membrane?

INWARD / OUTWARD / NO NET MOVEMENT.

An experiment to explain osmosis

Take some concentrated sugar solution in a thistle funnel. Cover the mouth of the thistle funnel with a cellophane paper (or egg membrane or animal bladder) and tie it securely. Invert the thistle funnel in a beaker containing water and suspend it as shown in Fig.4.4. Mark the level of the sugar solution on the stem of the thistle funnel. This is the **experimental set-up**.

As a **control** (for comparison), take another thistle funnel with plain water filled in it and suspend it in another beaker also containing water. Again mark the level on its stem.

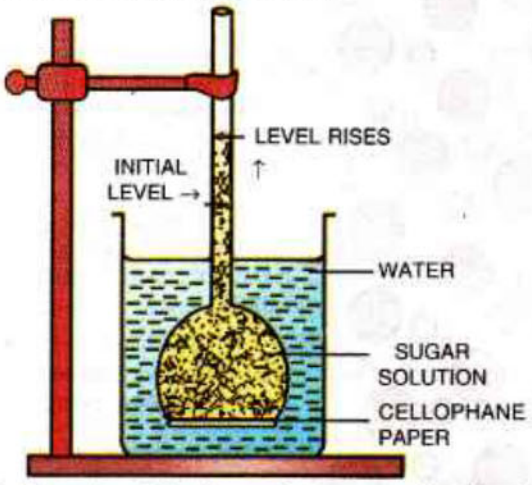


Fig. 4.4 : Experiment to demonstrate osmosis, showing thistle funnel containing sugar solution

- After a few hours, the level of the sugar solution in the thistle funnel in the **experimental set-up** will rise.
- The level of water in the thistle funnel **in the control** will remain unchanged.
- The level of water in the beaker in the experiment will drop slightly while the one in the beaker in the control will remain unchanged.
- If the water in the beaker in the experimental set-up is tasted, it is **not found sweet**.

Three main conclusions from this experiment :

1. In the experimental set-up, some water of the beaker has passed through the cellophane paper to enter the thistle funnel containing the sugar solution.
2. Sugar from the thistle funnel has not passed into the beaker.
3. The cellophane paper has acted as *selectively* or *differentially permeable membrane*. It has **allowed water molecules to pass through**, but **not the sugar molecules**.

The same experiment modified

If you had slightly modified the experimental set-up in Fig. 4.4 by taking a more concentrated sugar solution in the thistle funnel and very dilute or less concentrated sugar solution in the beaker, the result would still be the same, i.e., *the level of the solution in the thistle funnel would rise.* This again is because some water from the less concentrated sugar solution in the beaker moved into the more concentrated sugar solution in the thistle funnel, by crossing through the cellophane paper.

Rubber sheet and muslin instead of cellophane as a barrier.

If in the set-up, we had used a rubber sheet and in another similar set-up, a muslin cloth instead of cellophane as in the above experiment, what would happen? Obviously, no change in the **level of sugar solution** would occur in the first case – **the rubber sheet is impermeable** and would not allow the water molecules from the beaker to cross over to the other side.

In the second case, the meshes or **pores of the muslin cloth are so large** that they would not hold back even the sugar molecules, and the entire sugar

solution would flow down to a common level due to gravity. The muslin cloth is, therefore, freely permeable for sugar solution.

The same experiment can be performed by using a visking bag (semi-permeable membrane) as shown in Fig. 4.5. Place sugar solution in a knotted visking bag and insert a long glass capillary tube till some of the sugar solution rises into the capillary tube. Tie the mouth of the bag firmly round the capillary tube and support it on a clamp stand. Immerse the visking bag in a beaker with water. After about an hour, the level of sugar solution in the capillary tube rises. This rise is due to the water molecules diffusing through the wall of the Visking bag.

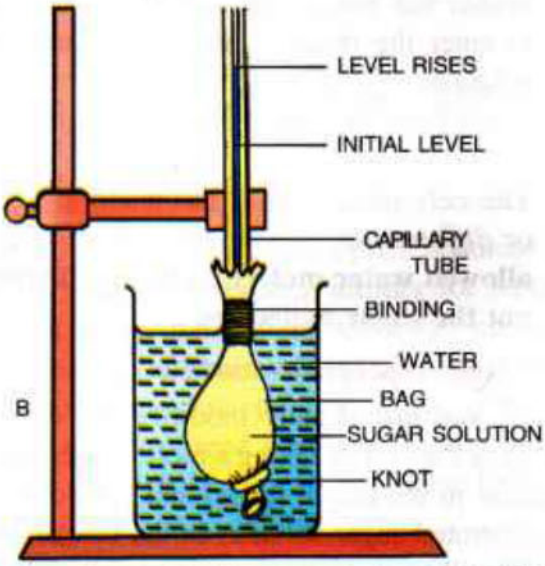


Fig. 4.5 : Experiment showing osmosis by using Visking bag containing sugar solution

Two key points in the above experiments

1. There are two liquids of different concentrations. The sugar solution has a higher concentration of sugar molecules, whereas there may be fewer, or no sugar molecules in the beaker. It is very important to understand that the concentration can also be visualized from the side of the solvent, *i.e.* there are more water molecules in a unit volume in the beaker than in the same volume of sugar solution in the thistle funnel in Fig. 4.4. Thus, there are two regions of different concentrations **(tonicity)** which you may express in the following ways —
   (i) two regions of different concentrations of water molecules, or
   (ii) two regions of different concentrations of sugar molecules.
2. The two liquids are separated by a cellophane paper which behaves like a semi-permeable membrane. ***A semi-permeable membrane is one which allows the passage of molecules selectively.*** It allows a solvent (*e.g.* water molecules) to pass through it freely but prevents the passage of the solute (sugar or salt molecules in solution) (Fig. 4.6).

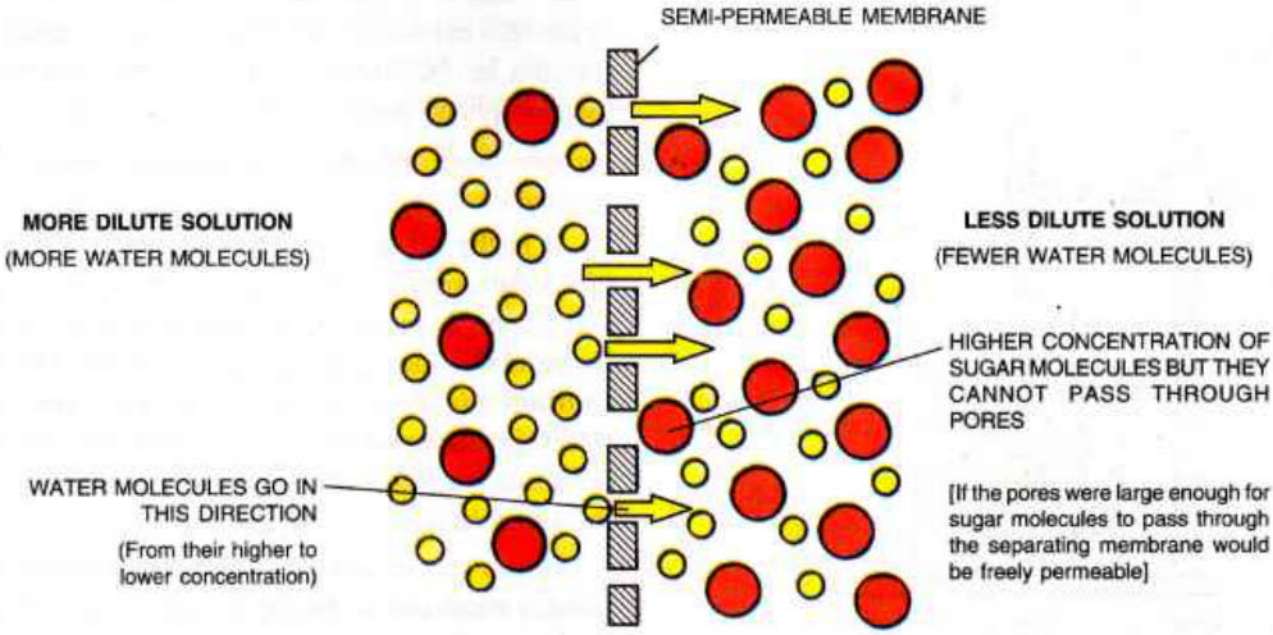


Fig. 4.6 : Schematic representation of osmosis and the nature of a semi-permeable membrane

How long can osmosis continue ?

Theoretically, osmosis should continue until the concentration of water molecules becomes equal (isotonic) on both sides of the membrane. In the experiment shown in Fig. 4.4, the column of sugar solution in the thistle funnel keeps rising upwards with the influx of water from the beaker, and with it, the weight of this column of solution would also increase. Such an increase in the weight of the rising column reduces further osmosis. A stage will be reached when no osmosis occurs even if the concentration of water molecules is not the same on the two sides of the membrane. In this state of equilibrium, the water molecules from the beaker tend to force upwards through the membrane, but the weight or the pressure from above holds them downwards.

B. OSMOTIC PRESSURE

If in the above experiment (Fig. 4.4), an airtight piston bearing some weight was introduced in the thistle funnel from the very beginning as shown in Fig. 4.7, the level of the solution would not rise at

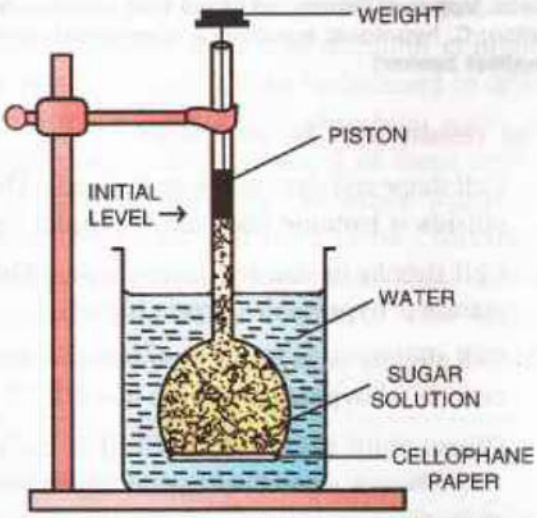


Fig. 4.7 : An experiment to demonstrate osmotic pressure

all, showing thereby that there was no entry of water. Thus, we may define osmotic pressure as:

Osmotic pressure is the minimum pressure that must be exerted to prevent the passage of the pure solvent into the solution when the two are separated by a semi-permeable membrane.

OR, very simply

Osmotic pressure of a solution is a *measure* of its tendency to take in water by osmosis.

In other words, osmotic pressure is equal to the weight or pressure required to nullify osmosis.

TONICITY. Relative concentration of the solutions that determine the direction and extent of diffusion is called tonicity. Based on it, the solution can be of three types : **isotonic, hypotonic** and **hypertonic** solutions.

1. ***Isotonic*** (*iso* : same, *tonus* : tension concentration). The relative concentration of water molecules and the solute on either side of the cell membrane is the same. In such a solution, there is no net movement of water molecules across the cell membrane. **(No osmosis)**

SWELLING UP OF RAISINS & SHRINKING OF GRAPES???

Practically all biology books mention the following:

"If you leave some raisins in water for a few hours, they swell up and if kept for long, they may even burst. In this case, the water continues to diffuse in through the membranous cover of the raisins. This influx of water builds up an internal pressure that may reach a limit, which the outer skin of raisins may no longer bear and they burst. The reverse will happen if grapes are immersed in a very strong sugar solution or even salt solution (25 - 30%). The water from the grapes will be drawn out and they will shrink".

How much is the truth ?

1. Raisins left in water for some time certainly swell up. The condition is reached due to passive absorption (imbibition).
2. The opposite experiment with grapes is doubted. I (the author) have tried it repeatedly and I would urge all biology teachers and students to try it and see if it really works the way we talk and teach about it. In my trials, fresh ripe grapes were kept in a fully saturated sugar solution for almost a week and nothing happened to the grapes! They did not shrink even a bit. How do we explain this ? In all probability, the outer skin of those grapes must have been impermeable.

Science is in doing things to investigate, and certainly so in such simple cases as the above experiment with grapes.

An enthusiastic student Wasiya Fargana of St. Mary Public School, Bangalore, repeated this experiment and got the same result – no shrinking (no exosmosis). However, *when the grapes were kept in saturated common salt solution for about a week, they shrank a little bit with the peel turning brownish as well as somewhat wrinkled suggesting some exosmosis.* The exact explanation is not available – perhaps strong salt somehow degraded the peel cells (cuticle) to permit some exosmosis. But this is just a hypothesis – the exact reason may be different.

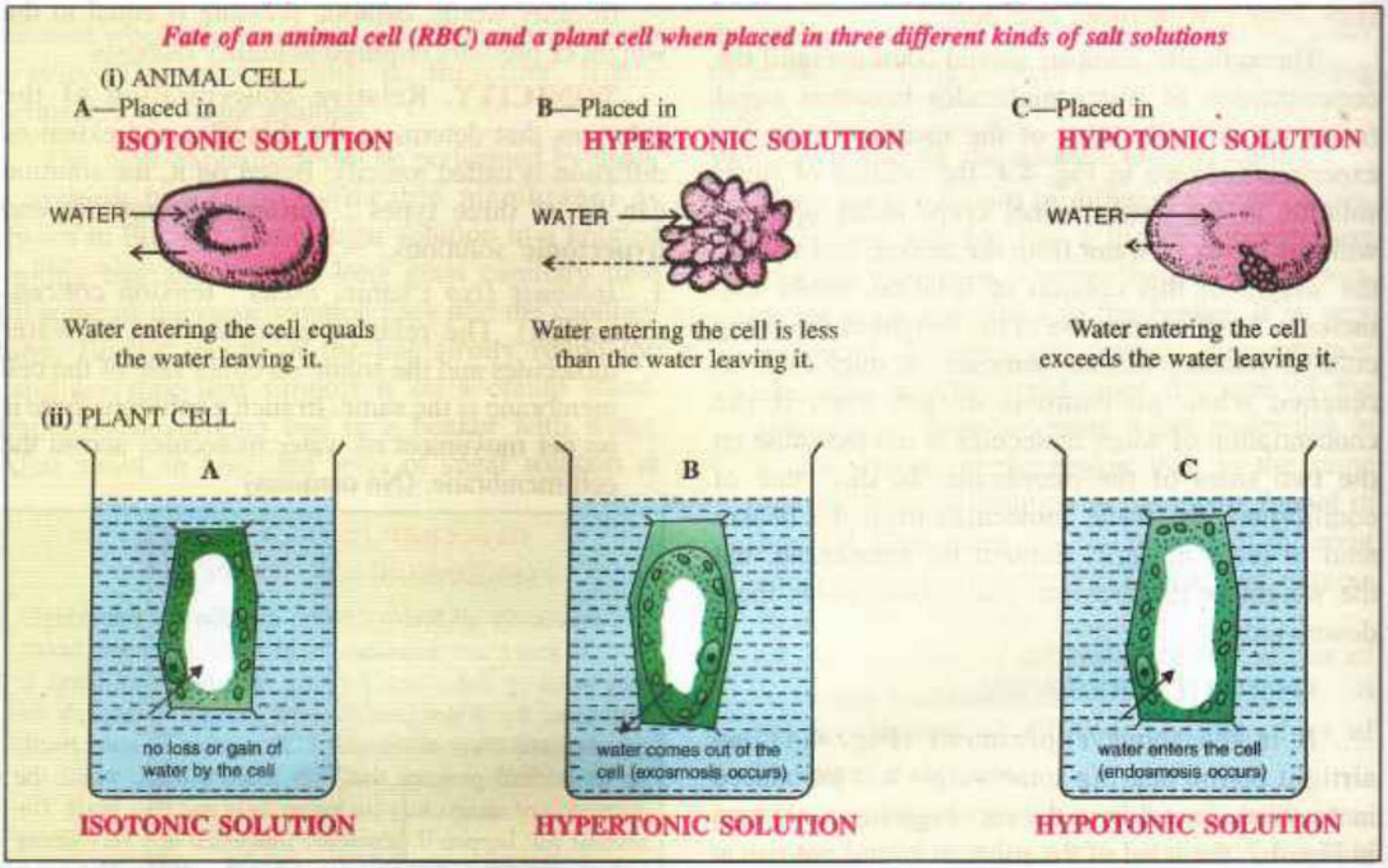


Fig. 4.8 : Salt solutions of different concentrations in relation to cells. Upper — human red blood cell; Lower — a plant cell. These were placed in — A. isotonic solution; B. hypertonic solution; C. hypotonic solution (A conceptual representation only; even the largest plant cell cannot match the size of the smallest beaker)

2. ***Hypotonic*** (*hypo* : lower). In this condition, the solution outside the cell has a lower solute concentration than the fluids inside the cell. As a result, the water molecules from outside will move into the cell **(endosmosis)**.
3. ***Hypertonic*** (*hyper* : higher). In this condition, the solution outside the cell has a higher solute concentration than the fluids inside the cell. Consequently, the water molecules from the interior of the cell will move out **(exosmosis)**.

[The three terms **isotonic**, **hypotonic** and **hypertonic** are also expressed as **isoosmotic, hypoosmotic** and **hyperosmotic** emphasising the numerical basis of total moles of solute per kilogram of water.]

To understand the above three conditions, we may suppose that (i) a red blood cell and (ii) a plant cell have been placed in three different kinds of solutions as shown in Fig. 4.8.

The results may be as follows :

A. Cell shape and size remain unchanged – The solution outside is **isotonic** (**iso:** similar, **tonic:** strength).

B. Cell shrinks in size and loses shape – The solution outside is **hypertonic** (**hyper:** higher).

C. Cell slightly enlarges or even bursts – The solution outside is **hypotonic** (**hypo:** lower).

[When fully distended, the cell is called turgid, *i.e.*, when it cannot withstand any further inflow of water molecules].

In the case of plant cells, another striking feature determines the behaviour of the cell when subjected to varying external fluid environments. This feature is the **rigidity of the cell wall** which resists bulging and protects the delicate cellular parts inside. The phenomena related to this behaviour are the **turgidity, plasmolysis** and **flaccidity** (described later in section 4.4.5 page 41).

Table 4.1 : Differences between diffusion and osmosis

DIFFUSION	OSMOSIS
1. **Liquids** and **gases** can diffuse over **considerable distances**	**Water** only transported over a short distance
2. Movement of the molecules of **solute** or **solvent**	Movement of the molecules of **only water** as a solvent
3. **Rapid in gases**, but slow in solutions	**Slow** process
4. Transport from **high** to **low** concentration along a **gradient**	Transport of **water** from a solution of low concentration (more water molecules) to that of a **high** concentration (fewer water molecules)
5. Occurs with or without a non-living **permeable** membrane	Either a living or non-living **semi-permeable** membrane needed
Definitions ***Diffusion*** is the transport of **gases** or **dissolved substances** in solution from a region of high concentration to a region of low concentration when the two are in direct contact.	***Osmosis*** is the transport of **water** through a semi-permeable membrane from a solution of low concentration to a solution of high concentration

4.4.4 Active Transport

Active transport is the passage of a substance (salt or ion) from its lower to higher concentration (opposite to what happens in diffusion), using energy from the cell, through a living cell membrane. [Active transport is in a direction opposite to that of diffusion.]

Certain nutrients such as ions of nitrates, sulphates, potassium, zinc, manganese, etc. **cannot pass through the cell membrane of the root cells easily**. This is because their concentration is higher inside the root cells, and it is so maintained in order to develop osmotic pressure for absorbing water. In this way, the concentration gradient of these ions is opposite to that of diffusion. In other words, to obtain them, these ions will have to be **"forcibly"** carried inward from the region of their lower concentration outside to the region of their higher concentration inside, and this requires energy supplied by the cell in the form of ATP.

PASSIVE TRANSPORT

Passive transport is nothing different from diffusion but just explaining its meaning. "Passive" refers to requiring no input of energy. There is a free movement of molecules from their higher concentration to their lower concentration.

? ***PROGRESS CHECK***

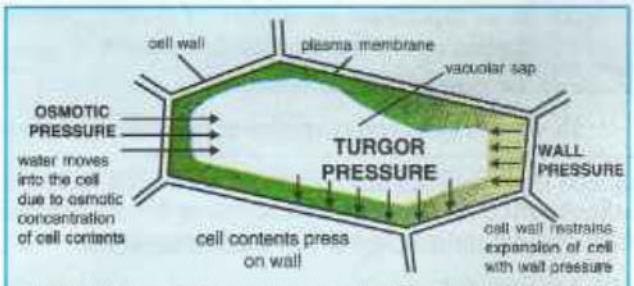
1. Tick-mark the correct statements :
   (i) Diffusion is the movement of molecules from a region of their lower concentration to that of a higher one. ☐
   (ii) Osmosis includes diffusion, but not vice-versa. ☐
   (iii) Osmosis is unidirectional. ☐
   (iv) Exosmosis may cause bursting of a cell. ☐
   (v) Semi-permeable membrane prevents the passage of the solute molecules. ☐
   (vi) In an experiment on osmosis, if external pressure is applied on a dilute solution, less water will pass into the concentrated solution. ☐
2. In what way is active transport opposite to diffusion?
   .....
3. A cell kept in a certain solution bursts after some time. Comment upon the kind of solution.
   .....
   .....
4. Which process– diffusion, osmosis or active transport, needs involvement of energy ?
   .....
   .....
5. Can we call diffusion passive transport ? If so, how?
   .....
   .....

4.4.5 Turgidity and Flaccidity (Plasmolysis)

Every living plant cell, 'directly or indirectly' is in contact with fluids. The root- hairs, in particular, are surrounded by soil water. All such cells are subjected to osmosis and the water continues to enter as long as the cell sap is more concentrated than the surrounding fluids.

– When a cell reaches a state where it cannot accommodate any more water, *i.e.*, it is fully distended, it is called **turgid** and the condition is called **turgidity**.

- When a cell is turgid, its wall is stretched under pressure from inside, and in its turn, it presses the cell contents towards the centre of the cell. *The pressure of the cell contents on the cell wall is called* **turgor pressure** and the pressure exerted by the cell wall on the cell content is called **wall pressure**.
- If, at any time, the cell wall is unable to bear the turgor pressure, it ruptures and the cell contents burst out. This is exactly what happens when fruits and vegetables sometimes burst.
- **When turgid, the cell is in a somewhat balanced state** — no more water is entering or leaving it. Its turgor pressure counter-balances the wall pressure and, therefore, there is no further absorption of water even though the concentration of solutes inside the cell may be greater than that outside the cell.



A plant cell showing osmotic pressure, turgor pressure and wall pressure represented together

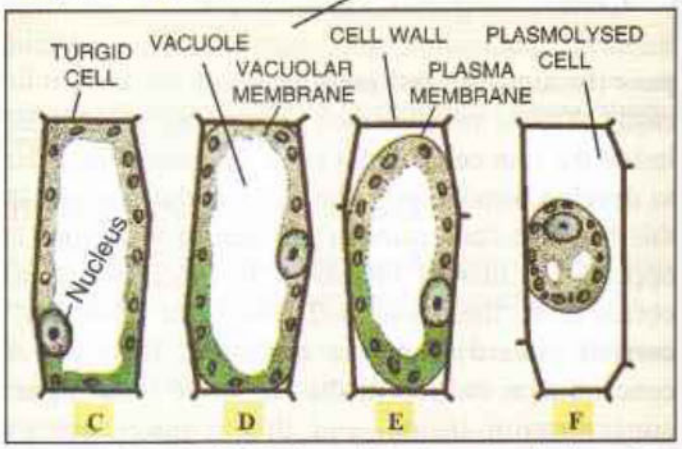
Plasmolysis and Flaccidity : When a living cell, such as the cell of a leaf of an aquatic plant, is placed in fresh water, it remains in a fully distended condition. Its plasma membrane remains in close contact with the cell wall and presses against it (Fig 4.9 A & C) just like a rubber bladder of a football pushes against the leather casing. If this plant cell is now kept in 5% salt solution for a few minutes, it will lose its distended appearance, the cytoplasm will shrink and the plasma membrane will withdraw from the cell wall (Fig. 4.9 B & D-F). This shrinkage from the cell wall is called **plasmolysis** and the cells in this state are said to be limp or **flaccid** (the condition is called **flaccidity**). *Flaccidity is the reverse of turgidity*. If, however, a plasmolysed (flaccid) cell is returned to water before it is dead, its protoplasm again swells up pressing tight against the cell wall. The recovery or the reversal of plasmolysis is called **deplasmolysis**. You can easily understand that the plasmolysis is the result of outflow of water from the cell and deplasmolysis is the result of its re-entry.

A – Cells in water, in normal turgid condition

B – After keeping in 5% salt solution for a few minutes, the protoplasm shrinks and the cell becomes flaccid (plasmolysed). If the plasmolysed cell is soon returned to the ordinary water, it regains its original (turgid) condition (deplasmolysed).

Fig. 4.9 : UPPER (A & B) : Plasmolysis of leaf cells in a water plant

LOWER (C - F) : Diagrammatic representation of sequence in plasmolysis



C – a turgid cell, D, E & F – the cell after immersion in a hypertonic solution showing the successive stages in the shrinkage of the protoplasm from the cell wall caused by the withdrawal of water from the vacuole, after immersing the cell in a hypertonic solution.

REMEMBER — THE TERMS DEFINED

Turgidity is the state of a cell in which the cell wall is rigid and stretched by an increase in the volume of vacuoles due to the absorption of water. The cell is then said to be turgid.

Plasmolysis is the contraction of cytoplasm from the cell wall caused due to the withdrawal of water when placed in a strong (hypertonic) solution.

Flaccidity is the condition in which the cell content is shrunken and the cell is no more "tight". The cell is then said to be flaccid.

USES OF TURGIDITY TO PLANTS

1. ***Turgidity provides rigidity to soft tissues such as the leaves.*** When there is not enough water in a leaf, it wilts, *i.e.*, its petiole and lamina become loose and the leaf droops down.

- Wilting of the leaves is usually noticed when a plant is exposed to the hot afternoon sun when the amount of water lost during transpiration is more than the water absorbed through the roots.
- In the evening, when transpiration is reduced, the quantity of water absorbed exceeds the loss of water through transpiration, the turgidity of the leaf cells is restored and the leaves again stand out.

Plasmolysis in practice

Salting of meat or addition of salt to pickles is a method of killing bacteria by plasmolysis - water is drawn out of the bacterial cells.
Weeds can be killed in a playground by sprinkling excessive salts around their base. Excessive application of fertilizers in the agricultural fields may similarly damage the roots and diminish the yield.

2. ***Turgor pressure helps to push through the hard ground*** as in mushrooms and in a seedling (Fig. 4.10). Sometimes, the roots of certain trees have been seen to crack the walls or a concrete floor of an adjoining building. This again is due to turgor pressure.

Fig. 4.10 : A germinating seed develops force to push through the upper layers of the soil

3. ***Turgor in root cells builds up root pressure.*** If you cut a well-watered pot plant (e.g. balsam) a few centimetres above the soil and immediately fix a glass tubing to it by means of a rubber connection, water will start coming out of the cut end of the stem and rise up in the glass tubing. This rising water can raise the mercury filled in a connected manometer (Fig. 4.11). This upward flow of water is due to a heavy pressure from the roots which is called **root pressure**.

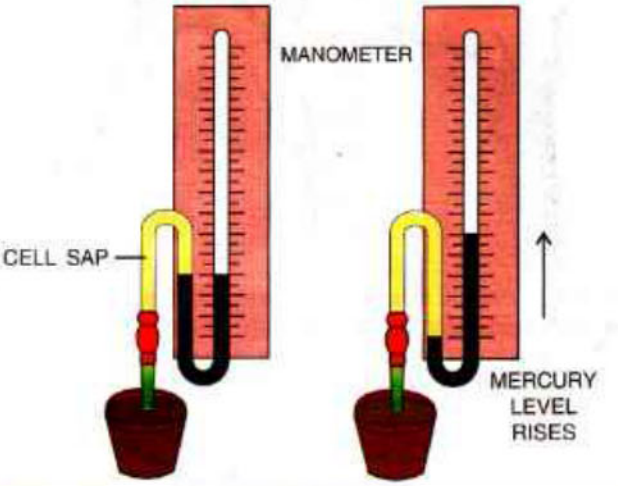


Fig. 4.11 : An experiment to demonstrate root pressure

Root pressure **is the pressure developed in the roots due to continued inward movement of water through cell-to-cell osmosis which helps in the ascent of cell sap upward through the stem.**

Due to root pressure, water (cell sap) can rise in the tube (or in the stem in natural condition) up to a certain height only. Loss of water (cell sap) through a cut stem is called "**bleeding**".

4. ***Turgor in the opening and closing of stomata.*** You have read about stomata in Class IX. Their opening and closing depend on the turgidity of guard cells. Each guard cell has a thicker wall on the side facing the stoma and a thin wall on the opposite side. Guard cells contain chloroplasts (Chapter 6, Fig. 6.2). As a result of the synthesis of glucose during photosynthesis and some other chemical changes, the osmotic pressure of the contents of the guard cells increases and they absorb more water from the neighbouring cells, thus becoming turgid. On account of turgor, the guard cells become more arched outwards and the aperture between them widens, thereby opening the stoma. At night, or when there is shortage of water in the leaf, the guard cells turn flaccid and their inner rigid walls become straight, thus closing the stomatal aperture.

5. ***Turgor Movement.*** The rapid drooping of the leaves of the sensitive plant (*Mimosa pudica*) is an outstanding example of turgor movement. If one of the leaves is touched, even lightly, the leaflets fold up and within 2 to 3 seconds, the entire leaf droops.

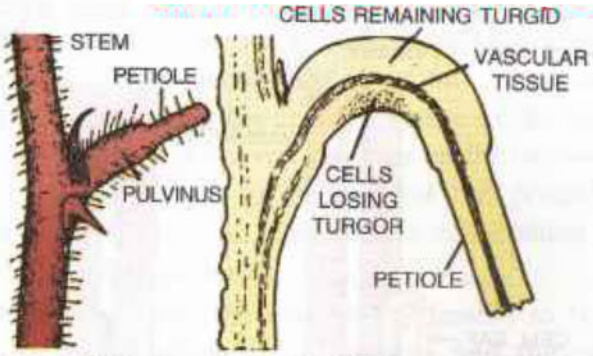


Fig. 4.12 : Petiole of sensitive plant (*Mimosa pudica*) is held up by turgid pulvinus tissue (left). When leaf is touched, cells of the lower side of pulvinus lose water, and the petiole collapses (right)

If the leaf is touched somewhat strongly, the wave of folding and drooping spreads from the stimulated leaf to all neighbouring leaves. Slowly, the leaves recover and again stand erect. In this plant, the stimulus of touch leads to loss of turgor at the base of the leaflets and at the base of the petioles called *pulvinus* (Fig. 4.12). Somewhat similar turgor movements are found in insectivorous plants whose leaves close up to entrap a living prey.

The bending movement of certain flowers towards the sun and the sleep movements of the leaves of certain plants at night are also due to turgor movements.

4.5 ROOT PRESSURE

Root pressure is the pressure developed in the roots due to the inflow of water, brought about due to the alternate turgidity and flaccidity of the cells of the cortex and the root hair cell, which helps in pushing the plant sap upwards.

Experience : If you cut off the shoot of a plant, the water pushes out from the root stump. This is due to root pressure.

Root pressure is built up due to cell-to-cell osmosis in the root tissue (Fig. 4.13 & 4.14). As one turgid cell presses the next cell, the force of the flow of water increases inward. When water reaches the xylem vessels (centrally placed vertical channels), it enters the pores of their thick walls with considerable force. Thus, the root pressure is one of the forces to

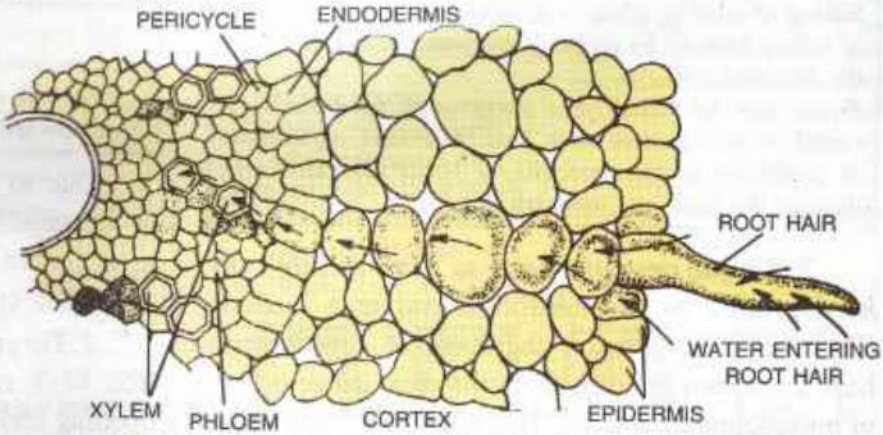


Fig. 4.13 : Diagrammatic cross-section of a part of a root showing by arrows the cell-to-cell conduction of water from a root hair to xylem

IMBIBITION AND TURGOR TOGETHER GENERATE MUCH FORCE

Imbibition is the passive absorption of water by substances such as cellulose (in cell wall) and starch. Turgor is the pressure set up inside the plant cells due to hydrostatic pressure on the cell walls on account of incoming water as a result of endosmosis. The seeds and grains swell up when soaked in water due to imbibition and endosmosis. The force generated by the water thus absorbed is strong enough to make the seed coats burst. Some other observed examples are as follows :

— Soaked seeds when kept in a fully filled closed container burst it open with a great pressure.

— Basement godowns fully stocked with bags containing **foodgrains** have got their walls cracked after the **rain-water** had flooded in.

A "biological" Trick.....

— Some cheats often play a trick. They take a large quantity of gram seeds, place them in a pit a couple of feet below the ground level, mount a "God" or a "Goddess" idol over the heap of grains and then cover up the entire set up by earth to level it with the ground. While one of the tricksters sits by the side of the spot, pretending to worship, the other sends word round the community that a certain "God" is to emerge on this spot in the next "couple of days". And it does "really happen!" The moisture in the ground gets into the seeds which swell up and create a force strong enough to push the earth above and then up and up emerges the "God" as the grains swell more and more. The ignorant faith-holding people are befooled.

raise water up through the stem into the leaves (Fig. 4.14). But this force alone cannot push water up to the top of a tall tree (you will read more about it in section 4.7).

Drops of water along leaf margin due to excessive root pressure (Guttation). In certain plants, like tomato, grass, banana or ferns, the root pressure is high enough to force the water all the way through the stem and comes out through the ends of leaf veins. This water apppears as tiny drops along the margins or the tips of the leaves (next chapter Fig. 5.12), especially in the early mornings. This loss of excessive water is called **guttation**.

? ***PROGRESS CHECK***

1. Name the following :
   (i) The state of a cell when it cannot accommodate any more water. .....
   (ii) Pressure of the cell contents on the cell wall. .....
   (iii) The part of a plant cell which is like the leather casing of a football .....
   (iv) The condition that is opposite to turgid. .....
   (v) The state of a plasmolysed cell after the re-entry of water .....
   (vi) The pressure under which water passes from the living cells of a root into xylem. .....

4.6 IMPORTANCE OF ROOT-HAIRS AND THE UPWARD MOVEMENT OF ABSORBED WATER AND MINERALS

Absorption of water by the root is by means of root-hairs. A root-hair contains cell sap which has a higher concentration of salts as compared to the outside soil water. This difference sets off osmosis and the outside water diffuses into the root-hair. From the cell bearing root-hair, water continues to pass to adjoining cells one after another to finally enter the xylem vessels (Fig. 4.13 & 4.14). The turgidity acquired by the cells in the process also helps to push the water upwards through the xylem vessels.

Absorption of mineral elements from the soil involves active transport by the cells. Minerals may also be absorbed as ions rather than as salts.

The dilute solution of water and mineral salts, absorbed from the soil by the roots, can be used

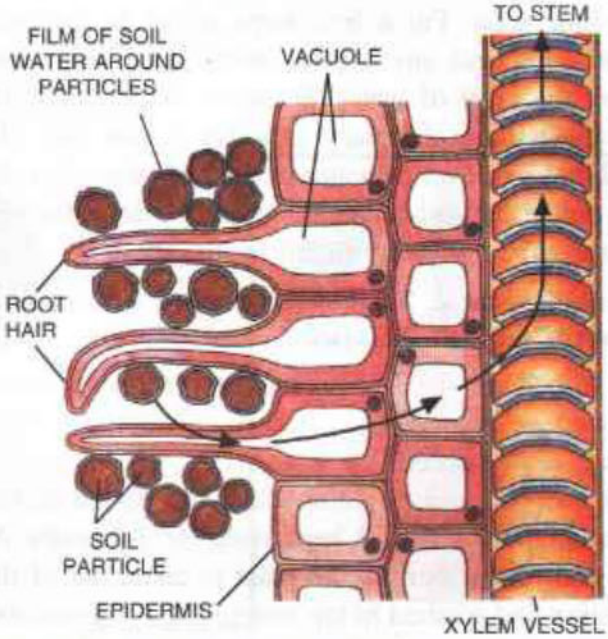


Fig. 4.14 : Root pressure builds up due to osmosis and turgidity of root cells, and up into the xylem vessel.

for food manufacture in the leaves, only if it can travel up to the highest points of the plant. This upward flow occurs through the xylem.

4.7 SOME EXPERIMENTS ON ABSORPTION AND CONDUCTION OF WATER IN THE PLANTS.

Experiment 1. **To show that roots absorb water** (Fig. 4.15).

Take a test-tube (A) filled with water. Pull out a young leafy plant (such as balsam) from the soil with its roots intact. Insert the roots into the

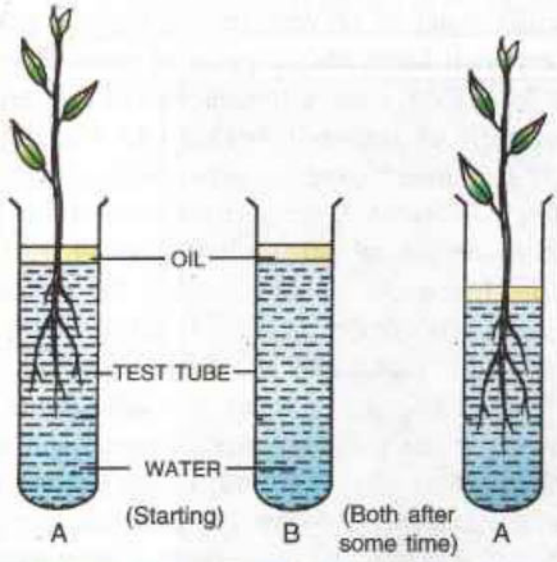


Fig. 4.15 : Experiment to show that the roots absorb water

test-tube soon. Put a few drops of oil in the test-tube to prevent any loss of water by evaporation. Mark the level of water. Set up a similar test-tube (B) but without the plant. In a day or two you will find that the level of water in the test-tube (A) falls but not in the test-tube (B), proving that water lost in test~tube A was absorbed by the roots.

***Experiment 2.* To show that water is conducted upwards through the xylem.**

A medium-sized young balsam plant is uprooted, washed and placed in a beaker containing a stain eosin solution (pink) in water (Fig. 4.16 page 47). The roots should be completely submerged in the solution. This set-up is kept aside for 3-4 hours. At the end of this period, the plant is taken out of the solution and washed in tap water. Then, a transverse section of the roots, stem and leaves is made and examined under a microscope. The xylem vessels will appear distinct from the rest, because these will be stained red by the dye.

Vascular bundles in the stem, root, leaf stalks and leaf veins are all continuous and form an unbroken system of tubes. Collectively, they form the transport system throughout the entire plant. Water and salt travel upwards mainly in the xylem and food substances travel up and down in the phloem.

***Experiment 3.* Conduction of water through xylem** can also be shown by another but delicate experiment (Fig. 4.17 p. 47). Take two leafy shoots such as those of a balsam plant, which have been cut under water to prevent any air bubbles getting in. Keep their lower ends dipping in water. Remove about 3 cm long, outer ring (phloem) of the stem in one of them as shown in beaker (A), keeping the central part intact (ringing experiment also called **girdling**). In the other beaker (B), remove an equal length of the central part (xylem) after incising the stem for full thickness and keeping the peripheral part intact. The shoots are then fixed to stands and are allowed to remain for about two days with their lower ends immersed in water. It will be found that the leaves in the first twig remain turgid and stand out almost normally, but those in the second twig get wilted and droop down. The experiment proves that water is conducted upwards in a plant through the deeper part, *i.e.* xylem.

***Experiment 4.* To show that food from the leaves is conducted downwards through the phloem in the stem.**

Cut a ring round the stem of a healthy potted plant or around a thin twig of guava or any other tree, deep enough to penetrate the phloem and cambium but not the xylem **(girdling)**. It will be seen that sap starts oozing out from the farther cut-margin of the stem showing thereby that sap in the peripheral parts flows in a downward direction. After some weeks, it will be observed that the part of the stem above the ring has grown in diameter (Fig. 4.18 p. 47), and the stem below the girdle has **stopped growing and may even die** when the stored organic contents of the lower part are exhausted. The fresh, healthy condition of the leaves, in this experiment, also proves that the leaves continue to get a supply of water through the deeper located xylem.

? ***PROGRESS CHECK***

1. Look at Fig. 4.15. Why was oil added over water in the test tubes ? .....
2. Look at the experiment shown in Fig. 4.16 on the next page. Why was it necessary to take coloured eosin solution in water in the beaker?
   .....
   .....
3. Which part in the stem, the xylem or the phloem, is located deeper internally ?
   .....
   .....
4. Look at Fig. 4.18 on the next page. Why has the stem below the ring stopped growing and even slightly decayed?
   .....

4.8 FORCES CONTRIBUTING TO ASCENT OF SAP

There are four main forces which contribute to the upward movement (ascent) of sap.

1. **Root pressure** builds up sufficient force to push the sap in the xylem vessels up to a certain height and may be enough for herbaceous plants.
2. **Capillarity** (narrow diameter) of xylem vessels causes the water from a lower level to rise to fill up the vacuum created by the loss of water due

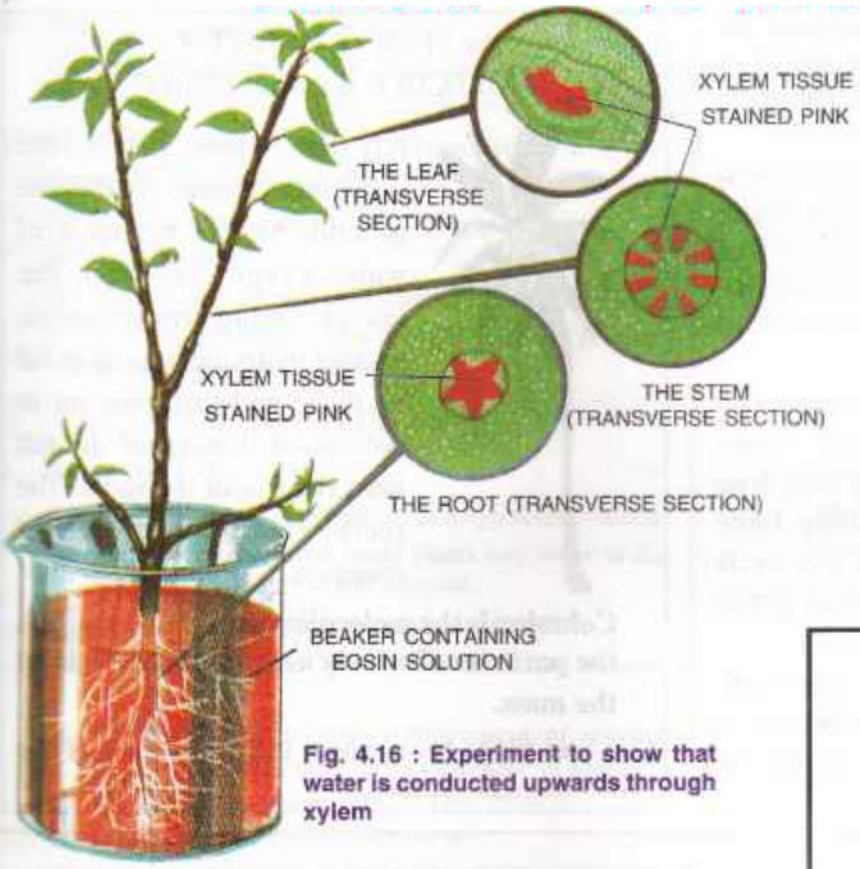


Fig. 4.16 : Experiment to show that water is conducted upwards through xylem

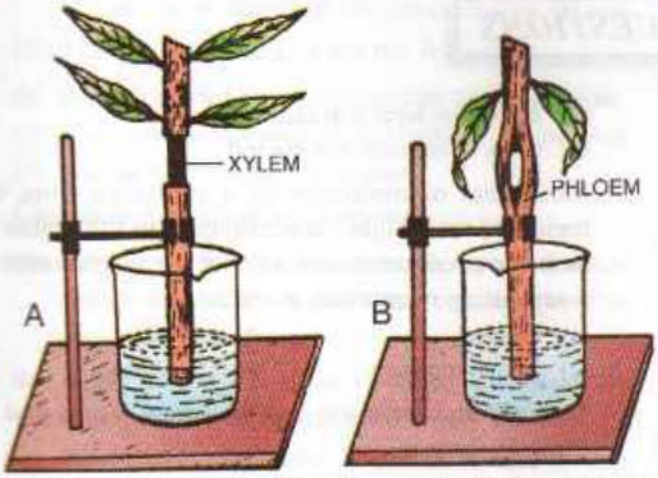


Fig. 4.17 : An experiment to show that water is conducted upwards through xylem
A—A twig with phloem removed and xylem intact,
B—A twig with xylem removed and phloem intact, leaves wilt

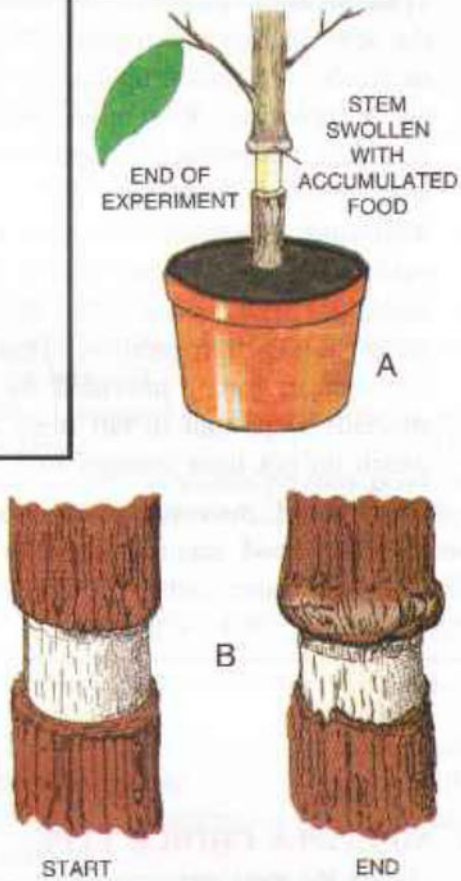


Fig. 4.18 : A — A woody stem was girdled by removing a ring of bark, leaving the xylem intact. A bulge develops above the girdle in a few weeks time. B — Bark compared at the start and at the end of the experiment

GIRDLING OF TREES

One of the numerous such cases that are occurring in the residential areas of several towns. But, here, one environment lover is looking after somehow to prevent the "death" of this peepal tree growing close to a four-storey house, whose occupant wanted to kill it by **girdling**.

to transpiration from the leaves. Narrower the diameter of a tube, greater will be the height of water rising in it exerting a force called **capillary force**.

3. **Transpiration pull**. As the water is lost from the leaf surface by transpiration, more water molecules are pulled up due to the tendency of water molecules to remain joined (**cohesion**), and thus to produce a continuous column of water through the stem.
4. **Adhesion**. It causes the water to stick to the surface of cells thus drawing more water molecules from below when the leaf cells lose water during transpiration. This pulling force (or suction force) provided by the leaves is specially important in tall trees, such as pines, which do not have enough root pressure.

Downward movement of sap is relatively simple. The food manufactured in the leaves is dissolved in water and it flows down mainly on account of the force of gravity.

WATER - UP AND UP
MOLECULE BY MOLECULE

All the water inside the coconuts comes from the ground. As one molecule of water evaporates from the leaves during transpiration, another molecule rises up to fill its place and this goes on in succession throughout the tall stem right from the roots. The secret lies in the force of cohesion.

Cohesion is the molecular attraction by which the particles of a body are united throughout the mass.

Can you guess from where the sweet taste of the "coconut milk" comes?

REVIEW QUESTIONS

A. MULTIPLE CHOICE TYPE

(Select the most appropriate option in each case)

1. Absorption of water by the plant cells by surface attraction is called :
   (a) Diffusion (b) Osmosis
   (c) Imbibition (d) Endosmosis
2. A plant cell placed in a certain solution got plasmolysed. What was the kind of solution ?
   (a) Isotonic sugar solution (b) Hypotonic salt solution
   (c) Hypertonic salt solution (d) Isotonic salt solution
3. The state of a cell in which the cell wall is rigid and stretched by the increase in volume due to the absorption of water is called
   (a) Flaccidity (b) Turgidity
   (c) Capillarity (d) Tonicity
4. Which one of the following is a characteristic NOT related with the suitability of the roots for absorbing water?
   (a) Tremendous surface area
   (b) Contain cell sap at a higher concentration than the surrounding soil water
   (c) Root hairs have thin cell walls
   (d) Grow downward into the soil
5. Movement of molecules of a substance from the region of their higher concentration to the region of their lower concentration without the involvement of a separating membrane, is called
   (a) Osmosis (b) Diffusion
   (c) Active transport (d) Capillarity
6. Osmosis and diffusion are the same except that in osmosis there is
   (a) a freely permeable membrane
   (b) a cell wall in between
   (c) a selectively permeable membrane in between
   (d) an endless inflow of water into a cell
7. The highest water potential (capacity to move out to higher concentrated solution) is that of
   (a) Pure water (b) 10% salt solution
   (c) Honey (d) 50% sugar solution
8. The space between the cell wall and plasma membrane in a plasmolysed cell is filled with
   (a) isotonic solution (b) hypotonic solution
   (c) hypertonic solution (d) water

9. What is responsible for guttation?
   (a) Osmotic pressure (b) Root pressure
   (c) Suction pressure (d) Capillarity

10. The most appropriate characteristic of a semi-permeable membrane is that
   (a) it has minute pores.
   (b) it has no pores.
   (c) it allows the solute to pass through but not the solvent.
   (d) it allows a solvent to pass through freely but prevents the passage of the solute.

B. VERY SHORT ANSWER TYPE

1. **Name** the following :
   (a) The **condition** of a cell placed in a hypotonic solution.
   (b) The **process** by which intact plants lose water in the form of droplets from leaf margins.
   (c) The **process** by which water enters root hairs.
   (d) The **tissue** concerned with upward conduction of water in plants.
   (e) The **term** for the inward movement of solvent molecules through the plasma membrane of a cell.
   (f) The **process** by which molecules distribute themselves evenly within the space they occupy.
   (g) The **pressure** which is responsible for the movement of water molecules across the cortical cells of the root.

2. **Give** the equivalent terms for the following :
   (a) Pressure exerted by the cell contents on the cell wall.
   (b) The condition in which the cell contents are shrunken.
   (c) Loss of water through a cut stem.

3. **Complete** the following statements :
   (a) Hypotonic solution is one in which the solution kept outside the cell has lower solute concentration than ..... the cell.
   (b) Active transport is one in which the ions outside the roots move in with expenditure of energy .....
   (c) The bending movements of certain flowers towards the sun and the sleep movements of certain plants at night are examples of ..... .

4. **Fill in the blanks** by choosing the correct alternative from those given in brackets.
   (a) When placed in a more concentrated solution, the cell contents will ..... **(shrink / swell up)**
   (b) The pressure by which the ..... molecules tend to cross the semi-permeable membrane is called osmotic pressure. **(salt / water)**
   (c) Active transport is in a direction ..... to that of diffusion. **(opposite / same)**

5. **Match** the items in column I with those in column II

Column I	Column II
(a) Xylem	(i) semi-permeable
(b) Phloem	(ii) permeable
(c) Cell membrane	(iii) downward flow of sap
(d) Root pressure	(iv) upward flow of water
(e) Cell wall	(v) guttation

C. SHORT ANSWER TYPE

1. **Differentiate** between the following :
   (a) Plasmolysis and deplasmolysis
   (b) Turgor pressure and wall pressure
   (c) Guttation and bleeding
   (d) Turgidity and Flaccidity

2. (a) **Mention** whether the following statements are **true** (T) or **false** (F).
   (i) A plant cell placed in hypotonic solution gets plasmolysed. (T/F)
   (ii) Addition of salt to pickles prevents growth of bacteria because they turn turgid. (T/F)
   (iii) Cells that have lost their water content are said to be deplasmolysed. (T/F)
   (iv) Xylem is the water conducting tissue in plants. (T/F)
   (v) The shrinkage of protoplasm, when a cell is kept in hypotonic solution. (T/F)
   (vi) The cell wall of the root cell is a differentially permeable membrane. (T/F)
   (b) **Correct** the false statements by altering the **last word** only.

3. **What** is the difference between 'flaccid' and 'turgid"? Give one example of flaccid condition in plants.

4. **Give reasons** for the following :
   (a) If you sprinkle some common salt on grass growing on a lawn, it is killed at that spot.
   (b) If you uproot a plant from the soil, its leaves soon wilt.
   (c) It is better to transplant seedlings in a flower-bed in the evening and not in the morning.
   (d) A plant cell when kept in a hypertonic salt solution for about 30 minutes turns flaccid.
   (e) Potato cubes when placed in water become firm and increase in size.

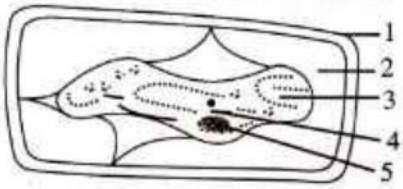
5. **Mention** whether the following statements are ***true*** **(T)** or ***false*** **(F)** and give **explanation** in support of your answer.
   (a) Plasmolysis is reverse of deplasmolysis. (T/F)
   (b) Guttation is another name for bleeding in plants. (T/F)
   (c) Soaked seeds burst their seed coats. (T/F)
   (d) If the phloem of a twig is removed keeping the xylem intact, the leaves of a twig wilt. (T/F)
   (e) Guttation in plants occurs maximum at mid-day. (T/F)
   (f) Dry seeds when submerged in water swell up due to endosmosis. (T/F)

D. LONG ANSWER TYPE

1. **Give** two examples of turgor movements in plants.
2. **Explain** the mechanism of closing and opening of the stomata.
3. Concentration of mineral nutrient elements is higher inside the root-hairs than in the surrounding soil. **How** do roots take them in from the soil ?
4. **Explain** how soaked seeds swell up and burst their seed coats.
5. Leaves of the sensitive plant wilt and droop down on a slight touch. **What** mechanism brings about this change ?
6. **What** is transpiration pull ? **How** is it caused ?

E. STRUCTURED/APPLICATION/SKILL TYPE

1. The following diagram represents a plant cell after being placed in a strong sugar solution.

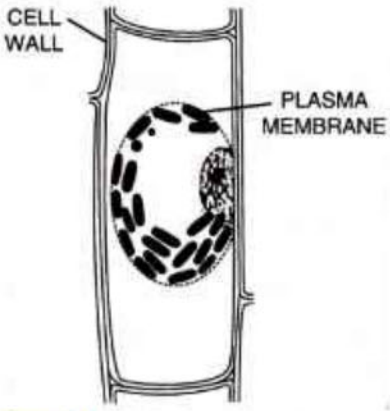


Guidelines 1 to 5 indicate the following :

(1) Cell Wall, (2) Strong Sugar Solution,
(3) Protoplasm, (4) Large vacuole,
(5) Nucleus

(a) **What** is the state of the cell shown in the diagram?
(b) **Name** the structure which acts as a selectively permeable membrane.
(c) If the cell had been placed in distilled water instead of strong sugar solution, **which** feature would not have been seen?
(d) **Name** any one feature of this plant cell which is not present in an animal cell.

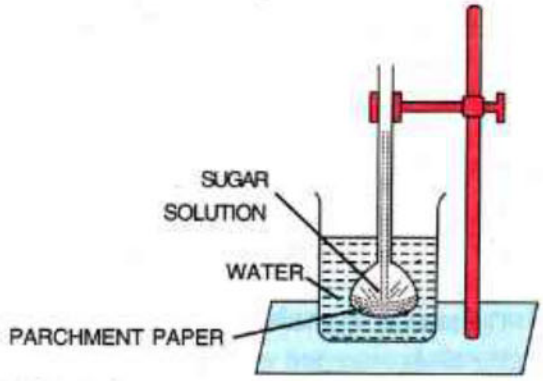
2. A leaf cell of a water plant was placed in a liquid other than pond water. After sometime, it assumed a shape as shown below :



(a) Give the term for the state of the cell it has acquired.
(b) **Comment** on the nature (tonicity) of the liquid surrounding the cell.
(c) **Redraw** in the space provided, the diagram of the cell if it is soon placed in ordinary water for some time.

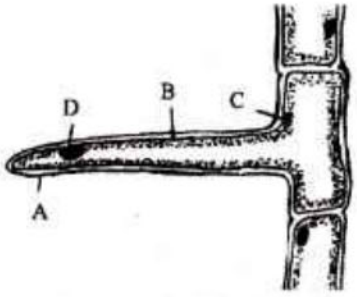
3. The diagram given below represents an experimental set-up to demonstrate a certain process. **Study** the same and **answer** the questions that follow :

p.50



(a) **Name** the process.
(b) **Define** the above-named process.
(c) **What** would you observe in the experimental set-up after an hour or so?
(d) **What** control experiment can be set up for comparison?
(e) Keeping in mind the root-hair, cell and its surroundings, **name** the parts that correspond to (1) concentrated sugar solution (2) parchment paper and (3) water in the beaker.
(f) **Name** any other substance that can be used instead of parchment paper in the above experiment.
(g) **Mention** two advantages of the process to the plants.

4. The diagram below represents a layer of epidermal cells showing a fully grown root hair. Study the diagram and answer the questions that follow:



(a) **Name** the parts labelled A, B, C and D.
(b) The root hair cell is in a turgid state. **Name** and **explain** the process that caused this state.
(c) **Mention** one distinct difference between the parts labelled A and B.
(d) **Draw** a diagram of the above root hair cell as it would appear when a concentrated solution of fertilizers is added near it.

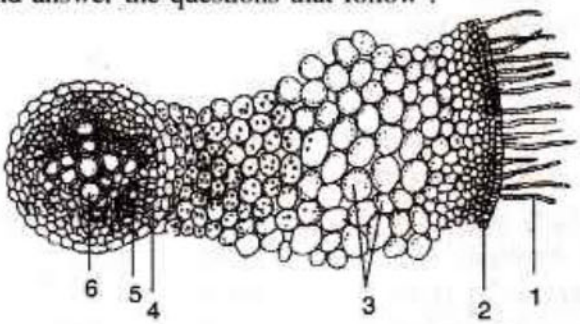
5. Two potato cubes each 1 cm^3 in size, were placed separately in two containers (A & B), the container (A) having water and the other (B) containing concentrated sugar solution. After 24 hours when the cubes were examined, those placed in water were found to be firm and had increased slightly in size and those placed in concentrated sugar solution were found to be soft and had somewhat decreased in size. Use the above information to answer the questions that follow :

(a) **Account for** the firmness and increase in the size of the potato cubes placed in water.

(b) **Account for** the softness and decrease in size of the potato cubes which were placed in sugar solution.

(c) **Name** and **define** the physical process being investigated in this experiment.

6. Given below is the diagrammatic representation of the transverse section of a part of a plant. Study it and answer the questions that follow :

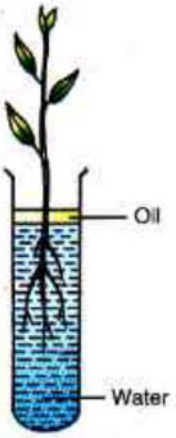


(a) **Name** the part of the plant that is shown.

(b) **Label** the parts 1 to 6.

(c) **Write** the functions of parts 3 and 5.

7. Study the diagram given below and answer the questions that follow:



(a) **Name** the process being studied in the above experiment.

(b) **Explain** the process mentioned in (a) above.

(c) **Why** is oil placed over water?

(d) **What** do we observe with regard to the level of water when this set up is placed in (1) bright sunlight (2) humid conditions (3) windy day?

(e) **Mention** any three adaptations found in plants to foster the process mentioned in (a) above.

8. **Show** by a series of diagrams, the change which a plant cell will undergo when placed in

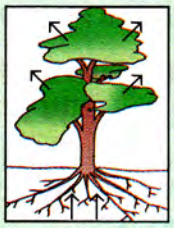
(a) Hypertonic salt solution and

(b) Hypotonic salt solution.

5 Transpiration

Syllabus : *Transpiration, process and significance; experimental work includes the loss in weight of a potted plant or a leafy shoot in a test tube, the use of cobalt chloride paper. Ganong's potometer and its limitations. The effect of external conditions on the rate of water loss should be stressed.*

Scope of syllabus : Mechanism of stomatal transpiration must be explained so that concept of the process is clear. Adaptations in plants to reduce transpiration to be discussed. A brief idea of guttation and bleeding should be given.



Transpiration is a very useful process for plants for two reasons : ***one***, creating suction force in the stem to enable the roots to absorb water and mineral nutrients, and ***two***, for cooling the plant in hot weather. The process is demonstrated and studied by a number of experiments, which are very interesting to perform.

5.1 TRANSPIRATION

Transpiration is the evaporative loss of water from the aerial parts (leaves and stem) of the plant.

OR

Transpiration is the loss of water in the form of water vapour from the leaves and aerial parts of the plant.

All plants continuously absorb water through their roots. This water is conducted upwards through the stem and is distributed to all the aerial parts including the leaves. Only a small quantity of this water (about 2%) is used by the plant in photosynthesis and other activities. The rest of it is almost lost to the atmosphere as water vapour during transpiration.

5.2 DEMONSTRATION OF TRANSPIRATION

Experiment 1. Take a medium-sized well-watered potted plant. Cover the plant with a transparent polythene bag and tie its mouth around the base of the stem (Fig. 5.1). Leave the plant in **sunlight** for an hour or two. Drops of water will soon appear on the inner side of the bag due to the saturation of water vapour given out by the leaves ***(the water vapours condense only if the outside temperature is cool enough)***. A similar empty polythene bag with its mouth tied and kept in sunlight will show no drops of water. This is a control to show that plants transpire water in the form of vapour. If tested with dry cobalt chloride paper, the drops will be confirmed as water only if the blue paper turns pink.

Fig. 5.1 : An experiment to demonstrate the release of water vapour (transpiration) from a plant, by enclosing the plant in a polythene bag.

Experiment 2 : (Fig. 5.2). Arrange three set-ups A, B and C as follows :

Set-up A. Take a small well-watered potted plant, preferably one with broad leaves. Enclose the pot completely within a polythene bag and tie the mouth of the bag firmly around the base of the stem. This would prevent the escape of water vapour from the pot. Now cover the entire plant under a bell jar as in (A).

Set-up B. Arrange another similar plant and cover it with a bell jar exactly in the same manner as the first one, except that here you also keep a piece of **dry cobalt chloride paper** by the side of the plant inside the bell jar (B). The paper may be pinned to a wooden stick or to a strip of cork sheet.

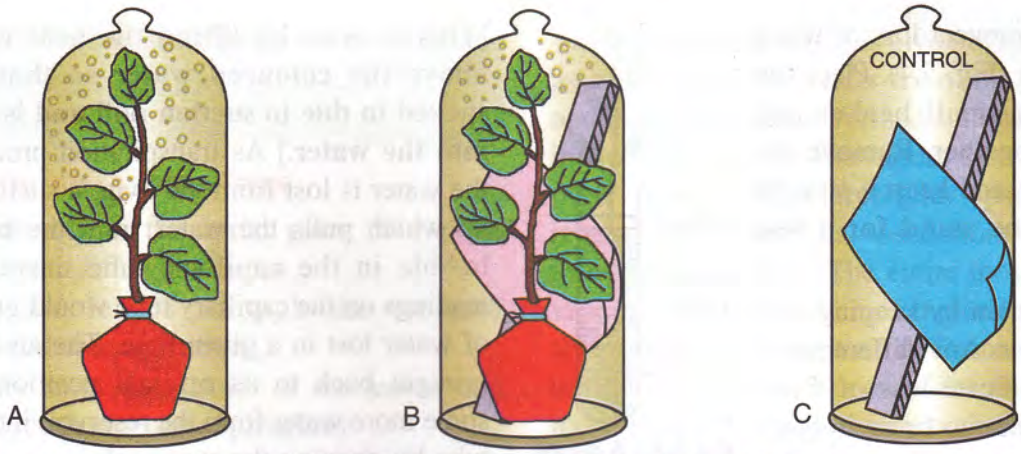


Fig. 5.2 : An experiment to demonstrate transpiration in plants. Firstly, the water droplets appear in bell jars A and B containing plants; secondly, the cobalt chloride paper turns from blue to pink in bell jar B but not in C

Cobalt chloride paper is an indicator of moisture : —	
Blue when dry	**Pink when exposed to moisture**

Set-up C. Take a third bell jar without the plant, but still containing a similar piece of cobalt chloride paper (C). Now, keep all the three bell jars together in the sun.

After about half an hour we observe that,

- The first bell jar (A) would show **water vapour condensing** on its inner walls.
- The second bell jar (B) would also show a similar **condensation** and at the same time, the initially blue cobalt chloride paper in it would **turn pink**.
- The blue colour of the cobalt chloride paper in the third bell jar (C) does not change at all and there are no water drops on the jar's inner walls either.

  The third bell jar in this experiment is a **control** which proves that there was no moisture in the air due to transpiration as there was no plant in it.

By taking the three bell jars as described above, there is a double visual proof of transpiration : (1) condensation of water vapour into droplets and (2) change of colour in cobalt chloride paper. You may simplify the experiment either by taking (B) and (C) only, or by taking the bell jar A and another empty bell jar without the plant or the paper.

5.3 MEASUREMENT OF TRANSPIRATION

There are a number of methods for measuring transpiration. Some of these are:

1. ***Weighing method.*** A small light weight potted plant can be weighed before and after the end of a certain period of time. The soil surface and the pot should be fully covered to prevent evaporation from the surfaces other than the plant. The loss in weight by the plant during that time is due to the loss of water by transpiration.

An improvement in the weighing method can be made by using a glass bottle with a graduated side tube, filled with water and a tube fitted into it as shown in Fig. 5.3A. The water level in the side tube falls to demonstrate loss of water through transpiration from the leaves.

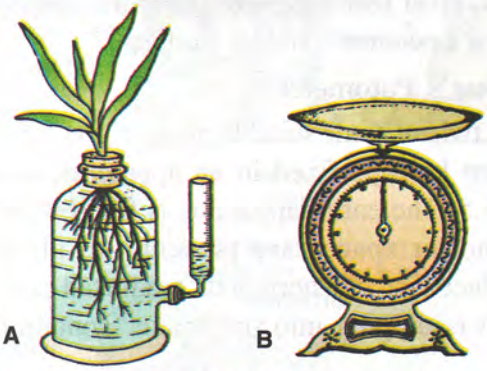


Fig. 5.3 : An experiment to show loss of water by volume as well as by weight

This would indicate the ***volume of water loss*** that can be compared with the loss in weight with the help of a weighing machine (B) or by converting cc into grams (1 cc water weighs 1g).

Another weighing experiment can be made by using a test-tube filled with water and inserting a leafy shoot (no roots) in it and pouring some oil on

the surface to prevent loss of water by evaporation (Fig. 5.4). Place the test-tube in a small beaker and weigh them together. Remove the intact test-tube and keep it straight in the test-tube stand for a few hours.

Weigh it again by keeping it in the same beaker. Any difference in weight will indicate loss of water by the shoot (due to transpiration). Since there are no roots to actively absorb water, the water loss through transpiration will be much less.

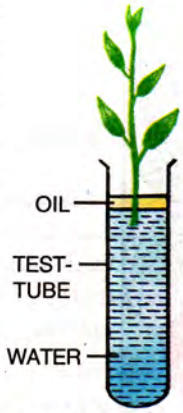


Fig. 5.4 : A shoot inserted in water transpires to show loss in weight

2. ***Potometer method.*** Potometer means a device that measures the rate of **water intake** by a plant (*poton*: drink, *meter* : measure), and this water intake is almost equal to the water lost through transpiration.

Note : Potometer's are of various types designed by various scientists to study and measure the rate of transpiration, namely, Farmer's potometer, and Ganong's potometer. which helps to measure the **rate of water intake by a plant**. Darwins potometer helps to demonstrate the **suction force created** due to transpiration and Garreau's potometer to demonstrate **unequal transpiration from the two surfaces of a dorsiventral leaf**. Given below is the commonly used Ganong's potometer and its working.

Ganong's Potometer :

A twig of some suitable plant (e.g. coleus) cut with a sharp knife is fixed in an apparatus as shown in Fig. 5.5. The entire apparatus is filled with water so that no air spaces are present. An air bubble is introduced into the horizontal graduated capillary tube which is dipping into the beaker containing water.

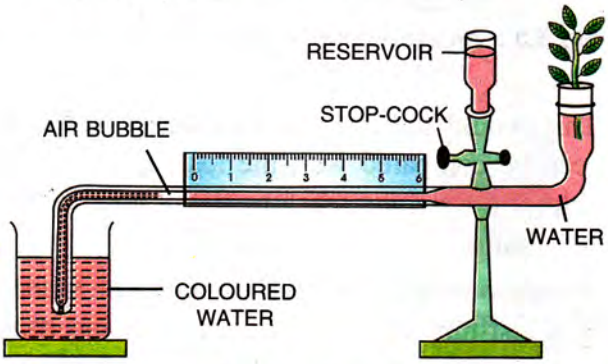


Fig. 5.5 : Ganong's potometer for measuring water uptake

[This is done by lifting the bent capillary tube above the coloured water so that air may be sucked in due to suction pull and is again dipped into the water.] As transpiration proceeds, *i.e.*, as the water is lost from the twig, a suction force is set up which pulls the water from the beaker and the bubble in the capillary tube moves along. The readings on the capillary tube would give the volume of water lost in a given time. The air bubble can be brought back to its original position by releasing some more water from the reservoir into the capillary tube by opening the stop cock.

[Potometers do not measure the water lost during transpiration but measure the water uptake by the cut shoot (L. *potos* : drink). Some of the water is used by the cells to carry out other processes, for example, manufacture of food (Photosynthesis). The potometer should be made completely water-tight and the twig should be cut obliquely (to allow larger surface for the water intake) and under water to avoid suction of an air bubble into the twig which will stop the absorption of water into the xylem.]

Limitations in the use of potometer

(i) Introducing the air bubble is not very easy.

(ii) The twig may not remain fully alive for a long time.

(iii) Any changes in the outside air temperature may affect the position of the air bubble in the capillary tube.

? *PROGRESS CHECK*

1. Transpiration is best defined as (tick-mark the correct option)
   (a) loss of water from the plant.
   (b) loss of water as vapour from the plants.
   (c) evaporation of water from the surface of leaves.
2. In one of the experiments to demonstrate transpiration, we used cobalt chloride paper. What are the characteristics of this paper that suit the experiment?
   .....
   .....
3. Look at the experiment shown in Fig. 5.4. Suppose you took a single flower with a long stalk dipping in water, instead of a leafy twig. Will it serve the purpose?
   Yes / No .....
   Give reason .....
   .....

4. Mention any two limitations in the use of potometers
   (i) .....
   (ii) .....

5.4 KINDS OF TRANSPIRATION

Transpiration from the aerial parts of a plant occurs from three different regions :

(i) From the leaves through the stomata **(stomatal transpiration)**,

(ii) Directly from the surface of the leaves and stems **(cuticular transpiration)**

(iii) From the lenticels which are the minute openings on the surface of old stems **(lenticular transpiration)**.

The major part of the transpiration occurs through the stomata, whereas the other two types of transpiration contribute very litttle.

5.4.1 Mechanism of stomatal transpiration

Stomata are minute openings in the epidermal layer of leaves. A stoma is surrounded by two bean-shaped guard cells (Fig. 6.2 p.65). During day-time, the stomata are wide open primarily for the intake of CO_2 for photosynthesis. The number of stomata may range from 1,000–10,000 per cm^2.

In stomatal transpiration, the water vapour escapes through the stomata of the leaf. Water, after absorption by the roots from the soil, rises up through the stem and reaches the tissues of the leaves through veins. A large number of spongy mesophyll cells in the leaves have their surfaces exposed to the intercellular spaces.

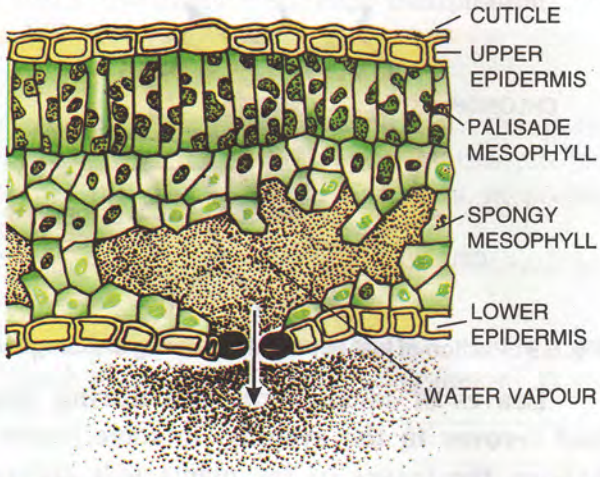


Fig. 5.6 : Vertical section of a part of a leaf showing diffusion of water vapour from its high concentration inside the porous regions of the leaf to the lower concentration in the outside atmosphere through stomata

These surfaces of the cells give out some of the water as a thin film. The water from this film evaporates and the water vapour formed saturates the air in the intercellular spaces. The vapour then diffuses into the other connecting intercellular spaces and finally reaches the sub-stomatal space, from where it escapes through the stomata. The entire movement of water vapour from the surface of the cell into the outside atmosphere is a result of diffusion (Fig. 5.6). The molecules of water vapour, like those of any gas, move from the region of their higher concentration to the region of their lower concentration.

Figure 5.7A shows the movement of water through a leaf. The cell sap in each cell exerts a turgor pressure outward on the cell wall. This pressure forces some water out of the cell wall into the air space between the cells. Here, the water evaporates and the water vapour diffuses through the

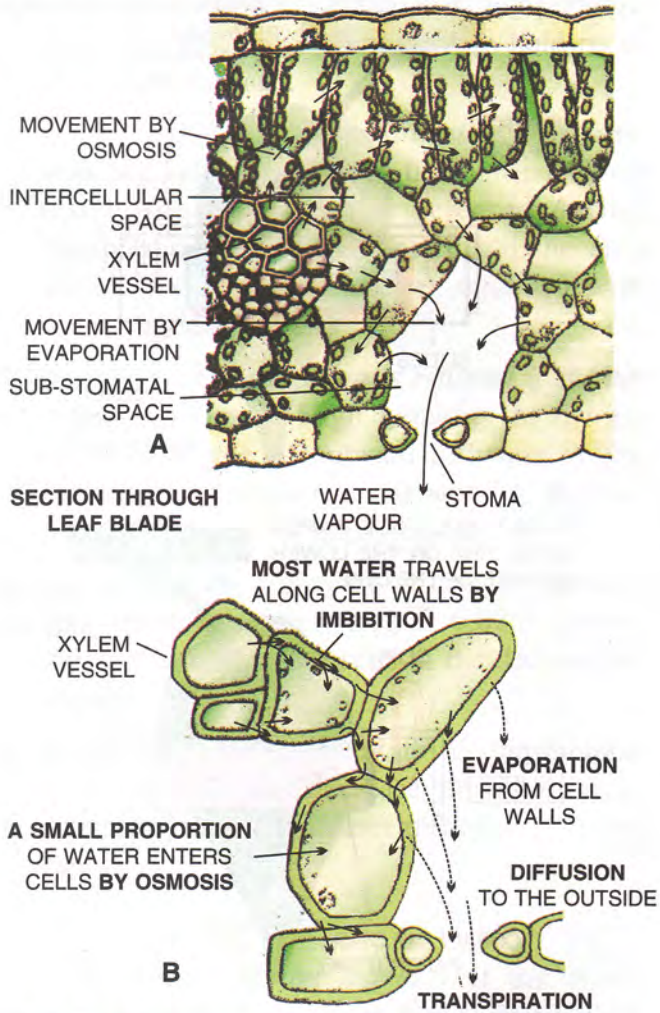


Fig. 5.7 : A–Movement of water through a leaf B–Probable pathway of water through leaf cells

air spaces between the mesophyll cells into the **sub-stomatal space** from where it finally goes out by diffusion through the **stomata**.

The cells that lose water in this way replace it by drawing more of it from the nearest vein. Most of this water travels **along the cell walls** (by **imbibition**) and only a small quantity enters the cell by osmosis (Fig. 5.7B).

Thousands of leaf cells evaporate water in this way, causing more of water to be pulled from below via the xylem vessels. ***The transpiration pull thus created can draw up water to about 50 metres or more in the tall trees.***

More transpiration occurs from the undersurface of a leaf. There are more stomatal openings on the undersurface of a **dicot leaf** and therefore, more transpiration occurs from the undersurface. This can be proved by an experiment in which pieces of **dry cobalt chloride paper** are attached to the two surfaces of a leaf and held in position by two glass slides on either side tied together by elastic bands or held by clips (Fig. 5.8). **The leaf should remain attached to its own plant.** The piece of paper which is facing the upper surface of the leaf either does not turn pink or turns pink in a much longer time than the one on the lower surface which turns pink much faster. This proves that more transpiration takes place from the lower surface, which is on account of the numerous stomata found on it.

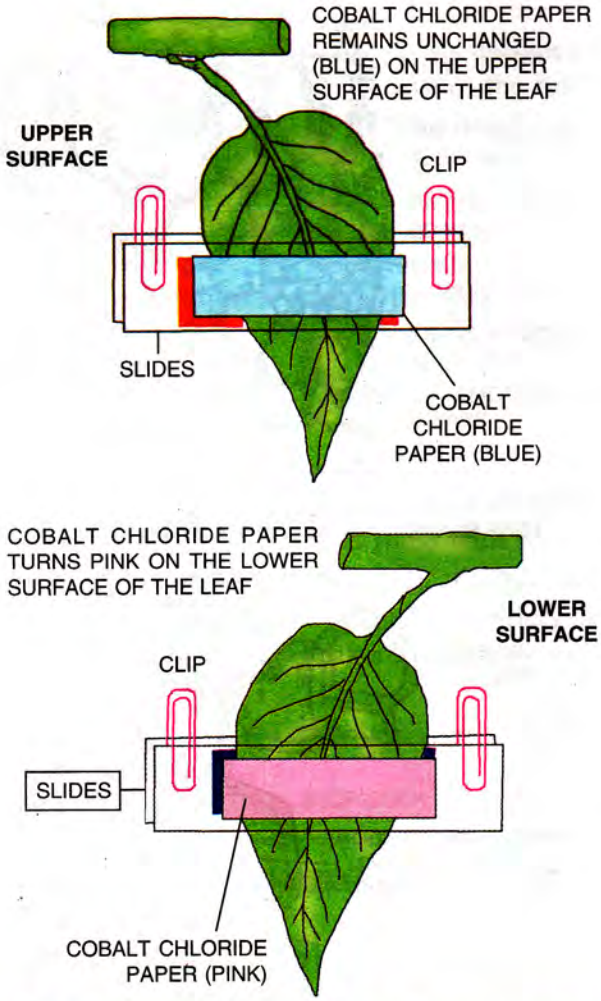


Fig. 5.8 : Result of an experiment to demonstrate the different magnitudes of transpiration from the two surfaces of a dicot leaf

Stomatal regulation of transpiration

Stomata (Fig. 5.9) are minute structures occurring in large numbers on the lower epidermis of a leaf. Transpiration occurs as long as the stomata are open, but it stops when they are closed. The opening and closing mechanism of stomata is regulated by the amount of water and solutes present in the guard cells. As the stomata open during the daytime, the diffusion of gases in and out starts fulfilling the need for photosynthesis as well as allowing transpiration. If for any reason, the water content of the leaf is falling short, the guard cells fail to remain turgid, rather, they turn flaccid (lose turgidity), thereby closing the stomatal opening and transpiration stops. A more detailed account of closing and opening mechanism of the stomata is given in the next chapter under section 6.4.

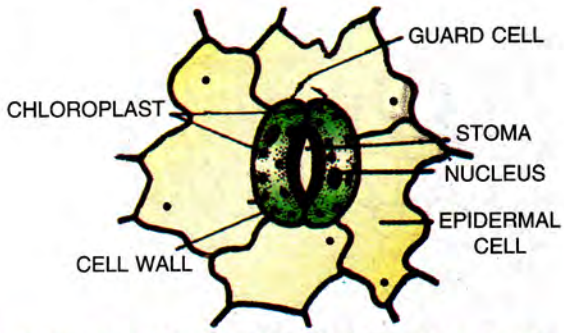


Fig. 5.9 : Portion of leaf epidermis showing one single stoma

Leaves of some plants wilt during midday and recover in the evening. In some plants, e.g. balsam, the leaves of the plants wilt during the midday in spite of the fact that there is plenty of water in the soil. In such cases, the rate of transpiration during midday exceeds the rate of

absorption of water by the roots. The cells, therefore, lose turgidity. In the evening or during the night, the stomata are constricted and the temperature is not high, therefore, there is no loss of water through transpiration and the turgidity of the leaves is re-acquired and they stand out erect.

Stomatal transpiration is controlled by the plant by adjusting the size of the stoma, whereas this does not happen in the case of cuticular and lenticular transpiration.

5.4.2 Cuticular transpiration

Cuticle is a waxy layer secreted by the epidermis on the two surfaces of the leaf. The thickness of the cuticle varies from plant to plant. Primarily, the cuticle serves to prevent evaporation of water from the leaf surfaces. However, some evaporation does occur. ***The greater the thickness of the cuticle, the lesser is the evaporation (transpiration).*** Desert plants tend to have thicker cuticles to cut down transpiration.

5.4.3 Lenticular transpiration

Lenticels are special openings that develop on the older stem in place of stomata. These allow diffusion of gases for respiration as well as for photosynthesis. ***Lenticels never close. They remain open all the time.*** Water from the cell surfaces directly facing the lenticel evaporates and contributes to transpiration.

The amount of transpiration from lenticels is certainly more than the cuticular transpiration, but very much less than the stomatal transpiration.

? ***PROGRESS CHECK***

1. Pick out from the following list, the parts through which the water vapour of transpiration leaves the leaf and rearrange them in proper sequence.
   Xylem vessels, mesophyll cells, stoma, intercellular space and substomatal space.
2. Does diffusion play a role in the passage of water vapour from the leaf during transpiration? If so, how ? .....
   .....
3. In any experiment to demonstrate transpiration, the leaf must remain attached to its parent plant. Why is this so?
4. Out of the three kinds of transpiration, which one is maximum and which one is minimum?
   (i) Maximum .....
   (ii) Minimum .....

5.5 FACTORS WHICH AFFECT TRANSPIRATION

A. EXTERNAL FACTORS

1. ***Intensity of Sunlight :*** During the day, the stomata are open to facilitate the inward diffusion of CO_2 for photosynthesis. At night they are closed. Therefore, ***more transpiration occurs during the day***. When it is cloudy during the day, the stomata are partially closed and transpiration is reduced.
2. ***Temperature :*** If the outside temperature is higher, there is more evaporation from the leaves, therefore, more transpiration. ***Increase in temperature allows more water to evaporate*** and the decrease in temperature reduces evaporation. Warm air can hold more water than cold air.
3. ***Velocity of wind : Transpiration increases with the velocity of wind.*** If the wind blows faster, the water vapour released during transpiration is removed faster and the area outside the leaf does not get saturated with water vapour.
4. ***Humidity : Transpiration is reduced if the air outside is humid.*** High humidity in the air reduces the rate of outward diffusion of the internal water vapour across stomata, thereby reducing the rate of transpiration.
5. ***Carbon dioxide :*** Increase in the CO_2 level in the outside air over normal 0.03% causes stomatal closure and results in the decrease of transpiration.
6. ***Atmospheric pressure :*** Rate of transpiration increases with the decrease in atmospheric pressure. Thus, it enhances diffusion of water vapour.

B. INTERNAL FACTOR

Water content of the leaves : If the water content of the leaves decreases due to insufficient absorption of water by the roots, the leaves wilt

and transpiration is reduced. Such ***reduction in transpiration is indirectly due to the closure of stomata*** and it is a natural mechanism of conserving water within the plant.

Adaptations in plants to reduce excessive transpiration

Many plants and specially those which grow in a dry climate have evolved a variety of permanent adaptations to curtail transpiration. Some of these adaptations are as follows :

1. ***Sunken stomata :*** The stomata may be sunken or covered by hairs (e.g. *Nerium*) (Fig. 5.10).

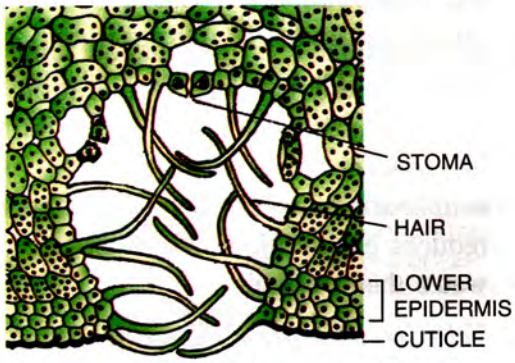


Fig. 5.10 : Sunken stomata covered by hair, in oleander *(Nerium)*

2. ***Fewer stomata :*** The number of stomata may be reduced.
3. ***Narrow leaves :*** The leaves may become narrower to reduce surface area (e.g. *Nerium*).
4. ***Reduced exposed surfaces :*** In some cases, leaves may get wavy, rolled or folded to reduce exposed surface.
5. ***Loss of leaves :*** In some cases, leaves may be dropped or may be absent or changed into spines as in most cacti.
6. ***Thick cuticle :*** The leaves may be covered by thick cuticle, (e.g. Banyan), and most evergreen trees.

? ***PROGRESS CHECK***

1. How will the following conditions affect transpiration ?
   (i) Still air .....
   (ii) Midday high temperature .....
   (iii) Dim sunlight .....
   (iv) Dry air .....
   (v) Insufficient absorption of water by the roots .....
2. List any three adaptations in plants to reduce transpiration.
   (i) .....
   (ii) .....
   (iii) .....

5.6 SIGNIFICANCE OF TRANSPIRATION

Transpiration has great significance for the plants. Its main advantages are: (1) cooling, (2) creating suction force, and (3) distributing water.

1. ***Cooling effect :*** Evaporation reduces temperature of leaf surface. Therefore, transpiration is useful to plants on hot sunny days. (At intense heat, the enzymes are destroyed).
2. ***Suction force :*** Transpiration helps in the ascent of sap by producing a suction force acting from the top of a plant. Evaporation from the leaves concentrates cell sap and increases their osmotic pressure. This draws water from the cells at the lower levels in a sequential manner (ascent of sap) and finally favours absorption of water from the soil by the roots (Fig. 5.11).

   Figure 5.11 also represents **the transpiration stream.** As the water evaporates from the leaves, a suction force is produced at the top

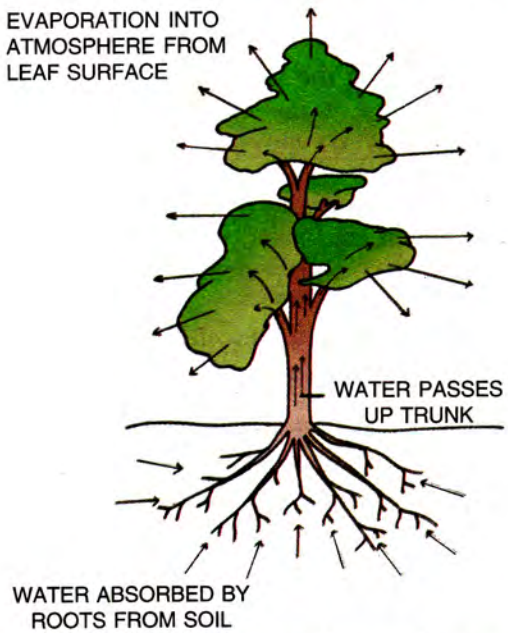


Fig. 5.11 : The transpiration stream

of the plant drawing more water up through the stem and making the roots absorb more of it from the soil.

3. ***Distribution of water and mineral salts:*** Since leaves are present at the tips of all branches and twigs, transpiration from their surfaces tends to draw water towards them and thus helps in the distribution of water throughout the plant body. Higher the rate of transpiration, greater the rate of absorption of water and solutes from the soil.

Is transpiration an **excretory process** in the plants ? ..... No!
It is not appropriate to relate transpiration to excretion or elimination of "excess water". Excretion wherever it occurs, is a deliberate active process carried out by the organism to get rid of unwanted and metabolic waste substances.

Transpiration affects climate

It has been shown experimentally that plants give out large quantities of water during transpiration.

- A full grown single sunflower plant is estimated to lose about **half a litre** of water per day in the form of water vapour.
- A single maize plant loses about **2 litres** of water per day.
- A large apple tree may lose about **30 litres** of water per day.

These figures give an idea of the huge quantities of water released into the atmosphere by vast stretches of fields and particularly forests. **Thus, transpiration increases the moisture in the atmosphere and brings rain.** In this way, transpiration from plants affects climate.

Forests contribute in bringing rain — Transpiration is the secret.

Table 5.1 : Differences between evaporation and transpiration

EVAPORATION	TRANSPIRATION
1. Loss of water from the surface of the water bodies in the form of vapour.	1. Loss of water in the form of vapour from aerial parts of the plant.
2. It is a physical change controlled by the temperature and humidity of the atmosphere.	2. It is a vital and partly a physical process controlled by both internal and external factors.
3. It is a fast process.	3. It is a slow process.

5.7 DIRECT LOSS OF WATER BY PLANTS — GUTTATION AND BLEEDING

Some plants may lose water directly, i.e., in liquid form and not as water vapour. It occurs in two ways — guttation and bleeding.

Guttation (*gutta* : to pour out, to drop) : The leaves of certain plants exhibit droplets of water along their margins in the morning (Fig. 5.12). This particularly happens in plants growing in warm humid conditions. **A humid environment hampers transpiration while the roots continue to absorb water from the soil**. This builds up a big hydrostatic pressure within the plant and "forces out" the excess water directly from the tips of veins in the leaf. Special pore-bearing structures called **hydathodes** are present on the margins of the leaf to allow this exudation. Guttation can be observed

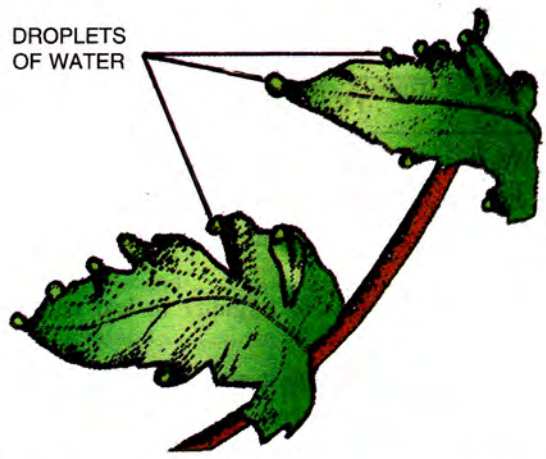


Fig. 5.12 : Leaves of a herbaceous plant showing guttation

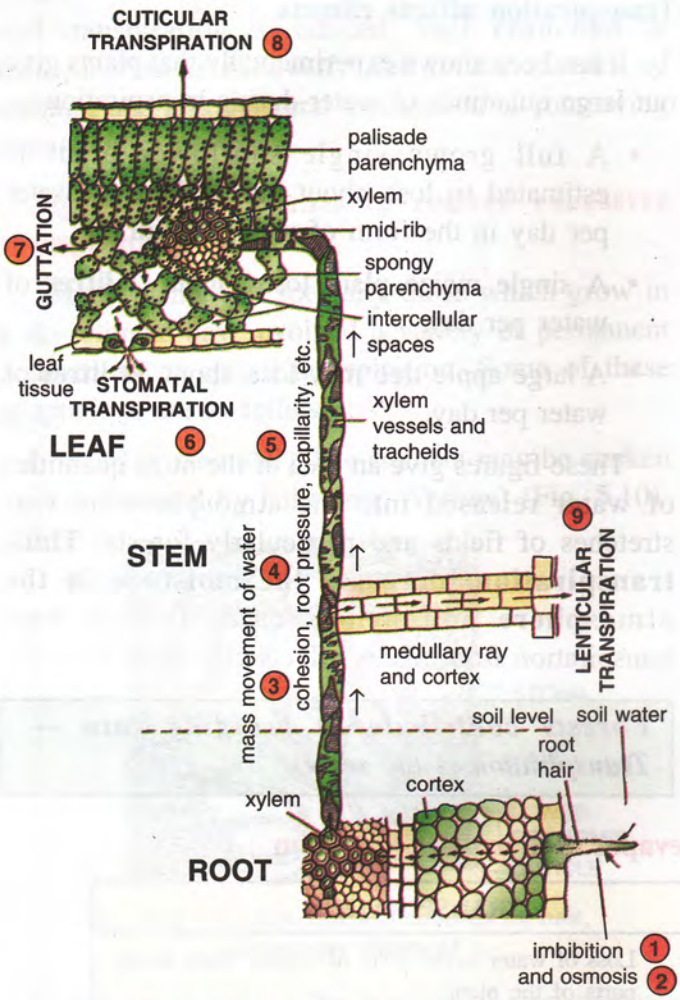


Fig. 5.13 : Diagrammatic representation of the path of water through the plant and the various physical forces which are responsible for the movement within and loss of water outside

in many plants and is quite common in banana, nasturtium and strawberry.

Bleeding : This happens only due to injury. The plant sap escapes ("bleeds") from the ruptured or cut surfaces of a plant. The root pressure generated by a plant assists in bleeding.

Summing up : The Fig. 5.13 schematically represents most of the phenomena (1 to 9) related to the intake and loss of water in a plant (through transpiration, etc.)

? PROGRESS CHECK

1. List any four advantages of transpiration to the plant.
   (i) .....
   (ii) .....
   (iii) .....
   (iv) .....
2. How would you justify the statement that transpiration contributes in bringing rain?
   .....
3. Differentiate between guttation and transpiration.
   .....
   .....
   .....
4. Plants have no blood, yet we sometimes say that a plant is "bleeding". How do you justify this ?
   .....
   .....

Table 5.2 : Differences between transpiration and guttation

TRANSPIRATION	GUTTATION / EXUDATION
1. Water is lost in the form of vapour.	1. Water is lost in the form of water droplets.
2. Pure water only changes into vapour.	2. Water lost contains mineral salts in solution.
3. Water vapour is lost through **stomata**, **lenticels** and cuticle.	3. Water is lost through pores (**hydathodes**) found at the ends of veins.
4. May lead to loss of turgidity in leaf cells to cause wilting.	4. No effect on the turgidity of leaf.
5. Stomatal transpiration is regulated by guard cells.	5. Opening of hydathodes cannot be regulated.
6. It occurs in the presence of sunlight.	6. It occurs at night or early morning.
7. It cools the plant body.	7. No such effect on the plant.
8. Occurs during dry conditions	8. Occurs in humid conditions.

REVIEW QUESTIONS

A. MULTIPLE CHOICE TYPE

(Select the most appropriate option in each case)

1. **Transpiration pull** will be maximum under which set of the following conditions?
   (a) Open stomata, dry atmosphere and moist soil
   (b) Open stomata, high humid atmosphere and well irrigated soil
   (c) Open stomata, high humid atmosphere and dry soil
   (d) Closed stomata, dry atmosphere and dry soil

2. With decrease in atmospheric pressure, the **rate of transpiration** will
   (a) increase (b) decrease rapidly
   (c) decrease slowly (d) remain the same

3. The **rate of transpiration** is more when
   (a) atmosphere is dry
   (b) temperature is high
   (c) humidity is high
   (d) atmosphere is dry and temperature is high

4. One of the **internal factors** which affect the rate of transpiration, is
   (a) big size of the leaf (b) colour of the leaf
   (c) sunken stomata (d) sunny day

5. **Guttation** takes place through
   (a) stomata (b) lenticels
   (c) lower epidermis of leaves (d) hydathodes

6. The loss of water as water vapour from the aerial parts of a plant is known as
   (a) evaporation (b) perspiration
   (c) guttation (d) transpiration

7. Transpiration will be **fastest** when the day is
   (a) cool, humid and windy
   (b) hot, humid and still
   (c) hot, humid and windy
   (d) hot, dry and windy

8. Most of the transpiration in tall trees occurs through
   (a) Stomata (b) Lenticels
   (c) Cuticle (d) Bark

9. Transpiration is **best defined** as
   (a) loss of water by the plant.
   (b) evaporation of water from the aerial surfaces of a plant.
   (c) loss of water, as water vapour, by a plant.
   (d) release of water by a plant into the atmosphere.

B. VERY SHORT ANSWER TYPE

1. **Name the following :**
   (a) **Openings on the stem** through which transpiration occurs.
   (b) The **process** by which the intact plant loses water in the form of droplets.
   (c) An **instrument** used to find the rate of transpiration.
   (d) A **plant** in which the **stomata are sunken**.
   (e) The **apparatus** to record the rate of transpiration in a cut shoot.
   (f) Any two **parts of a leaf** which allow transpiration.
   (g) The **structure in a leaf** that allows guttation.
   (h) **Loss of water as droplets** from the margins of certain leaves.

2. **Fill in the blanks :**
   (a) Transpiration is the loss of water as water ..... from the ..... parts of the plant.
   (b) Closing of ..... and shedding of leaves reduce .....
   (c) Transpiration helps in creating ..... force and in eliminating excess .....

C. SHORT ANSWER TYPE

1. Given below is an example of a certain structure and its special functional activity :

   chloroplasts and photosynthesis.

   In a similar way, **write the functional activity** against each of the following :
   (a) Hydathodes and .....
   (b) Leaf spines and .....
   (c) Lenticels and .....
   (d) Xylem and .....

2. (a) **State** whether the following statements are **True** (T) or **False** (F) ?
   (i) Most transpiration occurs at midnight. (T/F)

(ii) Transpiration creates a pull for upward movement of the sap. (T/F)

(iii) Wind velocity has an effect on transpiration. (T/F)

(iv) Voltmeter is an instrument used for measuring the rate of transpiration in green plants. (T/F)

(b) **Rewrite** the false statements, in *(a)* above, in the correct form by changing either the first or the last word only.

3. **Give suitable explanation** for the following :
   (a) A higher rate of transpiration is recorded on a windy day rather than on a calm day.
   (b) Excessive transpiration results in the wilting of the leaves.
   (c) Water transpired is the water absorbed.
   (d) More transpiration occurs from the lower surface of a dorsiventral leaf.
   (e) Cork and bark of trees help in preventing loss of water.
   (f) Perspiration and transpiration help to cool the body temperature of the organism.
   (g) On a bright sunny day, the leaves of certain plants roll up.
4. **Which** of the following statements are ***true*** and which ones are ***false***? Give reason in support of your answer.
   (a) Potometer is an instrument used for demonstration of transpiration occurring from the lower surface of a leaf.
   (b) Forests contribute in bringing rains.
   (c) Hydathodes are similar to stomata in plant physiology.
   (d) Atmospheric humidity promotes transpiration from a green plant.
   (e) Some desert plants have sunken stomata on their leaves.
   (f) Most transpiration occurs during midday.
5. **Differentiate** between guttation and bleeding in plants.

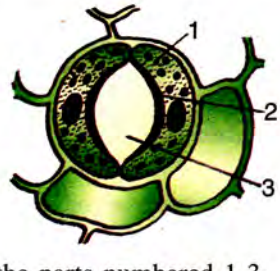
D. LONG ANSWER TYPE

1. **What** is wilting? Some plants show wilting of their leaves at noon even when the soil is well watered. Why is it so?
2. **Why** are the stomata in most plants more numerous on the lower surface of a leaf instead of being on the upper surface?
3. Suppose you have a small rose plant growing in a pot. **How** would you demonstrate transpiration in it?
4. **What** is a potometer?
5. **What** is lenticular transpiration? Mention one major difference between lenticular transpiration and stomatal transpiration.
6. **List** any three major factors that accelerate the rate of transpiration.
7. There is a general belief that forests tend to bring more frequent rains. **Can you explain** it scientifically?
8. **List** the four advantages of transpiration to the plants.
9. **Mention** any three methods by which the plants tend to reduce transpiration.
10. Droplets of water may sometimes be seen along the margins of the leaves of a banana plant, growing in wet soil, in the mornings. **Are** these dew drops? **Comment** upon your answer.
11. **Briefly explain** how the rate of transpiration is affected by
    (a) Intensity of light
    (b) Humidity of the atmosphere.

E. STRUCTURED/APPLICATION/SKILL TYPE

1. In an experiment, four freshly plucked leaves (A-D) of a plant, such as those of China-Rose, were treated as follows :
   (A) coated with vaseline on its upper surface.
   (B) coated on the lower surface.
   (C) coated on both surfaces.
   (D) left uncoated.

   All the four leaves A, B, C & D were left in a room for about 24 hours.
   (i) **Which leaf** would become most limp? Why ?
   (ii) **Which leaf** would show least limping? **Why** ?
2. Given below is a diagrammatic sketch (surface view) of a stomatal apparatus from a dicot leaf.

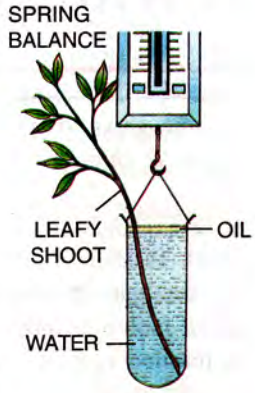


   (a) **Label** the parts numbered 1-3.
   (b) **Is this state**, open or closed?

(c) **Is this stoma**, of a dicot leaf or a monocot leaf?

(d) **Redraw** a sketch of the stomatal apparatus in the state opposite to the one shown here.

3. Given alongside is the diagram of an experimental set-up to demonstrate a certain phenomenon in plants.



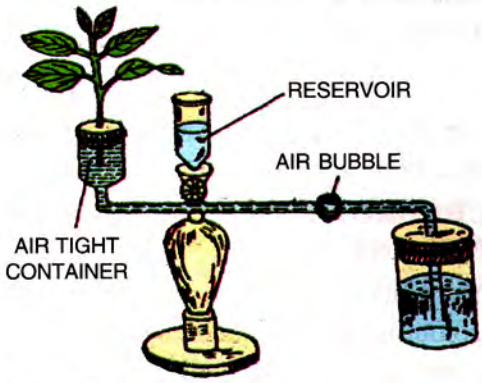
(a) **Name** the phenomenon being demonstrated.

(b) **What is** the purpose of putting oil in the test tube?

(c) **What** is the purpose of the spring balance in the set-up?

(d) **Would** it make a difference if the experimental set-up is kept in bright sunshine?

4. Given below is the diagram of an apparatus used to study a particular phenomenon in plants :



(a) **Name** the apparatus.

(b) **What** is it used for?

(c) **What** is the role played by the air-bubble in this experiment?

(d) **What** is the use of the reservoir?

(e) **What** happens to the movement of the air-bubble if the apparatus is kept :

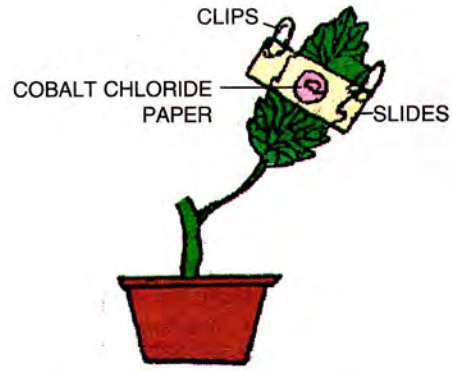
(i) in the dark; (ii) in sunlight; (iii) in front of a fan?

Give a reason in each case.

5. Given ahead is the diagram of an experimental set up to study the process of transpiration in plants. Study the same and then answer the questions that follow :

(a) **Name** the colour of dry cobalt chloride paper?

(b) **Is** the experimental leaf a monocot or a dicot? **Give** a reason to support your answer.



(c) **Why** are glass slides placed over the dry cobalt chloride papers?

(d) After about half an hour **what** change, if any, would you expect to find in the cobalt chloride paper placed on the dorsal and ventral sides of the leaf? Give a reason to support your answer.

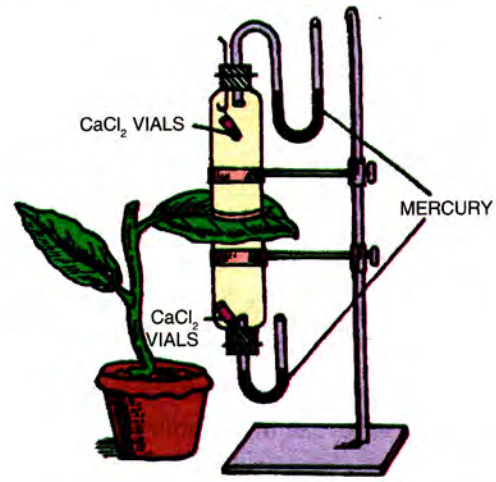
6. The apparatus shown in the following diagram is Garreau's potometer designed to demonstrate unequal transpiration from the two surfaces of a dorsiventral leaf. Before keeping the leaf in between the cups, anhydrous calcium chloride ($CaCl_2$) contained in two small vials were weighed and placed in both the cups. The ends of the cups were closed with corks through which two mercury manometers were connected. After few hours, $CaCl_2$ vials were taken out and weighed again.

(a) **What** is the purpose of keeping $CaCl_2$ vials inside the cup?

(b) After few hours $CaCl_2$ vials were taken out and weighed again. Will you expect any difference in weight? If so, give reason.

(c) **What** was the purpose of using a manometer?

(d) **What** do you mean by transpiration?



6 Photosynthesis — Provider of Food for All

Syllabus : *Photosynthesis: the nature of the process itself and the great importance of photosynthesis to life in general; experiments to show the necessity of light, carbon dioxide & chlorophyll and also the formation of starch and the output of oxygen ; carbon cycle.*

Scope of syllabus : The internal structure of chloroplast should be explained to give an idea of the site of light and dark reaction. Opening and closing of stomata should be explained. Teachers should stress upon the importance of a correct balanced chemical equation. The terms "photochemical" for light phase and "biosynthetic" for dark phase must be introduced. In the light reaction, activation of chlorophyll molecule followed by photolysis, release of O_2, formation of ATP and NADPH should be taught. In the dark reaction (detailed equations are not required), only combination of hydrogen released by NADP with CO_2 to form glucose to be discussed. Adaptations in a plant for photosynthesis and experiments with regard to the factors essential for the process should be discussed.

Photosynthesis, in a way, is the most significant life process – it provides food for all animal life including humans, and also the life supporting free oxygen gas in the atmosphere for breathing. A whole series of experiments on photosynthesis are worth performing. Hopefully, you will be able to see them THROUGH demonstrations.

6.1 PLANTS — SELF FOOD PRODUCERS

All living organisms need food. Animals obtain food from plants but plants prepare it for themselves by the process of photosynthesis.

6.2 WHAT IS PHOTOSYNTHESIS ?

Photosynthesis is an important activity of all green plants which are able to **synthesise food from carbon dioxide and water in the presence of chlorophyll and light energy**. The essential chemical steps in this process are the same in all green plants.

Photosynthesis is the process by which living plant cells, containing chlorophyll, produce food substances (glucose and starch), from carbon dioxide and water, by using light energy. Plants release oxygen as a waste product during photosynthesis.

Importance of photosynthesis

(1) ***Food for all.*** Photosynthesis is ultimately the source of energy and food for all living beings—directly for plants and indirectly for animals and humans who eat the plants or the plant-eating animals.

(2) ***Oxygen to breathe in.*** Photosynthesis is the only biological process which releases oxygen into the atmosphere. The oxygen supports all life on the earth.

6.3 CHLOROPHYLL – THE VITAL PLANT PIGMENT

Chlorophyll (*chloro* : green, *phyll* : leaf) is the green colouring matter found in plants. It is contained in microscopic cell organelles called chloroplasts (Fig. 1.1 B page 2).

Chloroplasts are minute oval bodies bounded by a double membrane, and their interior contains closely packed flattened sacs (**thylakoids**) arranged in piles (**grana**) lying in a colourless ground substance called

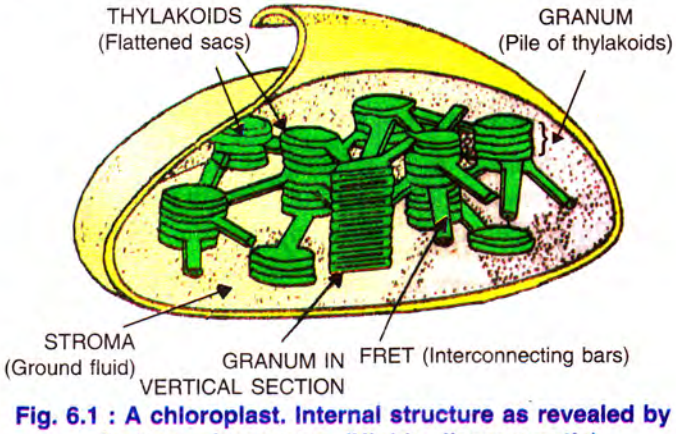


Fig. 6.1 : A chloroplast. Internal structure as revealed by electron microscope. (Highly diagrammatic)

stroma (Fig. 6.1). Ordinarily, there may be 40-50 chloroplasts in a cell. *The pigment **chlorophyll** is contained in the walls of **thylakoids**.* It is a highly complex substance, composed of carbon, hydrogen, oxygen, nitrogen and magnesium. Chloroplasts are mainly contained in the mesophyll cells located between the upper epidermis and the lower epidermis (*i.e.* in palisade cells and spongy cells) of leaves. These are also found in the guard cells of stomata and in the outer layers of young green stems.

There may be more than 500,000 chloroplasts per sq. mm. of leaf surface.

You will be surprised to know that there are nine types of chlorophyll. Two out of these, **chlorophyll-a** and **chlorophyll-b**, are best known and most abundant.

Chlorophylls absorb light at both ends of the visible spectrum - i.e. BLUE and RED light, and reflect away the green light. That is why, chlorophyll appears green. The absorbed blue and red lights are most effective for photosynthesis.

Too much light destroys chlorophyll

Chlorophyll is highly sensitive to light, so too much light may destroy it. However, the formation of chlorophyll itself depends on the exposure of the plant to light. The grass growing in the shade under a stone turns yellowish due to the non-formation of new chlorophyll and due to the disintegration of the older one in the absence of light.

6.4 REGULATION OF STOMATAL OPENING FOR LETTING IN CO_2

Stomata are minute openings occurring in large numbers on the lower surface of a leaf. The main function of the stomata is to let in CO_2 from the atmosphere for photosynthesis. When stomata are not in use for photosynthesis, *i.e.* when it is dark, they tend to close their openings so that water loss is minimised from the leaves through transpiration. When there is light, as after sunrise, they reopen to allow CO_2 to diffuse in. Transpiration occurs along with photosynthesis. Due to this process, one can say that ***transpiration is the price which the plant pays for photosynthesis***.

The closing and opening of the stomata are on account of the movement of water in and out of the guard cells. They have a **thick inner wall** facing the opening and a **thin outer wall** on the opposite side (Fig. 6.2); their cytoplasm contains chloroplasts.

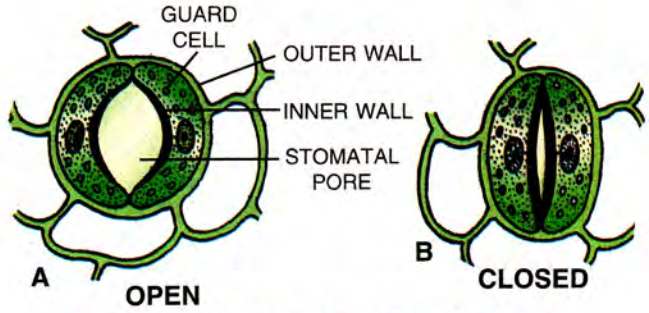


Fig. 6.2 The opening and closing of stomata.
A – Guard cells turgid, the stoma (mouth) opens,
B – Guard cells flaccid, the stoma closes.

Opening and Closing of Stomata

There are two theories about the opening and closing of stomata.

(1) Sugar concentration theory (old)

(2) K^+ ion concentration theory (recent)

(1) *Sugar concentration theory :*

According to the old sugar concentration theory, during daytime, the guard cells begin photosynthesis and the sugar (glucose) produced during the process increases the osmotic pressure which draws in water from the adjoining cells due to endosmosis. Hence, the guard cells **become turgid and bulge outwards** due to their thin outer wall, thus widening the stomatal opening lying in between (Fig. 6.2A). As the stomata open, the diffusion of gases in and out begins for fulfilling the need for photosynthesis and for allowing transpiration.

Closing of the stomata : If for any reason, the water content of the leaf is falling short, the water is drawn out of the guard cells due to exosmosis making them flaccid. As a result, their inner thick walls straighten to close the stomata.

(2) *K^+ ion concentration theory :*

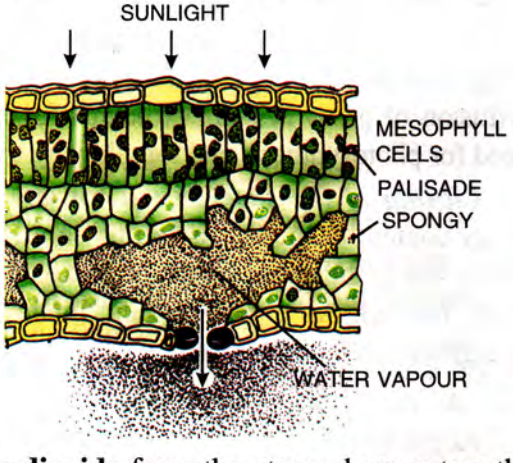
According to the recent K^+ ion concentration theory, the stomatal opening and closing depend on the generation of potassium ion (K^+) gradient. During daytime, the chloroplasts in the guard cells photosynthesise which leads to the production of ATP. **This ATP is used to actively pump the potassium ions of the adjacent cells into the guard cells.** Increased K^+ concentration in the guard cells makes them hypertonic, so, more water from the adjacent cells is drawn in and the cells become more turgid and they move outwards to open out the stomatal pore. Reverse happens at night. The K^+ ions leak out thus reducing the turgor of guard cells and the stomatal pore closes.

PROGRESS CHECK

1. Answer the following in "Yes" or "No"
   (i) All parts of a green plant carry out photosynthesis. Yes/No
   (ii) Photosynthesis is the only biological process that releases oxygen into the air. Yes/No
   (iii) Out of nine types of chlorophyll, chlorophyll a and b are most abundant. Yes/No
   (iv) Too much light destroys chlorophyll. Yes/No
   (v) No transpiration occurs during photosynthesis. Yes/No
   (vi) During sunlight, the guard cells turn flaccid to open the stomata. Yes/No

6.5 PROCESS OF PHOTOSYNTHESIS

Mesophyll cells (both **palisade** and **spongy**) in a leaf are the principal centres of this activity. During daytime, when sunlight falls on the leaf, the **light energy** is trapped by the chlorophyll of the upper layers of mesophyll, especially the palisade cells. This energy is utilized in chemical processes involved in the manufacture of food, where the raw materials used are carbon dioxide and water.



- **Carbon dioxide** from the atmosphere enters the leaf by diffusion down a concentration gradient (higher concentration outside the leaf, and less concentration inside) through the stomata.
- **Water** from the soil is taken up by the roots, sent up through the stem and finally to the leaves where it is distributed in the mesophyll tissue.

The chemical equation to represent this process is as follows :

$$6CO_2 + 12H_2O \xrightarrow[\text{chlorophyll}]{\text{light energy}} C_6H_{12}O_6 + 6H_2O + 6O_2 \uparrow$$

The glucose molecule $C_6H_{12}O_6$ is a simple sugar readily soluble in water.

The 6 molecules of H_2O liberated at the end of the process are those that are **re-formed** during a chain of reactions and not out of the original ones.

6.6 TWO MAIN PHASES OF PHOTOSYNTHESIS — (A) LIGHT-DEPENDENT PHASE AND (B) LIGHT-INDEPENDENT (DARK) PHASE

(A) LIGHT-DEPENDENT PHASE (PHOTO-CHEMICAL PHASE)

In this phase, light plays the key role. A series of chemical reactions occur in very quick succession, initiated by light and therefore, the phase is called the photochemical phase. The light reaction takes place in **thylakoids** (containing chlorophyll) of the chloroplasts.

The light reaction (photochemical phase) occurs in two main steps.

Step I. ***Activation of chlorophyll.*** The chlorophyll on exposure to light energy becomes activated by absorbing **photons** (photon is the smallest unit of light energy).

Step II. ***Splitting of water.*** The absorbed energy is used in splitting the water molecule (H_2O) into its two components (Hydrogen and Oxygen) and releasing electrons.

$$2H_2O \xrightarrow{\text{energy of 4 photons}} 4H^+ + 4e^- + O_2$$

The reaction is known as **photolysis**, which means ***splitting by light*** (*photo* = light, *lysis* = breaking).

> Photolysis is defined as the splitting of H_2O molecules into hydrogen ions and oxygen in the presence of **light** and **grana**.

End result of the products of photolysis

(1) The **hydrogen** ions (H^+) are picked up by a compound **NADP** (Nicotinamide adenine dinucleotide phosphate) to form **NADPH.**

$$NADP^+ + e^- + H^+ \xrightarrow{\text{enzyme}} NADPH$$

(2) The **oxygen** (O) component is given out as molecular oxygen (O_2).

$$2O \rightarrow O_2$$

(3) The **electrons** (e^-) are used in converting ADP (adenosine diphosphate) into energy-rich compound ATP (adenosine triphosphate) by adding one phosphate group P_i (inorganic phosphate).

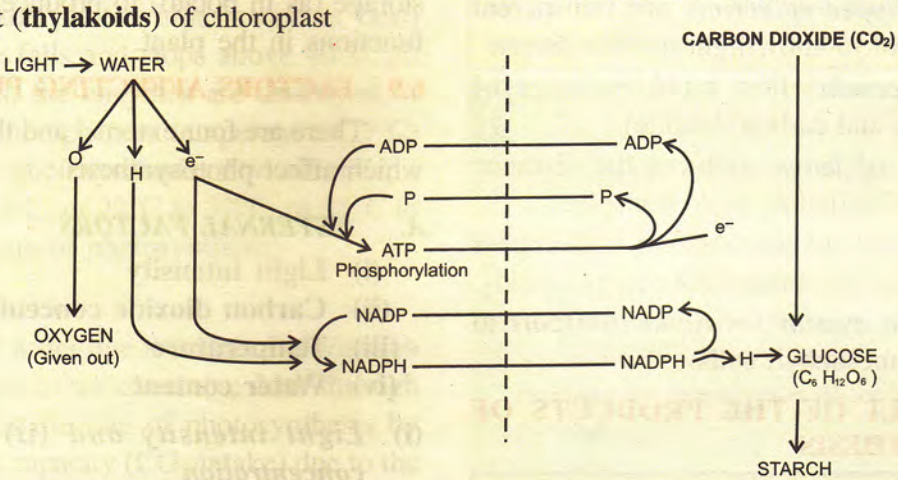
$$\underset{\text{(inorganic)}}{ADP + \text{Phosphate}} \rightarrow ATP$$

[This process is called **phosphorylation** (addition of phosphate) and since the energy used in

HIGHLY SIMPLIFIED SUMMARY OF THE EVENTS IN LIGHT REACTION AND LIGHT-INDEPENDENT REACTION OF PHOTOSYNTHESIS

LIGHT-DEPENDENT REACTIONS
Occur in chlorophyll-containing part (**thylakoids**) of chloroplast

LIGHT-INDEPENDENT REACTIONS
Occur in other part (**stroma**) of chloroplast



the process comes from light (photons), the process is termed as **photophosphorylation**]

(B) LIGHT-INDEPENDENT (DARK) PHASE also called *Biosynthetic phase*

The new term Light Independent Phase

The old term "dark phase" did not mean that it occurs when it is dark i.e. at night. It only meant that the reactions are not dependent on light. That is why, it is now better to call it "light independent phase."

The reactions in this phase do not require light energy, and occur simultaneously with the light reaction (time gap between the two being less than even one-thousandth of a second).

EXTRA **Not in syllabus**

Some details of the chemical steps during dark phase are as follows :

- The hydrogen of NADPH is used to combine it with CO_2 by utilising ATP energy to ultimately produce glucose ($C_6H_{12}O_6$).
- This fixation of CO_2 occurs in a number of steps using a special CO_2 acceptor compound RuBP (ribulose bisphosphate). [**Note :** Some write it wrongly as "..... biphosphate"].
- This fixation is catalysed by the enzyme **Rubisco** (Ribulose bisphosphate carboxylase).

Conversion of glucose into starch and other chemicals. Most green plants convert glucose into **starch** as soon as it is formed during photosynthesis. Several glucose molecules are transformed to produce one molecule of starch; this process is called **polymerisation.** Some plants change glucose to sucrose (cane sugar, which chemically is called disaccharide or double sugar), or some into oils, etc.

? ***PROGRESS CHECK***

1. Write the overall summary chemical equation of photo-synthesis. .....
2. Which single substance in the above equation is repeated in raw material as well as reproduced as an the end products? .....
3. What is the source of oxygen released in photo-synthesis — CO_2 or H_2O? .....
4. What happens in photolysis? .....
5. Dark reaction involves utilisation of CO_2 in producing $C_6H_{12}O_6$ (glucose). Why is this phase called dark reaction ? .....
6. Glucose produced during photosynthesis is soon polymerised into starch. What does polymerisation mean? .....
7. Why is it better to call the dark phase of photo-synthesis as "light-independent phase"? .....

6.7 ADAPTATIONS IN LEAF FOR PHOTO-SYNTHESIS

1. ***Large surface area*** for *maximum light absorption.* (Narrowing of leaves in certain

plants is to minimise transpiration in order to conserve water, as in oleander and pine).

2. ***Leaf arrangement*** *at the right angle to the light source to obtain maximum light.*
3. ***Cuticle and upper epidermis*** are transparent and water proof to allow light to enter freely.
4. ***Numerous stomata*** allow rapid exchange of gases (oxygen and carbon dioxide).
5. ***The thinness of leaves*** reduces the distance between cells facilitating rapid transport.
6. ***The chloroplasts*** are concentrated in the upper layers of the leaf to obtain light energy quickly.
7. ***Extensive vein system*** *for rapid transport* to and from the mesophyll cells.

6.8 END RESULT OF THE PRODUCTS OF PHOTOSYNTHESIS

There are three end-products of photosynthesis :
1. **Glucose ($C_6 H_{12} O_6$)**
2. **Water**
3. **Oxygen.**

1. *Glucose :* The **simple sugar glucose** is used in four different ways as required by the plant :

(i) immediately consumed by the plant cells
(ii) stored in the form of insoluble starch
(iii) converted into sucrose
(iv) used in synthesising fats, proteins, etc.

2. *Water :* The water produced in the process may be re-utilized in the continuance of photosynthesis.

3. *Oxygen :* Some of the oxygen may be used in respiration in the leaf cells (the phenomenon is called photorespiration), but the major portion of it is not required and it **diffuses out** into the atmosphere through the stomata. In a sense, even **this oxygen is not a waste**, because all organisms require it for their existence including the plants which require it at night.

Utilisation of Synthesised Food and its Translocation. Food manufactured in the leaf is required for use by all other parts of the plant. The glucose is formed in the leaf very rapidly during photosynthesis and it cannot be transported to other parts with the same rapidity. So, it is converted into **insoluble starch for temporary storage** in the leaf. At night, the starch is reconverted into soluble sugar which is transported in solution through the veins of the leaf and down through the phloem of the stem. In this way, it gets transported **(translocated)** to different parts of the plant where it may be reconverted into starch for storage (as in potato) to produce energy for various functions in the plant.

6.9 FACTORS AFFECTING PHOTOSYNTHESIS

There are four external and three internal factors which affect photosynthesis :

A. *EXTERNAL FACTORS*

(i) Light intensity
(ii) Carbon dioxide concentration
(iii) Temperature
(iv) Water content

(i) *Light intensity and* (ii) *Carbon dioxide concentration*

One would easily think that the rate of photosynthesis will increase with light intensity. To some extent, it is true (Fig. 6.3A). Photosynthesis increases with the light intensity up to a certain limit only, and then it gets stabilised at the point S′(0.02% CO_2). But if, at this point, the carbon dioxide concentration is increased, the photosynthesis also increases further (Fig. 6.3 B) and again gets stabilised at a point S″ = (0.05% CO_2) for the two factors together.

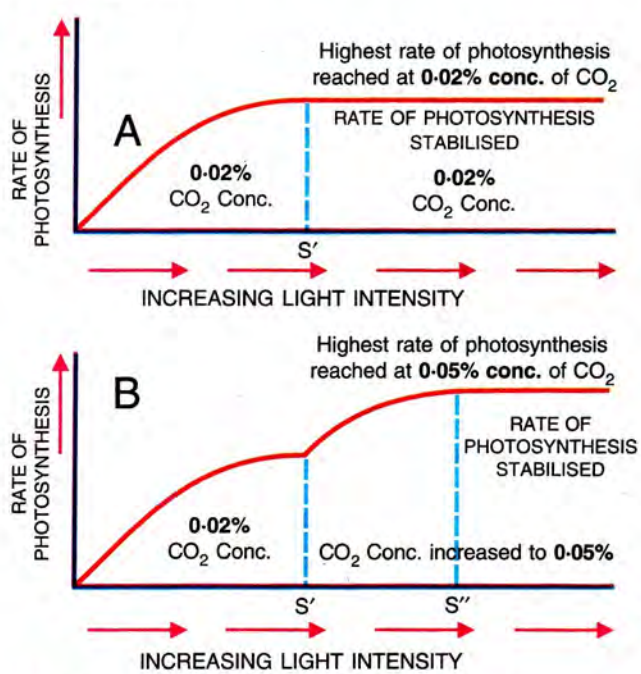


Fig. 6.3 : Photosynthesis at increasing light intensities and CO_2 concentrations

(iii) ***Temperature***

With the rise in temperature, the rate of photosynthesis rises. This rise occurs up to the optimum temperature of 35°C (maximum suitable temperature when the photosynthesis occurs best) after which the rate falls and stops above 40°C. At this uppermost limit, the enzymes are destroyed. A rise of 10°C up to the optimum temperature (35°C) doubles the rate of photosynthesis. *For example*, a rise from 20°C to 30°C, or 22°C to 32°C, or 25°C to 35°C, doubles the rate of photosynthesis.

(iv) ***Water Content***

The scarcity of water due to reduced absorption from the soil or due to an excessive loss through transpiration reduces the rate of photosynthesis by decreasing diffusive capacity (CO_2 intake) due to the closure of stomata. Only 1% of water absorbed by the root is utilised in photosynthesis.

B. INTERNAL FACTORS

(i) ***Chlorophyll*** – Nutritional deficiencies of minerals cause loss of chlorophyll, and hence the drop in trapping solar energy.

(ii) ***Protoplasm*** – Dehydration of protoplasm for some reason reduces the rate of photosynthesis. Similarly, the accumulation of carbohydrates (sugar and starch) also reduces the rate of photosynthesis.

(iii) ***Structure of leaf*** – The thickness of cuticle, the distribution of stomata and the size of the leaf influence the amount of light and the amount of CO_2 entering the leaf.

Dawn-to-Dusk natural changes in environmental conditions & photosynthesis

In every period of twenty-four hours, plants are subjected to a regular cycle of changes in light intensity, and the rate of photosynthesis increases from dawn to midday and declines as dusk approaches. Plants, like other organisms, respire, taking in oxygen and giving out carbon dioxide. **In light**, the effects of this respiratory activity are masked by those of photosynthesis and there is a net output of oxygen. In **darkness**, respiration alone is responsible for changes in the gaseous composition of a plant's surrounding atmosphere.

"Photosynthesis at night"???

Some people believe that PEEPAL tree is the only plant which gives out oxygen even during the night. Neither the release of such oxygen has been demonstrated practically nor such a view can stand scientific reasoning as at present.

? *PROGRESS CHECK*

1. How do the following favour increased photosynthesis?
   (i) Large surface area of the leaf .....
   (ii) Thinness of the leaf .....
   (iii) More numerous stomata .....
2. Name the three end-products of photosynthesis and mention the fate of each of them in the plant.
   (i) Name .....
   Fate .....
   (ii) Name .....
   Fate .....
   (iii) Name .....
   Fate .....
3. If we keep on increasing CO_2 concentration in the air, will the rate of photosynthesis also keep on increasing in direct proportion ?
   Yes/No .....
   Explain : .....

6.10 EXPERIMENTS ON PHOTOSYNTHESIS

A number of experiments can be performed for proving the various conditions and requirements necessary for photosynthesis.

Destarching (Removal of starch). A plant used for experiments on photosynthesis should initially be placed in the dark for 24 to 48 hours to destarch the leaves. During this period, all the starch from the leaves will be removed, to the storage organs and the leaves will not show the presence of starch.

A destarched plant is one whose **leaves** are free from starch.

A plant is destarched by placing it in the dark for 24 to 48 hours.

To test a leaf for starch (Iodine test).

- Dip the leaf in **boiling water** for a minute **to kill the cells**.
- Boil the leaf in methylated spirit over a water bath till it becomes pale-white due to the

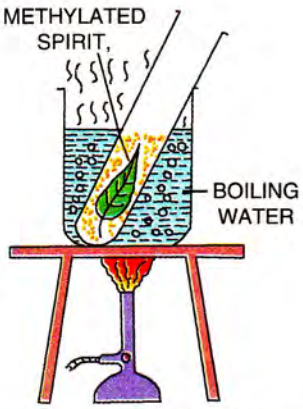


Fig. 6.4 : Removal of chlorophyll from a leaf

removal of chlorophyll (Fig. 6.4). The leaf now becomes hard and brittle.

- Place it again in hot water to **soften it**.
- Spread the leaf in a dish and pour **iodine solution*** on it. The presence of starch will be indicated by a **blue-black colour**. A leaf without starch will show brown colouration.

Experiment 1 : To show that chlorophyll is necessary for photosynthesis : Take a plant with variegated leaves having some green and some non-green areas. Examples : Coleus, Geranium and Croton.

- Destarch the leaves by keeping the plant in a dark room for a few days.
- Place the plant in the sun.
- After a few hours, pluck one leaf.
- Make its outline on paper and mark the green and non-green areas on the outline.
- Test the leaf for starch. Only the green parts of the leaf turn bluish, showing the presence of starch (Fig. 6.5).

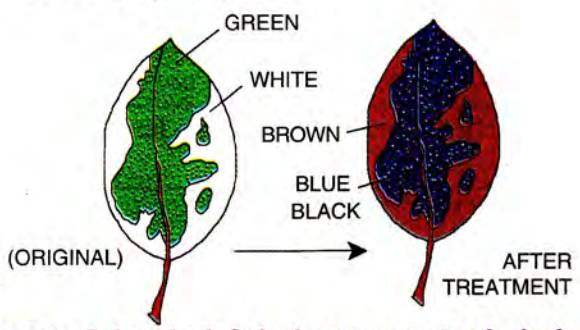


Fig. 6.5 : Coleus leaf. Only the green parts of a leaf give iodine test for the presence of starch proving that chlorophyll is necessary for photosynthesis

*** Composition of iodine solution is as follows :**
Iodine = 0.3 g; Potassium iodide = 1.5 g; Water = 100 ml

Experiment 2 : To show that sunlight is necessary for photosynthesis.

- Take a plant with destarched leaves.
- Cover one of its leaves with black paper on which a design is cut.
- Place this plant in the sun.
- After a few hours, test the leaf which is covered by black paper for the presence of starch.

It will be observed that only the parts of the leaf, which could get light through the cut out design as well as those that were left uncovered by the paper, turn blue-black, showing the presence of starch (Fig. 6.6).

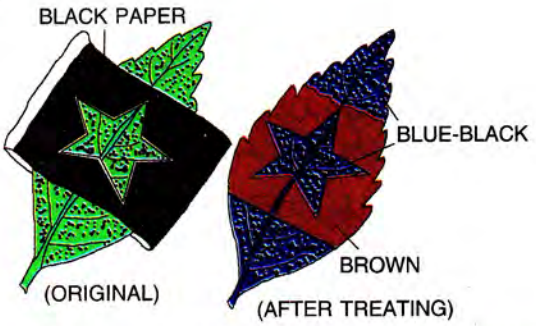


Fig. 6.6 : Only the parts of the leaf exposed to sunlight give the iodine test, proving that light is necessary for photosynthesis

Experiment 3 : To show that carbon dioxide is necessary for photosynthesis.

- Take a plant with **destarched** leaves.
- Insert a part (half) of one of its leaves (through a split cork) into a conical flask containing potassium hydroxide (Fig. 6.7A). (Potassium hydroxide absorbs carbon dioxide).
- Leave the plant in sunlight.
- After a few hours, test the leaf for starch.

The part of the leaf which was exposed to the atmospheric air becomes blue-black, and the part of the leaf inside the flask containing potassium hydroxide does not become blue-black, showing that carbon dioxide is necessary for photosynthesis. The part of the leaf outside the flask becomes the control experiment.

Note : The same experiment can be modified as given in Fig. 6.7 B. Half of the leaf outside the bottle will show the presence of starch while the other half will not.

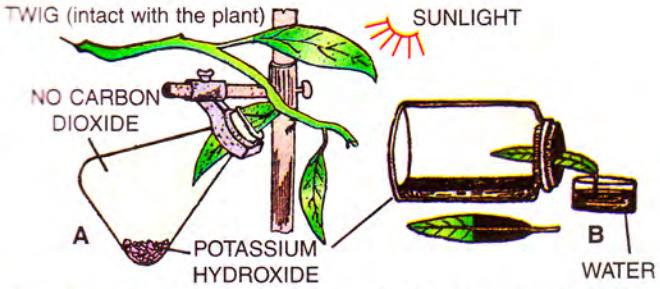


Fig. 6.7 : Experiment to prove that carbon dioxide is necessary for photosynthesis

Experiment 4 : To show that oxygen is produced during photosynthesis.

- Place some water plants (*Elodea* or *Hydrilla*) in a beaker containing pond water and cover them by a short-stemmed funnel.
- Invert a test-tube full of water over the stem of the funnel. (Ensure that the level of water in the beaker is above the level of stem of the inverted funnel).
- Place the apparatus in the sun for a few hours (Fig. 6.8). Bubbles of the gas will collect in the test-tube.
- Test the gas in the test-tube. A glowing splinter bursts into flame which shows the presence of oxygen.

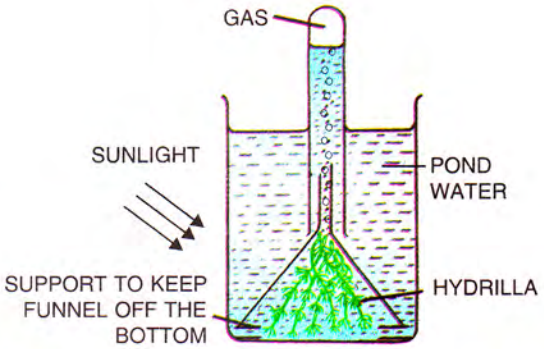


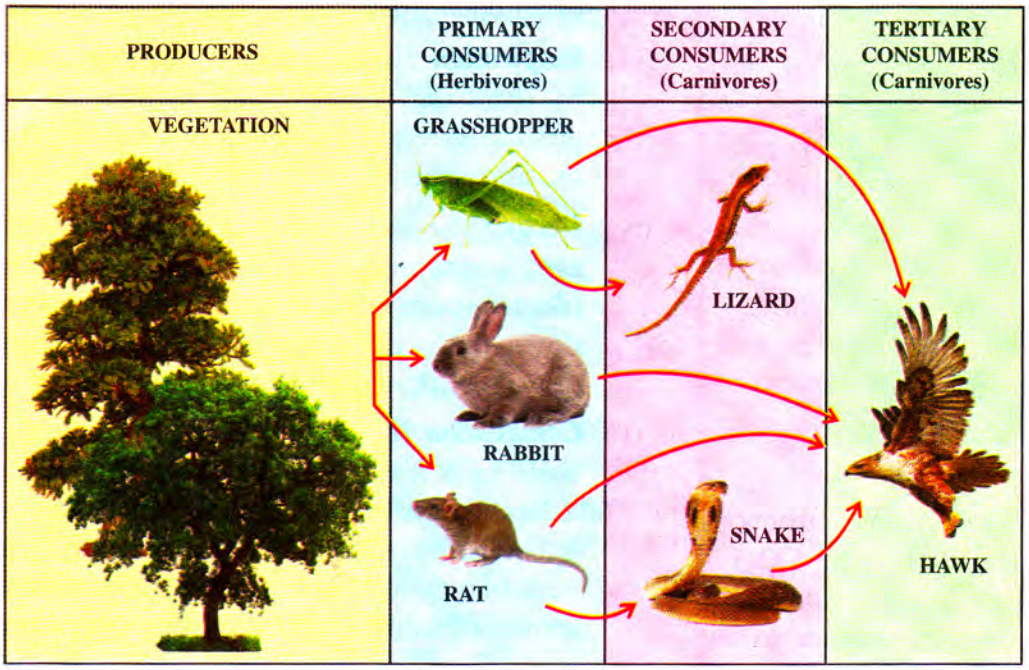
Fig. 6.8 : An experiment to show that oxygen is given out during photosynthesis

6.11 IMPORTANCE OF PHOTOSYNTHESIS

(The process supporting all life on the earth)

If there were no green plants, all life on the earth would come to an end.

1. *Provides food :* All animals, including humans, ultimately depend on plants for food. A herbivore (plant-eater) consumes the plant parts directly, while a carnivore (flesh-eater) eats flesh of an animal which in turn was a herbivore. This chain of food-dependence is called the **food chain** (Fig. 6.9). The food chain may have a number of intervening stages but the **starting point is always a plant** (producer) which produces its own food through photosynthesis.



How many food chains in all are shown here ?

3, 4, 5, 6, 7 or 9

Answer

Fig. 6.9 : Some examples of the food chain : Green plants (producers) provide food for all herbivores (primary consumers), herbivores are eaten up by carnivores (secondary consumers), the carnivores may be further eaten up by tertiary consumers (again called carnivores)

You can imagine several food chains, *for example* :

Corn → Rat → Snake → Hawk

Grass → Rabbit → Tiger

Grass → Grasshopper → Lizard → Kite

Grass → Insects → Frog → Snake → Peacock

Wheat → Man → Mosquito

Non-green plants such as **fungi** and **bacteria** obtain their nourishment from decaying organic matter in their environment. This matter comes from dead animals and plants, which in their own turn were dependent on photosynthesis.

2. ***Provides oxygen :*** The life-supporting gas, oxygen, is present in the atmosphere in a free state only because of photosynthesis. Scientists strongly believe that about 2 billion years ago, when there was no life on the earth in any form, there was no free oxygen in the atmosphere. Appearance of green plants set the stage for the animals to appear. Almost all organisms need oxygen for respiration.

? ***PROGRESS CHECK***

1. Why is it necessary to destarch a plant before performing an experiment on photosynthesis?

   .....

2. Why do we perform the iodine-test ?

   .....

3. What chemical do you use to remove CO_2 from inside a flask in certain experiments on photosynthesis ?

   .....

4. All food chains start with a plant. Why is this so?

   .....

5. The honey bee produces honey. In terms of the food chain, is the honey bee a producer or a consumer?

   .....

6.12 CARBON CYCLE (Fig. 6.10)

The carbon cycle is a series of chemical reactions in which carbon as a chemical element (in CO_2) is removed from the air, used by living organisms in their body processes and is finally returned to the air.

The essential steps in the carbon cycle are as follows :

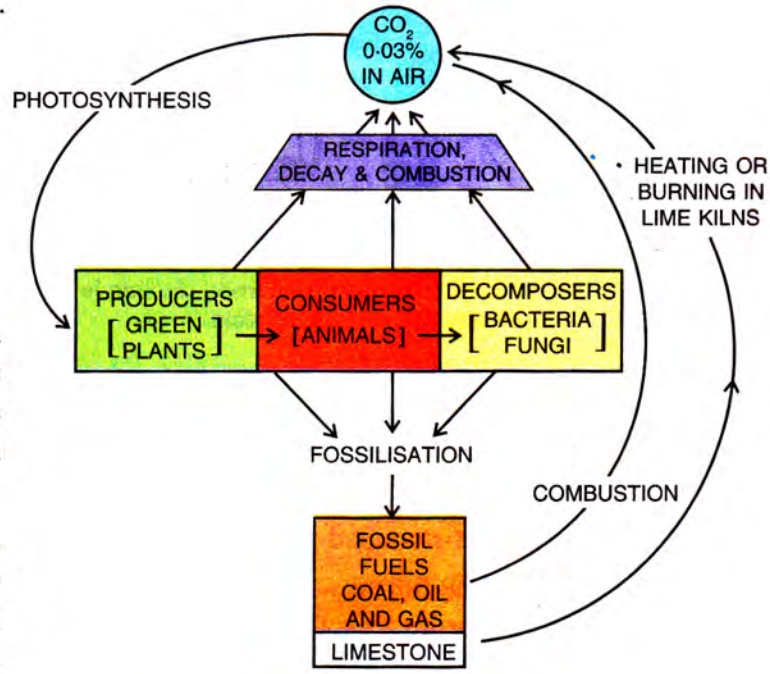


Fig. 6.10 : Carbon cycle

(i) ***Photosynthesis:*** Green plants **(producers)** use carbon dioxide of the air to produce carbohydrates (sugar, starch, etc.).

(ii) ***Food chains :*** Through food chains, the food (containing carbon in the carbohydrates and other products) passes on from plants to animals **(consumers)**. Carbon is an essential element of all body tissues of both plants and animals.

(iii) ***Respiration :*** All plants and animals, respire by oxidising carbohydrates in their cells to produce energy and give out carbon dioxide into the atmosphere.

(iv) ***Decay :*** The dead remains of plants and animals are consumed by bacteria and fungi **(decomposers)**, and in the process, they break down the organic matter, releasing carbon dioxide back into the atmosphere.

(v) ***Combustion (burning) :*** When a fuel such as wood or a fossil fuel like coal, petroleum or natural gas, is burnt, the carbon contained in it is oxidised to carbon dioxide, which is given back into the atmosphere. All the fuels named above originally come from living organisms.

(vi) A certain amount of carbon dioxide is released during heating or **burning of limestone** in lime kilns.

REVIEW QUESTIONS

A. MULTIPLE CHOICE TYPE

(Select the most appropriate option in each case)

1. The production of starch, and not glucose, is often used as a **measure of photosynthesis** in leaves because
   (a) starch is the immediate product of photosynthesis.
   (b) glucose formed in photosynthesis soon gets converted into starch.
   (c) starch is soluble in water.
   (d) sugar cannot be tested.
2. The **number of water molecules** required in the chemical reactions to produce one molecule of glucose during photosynthesis is.
   (a) six (b) twelve
   (c) eighteen (d) twenty-four
3. The **rate of photosynthesis** is NOT affected by.
   (a) light intensity (b) humidity
   (c) temperature (d) CO_2 concentration
4. Chlorophyll in a leaf is **required for**
   (a) breaking down water into hydrogen and oxygen.
   (b) emitting green light. (c) trapping light energy.
   (d) storing starch in the leaves.
5. If the **rate of respiration** becomes more than the rate of photosynthesis, plants will :
   (a) continue to live, but will not be able to store food.
   (b) be killed instantly.
   (c) grow more vigorously because more energy will be available.
   (d) stop growing and die gradually of starvation.
6. Which one **chemical reaction** occurs during photosynthesis?
   (a) Carbon dioxide is reduced and water is oxidised.
   (b) Water is reduced and carbon dioxide is oxidised.
   (c) Both carbon dioxide and water are oxidised.
   (d) Both carbon dioxide and water are reduced.
7. The **specific function** of light energy in the process of photosynthesis is to
   (a) reduce carbon dioxide. (b) synthesise glucose.
   (c) activate chlorophyll. (d) split water molecule.
8. A plant is kept in a dark cupboard for about 48 hours before conducting any **experiment on photosynthesis** in order to
   (a) remove chlorophyll from the leaves.
   (b) remove starch from the leaves.
   (c) ensure that no photosynthesis occurred.
   (d) ensure that the leaves are free from starch.
9. During photosynthesis, the **oxygen** in glucose comes from
   (a) CO_2 (b) water
   (c) both CO_2 and water (d) oxygen via air

B. VERY SHORT ANSWER TYPE

1. **Name** the following :
   (a) The category of organisms that prepare their own food from basic raw materials.
   (b) The kind of plastids found in the mesophyll cells of the leaf.
   (c) The compound which stores energy in the cells.
   (d) The first form of food substance produced during photosynthesis.
   (e) The organisms that can be called "natural purifiers" of the air.
   (f) The source of CO_2 for aquatic plants.
   (g) The part of chloroplast where the dark reaction of photosynthesis takes place
   (h) The tissue that transports manufactured type of starch from leaves to all parts of the plants.

C. SHORT ANSWER TYPE

1. **Mention one difference** between the following on the basis of what is given in brackets.
   (a) Respiration and photosynthesis (gas released).
   (b) Light and dark reactions (products formed).
   (c) Producers and consumers (mode of nutrition).
   (d) Grass and grasshopper (mode of nutrition).
   (e) Chlorophyll and chloroplast (part of plant cell).
2. **Identify** the **false statements** and **rewrite** them correctly by changing the first or the last word only.
   (a) Dark reaction of photosynthesis occurs during night time.
   (b) Immediate product of photosynthesis is glucose.
   (c) Starch produced in a leaf remains stored in it for 2-3 weeks before it is used by other parts of the plant.
   (d) Photosynthesis requires enzymes.
   (e) Green plants are consumers.
   (f) Photosynthesis results in loss of dry weight of the plants.
   (g) Photosynthesis stops at a temperature of about 35°C.
   (h) Photosynthesis occurs only in cells containing chloroplasts.
   (i) Green plants perform photosynthesis.
   (j) Algae are autotrophs.

3. **Fill in the blanks** with the appropriate answer from the choices given in the brackets.
   (a) The site of light reaction in the cells of a leaf is ..... (cytoplasm, stroma, grana).
   (b) The chemical substance used to test the presence of starch in the cell of a leaf is ..... ($CaCl_2$, iodine solution, Benedict solution).
   (c) Stroma is the ground substance in ..... (cytoplasm, chloroplast, ribosomes).
   (d) The dark reaction of photosynthesis is known as ..... (Hill reaction, cyclic phosphorylation, Calvin cycle).
   (e) In the flowering plants, food is transported in the form of ..... (sucrose, glucose, starch).
4. Are the following statements ***true*** or ***false***? **Give reason** in support of your answer.
   (a) The rate of photosynthesis continues to rise as long as the intensity of light rises.
   (b) The outside atmospheric temperature has no effect on the rate of photosynthesis.
   (c) If you immerse a leaf intact on the plant in ice cold water, it will continue to photosynthesise in bright sunshine.
   (d) Destarching of the leaves of a potted plant can occur only at night.
   (e) The starting point of carbon cycle is the release of CO_2 by animals during respiration.
   (f) If a plant is kept in bright light all the 24 hours for a few days, the dark reaction (biosynthetic phase) will fail to occur.
   (g) Photosynthesis is considered as a process supporting all life on earth.
5. Given below are five terms. **Rewrite the terms** in the **correct order** so as to be in logical sequence with regard to photosynthesis: *(i) water molecules, (ii) oxygen, (iii) grana, (iv) hydrogen and hydroxyl ions, (v) photons.*
6. **State** any *four* differences between photosynthesis and respiration.
7. "Oxygen is a waste product of photosynthesis." **Comment**.
8. Why is it necessary to place a plant in the dark before starting an experiment on photosynthesis? **Explain**.
9. In most of the experiments on photosynthesis, we use a de-starched leaf or plant. **What** is the purpose of de-starching?
10. **Why** is it not possible to demonstrate respiration in a green plant kept in sunlight ?
11. Most leaves have the upper surface more green and shiny than the lower one. **Why** ?
12. **How** would you **demonstrate** that green plants release oxygen when exposed to light?
13. **Describe** the main chemical changes which occur during photosynthesis in
    (i) Light reaction (ii) Dark reaction.
14. **Complete** the following food chains by writing the names of appropriate organisms in the blanks.
    (i) Grass → ..... → Snake → .....
    (ii) ..... → Mouse ..... → Peacock
15. **How** do non-green plants such as fungi and bacteria obtain their nourishment ?
16. All life owes its existence to chlorophyll. **Give reason**.
17. Complete the following by filling the blanks 1 to 5 with appropriate words/terms/phrases:
    To test the leaf for starch, the leaf is boiled in water to ..... (1). It is next boiled in methylated spirit to ..... (2). The leaf is placed in warm water to soften it. It is then placed in a dish and ..... (3) solution is added. The region, which contains starch, turns ..... (4) and the region, which does not contain starch, turns .....(5).

D. STRUCTURED/APPLICATION/SKILL TYPE

1. A candidate studied the importance of certain factors in photosynthesis. He took a potted plant and kept it in the dark for over 24 hours. In the early hours of the next morning, he covered one of the leaves with dark paper in the centre only. Then he placed the plant in sunlight for a few hours and tested the leaf which was covered with black paper for starch.
   (a) **What** aspect of photosynthesis was being investigated?
   (b) Is there any control in this experiment? If so, **state** it.
   (c) **Why** was the plant kept in the dark before the experiment?
   (d) **Describe** step by step, how the candidate proceeded to test the leaf for the presence of starch.
2. Photosynthesis in green plants is directly and indirectly dependent on so many plant structures. Explain briefly the role of the following structures in this process.
   (a) Guard cells .....

(b) Cuticle .....

(c) Mesophyll cells .....

(d) Xylem tissue in the leaf veins .....

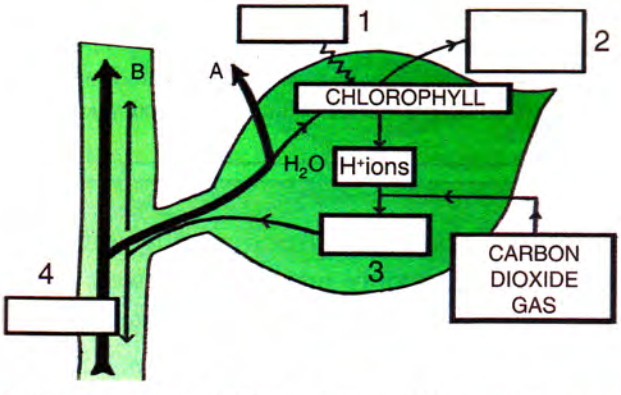
(e) Phloem tissue in the leaf veins .....

(f) Stomata .....

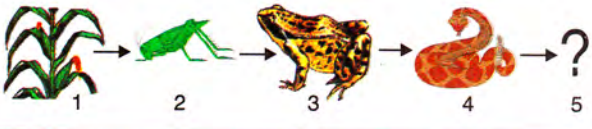
3. Given below is a schematic diagram to illustrate some aspects of photosynthesis.

(a) **Fill up** the gaps, in blank spaces (1-4), by writing the names of the correct items.

(b) **What phenomenon** do the thick arrows A and B indicate respectively ?



4. Given below is the representation of a certain phenomenon in nature. with four organisms 1-4.



(a) Name the phenomenon represented.

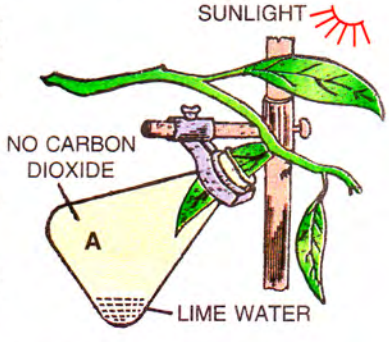
(b) Name any one organism that could be shown at No. 5.

(c) Name the **biological process** which was the starting point of the whole chain.

(d) Name one natural element which all the organisms 2-4 and even 5 are getting from No. 1 for their survival.

5. **Enumerate** the steps involved in testing a green leaf for the presence of starch.

6. Given alongside is the diagram of an experimental set-up :



(a) What is the objective of this experiment ?

(b) Will it work satisfactorily? Give reason.

(c) What alteration(s) will you make in it for obtaining expected result?

(d) Would you take any step before starting the experiment? Describe this step and explain its necessity.

7. **Draw** a neat diagram of the stomatal apparatus found in the epidermis of leaves and label the Stoma, Guard cells, Chloroplast, Epidermal cells, Cell wall and Nucleus.

ANSWER THE FOLLOWING SIMPLY IN "YES" OR "NO"

1. Chloroplast and chlorophyll are one and the same thing. .....
2. Oxygen given out in photosynthesis comes from the atmosphere. .....
3. The dark reaction of photosynthesis occurs during nighttime. .....
4. The immediate product of photosynthesis is glucose. .....
5. Photosynthesis can also occur in artificial light such as that of a 100 Watt electric lamp. .....
6. All the starch produced in a leaf remains stored in it for 2-3 weeks before it is used by other parts of the plant. .....
7. Photosynthesis requires involvement of enzymes. .....
8. Plants require several nutrients such as nitrogen, sulphur and iron. .....
9. Every green plant produces glucose as well as proteins and many other compounds. .....
10. All green plants are categorised as consumers. .....

Check your Answers 1-NO, 2-NO, 3-NO, 4-YES, 5-YES, 6-NO, 7-YES, 8-YES, 9-YES, 10-NO

Can we say —

"Chloroplasts are the kitchen of a cell!"?

NO! Not at all

The kitchen only cooks the food but does not produce it. It is the agricultural farms and orchards that produce it, and there again it is the chloroplasts in their cells which produce it.

A better analogy could be :

Chloroplasts are starch producing "factories", which need

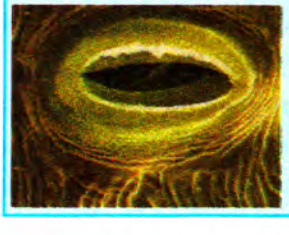
— **raw materials :** CO_2 and H_2O

— **energy :** sunlight

— **labourers :** enzymes

Why the name "Stoma" (singular of "stomata") ?

Is this the "mouth" of an old bearded toothless man ? If so, are there two "lips" **guarding** the "mouth opening"?

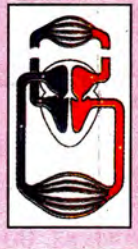


Yes, this is "mouth"! But not of a human. It is one of the hundreds of "mouths" called "stomata" present on the lower surface of green leaves. The Greek word "stoma" means "mouth" and its pleural form is "stomata".

7 The Circulatory System

Syllabus : *Circulatory System : Main features; the structure and working of the heart, blood vessels, structure and functions of blood and circulation of blood (only names of the main blood vessels entering and leaving the heart, liver and kidney will be required).*

Scope of Syllabus : Composition of blood (Structure and functions of RBC, WBC and platelets). Brief idea of tissue fluid and lymph. Increase in efficiency of mammalian red blood cells due to absence of certain organelles should be explained with reasons. A brief idea of blood coagulation. Structure of vein, artery and capillary should be explained with the help of diagrams to bring out clearly the relationship between their structure and function. ABO blood group system, Rh factor; concept of double circulation; concept systole and diastole; blood pressure. Reference to portal system should be made. Working of the heart along with names of the main blood vessels entering and leaving the heart, the liver and the kidney must be taught. Examination of a blood smear under a microscope.



Almost all organisms, including humans, have some kinds of fluids circulating in their bodies. Such fluids constitute the **distributing system** (to supply substances) as well as a **collecting system** (to pick up substances) to and from the various parts of the body including the remotest cell. In this chapter, we will study about the circulating fluids in our body, its composition and function.

7 A. BODY FLUIDS

7.1 NEED FOR TRANSPORT INSIDE THE BODY

Every organ in our body requires the involvement of the circulating body fluids. *For example* :

- The **digestive system** digests and absorbs nutrients which are needed to be transported to every body cell.
- **The respiratory system** draws in air, and the oxygen picked up from it in the lungs has to be transported to all parts of the body. Similarly, the CO_2 collected from the entire body has to be carried to the lungs for giving out.
- All the extra water, excess salts, and the nitrogenous wastes such as urea have to be removed from different parts and have to be sent to the **excretory system** to be thrown out of the body.
- **Hormones** secreted by the endocrine system have to be carried throughout the body by the circulating blood to act wherever required, and so on.

All such functions that need transport are performed by the two ***circulating fluids*** – the **blood** and the **lymph**. Besides transport, these fluids have some other functions also.

7.2 FLUIDS IN OUR BODY

There are three principal fluids in our body :

(i) **Blood**, contained in the heart and in the blood vessels (arteries, veins and capillaries) of the circulatory system,

(ii) **Tissue fluid**, occupying spaces between cells in the organs, and

(iii) **Lymph**, which is contained within lymph vessels and lymphatic organs such as the spleen and the tonsils.

Fig. 7.1 shows a diagrammatic representation of the relationship between blood, tissue fluid and lymph as they *circulate in their respective vessels* or spaces between the cells in different organs. It is clear from the diagram that blood in our body circulates in a closed manner *i.e.* all the time through blood vessels.

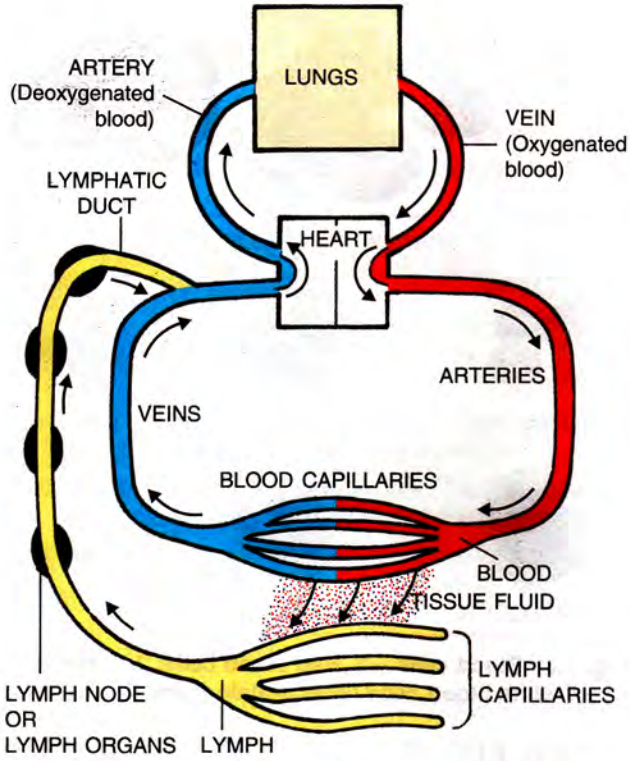


Fig. 7.1 Diagrammatic representation of blood and lymph circulation (Red-oxygenated blood, Blue-deoxygenated blood).

Such a type of blood circulation is called a **closed vascular system**. As against this, in certain animals such as insects, the blood mostly flows through open spaces, called an **open blood circulatory system**. Their blood flows from the heart to body tissue spaces without vessels.

[**Non-circulating fluids :** There are also some other fluids located in particular organs such as **synovial fluid** filled in the cavities of skeletal joints, **vitreous humour** in the eye, etc. They do not circulate.]

7.3 THE BLOOD

- **Never Stationary.** Blood is always in motion from the heart to the arteries and back through the veins.
- **Colour.** The blood is a somewhat thick fluid, **bright red** when taken from an artery or **dark red** when taken from a vein. [Conventionally, in the diagram, we show the **veins in blue** – this is just for contrast; the blood inside the veins is not blue, it is actually dark red].

  The above three principal fluids in our body are respectively described in section 7.5 (*blood*) and section 7.14 (*tissue fluid* and *lymph*).
- **Volume.** An average adult human contains 5 to 6 litres of blood by volume in his body.
- **Taste - saltish.** Perhaps we have all "tasted" our blood as in the case when there is a cut in the tongue or bleeding from the gums. The blood is slightly alkaline with a pH of 7.3 to 7.45 (7 is neutral, neither acidic nor alkaline).

7.4 FUNCTIONS OF BLOOD

The main functions of the blood in our body can be treated under two broad headings: (A) Transport and (B) Protection.

A. TRANSPORT BY BLOOD (Transport of digested food, oxygen, carbon dioxide, excretory substances, hormones, body heat).

1. **Transport of digested food** from the alimentary canal to the tissues. These substances are simple sugars like glucose, amino acids, vitamins, mineral salts, etc.
2. **Transport of oxygen** from the lungs to the tissues. It occurs by means of red blood cells in combination with haemoglobin in the form of an unstable compound oxyhaemoglobin, which on reaching the tissues breaks up to deliver oxygen.

$$Hb + O_2 \rightleftharpoons \underset{\text{oxyhaemoglobin}}{Hb.O_2}$$

3. **Transport of carbon dioxide** from the tissues to the lungs. It occurs partly in combination with haemoglobin and partly as solution in blood plasma.

$$Hb + CO_2 \rightleftharpoons \underset{\text{carbaminohaemoglobin}}{Hb.CO_2}$$

4. **Transport of excretory material** from the tissues to the liver, kidney or the skin for elimination or to render them harmless.
5. **Distribution of hormones** secreted by special glands (endocrine glands) directly into the blood.
6. **Distribution of heat.** The blood helps in keeping the temperature of the body uniform by distributing heat.

B. PROTECTION BY BLOOD

1. Blood forms a **clot** wherever there is a cut in a blood vessel. The clot serves to **prevent**
   (i) further loss of blood and
   (ii) the entry of disease-causing germs.

2. Its white blood corpuscles *protect the body* from diseases by **engulfing bacteria** which may have entered the body.
3. It produces **antitoxins** and **antibodies** which neutralise the poisonous substances or kill the germs which enter the body.

? ***PROGRESS CHECK***

1. Name the two fluids that circulate in the body.
2. In the diagrams we conventionally show veins in blue. What is the actual colour of the blood flowing through the following ?
   (i) In arteries (ii) In veins (iii) In capillaries
3. In a coloured diagram why do we generally show the pulmonary artery in blue and pulmonary vein in red colour ?
4. Name any four substances transported by blood.

7.5 COMPOSITION OF BLOOD

The blood consists of :

(i) **Plasma –** fluid part, constitutes 55-60 per cent of blood.

(ii) **Cellular elements –** red and white cells, and platelets, 40-45 per cent of blood.

7.5.1 PLASMA — The liquid portion of blood

The plasma is a light-yellow coloured, alkaline liquid. It mainly consists of :

Water	–	90 - 92%
Proteins	–	7 - 8%
Inorganic salts	–	1%
Other substances	–	traces

The inorganic salts include mainly **sodium chloride** and **sodium bicarbonate**. Among other substances contained in the plasma are **glucose, amino acids, fibrinogen, hormones, urea**, etc.

The plasma from which the protein fibrinogen has been removed is called **serum**.

7.5.2 CELLULAR ELEMENTS (Fig. 7.2)

The formed or cellular elements (i.e. shaped structures visible under magnification) of the blood are of three categories :

(1) Red blood cells (**erythrocytes**),

(2) White blood cells (**leukocytes**),

(3) Blood platelets (**thrombocytes**)

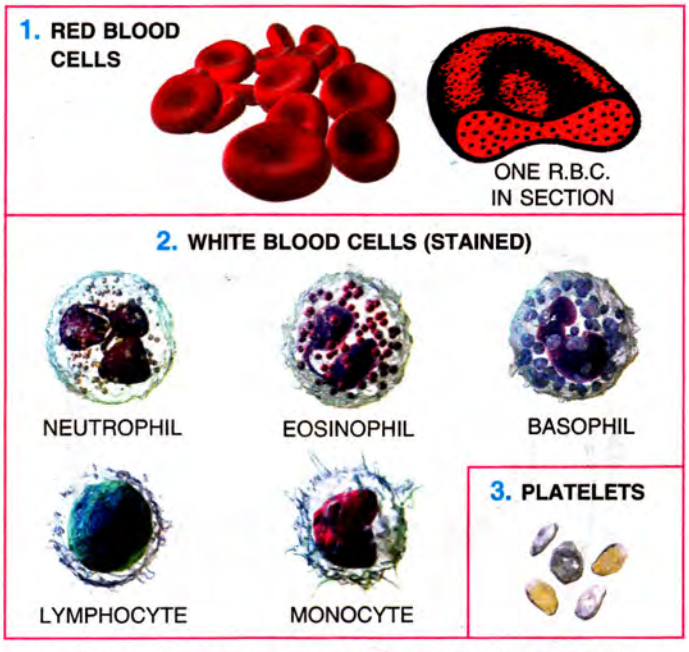


Fig. 7.2 : Blood cells – 1. Red blood cells; 2. various kinds of white blood cells (after staining) and 3. platelets.

(1) RED BLOOD CELLS (RBCs) — The oxygen carriers

Red blood cells are also called **erythrocytes** (*erythros*: red)

- These are minute biconcave disc-like structures, flat in the centre and thick and rounded at the periphery.
- These are very small — about 7 micron in diameter (1 micron = one-thousandth of a millimetre and is represented by the symbol "μ")
- The small size plus the concavities on either side provide a large surface area which makes them very efficient in absorbing oxygen.
- The small size enables the red blood cells to travel through very fine capillaries in the body where they have to travel in a single file.

An adult human male has about 5 million RBCs per cubic mm of blood and an adult female has slightly less about 4.5 million.

HAEMOGLOBIN – the effective chemical constituent of RBCs. The red blood cells have a colourless spongy body or *stroma* which contains a respiratory pigment **haemoglobin (Hb)**.

– The haemoglobin is formed of an iron-containing part (**haemin**) and a protein (**globin**).

– It has the ability to combine readily with oxygen

to form **oxyhaemoglobin**, an unstable compound which readily gives up oxygen to the needy tissues.

– Haemoglobin can carry a very small quantity of carbon dioxide in the form of carbamino-haemoglobin.

Is it correct to say that veins carry CO_2 and no oxygen?

NO!

Veins too carry oxygen but only a little less than the arteries!

Inside the lungs the haemoglobin (Hb) becomes 97-99 per cent saturated with oxygen. Inside the respiring tissues Hb releases only about 23% of its oxygen and the blood returning in veins still contains about 75% oxygen.

Carbon Monoxide Poisoning

Haemoglobin has very strong affinity for carbon monoxide forming a stable compound carboxyhaemoglobin (HbCO). This cuts down the capacity of the blood of transporting oxygen, sometimes resulting in death. *For example*, **carbon monoxide poisoning** may cause death due to furnaces burning in small rooms without ventilation.

Life and death of RBCs.

- In adults, the RBCs are produced in the ***marrow of long bones***, especially in the ribs, breast bone and ilium of hip girdle.
- In an embryo they are produced in the liver and spleen.
- In children, the RBCs are produced in bone marrow of all bones until 5 years of age.
- ***The mature red blood cells have no nuclei,*** but when they are being produced, they have one. As they mature, the nuclei are lost, *i.e.*, they become enucleated.
- ***The average life of an RBC is about 120 days***.
- The old and weak red cells are ***destroyed in the spleen, liver and bone marrow***; their iron part is retained in the liver while the rest is excreted as a bile pigment (bilirubin).
- In a normal adult, approximately 20,000,000 RBCs are destroyed every minute. In other words, about 1 per cent of the total erythrocytes in the body are destroyed everyday.

DEFICIENT, BUT MORE EFFICIENT !

Mammalian red blood cells

Mammalian red blood cells when mature circulate in the blood system and are devoid of certain organelles. They have

— no **nucleus**
— no **mitochondria**
— no **endoplasmic reticulum**

Thus, though deficient of the above organelles, the mature red blood cells, in reality, are more efficient in carrying out their task of picking up and delivering oxygen. The factors making them more efficient in this work are as follows :

1. **Loss of nucleus**, makes the red cells biconcave, thus increasing their surface area volume ratio for absorbing more oxygen.

   — Space in between increased
   — More RBCs can be accommodated in the same space
2. **Loss of mitochondria** means that the red cells cannot use oxygen for themselves (cellular respiration occurs in mitochondria). Thus all the oxygen, absorbed from the lungs, is transported and delivered to the tissues unconsumed. Secondly, loss of mitochondria means full transport of glucose in blood plasma, unused by the RBCs.
3. **No endoplasmic reticulum** means increased flexibility of RBCs for their movement through narrow capillaries.

More about the number of RBCs

- New born infants have a larger number of RBCs — about 6-7 million per cubic millimetre (1 mm^3).
- RBC count is lower by 5% during sleep.
- RBC count is higher during physical activity, pregnancy and emotional upsets.
- **People living at a height of 4,200 m and above, increase their RBCs by nearly 30%.**
- **Abnormally increased number of RBCs is called *Polycythaemia*, and their abnormally decreased number is known as *Erythropenia*.**

(2) WHITE BLOOD CELLS (WBCs) — White blood cells, or **leukocytes** (*leuko* : white), differ from red blood cells in having a nucleus and do not contain haemoglobin. Their number is much less, usually about **4000-8000 per mm^3** of blood. Most WBCs are amoeboid and can produce pseudopodia with which they can squeeze through the walls of the capillaries into the tissues (**diapedesis** *dia* : across, *pedesis* : oozing out) (Fig. 7.3).

Fig. 7.3 A white blood cell oozing out of the blood vessel (diapedesis).

Based on shape and other characteristics, the white blood cells are classified into two major categories (granular and non-granular) and five distinct types (Table 7.1 given below and Fig. 7.2 on page 78) as follows:

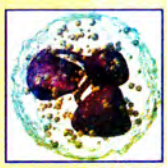
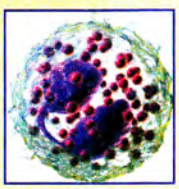
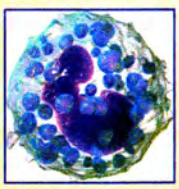
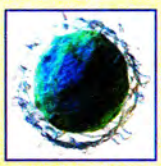
White blood cell Or White cells ?

Better term is "white cells" or Leukocytes (**leukos** : white) because they spend most of their time (90%) in tissue fluid or in the lymph and very little time (only about 10%) in the blood.

FUNCTIONS OF LEUCOCYTES (WBCs) — Body defence

1. ***Phagocytosis :*** This is a process in which most WBCs and particularly the **neutrophils engulf particle-like solid substances, especially bacteria**. This is a defensive mechanism against disease germs. An abnormal increase in WBC count up to about 50,000 or more per cubic mm indicates some infection in the body.
2. ***Inflammation :*** Inflammation occurs due to the reaction of tissues to injury and to localized invasion of germs. The inflamed spot has several characteristics: increased **local heat, redness, swelling, pain,** *etc.* Here the leucocytes (specially the monocytes and

Table 7.1 Different types of white blood cells (Leukocytes) after staining.

Two major categories of WBCs	Five cell type (abundance)	Appearance	Distinguishing features	Functions	Where produced
A. Granular • Cytoplasm contains granules • Nucleus usually constricted into lobes	**1.** Neutrophils (62%)		• Nucleus with 3-4 lobes • Granular cytoplasm • Stain with neutral dyes	Engulf bacteria (Phagocytosis)	Bone marrow
	2. Eosinophils (2·3%) count increases in allergies		• Nucleus with 2 lobes • Cytoplasmic granules large and stain dark red with eosin (acid dye)	• Engulf bacteria • Secrete antitoxins • Associated with allergy	Bone marrow
	3. Basophils (0·4%)		• Nucleus large indistinctly lobed Granules stain with basic dyes (e.g. methylene blue)	Release chemicals (histamine) for **inflammation** which dilate blood vessels	Bone marrow
B. Non-granular • Cytoplasm without granules, • a single large nucleus	**4.** Lymphocytes (30%)		• **Smallest** of WBCs • Single large nucleus	Produce **antibodies**	Bone marrow and Lymph glands (spleen, tonsils, etc.)
	5. Monocytes (5·3%)		• Nucleus large, kidney-shaped • At the site of infection, transform into macrophages	Ingest germs	Bone marrow

neutrophils) migrate through the walls of the blood vessels by **diapedesis** (Fig. 7.3), and fight against disease-causing germs. They also **destroy the damaged cells** by phagocytosis. **Pus** is mainly composed of the dead white blood cells together with the tissue cells destroyed by the bacteria.

3. ***Formation of antibodies :*** The WBCs (specially the **lymphocytes**) produce antibodies which kill or neutralise the germs, or the poisons from them. Introducing weakened germs or germ substances (vaccines) during vaccination stimulates formation of particular antibodies which, at a later period, would destroy the particular disease-causing germs if they enter into the body.

ANTIBODIES and "ANTITOXINS"

When disease-causing germs gain entry into the blood stream, they produce poisonous substances called **toxins** (meaning poisons). In response, the lymphocytes of the blood produce chemical substances called **antibodies** which circulate free in the blood plasma. The antibodies are specific to the toxins for which they are produced. The antibodies act as **antitoxins** which neutralise (detoxify) the poisonous effect of the toxins.

Antibodies may persist long after the disease has been overcome, and the person who has recovered becomes immune to the disease. This is the underlying principle of vaccination (a deliberate introduction of weakened disease germ to stimulate production of the specific antibodies).

ORIGIN AND LIFE OF WBCs :

The WBCs are produced in red bone marrow, lymph nodes and sometimes even in liver and the spleen. Their average life is about two weeks. The neutrophils live for only a few hours, and about 125 billion neutrophils are produced each day. The old and worn out WBCs are destroyed in the same manner as the RBCs.

Leukemia ***is a cancer of the tissue forming WBCs whose number increases manifold at the cost of RBCs. It is usually a fatal disease. Currently, the treatment is only blood transfusion.*** **Leucopenia** ***is the abnormal decrease in the number of WBCs.***

(3) BLOOD PLATELETS (Thrombocytes)
(Initiators of clotting of blood)

Blood platelets are minute oval or round structures, non-nucleated, floating in the blood. These are about 200,000 to 400,000 per cu. mm. of blood in an adult. The platelets are derived from some giant cells called megakaryocytes in the red bone marrow. These are budded off from the megakaryocytes in a manner that each one is completely surrounded with membrane. Their life span is 3 to 5 days and are destroyed mainly in the spleen (a lymphatic organ located in the abdomen). They are very important in clotting of blood. At the site of injury, the platelets disintegrate to release a chemical substance thrombokinase which initiates the process of clotting of blood.

? ***PROGRESS CHECK***

1. Name the following :
   (i) The yellow coloured fluid part of the blood.
   (ii) The respiratory pigment contained in RBCs.
   (iii) Any two organelles absent in mature RBCs.
   (iv) The process of WBCs squeezing out through the walls of the blood capillaries.
2. Mention the following :
   (i) Average life span of RBCs.
   (ii) Range of RBCs per mm^3 in a normal adult human female.
   (iii) The two major categories of WBCs.
   (iv) Blood cells involved in leukaemia.

7.6 CLOTTING OF BLOOD (COAGULATION)

When a blood vessel is cut, blood escapes from it. But soon a clot is formed on the wound (Fig. 7.4) and the flow of blood is stopped. If it were not so, the injured person would bleed to death. Clotting (also called *coagulation*) occurs in a series of steps as follows :

1. The injured tissue cells and the platelets which disintegrate at the site of the wound release a substance **thrombokinase** (also called **thromboplastin**). (More recently it is called "Factor X" or Stuart factor).
2. The thrombokinase acts as an enzyme and with the help of the *calcium* ions present in the plasma, it converts a substance **prothrombin** (inactive) of the plasma, into **thrombin** (active).

3. Thrombin in the presence of calcium ions, reacts with the soluble **fibrinogen** of the plasma to convert it into insoluble **fibrin**. Fibrin is a solid substance that forms threads. These microscopic threads of fibrin are sticky and form a network (mesh) at the wound.
4. Blood cells are trapped in the network of the fibrin; the network then shrinks and squeezes out the rest of the plasma which is in the form of a clear liquid, the **serum**. The solid mass which is left behind is called **clot** (or **thrombus**).

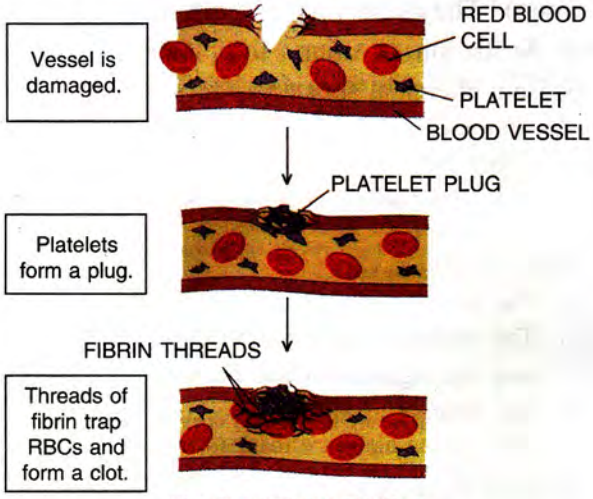
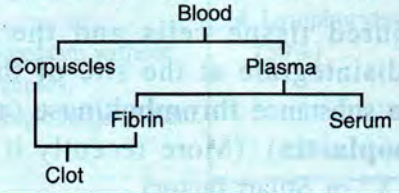


Fig. 7.4 Blood clotting

Main reactions in blood clotting

1. **Injured** Tissue Cells & Platelets —release→ Thromboplastin (or Thrombokinase) Presently called Factor X
2. **Prothrombin** (Inactive) Found in blood plasma (also called thrombinogen) —+Ca ions→ Thrombin (Active) Acts like an enzyme
3. **Fibrinogen** (Soluble) → Fibrin (Insoluble) Threads make a network
4. Fibrin —+ RBCs→ CLOT

The fate of blood in blood clotting :



BLOOD CLOTTING IN A TEST-TUBE

If some blood is taken in a test-tube, a clot will form in the usual way and the serum squeezed out from the clot will collect on the surface (Fig. 7.5).

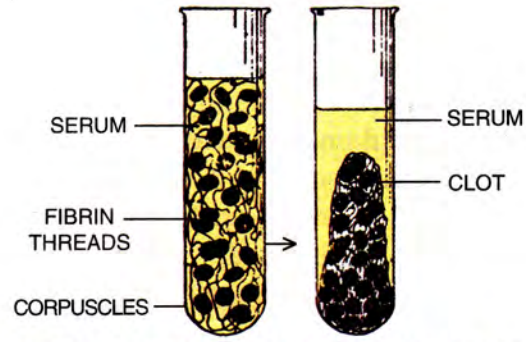


Fig. 7.5 Left, coagulated blood; the fresh clot consists of fibrin strands, corpuscles and serum. Right, coagulated blood after standing for some time; clot has separated from the serum. (*Highly diagrammatic*)

If the **number of platelets** falls to an abnormally **low count**, then also the coagulation occurs very slowly and often leads to haemorrhage. Such a situation occurs in certain diseases as in the **viral dengue fever** which has taken hundreds of lives in Delhi and other states of India since 1996 till date.

It is a wrong notion that clotting is dependent on the exposure of blood to air. In fact, clotting can be caused by the movement of blood over a rough surface as on cholesterol deposit on the inside of a blood vessel.

7.7 BLOOD TRANSFUSION AND BLOOD GROUPS (ABO and Rh systems)

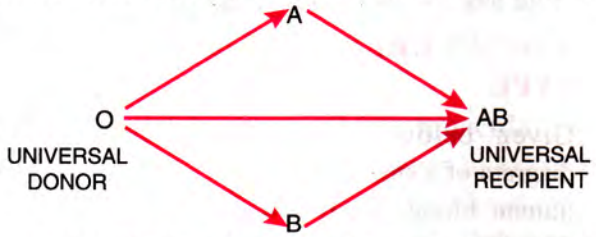
Sometimes it becomes necessary to inject blood into the body of patients undergoing surgical operation. This is called ***blood-transfusion***. Blood taken from a healthy person (*donor*) is introduced through one of the patient's veins. But for doing so, it is necessary that the kind or the type of blood to be transfused should match (or be compatible) with the type of blood of the receiving person (*recipient*).

The concept of blood grouping was discovered by Karl Landsteiner. RBC's of human beings have specific proteins on their surface. These proteins are called antigens. The plasma of the blood has its complementary antibodies. In humans there are two types of antigens. 1. *Antigen A* 2. *Antigen B*. Depending on the presence or absence of these antigens there are four types of blood groups as shown in the table.

Blood group	*Antigens on RBC*	*Antibodies in plasma*
A	Antigen A	anti b
B	Antigen B	anti a
AB	Antigen A & B	no antibody
O	No antigen	Both anti a and anti b

There are several systems of blood grouping. But two of them, **ABO system** and **Rh system** are most important.

ABO System : According to the ABO system, the human blood is classified into four types — A, B, AB and O. Besides the transfusion of one's own type of blood (A to A, AB to AB, etc.), the other possible transfusions can be made as follows :



Accordingly, O type blood can be given to persons of all types of blood *i.e.* to O, A, B & AB. Hence a person with O type is called **universal donor**. A person with AB type of blood can receive blood from all types, *i.e.*, from AB, A, B & O, and is, therefore, called **universal recipient**. A person with A type can receive blood from A and O types and a person with B type from B and O types only.

The summary of matching (**compatibility**) and mismatching (**incompatibility**) in ABO system is given in the table below:

Table 7.2 Summary of ABO Blood Group matching (Compatibility)

Blood group of Donor	Blood group of recipient			
	A	B	AB Universal recipient	O
A	✓	✗	✓	✗
B	✗	✓	✓	✗
AB	✗	✗	✓	✗
O Universal donor	✓	✓	✓	✓

Rh system : The blood of most people contains a substance called Rh factor. (Rh *stands for Rhesus, our common monkey, in which the factor was first discovered*). When the blood of such an individual (Rh-positive) is transfused into persons lacking it (Rh-negative), the blood of the recipient develops an antibody for Rh substance (gets sensitized) within about two weeks of transfusion. Now, if a second transfusion be given to such Rh-negative person, the antibody produced by the first transfusion causes a reaction with the transfused blood, which may even lead to death. This is similar to the development of an allergy.

Rh factor in pregnancy : An Rh-negative woman may become sensitive if she carries an Rh-positive child in her uterus (when the husband is Rh-positive). The first Rh-positive child will be normal, but if it sensitizes the mother, the second positive child if conceived soon, may have a problem, sometimes leading to the death of foetus and abortion.

[**Rh-positive** may be written in short as **Rh+ve** or as **Rh$^+$** and similarly, the **Rh-negative** may be written as **Rh-ve** or as **Rh$^-$**]

? ***PROGRESS CHECK***

1. State which of the following statements are **True**.
   (i) Process of coagulation starts with the release of a substance from RBCs.
   (ii) Blood fails to clot readily in the case of deficiency of calcium.
   (iii) The solid fibrin and thrombin are one and the same thing.
   (iv) The clear liquid that oozes out after the formation of a clot is serum.
2. Name the following :
   (i) The category of vitamin required for clotting of blood.
   (ii) Any two diseases related with blood clotting .
   (iii) The antibodies present in the plasma of O type blood group.
   (iv) The animal for which Rh stands in the context of blood group.

REVIEW QUESTIONS

A. MULTIPLE CHOICE TYPE

(Select the most appropriate option in each case)

1. Agranulocytes are :
   (a) lymphocytes and monocytes
   (b) lymphocytes and basophils
   (c) eosinophils and basophils
   (d) eosinophils and monocytes
2. White blood cells engulf bacteria in a process called:
   (a) diapedesis (b) phagocytosis
   (c) active transport (d) passive transport

B. VERY SHORT ANSWER TYPE

1. Given below are certain structures, write the term for the functional activity.
   (a) Blood platelets and .....
   (b) Neutrophils and .....
   (c) Erythrocytes and .....
   (d) Lymphocytes and .....
   (e) Bone marrow and .....
2. Name the following :
   (a) The cells which transport oxygen to the different parts of the human body.
   (b) The cells that initiate blood clotting.

C. SHORT ANSWER TYPE

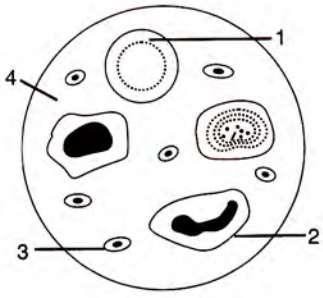
1. **Enumerate** the structural differences between white blood cells and red blood cells.
2. **Why is it necessary** to know the blood groups before giving transfusion?
3. **Differentiate** between members of each of the following pairs with reference to phrases in brackets:
   (a) Antibodies and antibiotics (Source)
   (b) RBC and WBC (Structure)
   (c) Serum and vaccine (Composition)
4. Complete the following statement by **filling in the blank** from the choices given in the brackets.
   An anticoagulant present in the blood is ..... (heparin, hirudin, thromboplastin, calcium).

D. LONG ANSWER TYPE

1. **What** are the functions of blood plasma?
2. **What** are the main steps in coagulation of blood?
3. **What** are the following?
   (a) Rh factor (b) Universal donor (c) Diapedesis
4. **Is it possible** for the blood to clot under the skin? **Give reason** in support of your answer.
5. **State** any five functions of the blood.

E. STRUCTURED/APPLICATION/SKILL TYPE

1. Given below is a diagram of a smear of human blood. Study the same and answer the questions that follow :-



   (a) **Name** the parts 1, 2, 3 and 4 indicated by guidelines.
   (b) **Mention** two structural differences between the parts labelled '1' and '2'.
   (c) **What** is the main function of the parts labelled 1, 2 and 3 respectively ?
   (d) **What** is the life span of the part labelled '1'?
   (e) **Name** a soluble protein found in '4' which helps in the clotting of blood.

7 B. THE CIRCULATORY SYSTEM

7.8 BLOOD CIRCULATORY SYSTEM

The circulatory system consists of **heart, arteries, veins** and **capillaries**.

7.8.1 The Heart

Location (not on the left side, but it is felt so.)

The heart is right in the centre between the two lungs and above the diaphragm. The narrow end of the roughly triangular heart is pointed to the left side (Fig. 7.6) and during working, the contraction of the heart is most powerful at this end giving a feeling that the heart is on the left side.

Covering : The heart in adult humans is about the size of our closed fist – 12 cm in length and 9 cm in width. It is protected by a double walled

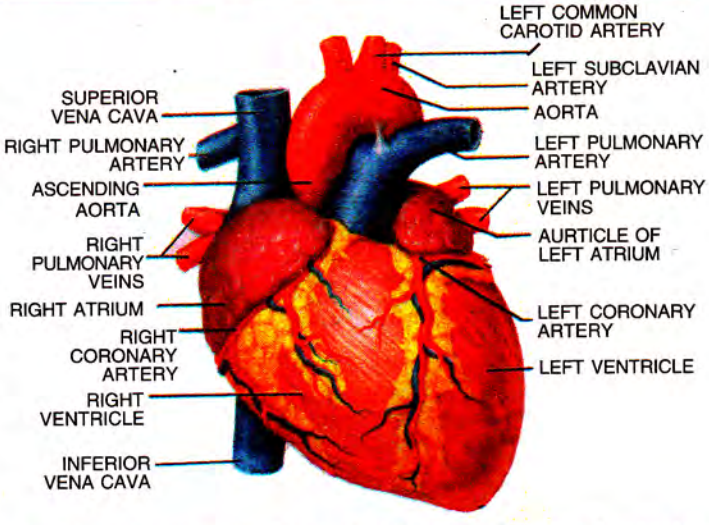


Fig. 7.6 Human heart (front view) showing the blood vessels arising and entering it.

membranous covering called **pericardium**. It contains lubricating pericardial fluid which reduces friction during heart beat and protects it from mechanical injuries.

Chambers of the heart (Fig. 7.7)

The heart consists of four chambers – two upper **atria** *(sing. atrium)* and two lower **ventricles**. The **atria** (also called **auricles**) **have thinner walls** because their major function is to receive blood from the body and *pump it into the very next ventricles*.

The **ventricles have thick muscular walls** (Fig. 7.7) because they have to pump blood to long distances. The right ventricle pumps blood only up to the lungs for oxygenation. But the left ventricle pumps it up to the farthest points in the body, such as, up to the toes in the feet or up to the brain against gravity, and so its walls are thicker.

7.8.2 Blood vessels entering and leaving the heart (Figs. 7.6, 7.7 and 7.8)

A. Blood vessels entering the heart

The right atrium receives two large vessels – **anterior vena cava** and **posterior vena cava**.

(1) **Anterior vena cava** (also called superior vena cava or precaval) brings deoxygenated blood from the anterior or upper regions of the body including head, chest and arms.

(2) **Posterior** (or inferior) **vena cava** brings blood from the posterior or the lower region of the body including abdomen and legs.

The left atrium receives 4 pulmonary veins (two from each lung). The pulmonary veins bring oxygenated blood.

B. Blood vessels leaving the heart

Arising from the ventricles are two large blood vessels.

1. The **pulmonary artery** arises from the right ventricle and carries deoxygenated blood to the lungs for oxygenation.
2. The **aorta** arises from the left ventricle and carries oxygenated blood to supply it to all parts of the body.

Coronary arteries. You can also see in Fig. 7.6 two **coronary arteries** (right and left) arising from the base of the aorta. These supply the heart muscles. When there is blockage in any coronary artery or in any one or more of their branches there is a **"deadening"** of the corresponding area of heart muscles leading to **"myocardial infarction"** or a heart attack in popular language. The cardiac veins

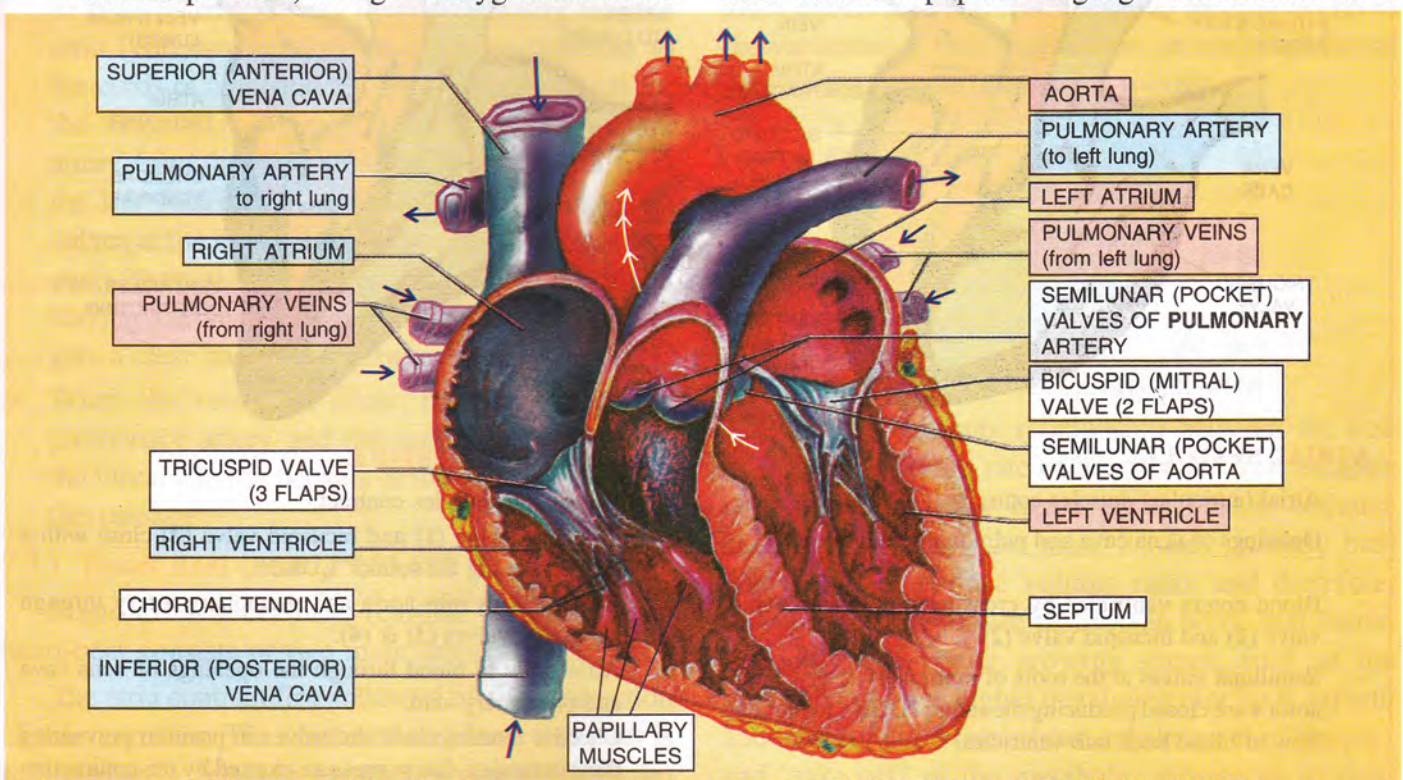


Fig. 7.7 Internal structure of the human heart and the associated blood vessels (diagrammatic)

collect blood from heart walls and pour it into the right auricle. **"Angina pectoris"** is the chest pain due to insufficient supply of blood to the heart muscle.

Heart — A bank cashier!

The bank cashier handles so much money everyday, but what he can use for himself is only the salary he gets. Is it not similarly true for the heart? It handles so much blood every minute but it can use only that much which it gets through coronary arteries supplying its muscular walls.

7.8.3 Valves regulate the flow of blood in a single direction

There are four valves in the heart as follows :

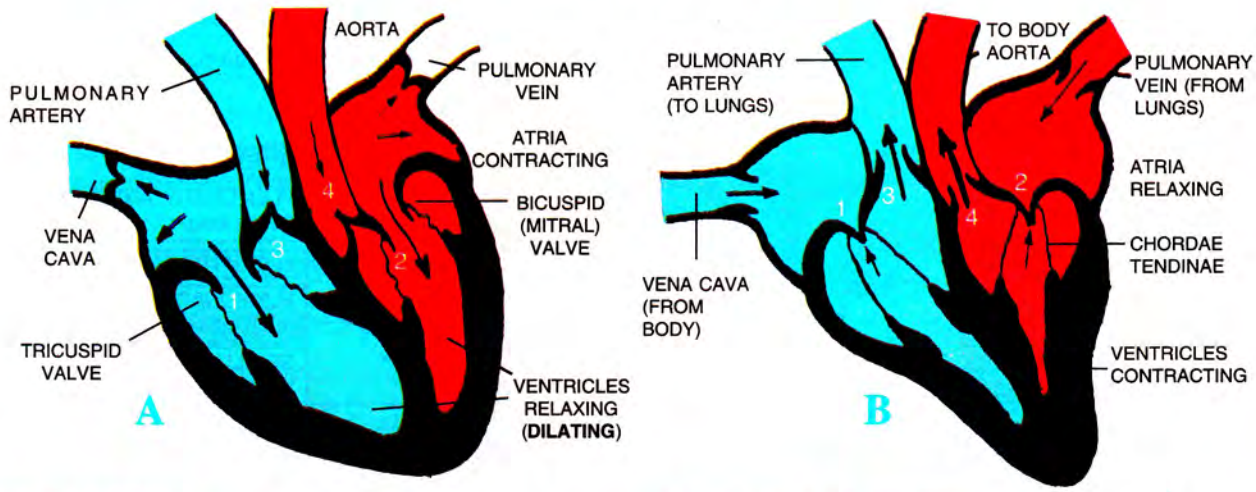
1. **Right atrio-ventricular valve** is located at the aperture between the right auricle and the right ventricle. It has **three** thin triangular leaf-like flaps (cusps) and is therefore also called **tricuspid valve**. The apices (pl. of apex) of the flaps are held in position by tendinous cords (**chordae tendinae**) arising from the muscular projections of the ventricle wall known as **papillary muscles**.
2. **Left atrio-ventricular valve** is located in a similar way on the left side of the heart. It has **two** cusps, and is, therefore, called **bicuspid** (also **mitral**) **valve**.
3. **Pulmonary semilunar valves** are located at the opening of the right ventricle into the pulmonary artery. These are pocket-shaped and three in number.
4. **Aortic semilunar valves** are located at the point of origin of aorta from the left ventricle. These are also three in number and pocket-shaped.

Fig. 7.8 Two main phases of heart beat: A – Atrial systole and B – Ventricular systole.

ATRIAL SYSTOLE AND VENTRICULAR DIASTOLE

[Note the valves that are closed or open]

VENTRICULAR SYSTOLE AND ATRIAL DIASTOLE



ATRIAL SYSTOLE

- Atrial (auricular) muscles contract
- Openings of vena cava and pulmonary vein close
- Blood enters ventricles by crossing through tricuspid valve **(1)** and bicuspid valve **(2)**.
- Semilunar valves at the roots of pulmonary artery **3** and aorta **4** are closed producing the sound "DUP", to prevent flow of blood back into ventricles.

VENTRICULAR SYSTOLE

- Ventricular muscles contract.
- Tricuspid valve **(1)** and bicuspid valve **(2)** close with a jerk producing the sound "LUBB".
- Blood passes into aorta and pulmonary artery through semilunar valves **(3)** & **(4)**.
- Atria draw in blood through the openings of vena cava and pulmonary vein.
- Chordae tendinae hold the valves in position preventing their upturning due to pressure exerted by the contracting ventricles

PROGRESS CHECK

1. Fill in the blanks :
   (i) Ventricles have ..... walls when compared with those of auricles.
   (ii) Ventricles give rise to two large blood vessels called ..... and .....
2. Where are the following located ?
   (i) Tricuspid valve (ii) Mitral valve
   (iii) Pulmonary semilunar valves
3. Can you answer why the pulmonary artery shown in Fig. 7.6 is blue in colour ?

7.9 CIRCULATION OF BLOOD IN THE HEART

- It starts with the **contraction of the two atria** (auricles). The ventricles at this time are **relaxing** (or **dilating**) and are empty (Fig. 7.8A). Therefore, the blood from the atria passes into the ventricles easily.
- Next, the **ventricles contract**, and the atria relax. The blood from the ventricles under pressure tends to return to the atria, but the flaps of the two **cuspid** (meaning pointed projection) **valves** get tightened and puffed up, thus closing the passage and preventing the return of blood (Fig. 7.8B). The chordae tendinae hold the flaps of the valves in position and prevent their overturning into the atria (you can compare the chordae tendinae to the cords of a parachute). The only course left for the ventricular blood is to enter the pulmonary artery from the right ventricle and the aorta from the left ventricle. The mouths of the pocket-like valves at the bases of these two blood vessels face away from the ventricles. Therefore, the blood leaving the ventricles presses the valves flat and gets a clear passage in between.
- When the ventricles dilate, the blood from the pulmonary artery and the aorta tends to return, the blood fills the pockets of the valves and closes the passage.

7.9.1 Heart Beat (nearly 1,03,680 times in a day)

Steps of a heart-beat (cardiac cycle) – Each heart-beat consists of two main steps :

The atria contract first followed by the contraction of the ventricles. The **contraction phase** (**systole**) is followed by a relaxing **expansion phase** (**diastole**) (Fig. 7.8).

Each full beat of the human heart lasts for about 0.85 seconds.

Systole of atria (auricles)	–	0.15 sec
Systole of ventricles	–	0.30 sec
All chambers in relaxed state	–	0.40 sec

At the end of ventricular systole, the ventricles start relaxing (**ventricular diastole**). Meanwhile the atria (auricles) have also been relaxing (**atrial diastole**) and for a short period, both the atria and the ventricles are in a relaxed state (joint diastole). The whole sequence of events in the heart beat is called **cardiac cycle.**

The Heart Sounds–"LUBB" and "DUP"

If you hear your heart sound by placing a stethoscope on your chest, you will hear two sounds "LUBB and "DUP" in short succession followed by a gap.

The first sound "LUBB" is produced when the **atrio-ventricular** ***(tricuspid and bicuspid)*** valves get closed sharply at the start of ventricular systole.

The second sound "DUP" is produced when at the beginning of ventricular diastole, the **semilunar valves** at the ***roots of aorta and pulmonary artery*** get closed.

Rate of heart-beat varies among different species and even in individuals of the same species. Some of the variations in beats per minute (at rest) in different species are (approximately) as follows :

Whale	15
Elephant	25
Horse	40
Adult men	64–72
Adult women	72–80
Cat	120
New born infant	140
Rat	250
Sparrow (in vigorous activity)	800 – 900

Do you find any relationship between the size of the body and the rate of heart beat ? Yes, **smaller the size, faster the heart rate**. This is because smaller the animal, the more it loses its body heat due to higher surface volume ratio, and therefore, the increased heart-rate distributes body heat faster. Secondly, the young growing stages, such as the human baby, have higher metabolism for body growth and therefore, the faster heart rate keeps the "supply" and "take off" of the metabolic substances in right quantities.

7.9.2 Pacemaker

The impulse or command which starts the heart-beat arises in **"Pacemaker" (sinu-atrial node, "SAN")** located in the walls of the right auricle (Fig. 7.9). This impulse is relayed to the ventricles with the help of special conducting fibres.

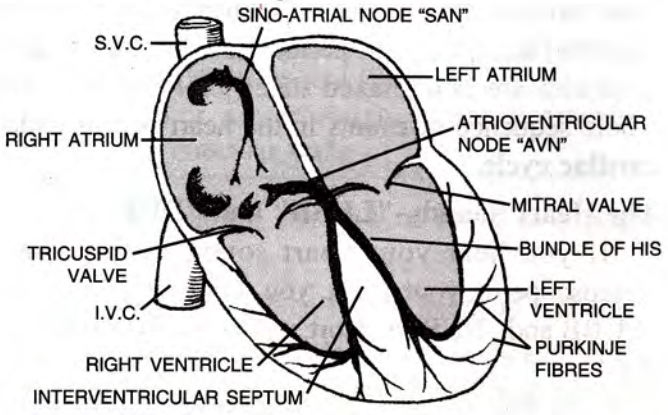


Fig. 7.9 : Internal structure of heart, showing location of "pacemaker" (SAN) and another contraction centre; "AVN" (atrioventricular node).

The Pacemaker (SAN) is present near the opening of the superior vena cava and the AVN node (atrio-venticular node) is found near the interauricular septum near the tricuspid valve. A bundle of muscle fibres called 'Bundle of HIS' begins from AVN and extends to the interventricular septum. Bundle of HIS consists of branches of fibres running along the wall of the ventricle, called 'Purkinje fibres'. All these together form a system which creates an impulse and conducts it to every part of the heart.

Sometimes the "pacemaker" becomes faulty causing heart trouble. An artificial "pace-maker" may be fixed in the heart of such a person.

? ***PROGRESS CHECK***

1. Name the following :
   (i) Contraction phase of heart.
   (ii) The structure that holds the heart valves in position.
2. Mention the phase of heart beat in which both the atrio-ventricular valves are closed.

7.10 THE BLOOD VESSELS

The blood vessels are branched tubes extending from the heart to all parts of the body. They are of three kinds – arteries, capillaries and veins.

An ARTERY is a vessel which carries blood away from the heart towards any organ. It has

- ***thick muscular walls*** (Fig. 7.10),
- a ***narrow lumen*** (the central bore), and
- the ***blood in it flows in spurts*** which correspond to the ventricular contractions of the heart.

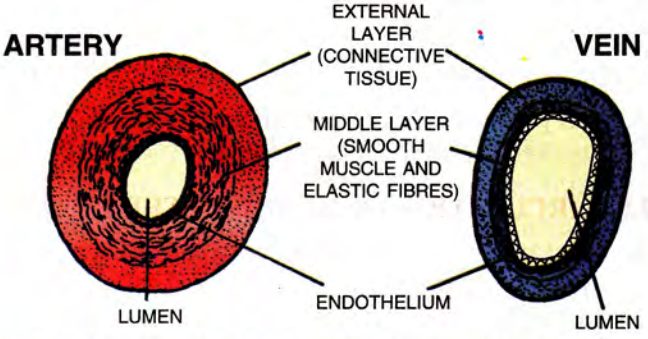


Fig. 7.10 : Structural difference between artery and vein

A ***VEIN is a vessel which conveys the blood away from an organ towards the heart.***

Characteristics of vein :

- ***thin muscular walls***,
- a ***wider lumen,***
- the ***blood in it flows uniformly***, and
- it contains ***thin pocket-shaped valves*** (Fig. 7.11) whose openings face in the direction of the heart; these valves prevent the backflow of the blood.

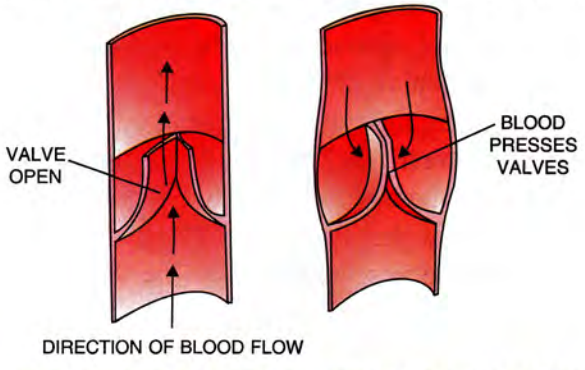


Fig. 7.11 : Valves in a vein regulate the flow of blood in the direction of the heart.

The smallest or the final branch of an artery is called an **arteriole**. Arterioles are highly muscular and can change their diameter manifold. The arteriole breaks up into capillaries (Fig. 7.12A).

A ***CAPILLARY*** is a very ***narrow tube*** (about 8 micrometres in diameter);

- its wall consists of a single layer of squamous epithelial cells (endothelium), and

has ***no muscles*** (Fig. 7.12B). The total number of blood capillaries present in the whole body is almost inconceivable.

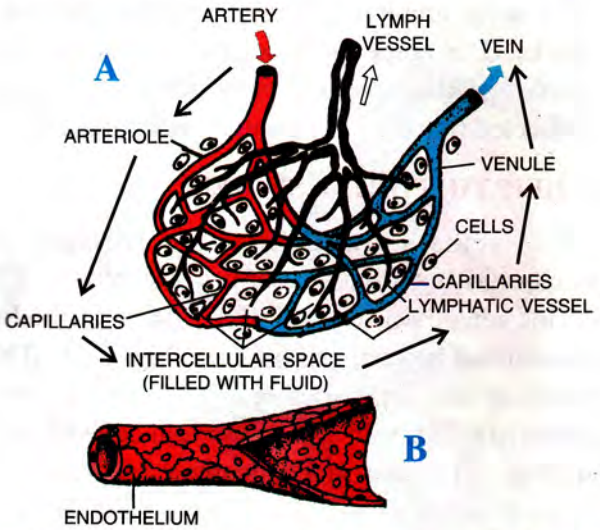


Fig. 7.12 : A. Diagrammatic relationship of artery, capillaries and vein (Blindly ending lymphatic vessels are also usually associated with blood capillaries). B. A capillary, formed of a single layer of epithelial cells.

If all the blood capillaries of the body were placed end to end in a row they could extend to a length of 100,000 kilometres. Their total wall surface would be more than 500 square metres.

Functions of capillaries :

(i) To allow **outward diffusion of oxygen** into the intercellular fluid and from there into the tissue cells.

(ii) To allow **inward diffusion of carbon dioxide** from the intercellular fluid.

(iii) To allow inward and outward **diffusion of substances** like glucose, amino acids, urea, hormones, etc.

(iv) To allow **leucocytes** (WBCs) **to squeeze out** through the capillary walls by means of amoeboid movement.

The capillaries have the power of dilating **(vasodilation)** and contracting **(vasoconstriction)** which respectively increases or decreases the blood supply to the body parts. Evidence of these changes in capillaries is seen in the colour of the skin.

- Walk in the hot sun– Face turns pink (increased blood flow).
- When it is too cold, face turns bluish (reduced blood flow).

The capillaries gradually reunite and increase in size assuming the same three layers (connective tissue layer, muscular layer and endothelium) as in arteries and veins. The smallest united common branch is called a **venule**. The venules join to form larger veins. Compared with arterioles the venules are larger with much weaker muscular coat.

Table 7.3 Differences between arteries and veins

ARTERIES	VEINS
A. Definition :	
Blood vessels which carry blood **away from the heart and into an organ.**	Blood vessels which carry blood **away from an organ and towards the heart.** (Except hepatic portal vein).
B. Structure :	
1. Progressively branched, **decreasing in size.**	1. Progressively unite **increasing in size.**
2. Smallest artery **breaks into arterioles.**	2. Smallest vein **arises from venules.**
3. Have **thick and more muscular walls.**	3. Have **thin and less muscular walls.**
4. Walls are **elastic.**	4. Walls are **non-elastic.**
5. Have **narrower lumen.**	5. Have **wider lumen.**
6. Have **no valves** in their inner lining.	6. **Have valves** in their inner lining to prevent backward flow of blood.
7. Can constrict or dilate to control blood flow.	7. Can not constrict.
8. Usually **deeper** placed.	8. Usually more **superficial** (nearer the skin).
9. **Do not collapse** when empty.	9. **Collapse** when empty.
C. Blood composition and flow	
1. Carry fully **oxygenated blood** (except pulmonary artery).	1. Carry partially **deoxygenated & CO_2 laden blood** (except pulmonary vein).
2. Blood flows with **jerks** and under **great pressure.**	2. Blood flows **continuously** and under very little pressure.

? PROGRESS CHECK

1. Fill in the blanks

(i) The ..... have thin and less muscular ....., and have ..... to prevent back flow of .....

(ii) ..... carry blood to an organ and break up into ..... ending in capillaries.

(iii) Walls of capillaries consist of a single layer of squamous ..... cells.

(iv) The substances to and from the tissues diffuse through the walls of .....

7.11 THE TWO BLOOD CIRCULATIONS — PULMONARY AND SYSTEMIC

The general plan of blood circulation in our body is shown in Fig. 7.13. Blood flows twice in the heart before it completes one full round : (1) the short **pulmonary** (lung) **circulation** and (2) the long **systemic** (general body) **circulation**. For this reason the blood circulation in the human body is also called **"double circulation"** (see also Fig. 7.15).

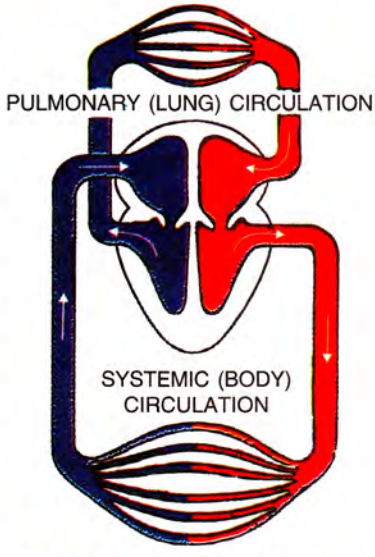


Fig. 7.13 : General plan of double circulation of blood in the human body.

(1) The **pulmonary circulation** pertains to the lungs. It starts in the **pulmonary artery** arising from the right ventricle which soon divides into two branches that enter the respective lungs. **Pulmonary veins** collect the oxygenated blood from the lungs and carry it back to the left auricle of the heart.

(2) The **systemic circulation** pertains to the major circulation in the body. It starts with the **aorta** that arises from the left ventricle (Figs. 7.8 & 7.14). The aorta arches back and continues behind as **aorta**. The aorta sends arteries to various body parts and their tissues. From there the blood is collected by veins and poured back into the heart.

7.12 HEPATIC PORTAL SYSTEM

The veins starting from the stomach and intestines do not directly convey the blood to the posterior vena cava. Instead they first enter the liver as a combined **hepatic portal vein** (Fig. 7.14). There it breaks up into capillaries in contrast to the general characteristic of a vein and a new vein called **hepatic vein** (Fig. 7.15) is formed by their reunion which joins the posterior vena cava. By definition, therefore, ***a portal vein is one which starts with capillaries and also ends in capillaries.***

UTILITY OF HEPATIC PORTAL SYSTEM

The food absorbed by the stomach and intestines is first brought to the liver which acts like a store to regulate the quantity of nutrients flowing into the general blood circulation, for example, excess sugar is stored as glycogen. Also, certain poisons if absorbed through food, are detoxified (rendered harmless) in the liver.

MAIN BLOOD VESSELS

The syllabus prescribes only the names of main blood vessels of the **liver** and the **kidney** and those entering and leaving the **heart**. These are listed as follows :

HEART

A. Blood vessels entering the heart

1. Anterior vena cava (from upper parts of our body into **right** atrium). It is formed by the union of jugular vein and subclavian vein.
2. Posterior vena cava (from lower parts of body into **right** atrium)
3. Pulmonary veins (two veins from each lung into **left** atrium)

B. Blood vessels leaving the heart

1. Pulmonary artery (from right ventricle **to lungs**)
2. Aorta (from left ventricle to all other parts of body)

LIVER

A. Blood vessels entering the liver

1. Hepatic artery (from aorta into liver)
2. Hepatic portal vein (from stomach and intestine into liver)

B. Blood vessel leaving the liver

1. Hepatic vein (from the liver into posterior vena cava)

KIDNEY

A. Blood vessel entering the kidney

1. Renal artery (from aorta into kidney)

B. Blood vessel leaving the kidney

1. Renal vein (from kidney into posterior vena cava)

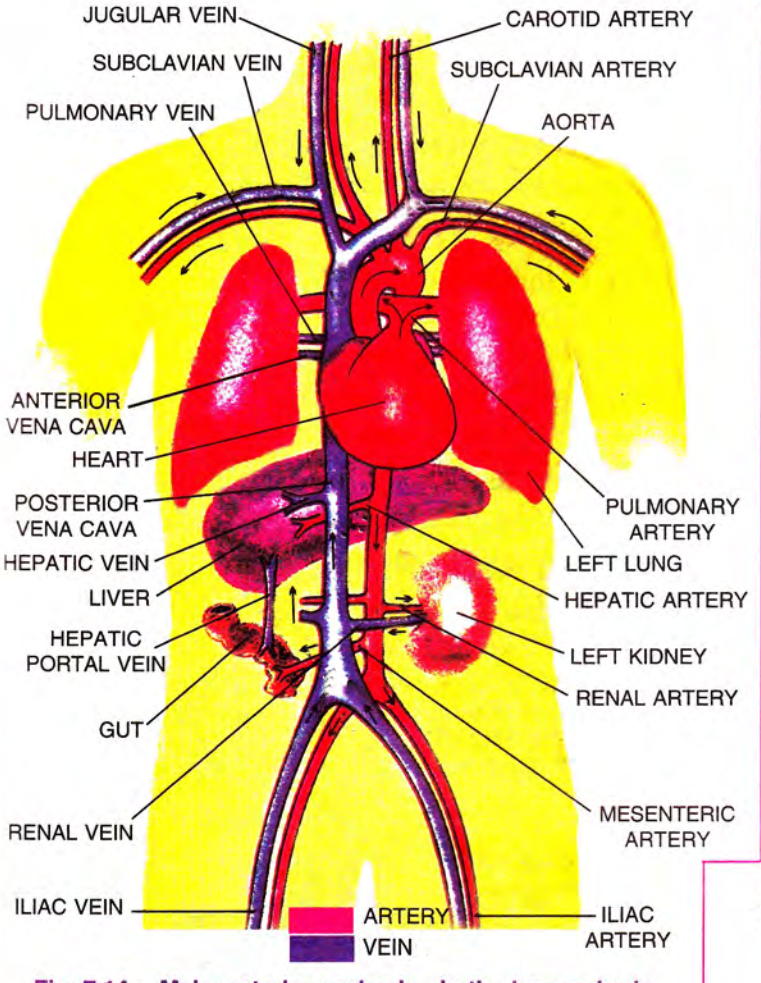


Fig. 7.14 : Major arteries and veins in the human body.

PROGRESS CHECK

1. Name the two major circulations of blood in the human body.
2. From *where to where* do the following blood vessels carry blood ?
   (i) Pulmonary artery
   (ii) Posterior vena cava
   (iii) Renal artery
   (iv) Hepatic vein
   (v) Hepatic portal vein
3. Define portal vein.

The colour differentiation

Arteries — Red
Veins — Blue

Conventionally in the diagrams, we show arteries in red colour and veins in blue. This colour differentiation is not wholly true. The oxygenated blood transported by the arteries is *bright red,* but the deoxygenated and CO_2 transporting blood is pale red (certainly not blue). But if you ever look at the prominent veins on the arms or hands especially of the old people outwardly they do look bluish and that is due to the much thicker muscular walls of the veins.

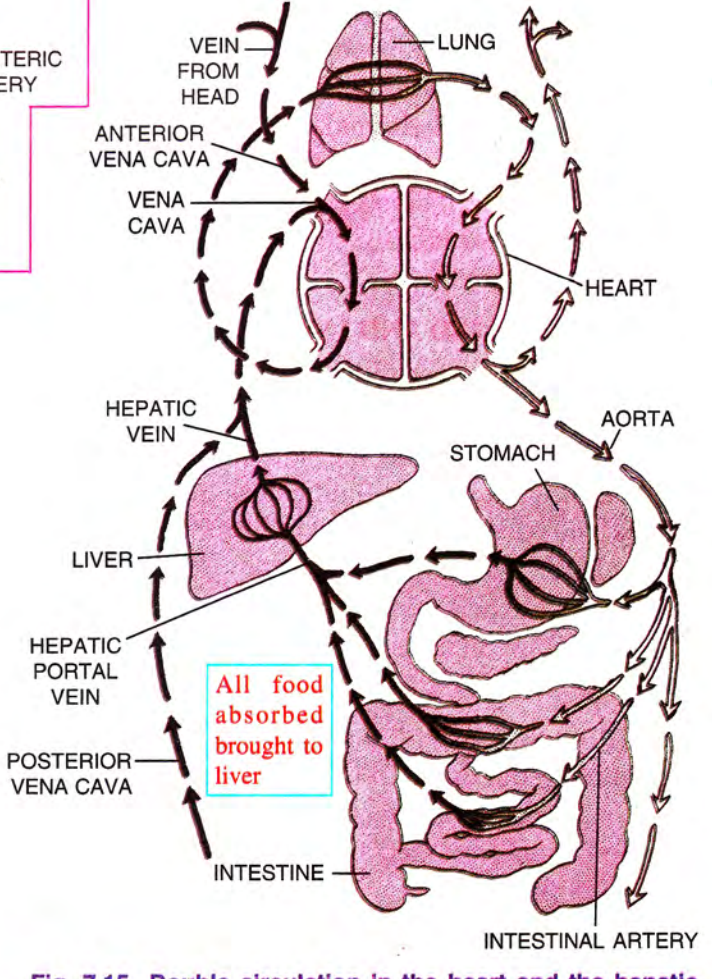


Fig. 7.15 Double circulation in the heart and the hepatic portal system through liver (highly diagrammatic)

7.13 THE PULSE

The arteries on account of their elastic muscular walls distend every time blood is forced through them due to the contraction of the heart. This distension can be easily felt by pressing your finger gently over an artery that has come up superficially, such as the radial artery of the wrist on the side of the thumb. ***Counting of the pulse is indirectly the counting of the heart beat.*** The pulse rate increases due to physical exercise or even under certain emotions.

PULSE is the alternate expansion and elastic recoil of the wall of the artery during ventricular systole. This is how you count it. →

BLOOD PRESSURE (useful to know)

Blood pressure is the pressure which the blood flowing through the arteries exerts on their walls. There are two limits of this pressure – the upper limit (**systolic pressure**) which is at the time when fresh blood is pushing through the artery as a result of the ventricular contraction of the heart. The lower limit (**diastolic pressure**) is the one recorded when the wave has passed over. The normal blood pressure for the adults is 100 - 140 mm (systolic) and 60-80 mm (diastolic). A rise in blood pressure above 140/90 is known as **hypertension** (high blood pressure in popular language).

7.14 TISSUE FLUID AND LYMPH

A. Tissue Fluid (or Intercellular Fluid)

As the blood flows in the capillaries of the tissues, the plasma and the leucocytes "leak out" through their walls. This fluid bathes the cells and is called the **tissue fluid** or the intercellular or extracellular fluid (Fig. 7.1). It is from this fluid that the cells absorb oxygen and other required substances, and in turn, give out carbon dioxide and other wastes back into it.

B. Lymph and Lymphatic System

Some of the tissue fluid may be reabsorbed into the blood vessels, but most of it enters another set of minute channels named lymph vessels where it is called **lymph**.

The main lymph vessels are shown in Fig. 7.16. The lymph flows in these vessels due to contraction of the surrounding muscles. This again is a beneficial effect of physical exercise. The lymph vessels on the way drain lymph into **lymph nodes** from where fresh lymph channels arise and ultimately pour the lymph into the major anterior veins close to their entry into the right auricle, and is again in circulation.

Composition of Lymph :

(a) Cellular part

- Only leukocytes (mostly *lymphocytes*) (No blood platelets)

(b) Non-cellular part

- Water – 94%.
- Solids (proteins, fats, carbohydrates, enzymes, antibodies, etc.) – 6%.

Functions of Lymph :

(i) ***Nutritive :*** Supplies nutrition and oxygen to those parts where blood cannot reach.

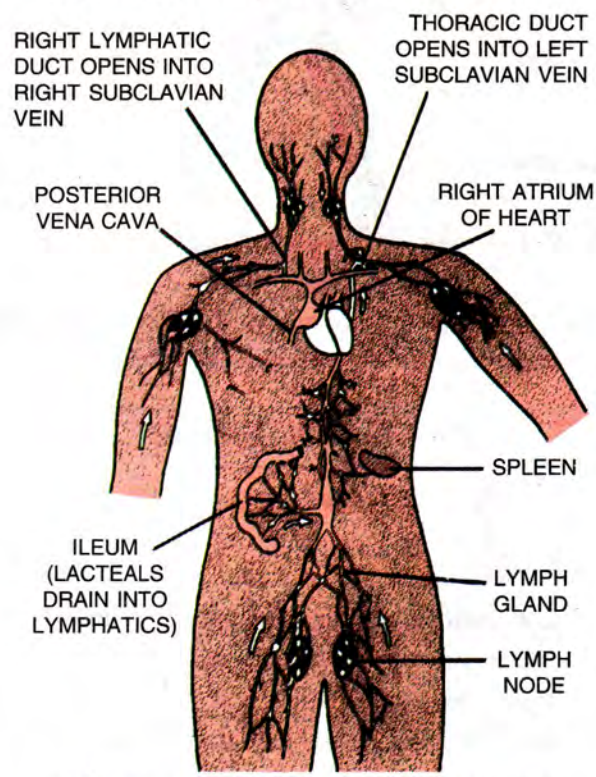


Fig. 7.16 Distribution of main lymph vessels in the human body.

(ii) ***Drainage :*** It drains away excess tissue fluid and metabolites and returns proteins to the blood from tissue spaces.

(iii) ***Absorption :*** Fats from the intestine are absorbed through lymphatics (lacteals located in the intestinal villi.)

(iv) ***Defence :*** Lymphocytes and monocytes of the lymph function to defend the body. The lymphatics

also remove bacteria from the tissues. Haven't you ever experienced painful swellings in your groins or in the axils of arms when you get a boil or injury in the limbs ? This is a protective sign.

The lymph nodes tend to localize the infection and prevent it from spreading to the body as a whole. The **tonsils** on the sides of the neck are also lymph glands.

7.15 THE SPLEEN

The spleen is a large lymphatic organ, about the size of a clenched fist, reddish brown in colour and situated in the abdomen behind the stomach and above the left kidney.

Functions of spleen

1. It acts like a **blood reservoir**. In an emergency such as haemorrhage, physical or emotional stress, or in carbon monoxide poisoning, the spleen releases the stored blood into the blood stream.
2. It **produces lymphocytes**.
3. It **destroys worn-out red blood cells** (sharing this function with the liver).
4. In an **embryo it produces RBCs**.

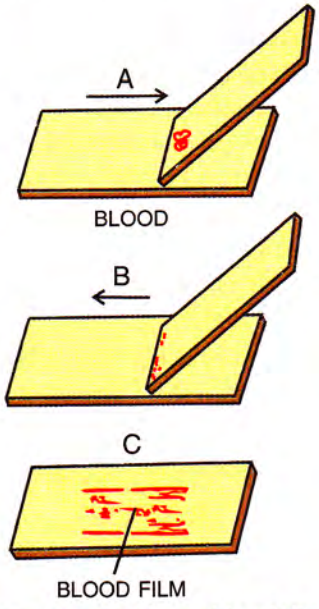


Fig. 7.17 Making a blood film

7.16 EXAMINATION OF BLOOD CORPUSCLES UNDER A MICROSCOPE

Take two clean slides. Clean the skin of your finger tip and prick it with a **sterilized** needle. Wipe off the first blood which oozes out. Gently squeeze the finger tip and take a drop of blood near the right end of one slide. Immediately put the second slide held at an angle of about 60° over the first slide close to the drop of blood and pull it gently to touch the drop (Fig 7.17A) Wait until the blood gets evenly distributed across the touching margin of the second slide (Fig 7.17B). Now push the second slide over the first one smoothly and a bit quickly and take it off. A very fine layer of blood will be formed on the first slide and that is the blood smear or the blood film (Fig. 7.17C). Allow the blood smear to dry and stain it with **Leishman stain**. Cover the smear with a few drops of the stain. After two minutes, add an equal volume of distilled water. Allow the mixture to remain for another two minutes. Pour off the mixture and rinse in tap water. Examine under the microscope after the slide is dry. You will find the cells as shown in Fig. 7.18.

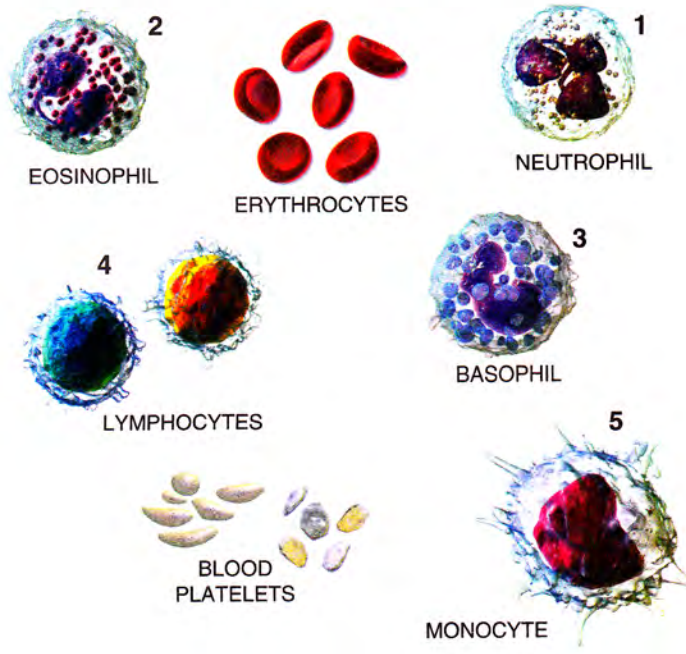


Fig. 7.18 Different kinds of blood cells (highly magnified)

PROGRESS CHECK

1. What is pulse ?
2. What are the normal values of blood pressure in a normal human adult ?
3. Which kind of cells are mostly found in lymph?
4. List the three functions of lymph.
5. Name the two main lymphatic organs in humans.
6. Name the following:
   (i) The most numerous kind of leucocytes.
   (ii) Part of lymphatic system concerned with absorption of fats from the intestine.
   (iii) A special lymphatic node on the sides of the neck.

REVIEW QUESTIONS

A. MULTIPLE CHOICE TYPE

(Select the most appropriate option in each case)

1. The nearest organ to which the heart supplies oxygenated blood is
   (a) Lung (b) Stomach
   (c) Intestine (d) Heart itself
2. When a doctor is recording your pulse, he is pressing on your wrist exactly on a
   (a) vein (b) capillary
   (c) artery (d) arteriole
3. The valve present between the right atrium and the right ventricle is the
   (a) tricuspid valve (b) bicuspid valve
   (c) semi-lunar valve (d) mitral valve
4. The blood vessel supplying blood to the kidney is the
   (a) renal vein (b) renal artery
   (c) dorsal aorta (d) hepatic vein
5. Angina Pectoris is due to
   (a) defective nutrition
   (b) inadequate supply of oxygen to the heart muscle
   (c) defective functioning of mitral valve
   (d) infection by a virus
6. The chief function of lymph nodes is to
   (a) produce WBCs (b) produce hormones
   (c) destroy old RBCs (d) destroy pathogens
7. Heart sounds are produced due to
   (a) Closure of tricuspid and bicuspid valves.
   (b) Rushing of blood through valves producing turbulence.
   (c) Closure of atrioventricular and semilunar valves.
   (d) Entry of blood into auricles.

B. VERY SHORT ANSWER TYPE

1. **What** are the average values of blood pressure in a normal adult human ?
2. **Is it true** that your heart beats more than one lac times per day ?
3. **Name** the following :
   (a) Any one vein which starts from an organ and ends in another organ besides the heart.
   (b) The kind of blood vessels which have no muscular walls.
   (c) An artery which carries impure (deoxygenated) blood.
   (d) The kind of blood cells which can squeeze out through the walls of one category of blood vessels.
   (e) The smallest common blood vessels formed by the union of capillaries.
   (f) The blood vessel which start from capillaries and end in capillaries.
   (g) The phase of the cardiac cycle in which the auricles contract.
   (h) The valve present in between the chambers on the right side of the human heart.
   (i) The phase of the cardiac cycle in which the ventricles get filled with blood from the atrium.
   (j) The fluid found between the membranes of the heart.
4. **State** the chief functional activity of each of the following :
   (a) Blood platelets .....
   (b) Neutrophils .....
   (c) Erythrocytes .....
   (d) Lymphocytes .....
   (e) Bone marrow .....
5. **Complete** the following statements by **filling in the blanks** from the choices given in the brackets.
   (a) The blood vessel that begins and ends in capillaries is the ..... (hepatic artery, hepatic portal vein, hepatic vein)
   (b) A blood vessel which has small lumen and thick wall is ... (capillary, lymphatic duct, artery, venule)
   (c) The valve which prevents back flow of blood in the veins and lymph vessels ... (mitral valve, tricuspid valve, semilunar valve).
6. Note the relationship between the first two words and **suggest** the suitable word/words for the fourth place :
   (a) Lubb : Atrioventricular valves :: Dup : .....
   (b) Coronary artery : Heart :: Hepatic artery: .....
7. Give **reason**, why a matured mammalian erythrocyte lacks nucleus and mitochondria?

C. SHORT ANSWER TYPE

1. **What** does the term "double circulation" mean?
2. **When** are the sounds "LUBB" and "DUP" produced respectively during heart beat ?
3. **Why** do people have a common belief that the heart is located on the left side of the chest ?
4. **Differentiate** between members of each of the following pairs with reference to the aspect asked within brackets :
   (a) Erythrocytes and leucocytes (function)
   (b) Artery and vein (direction of blood flow)

(c) Artery and vein (type of blood primarily flowing through)

(d) Tricuspid and bicuspid valves (location).

5. **Match** the items in Column 'A' with those in Column 'B'. Rewrite the correct matching pairs.

	Column A	Column B
(a)	SA Node	Plasma
(b)	Defective haemoglobin in RBC	Serum
(c)	Muscle fibres located in heart	Pacemaker
(d)	The liquid squeezed out of blood during clotting	Sickle cell anemia
(e)	Never tires, keep on contracting and relaxing	Purkinje fibres
(f)	Cardiac cycle	Cardiac muscle
(g)	Liquid part of the blood without corpuscles	0·85 sec

6. The table below is designed to indicate the transport of certain substances in our body. **Fill in the blanks** with suitable answers.

	Substance	*From*	*To*
1.	.....	Lungs	Whole body
2.	Carbon dioxide	.....	.....
3.	Urea	.....	.....
4.	Digested carbohydrates	Intestine	.....
5.	.....	.....	Target organs

D. LONG ANSWER TYPE

1. **Explain** the following terms :

(a) Endothelium (b) Lymph nodes

(c) Venule (d) Diastole

2. **Give** the structural differences between an artery and a vein.

3. **What** are the functions of tonsils and spleen?

4. **How** do you account for the following differences?

(a) The left ventricle has thicker walls than the right ventricle.

(b) The walls of the right ventricle are thicker than those of the right auricle.

5. **Give reason** for the following :

(a) The walls of the left ventricle are thicker than the walls of all other chambers.

(b) Blood flowing away from the stomach and intestines is put into circulation via the liver and not directly.

(c) The blood groups of both the donor and recipient must be known before transfusing blood.

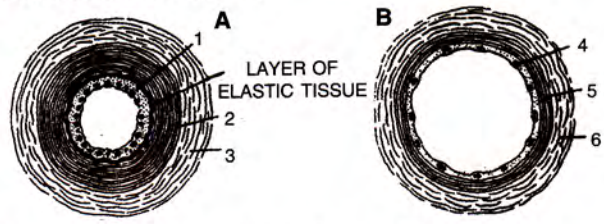
(d) Only the veins and not the arteries are provided with valves.

(e) Atrial wall is less muscular than the ventricular wall.

(f) The arteries are deep seated in the body.

E. STRUCTURED/APPLICATION/SKILL TYPE

1. Given below are the diagrammatic sketches of two kinds of blood vessels.



(a) **Identify** the blood vessels A and B.

(b) **Name** the parts numbered 1 to 6.

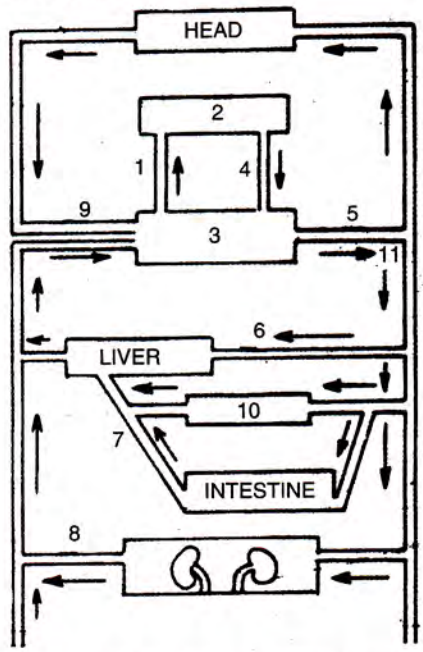
(c) **Mention** any two main differences between A and B.

2. Given below is a highly schematic diagram of the human blood circulatory system.

(a) **Which part** (state the number) represents the heart? Give reason in support of your answer.

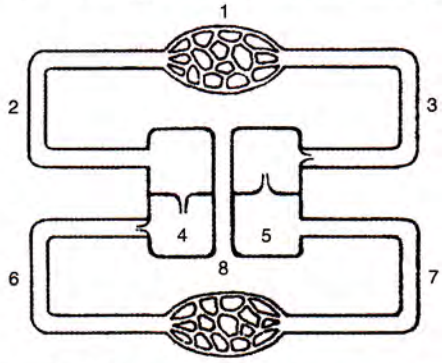
(b) **Which numbers** represent the following respectively?

Aorta	Renal Vein
Hepatic portal vein	Stomach
Pulmonary artery	Dorsal aorta
Superior vena cava	



3. Given on the next page is a simple diagram of the circulation of blood in a mammal showing the main blood vessels, the heart, lungs and body tissues. The

blood vessel, labelled 6, contains deoxygenated blood and the valve leading to it has three semi-lunar pockets.

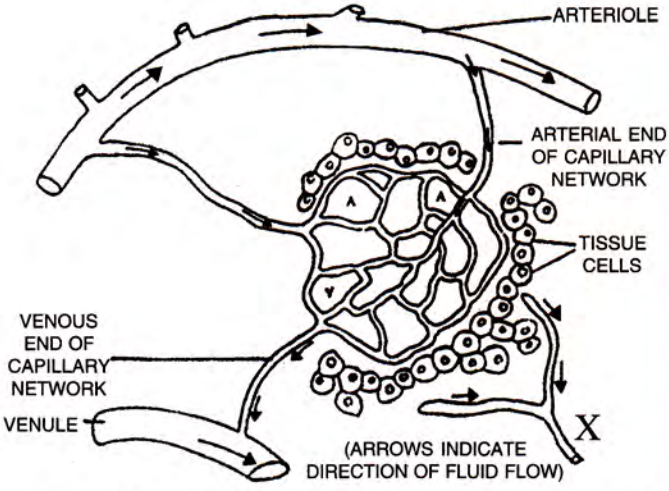


(a) **Name** the blood vessels and organs marked by numbers 1 to 8.

(b) **What is meant** by the term 'double circulation' of blood in mammals?

(c) **What** is diastole?
[There is an "error" in the diagram. According to the usual practice the pulmonary (lung) circulation is shown upward and the systemic downward, but here it is reversed].

4. The diagram below shows part of the capillary bed in an organ of the human body. Some of the blood arriving at the capillaries at points labelled A, moves out into the spaces between the tissue cells. **Study the diagram** and **answer** the questions that follow :



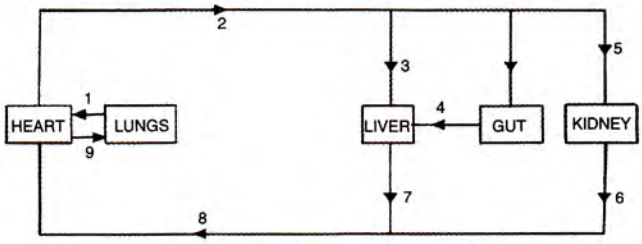
(a) **When** the liquid from the blood surrounds the cells, what is it called?

(b) **Name** any one important component of the blood which remains inside the capillaries and fails to move out into the spaces.

(c) Some of the liquid surrounding the cells does not pass directly back into the blood but eventually reaches it by another route through vessel X. **Name** the fluid present in vessel X.

(d) **State** two important functions performed in our body by the fluid present in the vessel X.

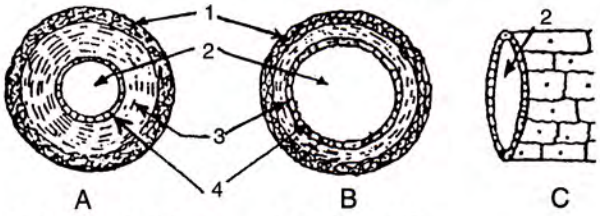
5. The following simplified diagram refers to the outline plan of the circulation of blood in a mammal. **Study the diagram** and **write** the number and the name of the blood vessel in each case as mentioned ahead.



(a) Several hours after a meal containing a lot of protein, **which vessel** will contain the highest concentration of urea ?

(b) **Which vessel** would contain the highest concentration of amino acids and glucose soon after a meal?

6. The figures given below show diagrammatic cross sections of three kinds of blood vessels.



(a) **Identify** the blood vessels A, B and C.

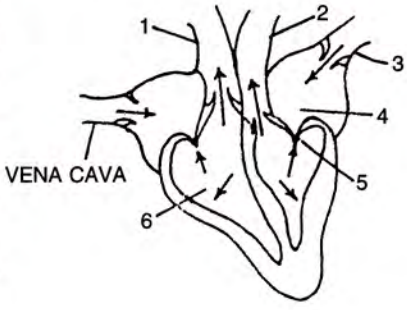
(b) **Name** the parts labelled 1-4.

(c) **Mention** two structural differences between A and B.

(d) **Name** the kinds of blood that flow through A and through B respectively.

(e) In **which** one of the above vessels referred to in (a) above does the exchange of gases actually take place?

7. The diagram given alongside represents the human heart in one phase of its activity. Study the same and then answer the questions that follow :



(a) **Name** the phase.

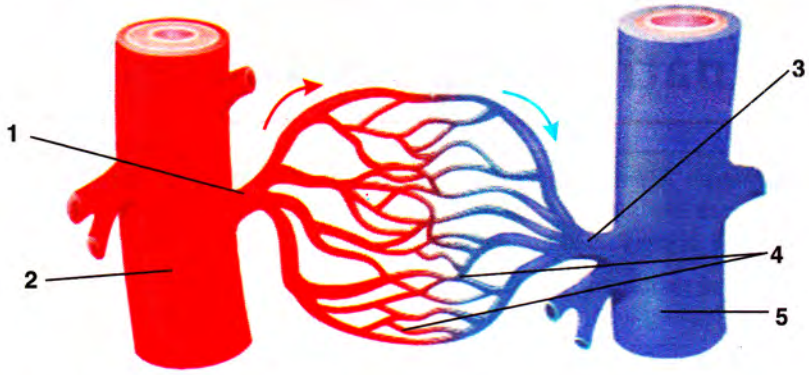
(b) **Which part** of the heart is contracting in this phase? Give a reason to support your answer.

(c) **Name the parts** numbered 1 to 6.

(d) **What type of blood** flows through the parts marked '1' and '2' respectively?

(e) **How many valves** are closed in this phase?

8. Given below is a diagrammatic representation of certain types of blood vessels in human body.



(a) Identify the types of blood vessels numbered 1 to 5.

(b) Where can such an arrangement be found as an example — in lungs or in heart walls ?

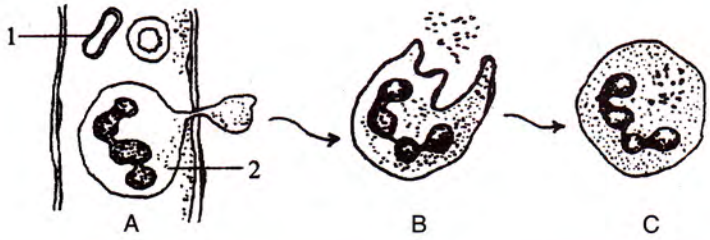
9. Study the following diagram carefully and then answer the questions that follow:

(a) Name the cell labelled 1.

(b) Identify the phenomenon occurring in A.

(c) Mention two structural differences between 1 and 2.

(d) Name the process occurring in B and C and state the importance of this process in the human body.



Extra Knowledge

Why the blood types named as A, B, AB and O ? Why not A, B, C & D ?

This is related to the two types of antigens (antigen A and antigen B) present on the RBCs either singly (**blood group A** and **blood group B** respectively) or both together (as **AB**), but having no antigen on RBCs meaning "Zero" antigen, refers to the blood group "O" (actually Zero).

Blood groups in common parlance "A+ve" / "B–ve" / "O+ve", etc., etc.

Are these the types of a single blood group? ..... No!!

But a common man when required to get blood transfusion, thinks so.

Actually, these are the possible combinations from two blood group systems : *one*, the **ABO system** and *two*, the **Rh system**.

Check up the details in section 7.7 page 82.

8 The Excretory System [Elimination of Body Wastes]

Syllabus : *Excretory System : Elementary treatment of the structure and function of the kidneys; the kidneys treated as comprising cortex and medulla and consisting of a branched system of tubules well supplied with blood vessels leading to the ureter (details of the courses of the tubules and their blood vessels not required).*

Scope of Syllabus : External and internal structure of the kidney; parts of the excretory system along with the blood vessels entering and leaving it should be taught with the help of charts or models. Students should be able to draw the diagrams with correct labelling and know the functions of various parts. A general idea of the structure of a kidney tubule nephron should be given. A brief idea of ultra filtration, selective reabsorption and tubular secretion in relation to the composition of blood plasma and urine formed.

A large number of waste products are formed during metabolic activities in the body.

- Large amounts of CO_2 and H_2O are produced by metabolism of carbohydrates, fats and proteins.
- Nitrogenous wastes such as ammonia, urea, uric acid, etc., are formed from proteins and other complex nitrogenous compounds.
- These nitrogenous products become toxic or harmful if retained inside and hence are sent out with the help of the excretory system.

8.1 EXCRETION (*ex :* out, *crete:* flow)

The process of removal of chemical wastes (mainly nitrogenous) from the body is known as 'excretion'. Excretion plays an important role in maintaining the homeostatic (steady state) condition of the body.

Organs which are concerned with the formation, storage, and elimination of urine constitute the 'Excretory system'.

Excretory system or Urinary system ?

Excretion should not be confused with defaecation (meaning passing out faeces, *i.e.* the undigested food from the intestine).

Similarly, passing out CO_2 through the lungs is a part of respiration and not excretion.

In humans, the term ***urinary system*** is more appropriate than the excretory system.

8.2 SUBSTANCES TO BE GOT RID OFF

There are a number of chemical substances which are regularly formed in our body or which are absorbed through the food that must be got rid of—otherwise they become harmful. Some such substances are : (1) Carbon dioxide and water (respiratory products) (2) Nitrogenous metabolic wastes (3) Excess salts and vitamins (4) Water (5) Bile pigments.

(1) **Carbon dioxide** and **water :** Every living cell liberates energy by oxidizing glucose with the production of carbon dioxide and water.
- ➢ Carbon dioxide is eliminated through the lungs.
- ➢ The water becomes a part of the rest of the water in the body.

(2) **Nitrogenous metabolic wastes :** These include urea, uric acid and ammonia. These are produced mainly in the liver from the dead protein–remains of the other tissues that are brought to it. Any extra amino acids (digestion products of protein) cannot be stored in the body. They are broken down in the liver to produce usable (also storable) glucose, and the urea that has to be excreted out. ***Urea is highly poisonous; if allowed to accumulate in the blood to a certain level, it causes death.***
- ➢ Urea is excreted out through the kidneys.

(3) **Excess salts** such as common salt (NaCl) and even some ***excess water-soluble vitamins*** (B & C) need to be eliminated.
- ➢ Salts are mainly given out by the kidneys.

(4) **Water** is taken in with food and beverages, in large quantities.

- The excess quantity of water is removed which, incidentally, also serves a useful purpose of dissolving the harmful materials to carry them out.

(5) **Bile pigments** (chiefly yellow bilirubin) are the breakdown products of the haemoglobin of the dead RBCs. The liver cells extract it from the circulation and secrete it into the bile juice poured into the duodenum through the common bile duct. These pigments are modified in the intestine to pigments that give faeces their yellowish brown colour. Some of these pigments are excreted in urine.

***Excretion** is the removal of all **harmful** and **unwanted** products from the body, especially the nitrogenous wastes.*

8.3 THE EXCRETORY ORGANS

Excretion in humans (mammals) is brought about by the following organs :

1. **Kidneys :** These are the primary excretory organs throwing out excretory products (chiefly **urea**) in the form of urine.
2. **Sweat glands :** Excretion by sweat glands is incidental. These glands are primarily concerned with cooling (thermoregulation). The sweat secreted carries with it small amounts of nitrogenous wastes. Sweat glands pass out sweat only when required for cooling, so truly they are not excretory.
3. **Lungs :** Excretion by lungs in the form of *carbon dioxide* released in the expired air.

? PROGRESS CHECK

1. Given below is a list of substances – select the ones that need to be got rid off from the body.
   Glucose, excess water, amino acids, urea, carbon dioxide, excess common salt, glycogen, uric acid.
2. (i) Undigested and unabsorbed food which passes out is termed as excreta in popular language. Is it a kind of excretion ? Yes/No
   (ii) Give reason in support of your answer.

8.4 KIDNEYS (URINARY SYSTEM)

The **kidneys** (Fig. 8.1) are two bean-shaped organs about 10 cm long and 6 cm wide, located on either side of the backbone and protected by the last two ribs. The right side kidney is at a slightly lower level than the left one. A tube, the **ureter,** arises from the notch (**hilum**) in the median surface of each kidney and connects behind with the **urinary bladder** in the lower part of the abdomen. The front end of the ureter is somewhat expanded into the kidney and is called the **pelvis** (Fig. 8.2) (Lat. **pelvis** : basin/cup). The urine produced in the kidneys constantly flows through the ureters and collects in

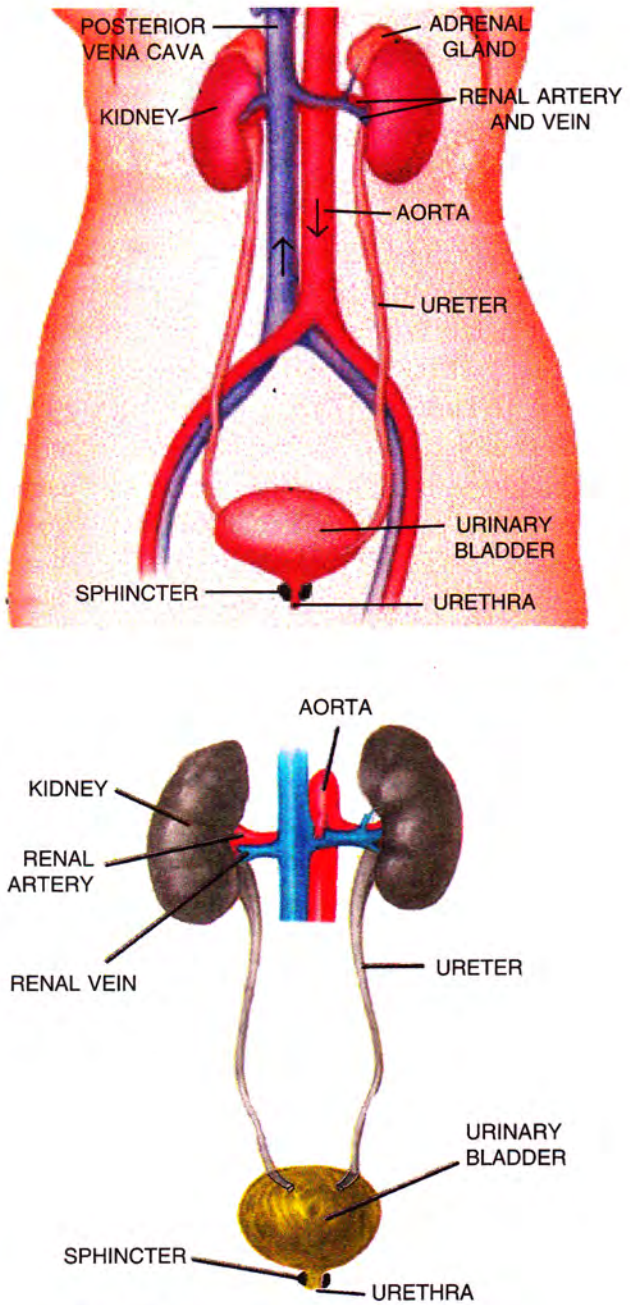


Fig. 8.1 : Upper – The urinary system, Lower – The urinary system (diagrammatic)

the urinary bladder. The urine is intermittently emptied from the urinary bladder to the outside of the body through the urethra. The openings of the ureters (into the bladder) are somewhat projecting and act like valves to prevent the backflow of urine when the bladder contracts to pass out the urine. A sphincter (circular muscle) guards the opening of the bladder into the urethra and relaxes only at the time of *urination (micturition)* under an impulse from the brain.

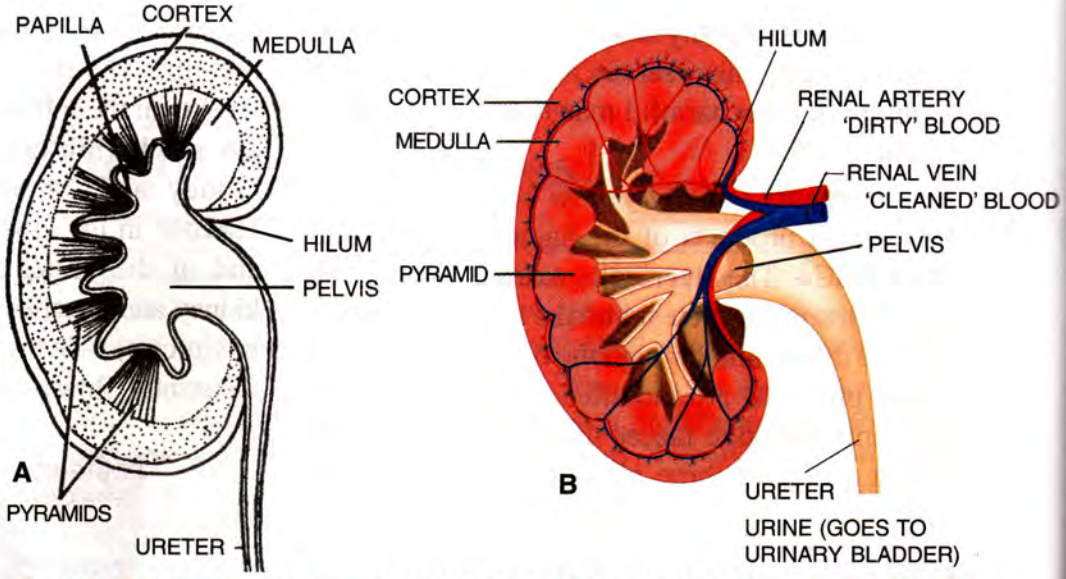


Fig. 8.2 : A kidney in longitudinal section : A–simplified, B–along with blood supply

8.4.1 Internal Structure of the kidney

A longitudinal section of the kidney (Fig. 8.2) shows two main regions—an outer dark **cortex** and an inner lighter **medulla**. The medulla is composed of a finely striped substance arranged in several **conical pyramids**. The apex of each pyramid **(papilla)** projects into the pelvis of the kidney.

The kidney is composed of an enormous number of minute tubules called **uriniferous tubules** or **nephrons** or **renal tubules** or just **kidney tubules**. These are the structural as well as functional units of the kidney.

8.4.2 Structure of a Kidney tubule

Each kidney tubule (Fig. 8.3) has the following parts :

Bowman's capsule : It is a thin-walled (single-cell thick epithelium) cup, something like a hollow ball pressed deep on one side. Its hollow internal space continues into the tubule. The outer concavity of the cup lodges a knot-like mass of blood capillaries, called **glomerulus.** The **Bowman's capsule and the glomerulus together** are called ***Malpighian capsule* or just *renal capsule*.**

Proximal or **first convoluted tubule (PCT)** is the starting convoluted region of the tubule ("proximal" means nearer, *i.e.* nearer to the Bowman's capsule).

Both the Bowman's capsule and the proximal convoluted part lie in the cortex giving it a dotted appearance in sectional view (Fig. 8.2A).

Middle U-shaped part (Loop of Henle) is shaped like a hair-pin; it is not convoluted. It runs in medulla to turn back and to re-enter the cortex to continue into the next convoluted region of the tubule.

Distal convoluted tubule (DCT) (again lying in the cortex) is the end part of the kidney tubule ("distal" means farther, i.e. farther or away from the Bowman's capsule). It opens into a **collecting duct**. The collecting duct receives the contents of many kidney tubules and pours it as urine in the pelvis of the kidney.

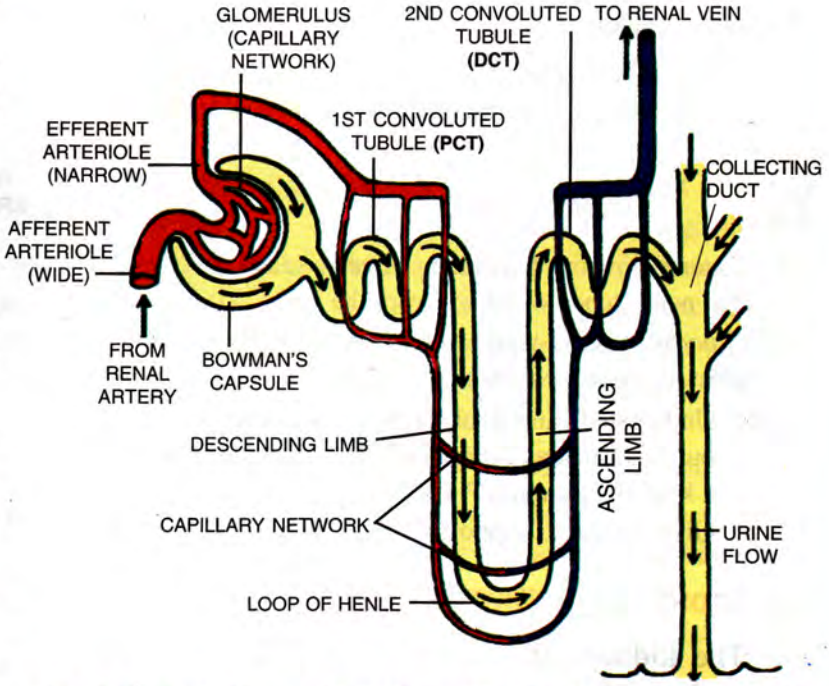


Fig. 8.3 : A single renal (uriniferous) tubule, highly diagrammatic

URINIFEROUS TUBULES

Tiny, so many, and for so much!

- *Total number in both kidneys : Approximately* ***2 million***
- *Each single tubule :* ***4–5 cm long***
- *Total length of all tubules together : more than* ***60 km***

This great length provides a huge surface for reabsorption of usable substances specially water, as the contents move through them.

- *Blood flowing through kidneys* ***per minute = 1 litre***
- *Glomerular filtrate produced in* ***24 hours = 160 litres***
- *Urine produced from glomerular filtrate after reabsorption* ***per day = 1.2 litre***

BLOOD SUPPLY TO THE KIDNEY TUBULES

A pair of renal arteries branch off from the dorsal aorta to enter the respective kidneys (Fig. 8.1). Each renal artery branches and rebranches several times to give rise to arterioles; each such arteriole enters a Bowman's capsule under the name of **afferent arteriole** (*afferent* : to bring to). This afferent arteriole breaks into a number of capillaries which form a knot-like mass **(glomerulus)** closely fitting inside the Bowman's capsule (Fig. 8.4). The reuniting capillaries of the glomerulus form the **efferent arteriole** (*efferent* : to carry away). The efferent arteriole after emerging from the Bowman's capsule runs a short distance and breaks up into a **secondary capillary network** (vasa recta) which surrounds the renal tubule, and rejoins to form a vein (Fig. 8.3) By uniting again and again with other veins of the kidney it ultimately forms the renal vein which leaves the kidney at the median surface to pour the blood into the posterior vena cava.

350 times a day through kidneys!

All the body blood passes through the kidneys 350-400 times a day at the rate of 1–2 litres per minute.

? PROGRESS CHECK

1. Name the following :
   - (i) The tube arising from the notch of the kidney on the median side and connecting behind with the urinary bladder.
   - (ii) The tube that passes the urine to the outside of the body.
   - (iii) The inner lighter coloured region of the kidney.
   - (iv) Knot-like mass of blood capillary inside Bowman's capsule.
   - (v) The structural and functional unit of the kidney.
   - (vi) The blood vessel which :
     - (a) enters malpighian capsule.
     - (b) leaves malpighian capsule
2. Given is a jumbled list of the parts of a certain body structure — Loop of Henle, Bowman's capsule, distal convoluted tubule, glomerulus, proximal convoluted tubule.
   - (i) Name the structure to which the listed parts belong.
   - (ii) Rearrange the parts in their proper sequence from the starting point to where they end.

8.4.3 Function of the Kidney–Formation of urine

The formation of urine occurs in *two* major steps; (I) **ultrafiltration** and (II) **reabsorption**.

(I) ULTRAFILTRATION

The blood flows through the glomerulus **under great pressure** which is much greater than in the capillaries elsewhere. The reason for this greater pressure is that the **efferent (outgoing) arteriole is narrower** than the afferent (incoming) arteriole. This high pressure (hydrostatic pressure) causes the liquid part of the blood to **filter out** from the glomerulus into the renal tubule. This filtration under extraordinary force is called **ultrafiltration**. During ultrafiltration almost all the liquid part of the blood (plasma along with most of its organic and inorganic substances including urea, glucose, amino acids, etc.) comes out of the glomerulus and passes into the funnel-shaped cavity of the Bowman's capsule (Fig. 8.4). The fluid entering the renal tubule is called the **glomerular filtrate**. The glomerular filtrate consists of water, urea, salts, glucose and other plasma solutes. The thicker part of the blood left behind in the glomerulus after ultrafiltration, namely,

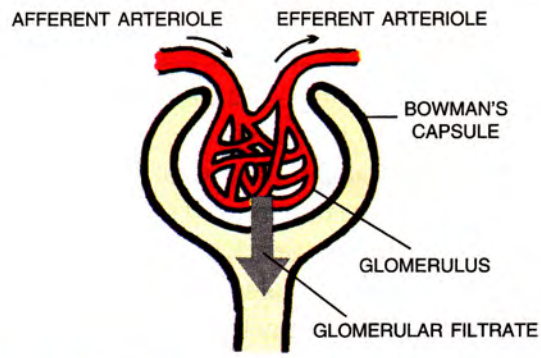


Fig. 8.4 : Diagrammatic sketch of one malpighian capsule (Bowman's capsule + glomerulus)

the two kinds of corpuscles, proteins, and other large molecules are carried forward through the efferent arteriole. Thus, the blood proceeding away from the glomerulus is relatively thick.

(II) REABSORPTION

The glomerular filtrate entering the renal tubule is not urine. It is an extremely dilute solution containing a lot of usable materials including **glucose** and some salts such as those of **sodium**. As the filtrate passes down the tubule, much of the water is reabsorbed together with the usable substances. But their reabsorption is only to the extent that the normal concentration of the blood is not disturbed. This is called ***selective absorption***.

Certain substances like potassium (K^+) in the normal course, and a large number of foreign chemicals including drugs like penicillin are passed into the forming urine in the distal convoluted tubule. This passage involves the activity of the cells of the tubular wall, and hence it is called ***tubular secretion***.

The filtrate left after reabsorption and tubular secretion is called ***urine***.

Table 8.1 Steps in Urine Formation

Part of renal tubule	Activity
1. GLOMERULUS	– Ultrafiltration
2. BOWMAN'S CAPSULE	– Receives glomerular filtrate
3. PROXIMAL CONVOLUTED TUBULE	– Reabsorbs most water (about two-thirds), and much of glucose and sodium and chloride ions
4. LOOP OF HENLE	– Some absorption of water and sodium ions
5. DISTAL CONVOLUTED TUBULE	– Reabsorption of remaining chlorides and some water. – Walls secrete potassium and foreign chemicals such as penicillin and other drugs into the forming urine

Urine excretion – Final urine passes into collecting ducts to the pelvis and through the ureter into the urinary bladder by ureteral peristalsis (waves of constriction in the ureters) and due to gravity. Urine is expelled from the urinary bladder through the urethra (in the penis in males, and directly in females) by relaxation of the sphincter muscles located at the opening of the urinary bladder into the urethra under impulse from the nervous system. Such a process is called ***micturition***.

All these functions involved in urine formation require energy, hence the oxygen demand of the kidneys is 6 to 7 times higher than what is required by muscles.

Physical properties of urine

- **Colour :** Clear yellow (due to pigment urochrome). Colour varies with the diet.
- **Volume :** 1 to 1.5 litres per day but varies.
- **pH :** 5 to 8 i.e., usually it is slightly acidic (pH = 6). Protein diet makes it more acidic while vegetable diet makes it alkaline.
- **Odour :** On standing, the smell of urine becomes strong, ammonia-like due to bacterial activity, otherwise faint smell.
- **Specific gravity :** 1.003 to 1.035

8.5 CONSTITUENTS OF URINE

The normal human urine consists of about 95% of *water* and 5% of *solid wastes* dissolved in it. The percentage of the solid wastes may slightly vary according to the food taken and according to the time after taking food but usually these are approximately (in grams per litre of urine) as follows :

Table 8.2 Constituents of Urine

Organic in (g/L)		*Inorganic in (g/L)*	
Urea	2·3	Sodium chloride	9·0
Creatinine	1·5	Potassium chloride	2·5
Uric acid	0·7	Ammonia	0·6
Others	2·6	Others	2·5

Besides the normal constituents, the urine may pass out certain hormones and also certain medicines like the antibiotics and the excess vitamins.

Abnormal constituents in urine

(i) **Blood cells / Haematuria** — in this, the blood passes with urine, due to infection in urinary tract, kidney stone or tumour.

(ii) **Glucose / Glycosuria** — excess glucose passes with urine, due to ***diabetes mellitus*** (sugar diabetes).

TASTE OF URINE ?

It may sound awkward to talk about the taste of urine. However —

- Normally, it is **saltish**.
- When **sweetish**, the condition may be due to

sugar diabetes, urine containing the sugar glucose (due to insufficient insulin), and ants gather to lick the urine of a diabetic person.

- When **tasteless**, it is due to much water in the urine, a condition called ***diabetes insipidus*** (due to insufficient ADH hormone) ("insipid" means tasteless).

(iii) **Albumin** — Due to high blood pressure, OR due to increased permeability of the Bowman's capsule membrane on account of bacterial infection.

(iv) **Bile pigments** — anaemia, hepatitis (jaundice) or due to liver cirrhosis.

8.6 REGULATION OF URINE OUTPUT

The pituitary gland and **Diuresis** (increased production of urine) – Concentration of the urine by water reabsorption is controlled by antidiuretic hormone (ADH) secreted by the posterior lobe of the pituitary gland (Page 140). If ADH secretion is reduced, there is an **increased production of urine**, this is called 'diuresis'. Substances that increase the formation of urine are called 'diuretics', *e.g.*, liquid diets, tea, coffee, alcohol, etc.

GOUT AND KIDNEY STONES

Uric acid is relatively less soluble in water and may crystallize and get deposited in the joints causing gout. Excessive uric acid and certain salts like calcium oxalate may be the source of kidney stones, when the kidneys are not working fully normally.

? *PROGRESS CHECK*

1. State if the following statements are ***true*** or ***false***.
   (i) The blood flows through glomerulus under great pressure.
   (ii) Glomerular filtrate consists of many substances such as water, salts, glucose and white blood corpuscles.
   (iii) Sodium chloride contained in glomerular filtrate is fully reabsorbed in the renal tubule.
   (iv) Besides the normal constituents, the urine may pass out excess vitamins but not the antibiotics.
   (v) Excessive uric acid and urine may produce kidney stones.

8.7 OSMOREGULATION

The kidney while removing wastes like urea from the blood also regulates its composition, *i.e.*, the percentage of water and salts. This function is called **osmoregulation** — it implies ***the regulation of osmotic pressure of the blood.***

Drinking enough water directly or through food helps the kidneys in their proper working. In tropical climates, as in our own country, we drink a lot of water during summer. Yet **we urinate fewer times in summer than in winter and the urine passed is generally thicker.** The reason is that in summer, we lose a considerable part of water through perspiration and the kidneys have to reabsorb more water from the urine making it more concentrated.

In **cholera**, the patient suffers from vomiting and watery bowels. His intestines are unable to absorb water into the blood. The result is that his kidneys reabsorb almost all the water from the urine in the renal tubules and with it even the urea. Ultimately the patient may die due to poisoning by the accumulation of high quantities of urea in his body (uremia). The immediate treatment is to replenish water in the blood by glucose-saline drip or by giving oral rehydration solution (ORS) through the mouth.

The water balance in human body

The adult human body contains nearly 40 litres of water which forms 60% of the body weight.

Average daily loss and gain of water in an adult human male in good health at rest in temperate climate :-

	Loss	mL	%
1.	*In urine (by kidneys)*	*1500*	*(60%)*
2.	*In sweat (by skin)*	*500*	*(20%)*
3.	*In breath (by lungs)*	*400*	*(16%)*
4.	*In faeces*	*100*	*(4%)*
		Total = 2500	
	Gain		
1.	*In drink (as water or in beverages)*	*1500*	*(60%)*
2.	*In food*	*700*	*(25%)*
3.	*Metabolic water (product of cellular respiration)*	*300*	*(12%)*
		Total = 2500	

(The intake and output of water would slightly vary according to the climate and the lifestyle of a person)

8.8 MISCELLANEOUS INFORMATION

Artificial Kidney : If one kidney is damaged or removed for some reason, the other kidney alone is sufficient for excretory needs and the person can lead a normal life. But failure of both the kidneys would lead to death. Artificial kidney is a **dialysis**

Table 8.3 A Summary of Excretion in Humans

Excretory substances	Excretory organs	Remarks
Carbon dioxide	Lungs	As a gas in expired air
Minerals salts, Nitrogenous waste products : 1. Mainly urea 2. Creatinine 3. Uric acid	Kidneys	As constituents of urine
	Skin	As constituents of sweat, though sweat contains only small quantities of nitrogenous products
Water	Kidneys	Excess water excreted out as the main constituent of urine
	Skin	Water lost as the main constituent of sweat
	Lungs	Water lost as water vapour in expired air.
Bile pigments (from haemoglobin breakdown)	Liver	Through the intestines (via bile juice poured into duodenum).

machine. The patient's blood is led from the radial artery in his arm through the machine where the urea and excess salts are removed and the purified blood is returned to a vein in the same arm. In cases of permanent damage to the kidneys, dialysis is to be repeated for about twelve hours twice a week

REVIEW QUESTIONS

A. MULTIPLE CHOICE TYPE

(Select the most appropriate option in each case)

1. Excretion primarily involves
   (a) removal of all byproducts during catabolism.
   (b) removal of byproducts during anabolism.
   (c) removal of nitrogenous wastes.
   (d) throwing out excess water
2. Maximum amount of water from the glomerular filtrate is reabsorbed in
   (a) proximal convoluted tubule
   (b) descending limbs of loop of Henle.
   (c) ascending limb of loop of Henle.
   (d) distal convoluted tubule.
3. Which one of the following in real sense is NOT an excretory activity ?
   (a) Giving out carbon dioxide
   (b) Passing out faecal matter
   (c) Sweating
   (d) Removal of urea.
4. In humans, urea is formed in
   (a) ureter (b) liver
   (c) spleen (d) kidney

B. VERY SHORT ANSWER TYPE

1. Name the following :
   (a) The organ which produces urea.
   (b) The outer region of kidney containing the Bowman's capsule.
   (c) The tuft of capillaries inside the Bowman's capsule.
   (d) The part of kidney tubules where the term urine is first used for the fluid in it.
   (e) The vein in which urea concentration is maximum.
2. Given below are two sets (a and b) of five terms each. **Rewrite** the terms in their correct order so as to be in logical sequence.
   (a) Afferent arteriole, renal vein, capillary network, glomerulus, efferent arteriole.
   (b) Renal artery, urethra, ureter, kidney, urinary bladder.
3. In each one of the following sets of body parts or substances or processes, **pick out** the one item which overall includes the remaining four
   (a) Glomerular filtrate, Bowman's capsule, ultrafiltration, glomerulus, blood plasma.
   (b) Skin, liver, lungs, kidneys, excretion.
   (c) ADH, water, pituitary, osmoregulation, urine.
   (d) CO_2, bile pigments, water, excretion, urea.

C. SHORT ANSWER TYPE

1. **Write down** the functional activity of the following parts,
   (a) Glomerulus .....
   (b) Henle's loop .....
   (c) Ureter .....
   (d) Renal artery .....
   (e) Urethra .....
2. **Why** is excretion necessary ? Name the common excretory substances in our body.
3. **What** is a uriniferous tubule? How does it function?
4. **Why** is it necessary to maintain a normal osmotic concentration of the blood?
5. If you donate one kidney to a needy patient, **would** it cause any harm to you? Give reason.
6. In summer the urine is slightly thicker than in winter. **Explain** the reason.
7. **Differentiate** between the following pairs of terms :
   (a) Bowman's capsule *and* malpighian capsule.
   (b) Renal cortex *and* renal medulla.
   (c) Renal pelvis *and* renal papilla.
   (d) Urea *and* urine.
   (e) Excretion *and* katabolism.
8. **Name** the main nitrogenous metabolic waste excreted out by mammals including humans.
9. **Match** the items in **Column I** with those in **Column II** and write down the matching pairs.

Column I	Column II
(a) Bowman's capsule	(i) Renal artery
(b) Contains more CO_2 and less urea	(ii) Regulates amount of water excreted
(c) Antidiuretic hormone	(iii) Renal vein
(d) Contains more urea	(iv) Glomerulus

10. **Fill** in the blanks in the following passage to make it a meaningful description.

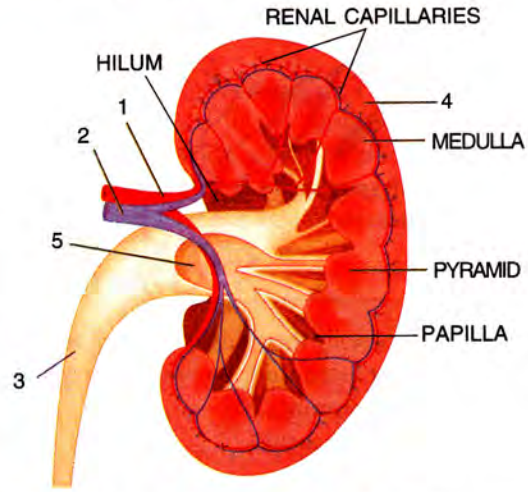
    In a nephron, the ..... flows through the ..... under great pressure. The reason for this great pressure is that the ..... (outgoing) ..... is narrower than the ..... (incoming). This high pressure causes the ..... part of the blood to filter out from the ..... into the..... capsule.

D. LONG ANSWER TYPE

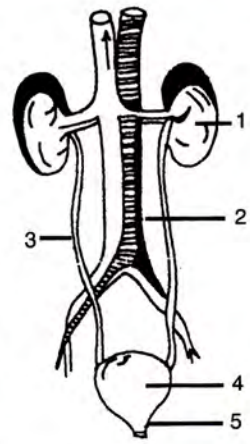
1. **Define** the following terms :
   (a) Ultrafiltration
   (b) Micturition
   (c) Renal pelvis
   (d) Urea
   (e) Osmoregulation
2. **Explain** the terms ultrafiltration and selective absorption.
3. **What** is dialysis ? Under what condition is it carried out ?

E. STRUCTURED/APPLICATION/SKILL TYPE

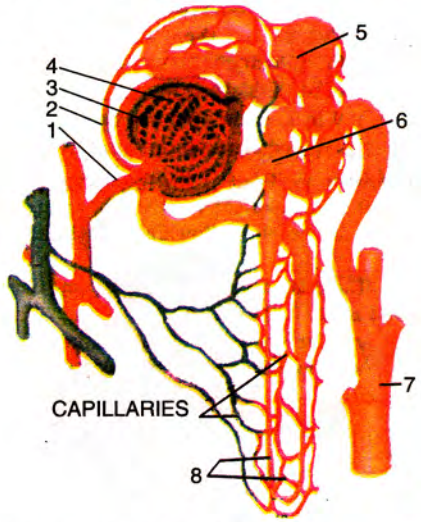
1. Look at the figure given below. It is a section of human kidney as seen from the front.



   (a) **Is** it the left kidney or the right one ? Give reason in support of your answer.
   (b) **Is** it a longitudinal section or a cross-section?
   (c) **Name** the parts numbered 1-5.
   (d) **Which** area/part (give its name and the number given on the diagram) contains the following respectively :
      (i) Malpighian capsule
      (ii) The pyramids
      (iii) Freshly collected urine
2. Given alongside is the figure of certain organs and associated parts in the human body. Study the same and answer the questions that follow :
   (a) **Name** all the organ-systems shown completely or even partially.
   (b) **Name** the parts numbered 1 to 5.
   (c) **Name** the structural and functional unit of the part marked '1'.
   (d) **Name** the two main organic constituents of the fluid that flows down the part labelled '3'.
   (e) **Name** the two major steps involved in the formation of the fluid that passes down the part labelled '3'.



3. The following diagram represents a mammalian kidney tubule (nephron) and its blood supply.



Parts indicated by the guidelines 1 to 8 are as follows :

1. Afferent arteriole from renal artery;
2. Efferent arteriole
3. Bowman's capsule,
4. Glomerulus;
5. Proximal convoluted tubule with blood capillaries;
6. Distal convoluted tubule with blood capillaries;
7. Collecting tubule;
8. U-shaped loop of Henle.

Study the diagram and answer the questions that follow:

(a) Where does ultrafiltration take place ?

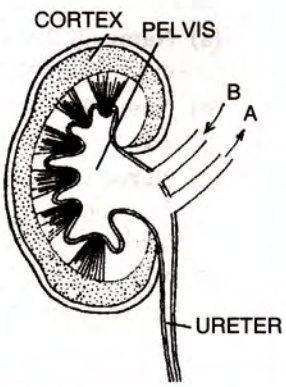
(b) Which structure contains the lowest concentration of urea ?

(c) Which structure contains the highest concentration of urea ?

(d) Which structure (normally) contains the lowest concentration of glucose ?

(e) Where is most water reabsorbed ?

4. Given alongside is a highly simplified (but also somewhat wrong) diagram of the human kidney cut open longitudinally. Answer the questions that follow.



(a) **Define** excretion.

(b) **Name** the functional units of the kidneys.

(c) **Why** does the cortex of the kidney show a dotted appearance ?

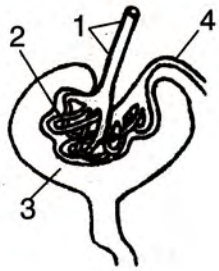
(d) **Mention** two functions of the kidney.

(e) **Write** two differences in the composition of the blood flowing through the blood vessels, 'A' and 'B'.

[There is an error in the diagram. Can you identify it ?]

Answer : The blood vessels A & B do not open into the pelvis or ureter but enter into the medulla

5. Study the diagram given alongside and then answer the questions that follow:



(a) **Name** the region in the kidney where the above structure is present?

(b) **Name** the parts labelled 1, 2, 3 and 4.

(c) **Name** the stages involved in the formation of urine.

(d) **What** is the technical term given to the process occurring in 2 and 3? Briefly describe the process.

WHAT ARE THESE — EXCRETION OR SECRETION ?

Think of the following :

Tears
Sweat
Saliva
Milk
Insulin
Urine

Hint : Think of their utility to the organism.

SECRETION is giving out by a cell or a gland some substance that has some utility for the body.

EXCRETION is the passing out of substances that have no further use in the body or are harmful.

Answer : Except urine, all others listed above are secretions.

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**.

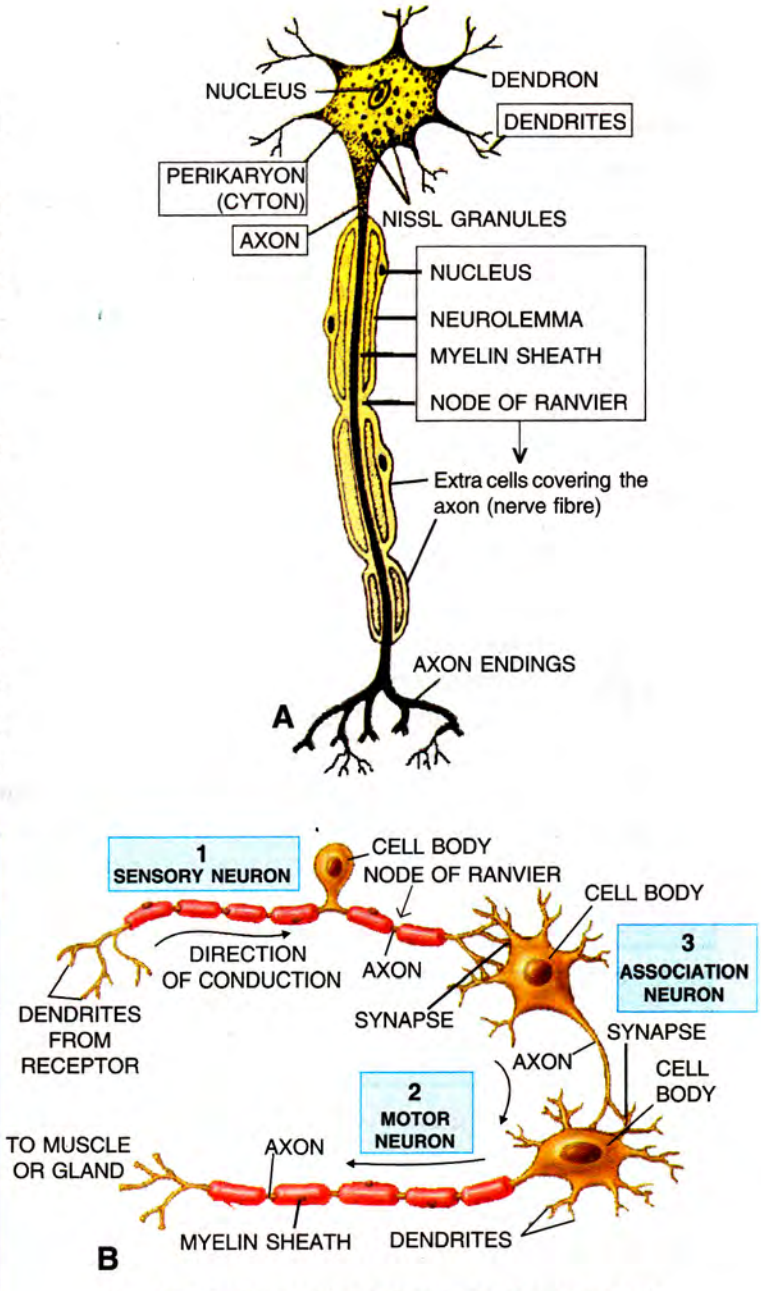


Fig. 9.1 : A–Generalised structure of a nerve cell. B–Three types of neurons (sensory, motor and association), synapse between them and the direction of transmission of nerve impulse

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.

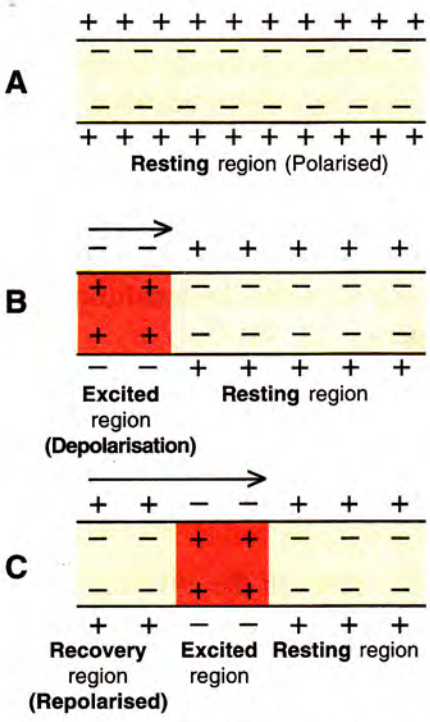


Fig. 9.2 : Conduction of nerve impulse through a nerve fibre

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.

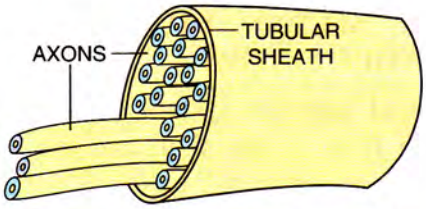


Fig. 9.3 : A nerve, formed of a bundle of axons.

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).

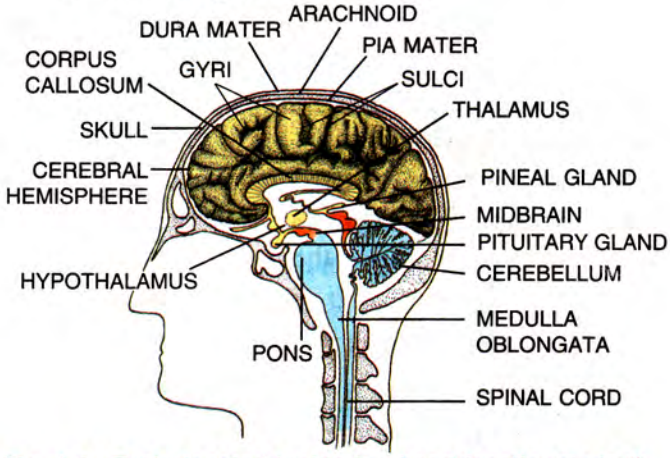


Fig. 9.4 : Brain located inside the head (sectional view)

- 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.

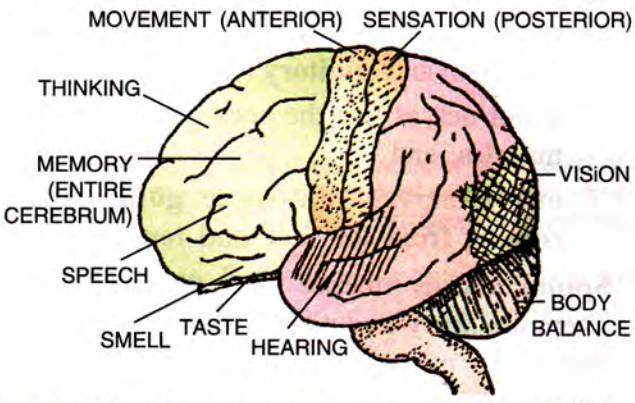


Fig. 9.5 Major functions of the different areas of the brain

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).

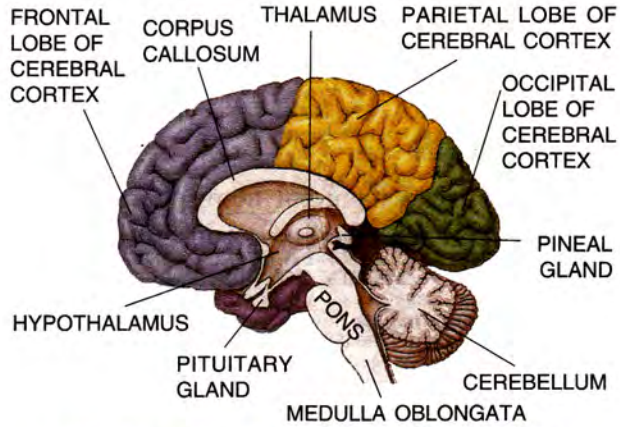


Fig. 9.6 : Brain in median (sagittal) section

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,**

midbrain and **hindbrain**. The various parts under 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

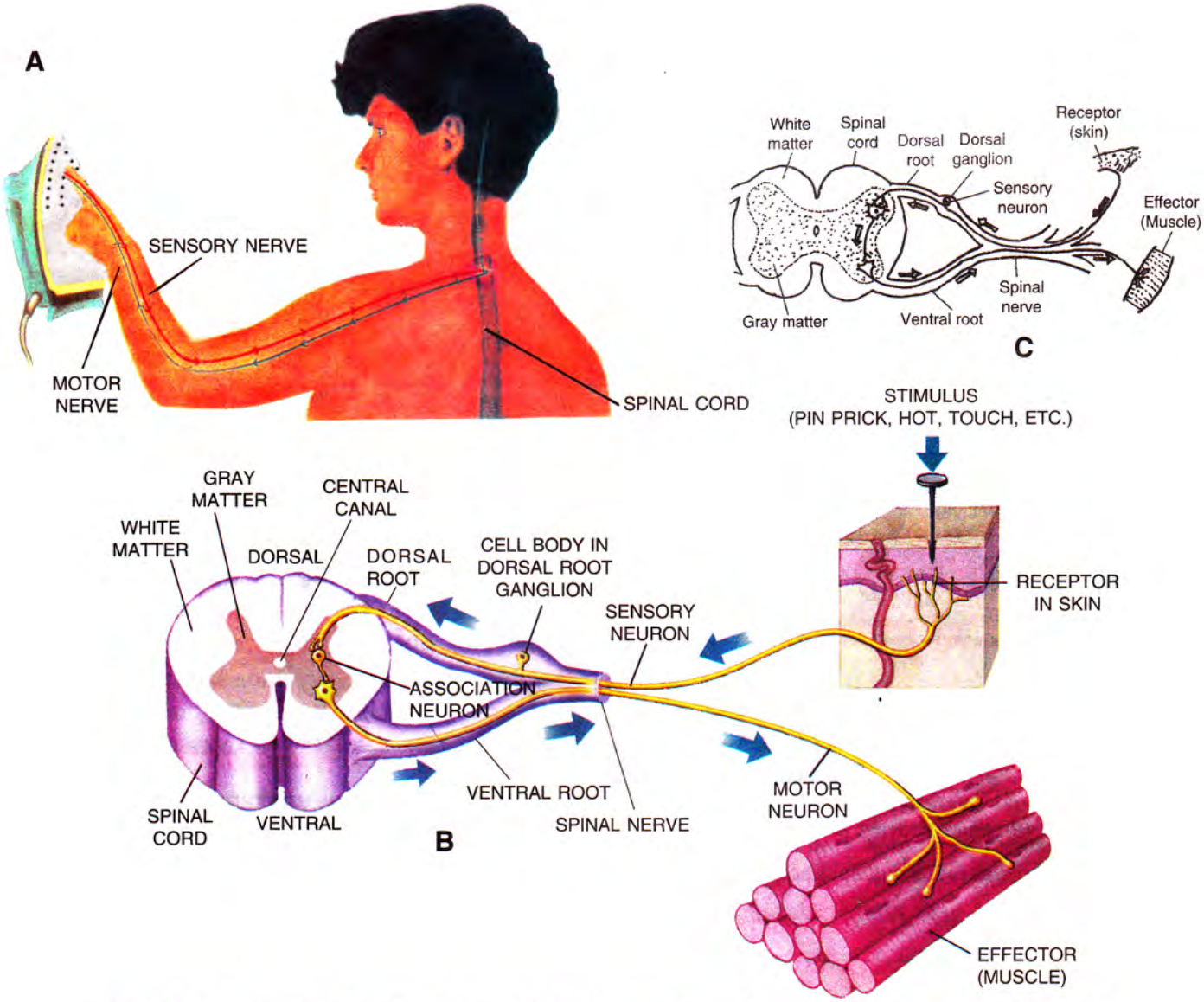


Fig. 9.7 : A–A simple reflex of withdrawal of hand on touching a hot iron, brought out by spinal cord
B–Diagrammatic sketch of the internal structure of spinal cord and nervous pathway in spinal reflex
C–Simplified scheme of the same spinal reflex action

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.

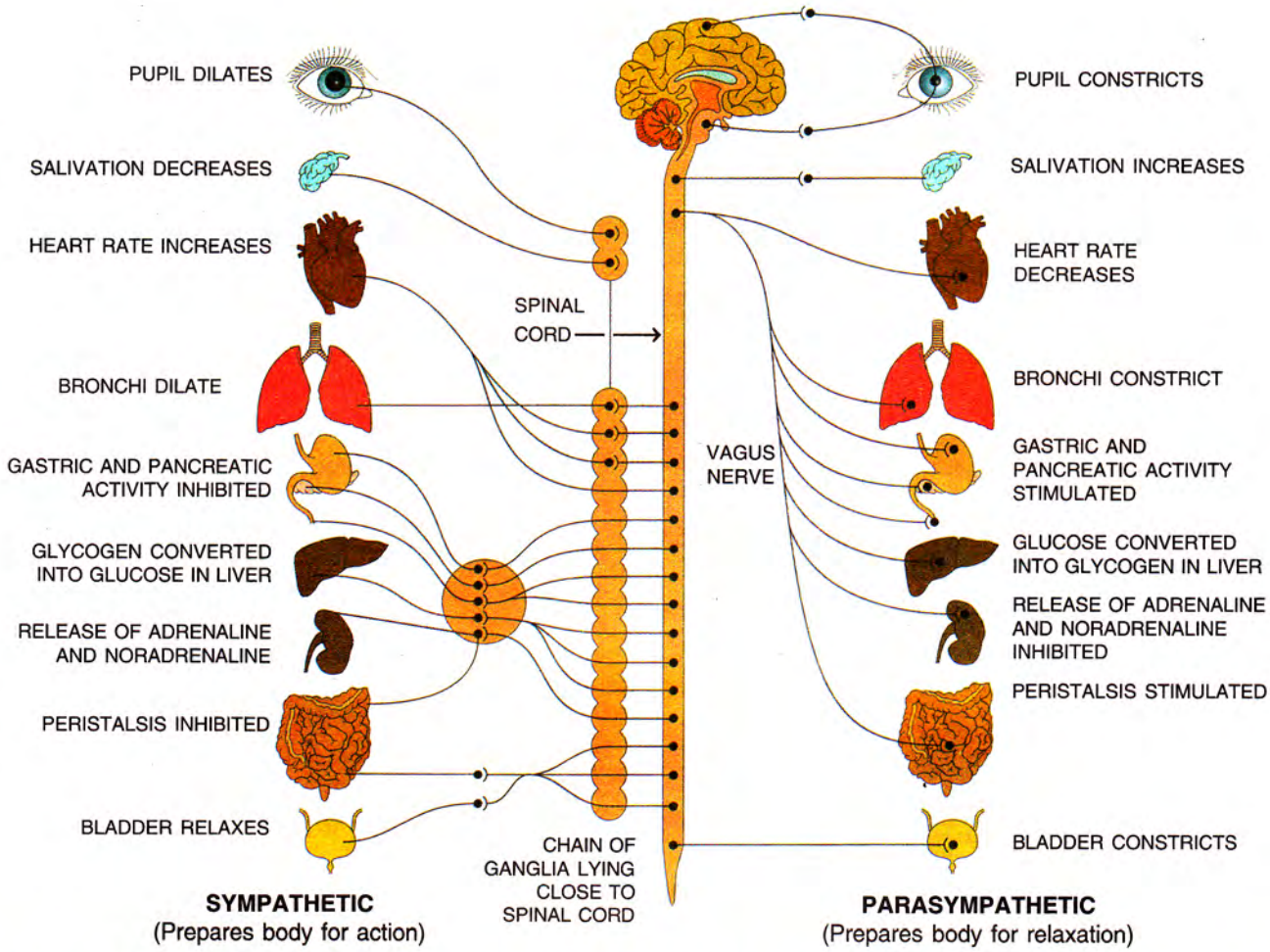


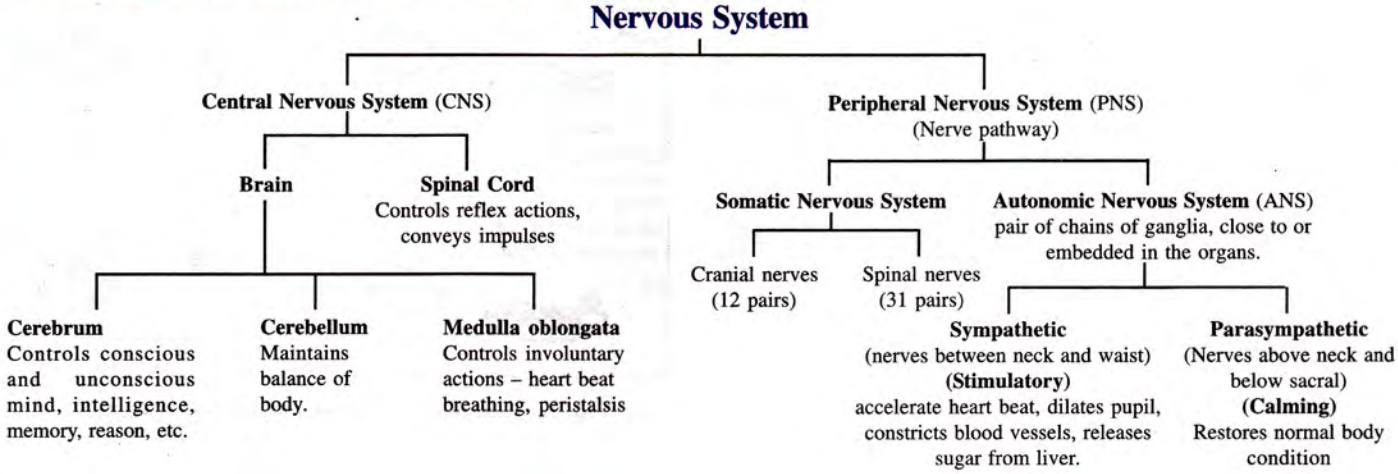
Fig. 9.8 : Autonomic nervous system showing the opposing effects of its two parts – sympathetic and parasympathetic

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.

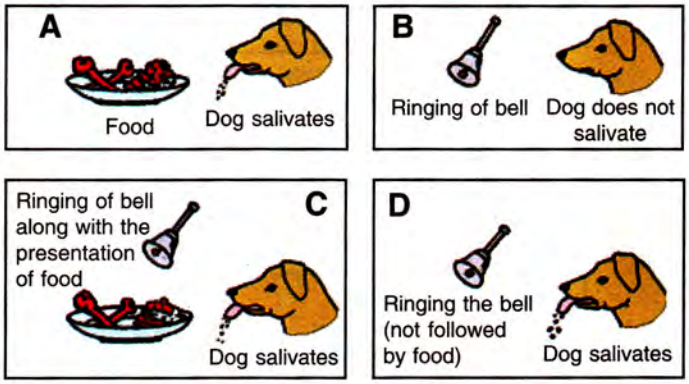


Fig. 9.9 : Pavlov's experiment to demonstrate a conditioned reflex

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.

B. Conditioned (Acquired) Reflexes :

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 flashed "like a reflection" through the same spinal 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.

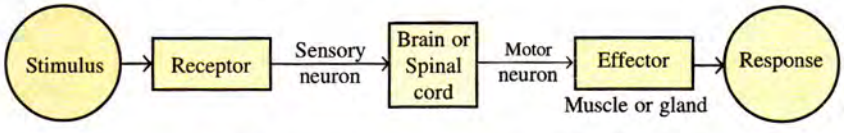
PATH OF REFLEX ARC

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.

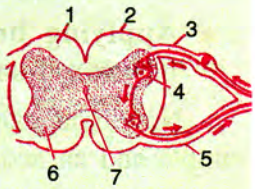
REMEMBER

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 :

(a) The dorsal root ganglion of the spinal cord contains 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 .....

(b) Autonomic nervous system .....

(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 B. SENSE ORGANS — EYE AND EAR

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**.

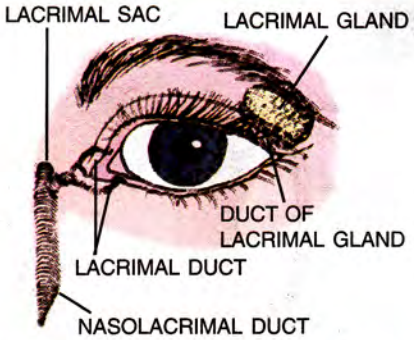


Fig. 9.10 : Lacrimal (tear) apparatus of the human eye

- 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**.

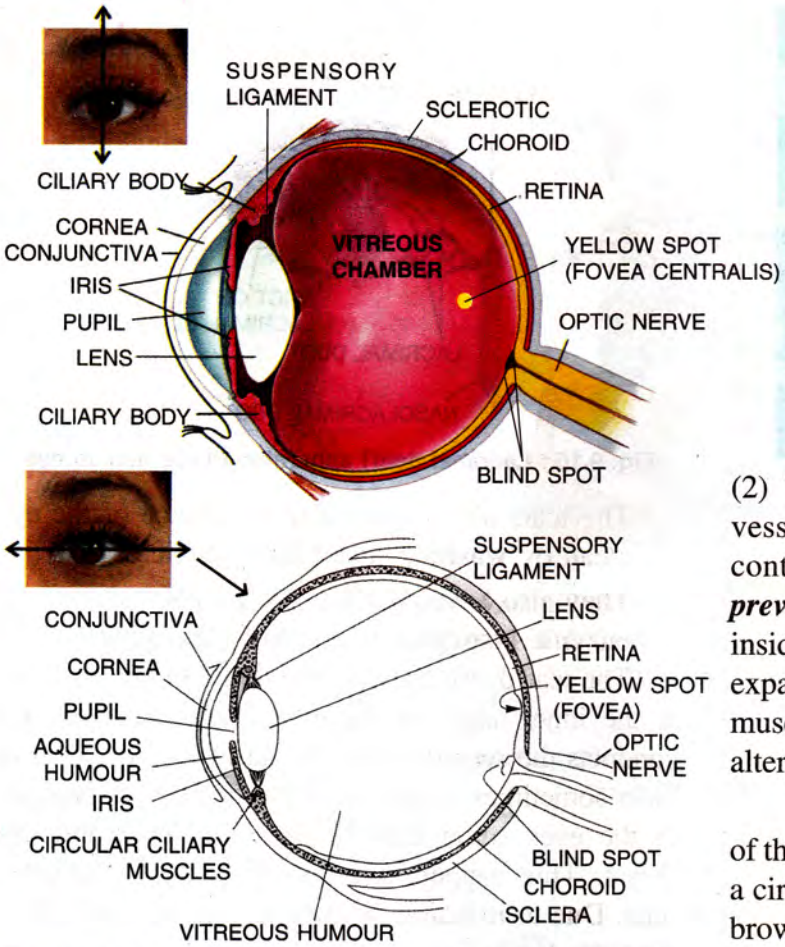


Fig. 9.11 : (Upper)–Right half of the left eye (V.S.), colour contrasted, (Lower)– Horizontal section of the eye. In simple black and white for practising to draw

(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.

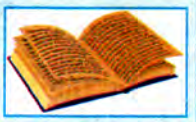
(3) The **retina** or the innermost layer is sensitive to light. It contains two types of sense cells called **rods** and **cones**.

- 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.

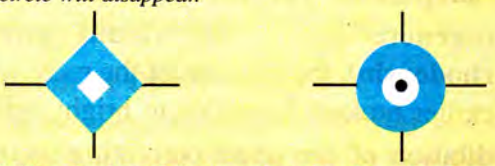


Fig. 9.12 : A chart for experiencing the blind spot

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.

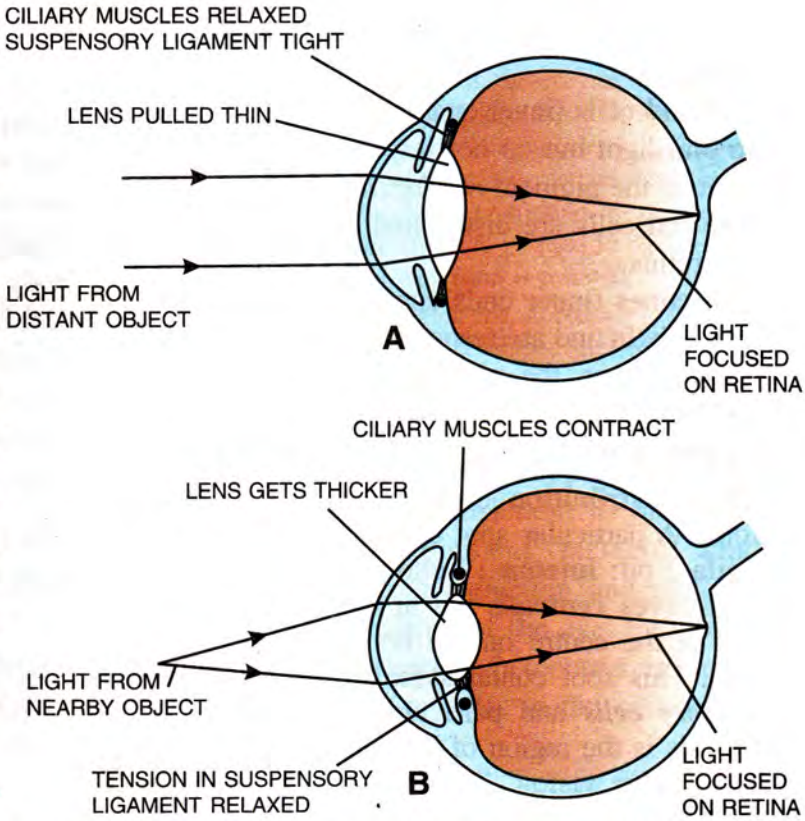
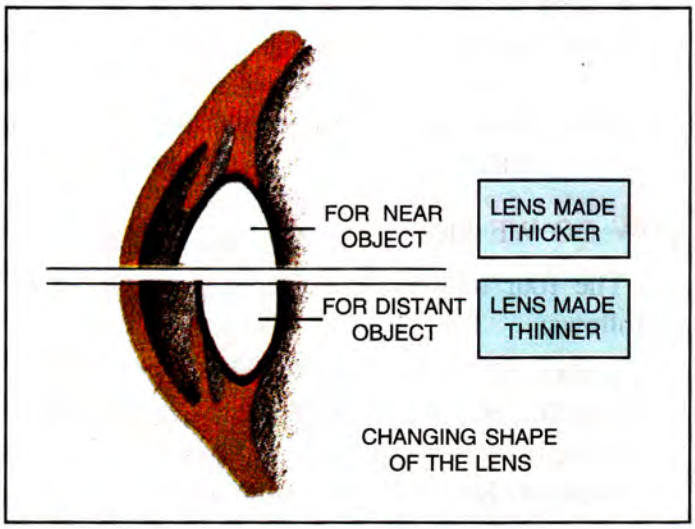


Fig. 9.13 : Accommodation of the eye: A – for distant object; B – for near object

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).

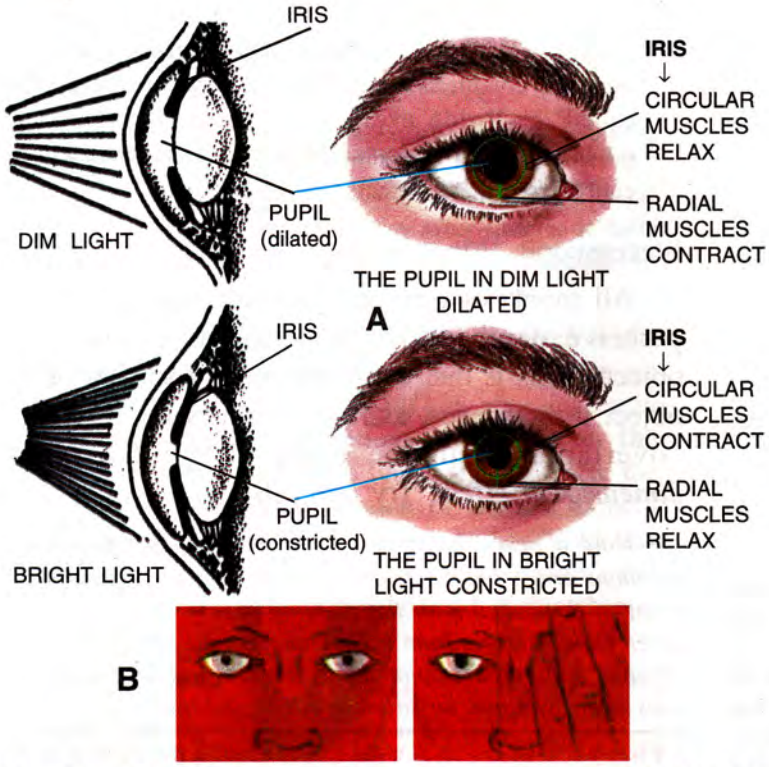


Fig. 9.14 : A–Size of pupil in dim light and bright light. B–One can as well experience the pupil reflex by covering one eye, the pupil of the other eye opens up as a result of reflex linking the two eyes

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

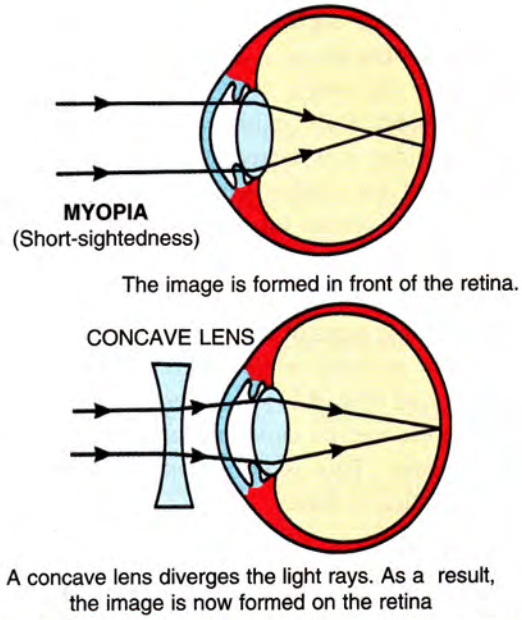


Fig. 9.15 : Short-sightedness (Myopia) and its correction by a CONCAVE LENS

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**

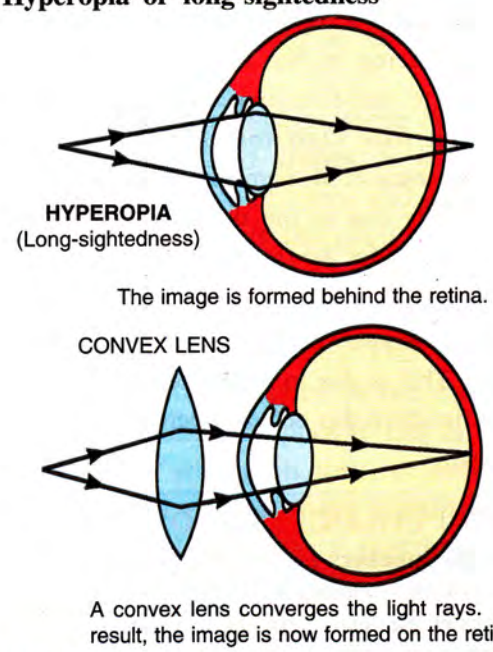


Fig. 9.16 : Long-sightedness (Hyperopia) and its correction by a CONVEX LENS

Far or **long-sightedness** (**Hyperopia**, old term-**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.

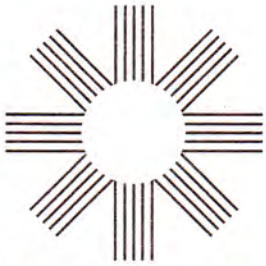
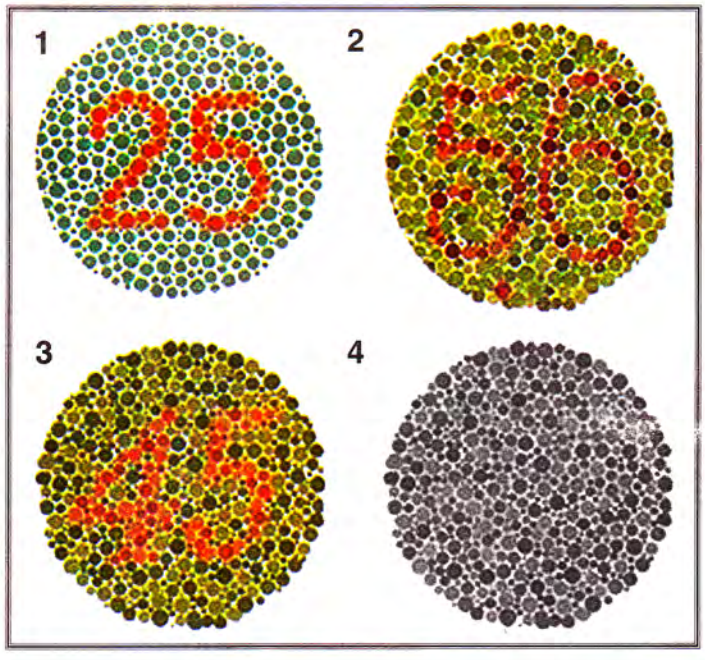


Fig. 9.17 : Do you suffer from astigmatism? Shut one eye and look at this picture. If all the lines appear equally dark, you do not. But if some sets of lines appear dark and those at right-angles to them appear lighter, then you do. Try the same with the other eye

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.



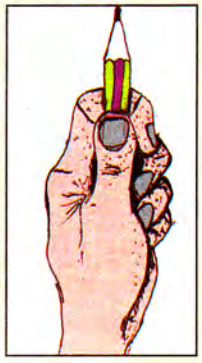
8. **Squint :** In this defect, the two eyes somewhat converge leading to what is called **"cross eye"**. An opposite condition appears when they diverge and is called the **"wide eye."** Both conditions may cause double vision or diplopia. Surgery and suitable exercise can correct these defects.

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.

After-images — the basis of motion pictures.

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.

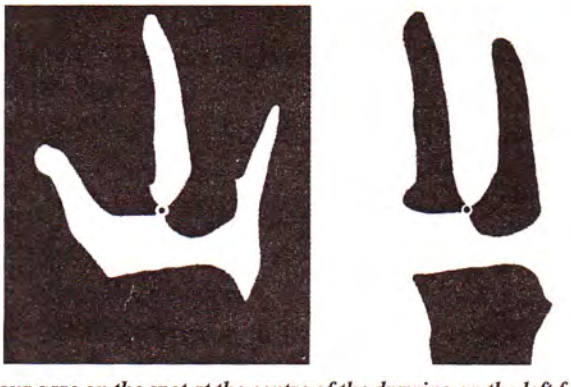
In a movie, pictures are projected on a screen at the rate of about 24 pictures per second, but we cannot see the individual frames on account of the after-images in our eyes. The **life-like continuous movement on the screen is an illusion**. Television too is similar, where the scanning beam of a picture 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.

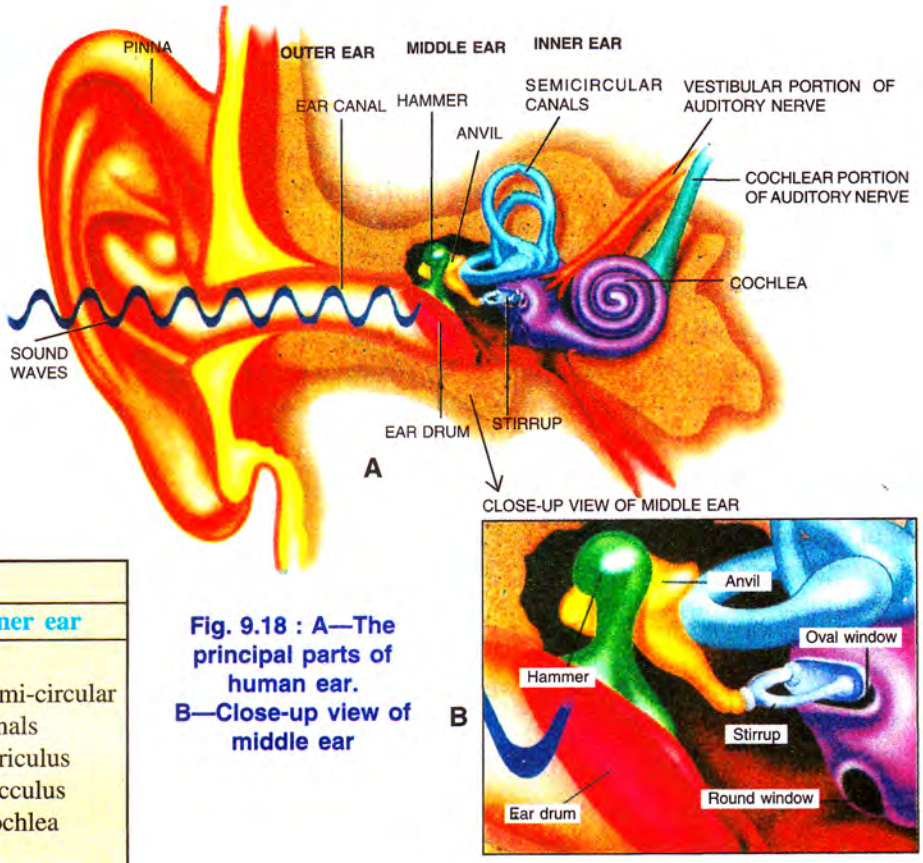
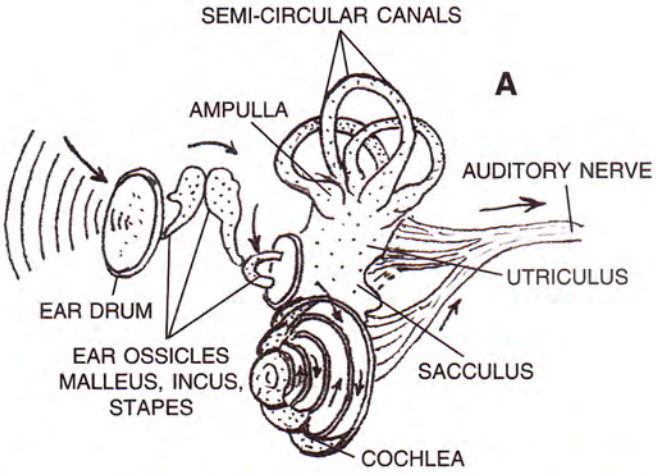
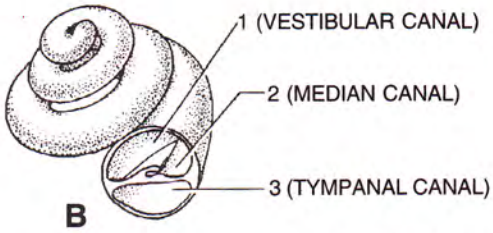


Fig. 9.18 : A—The principal parts of human ear. B—Close-up view of middle ear

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





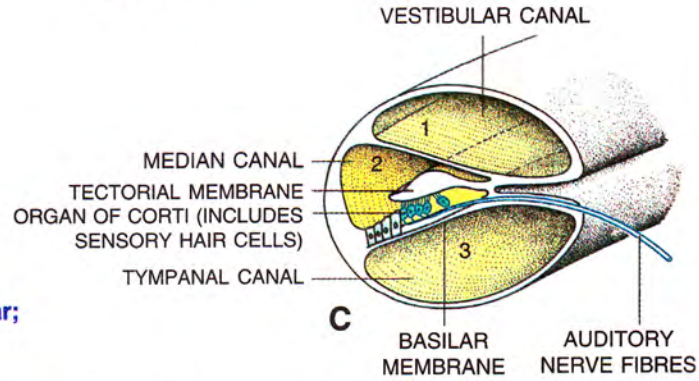


Fig. 9.19 A–The course of perception of sound in human ear; B. Cochlea, and its inner cavities, C–Inner cavity of cochlea showing three parallel canals

(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

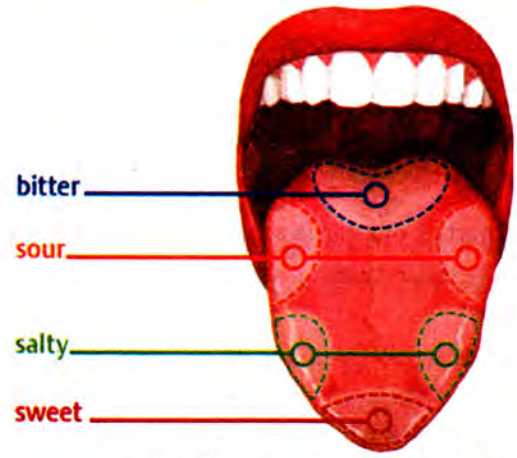


Fig. 9.20 Different taste areas of tongue

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.

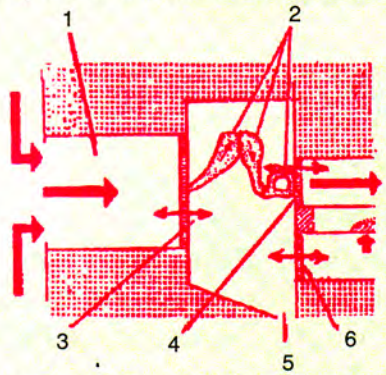
9.7.5 The Sense of Smell *(Extra – not specified in syllabus)*

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

the **function** of each :

(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?

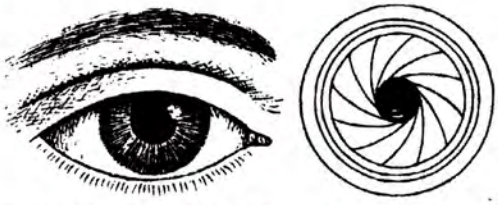
8. **What is meant** by *Power of accommodation* of the eye? **Name** the muscles of the eye responsible for the same. .....

E. STRUCTURED/APPLICATION/SKILL 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.

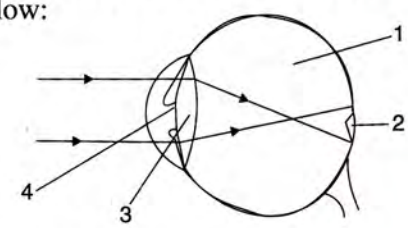
2. With reference to the human ear, answer the questions that follow:
   (a) **Give** the technical term for the structure found in the inner ear.
   (b) **Name** the three small bones present in the middle ear. **What** is the biological term for them collectively?
   (c) **Name** the part of the ear 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



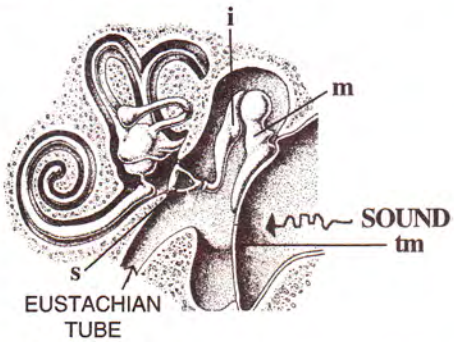
   (a) **Name** the corresponding parts of the eye and the camera shown here that are comparable in function.
   (b) **Explain** the mode of working and the functions of the parts of the eye mentioned above.

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.

5. The figure below is the sectional view of a part of the skull showing a sense organ :



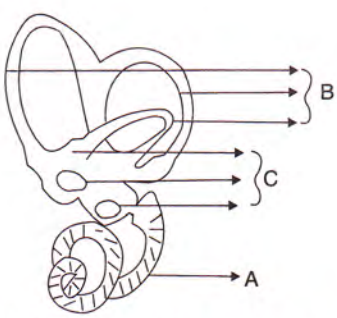
(i) **Name** the sense organ.

(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.

(i) Give the collective biological term for Malleus, Incus 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'.

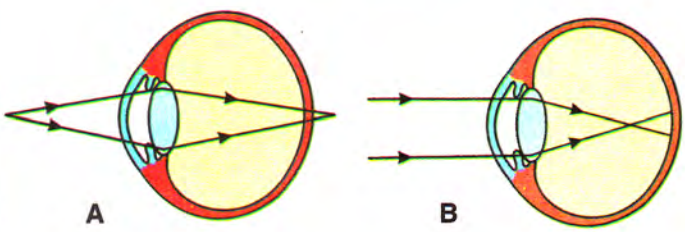
7. **Draw** a labelled diagram of the inner ear. Name the part of the inner ear that is responsible for static balance in human beings.

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 ?

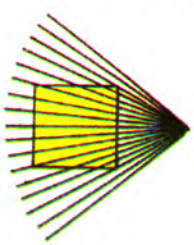


OPTICAL ILLUSIONS

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

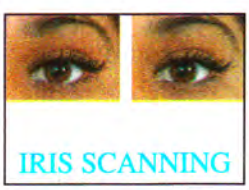
Two other examples of illusions are given below.

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.

10 Endocrine Glands — "The Producers of Chemical Messengers"

Syllabus : *Endocrine System : General study of the following glands : Adrenal, Pancreas, Thyroid and Pituitary. Difference in Endocrine and Exocrine glands.*

Scope of syllabus : Correct location and shape of the gland in the human body should be discussed along with the hormones they secrete (Pancreas : insulin and glucagon to be taught; Thyroid : only thyroxin to be taught). Effects of hypo-secretion and hyper-secretion of hormones must be discussed. The term tropic hormones should be explained in the study of pituitary. Brief idea of feedback mechanism must be given.

Endocrine glands are such glands which secrete hormones. Hormones are extremely important secretions for the regulation of body activities. The full set of endocrine glands in the body includes numerous glands, but the syllabus specifies only a few of them as mentioned above.

10.1 NEED FOR THE REGULATION OF BODY ACTIVITIES

The activities in our body are highly complex and they need to be so regulated that every activity takes place ***at a proper time and in a correct sequence***. For example, the gastric juice, bile and pancreatic juice should be poured into the food canal only when there is food in it. Though this kind of regulation is done to some extent by the nervous system (Chapter 9), it is also brought about by ***chemical regulators*** called ***hormones*** (*horma:* to stir up // to excite // to put into action).

Seven major differences in the action of the nervous system and of hormones in the regulatory mechanism in our body are listed in Table 10.1 below:

Hormones are secretions from specific cells or glands in the body, and are carried to all parts by the blood, but their effect is produced in one or more specific parts (**target** organ or cells) only.

Most hormones are secreted by special glands, the **endocrine glands** (*endo*: inside, *crine:* separate) meaning "secrete internally", also called ductless glands because their ***secretions are poured directly into the blood*** and not through any special duct.

Certain hormones are also produced from some such glands or body parts which otherwise have a different primary function; for example, the stomach & duodenum.

Table 10.1 : Differences between hormonal control and nervous control

Hormonal control	Nervous control
1. Usually **slow**.	1. Immediate/**Rapid**.
2. Transmitted **chemically** through blood.	2. Transmitted **electro-chemically** through the nerve fibres and chemically across synapses.
3. Affects **different organs** (**widespread** in body).	3. Affects only the particular muscles or the gland (**local**).
4. Effect is **short term** or **long-lasting**.	4. Effect **only short-lived**.
5. **Can affect growth.**	5. **Cannot affect growth.**
6. Can bring about specific chemical changes and **regulates metabolism.**	6. Does not influence chemical changes and **cannot regulate metabolism.**
7. **Cannot be modified** by learning from previous experience.	7. **Can be modified** to some extent by learning from previous experience.

Endocrine system. Endocrine system consists of several glands/glandular cells which bring about the overall common function of chemical coordination in the body. Almost all endocrine glands act in a coordinated manner. They activate each other and work as a system of organs called **endocrine system**. A system is defined as a group of organs performing an overall **common** function.

10.2 GENERAL PROPERTIES OF HORMONES

1. Hormones are secreted from their source **directly into the blood** (and not into lymph).
2. They **regulate** the physiological processes **by chemical means**. They affect the enzyme systems of the body.
3. They **act on target organs or cells** usually away from their source.
4. Hormones produced in one species usually show **similar influence in other species**.
5. They are produced in **very small quantities** and are **biologically very active**. For example, adrenaline is active even in a concentration of 1 part in 300,000,000 parts.
6. Chemically, some hormones are **peptides (proteins such as insulin)** which are water soluble, some are **amines** (derived from **amino acids such as adrenaline**) again water-soluble and some are **steroids** derived from cholesterol such as testosterone which are lipid-soluble.
7. Their **excess** (hypersecretion/oversecretion) **or deficiency** (hyposecretion/undersecretion), both may **lead to serious consequences**.
8. Hormones are **not stored** in the body and are excreted from the system.

Hormone is a secretion from some glandular part of the body, which is poured into blood and which acts on the target organs or cells of the same individual, bringing about coordination between distant parts of the body.

? PROGRESS CHECK

1. Fill in the blanks by selecting the appropriate alternative from those given in brackets.
   (i) Regulation of activities inside the body are brought about by ..... and ..... systems. **(nervous/digestive/endocrine)**
   (ii) Hormones are secreted directly into the ..... **(organs/lymph/blood)**.
   (iii) Chemically, some hormones are ....., some steroids, some ..... **(proteins/amines/carbohydrates)**.
   (iv) Both ..... or deficiency of hormones lead to serious consequences **(excess/absence)**.
   (v) Hormones produced in one species usually show ..... influence in other species. **(similar/different)**.
2. Give the characteristics of hormones pertaining to
   (i) Site of action .....
   (ii) Chemical nature .....
   (iii) Manner of transportation. .....

10.3 ENDOCRINE GLANDS

The principal endocrine (hormone-producing) glands in the human body have been shown in Fig. 10.1.

These are enumerated below (only the ones in bold face are included in the syllabus):

1. **Adrenal**
2. **Pancreas**
3. **Thyroid**
4. **Pituitary**
5. Parathyroid
6. Thymus
7. Gonads

We shall try to explain the major functions of each endocrine gland.

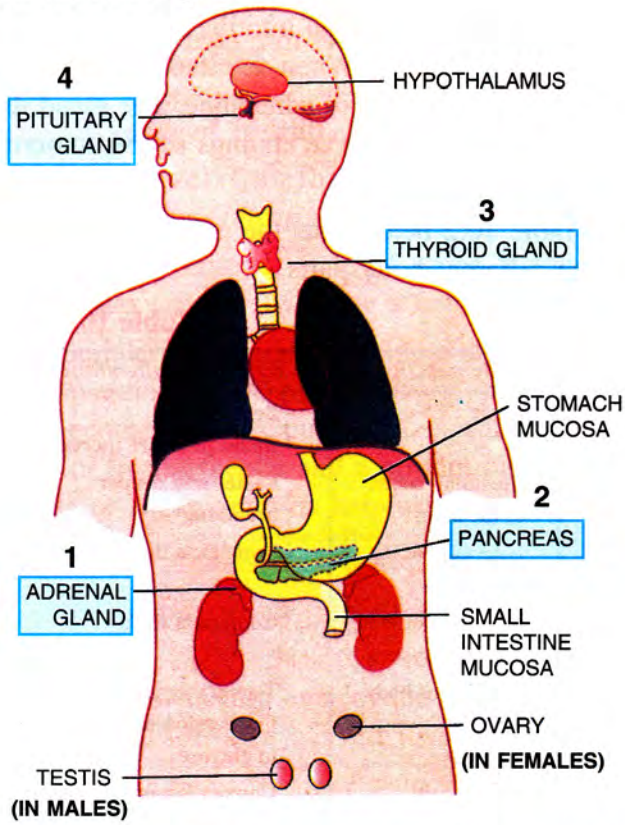


Fig. 10.1 : The principal endocrine glands. (Both sexes have the same endocrine glands except the sex glands *i.e.* ovaries in female and testes in male). The syllabus specifies only four (the ones in boxes 1-4)

1. ADRENAL GLANDS

The adrenal glands are like caps above the kidneys (*ad:* near, *renal:* kidney). Each adrenal gland consists of two parts — (i) a central *medulla* and (ii) a peripheral *cortex*.

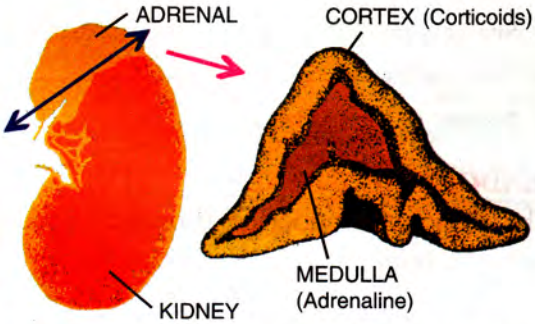


Fig. 10.2 : Position of adrenal on kidney, and its two parts in cross section which secrete respective hormones.

(i) Adrenal medulla secretes **adrenaline** (also called epinephrine and noradrenaline). Adrenaline is a hormone, which prepares the body to meet any emergency situation, for **"fight"** *i.e.* to face danger or for **"flight"**, to run away from it. Extra energy and strength is provided to the body in that situation. Extra hormone is released into the blood at the time of emotional stress. When **excited** or **angry** our adrenals produce a lot of adrenaline. The gland itself is stimulated by the nerve endings of the autonomic nervous system.

Table 10.2 below lists the effects of adrenaline on the different body parts.

FUNCTIONS OF ADRENALINE—THE EMERGENCY HORMONE

- It **increases heart** beat accompanied by an increase in blood pressure.
- It **increases blood supply to the muscles** while decreasing it to skin and visceral organs.
- **More glucose is released** into the blood by the liver (like putting more fuel into the engine). [The final dash to win a raoe is under the influence of adrenaline].

(ii) Adrenal cortex secretes many hormones but the best known hormone is **cortisone** (which suppresses inflammation).

The cortical hormones are categorised as :

a. **Mineralocorticoids :** regulates mineral metabolism, specially Na^+ and K^+ ions.

b. **Glucocorticoids :** regulates carbohydrate, protein and fat metabolism.

In general, the cortical hormones

- Increase blood glucose concentration.
- influence fat and protein metabolism.
- regulate salt and water balance in the body.
- adapt the body to "stresses" such as extreme heat or cold, burns, infections, *etc.*
- Certain cortical hormones behave like sex hormones. They are both male as well as female hormones in both sexes. An overgrowth of cortex in young children leads to a premature sexual maturity.

Table 10.2 : Responses to Adrenaline

	Body part	*Effects of adrenaline*	*Biological advantage*	*Effect or sensation*
1.	Heart	**Beats faster** **Blood pressure increases**	Sends more glucose and oxygen to the muscles	**Thumping heart**
2.	Breathing centre of the brain	**Faster and deeper breathing**	Increased oxygenation of the blood; rapid removal of carbon dioxide	**Panting**
3.	Arterioles of the skin	**Constricts them**	Less blood going to the skin means more is available to the muscles	**Person turns pale**
4.	Arterioles of the digestive system	**Constricts them**	Less blood for the digestive system, allows more to reach the muscles	**Dry mouth**
5.	Muscles of body	**Tenses them**	Ready for immediate action	**Tense feeling; shivering**
6.	Liver	**Conversion of glycogen to glucose**	Glucose available in blood for energy production	**No sensation**
7.	Fat deposit	**Conversion of fats into fatty acids**	Fatty acids available in blood, for muscle contraction	

In addition, adrenaline also increases clotting capacity of the blood, **dilates pupil of the eye**, stimulates uterine contraction during labour (delivery of baby), stimulates muscle of the hair follicles. (These functions are in general the same as those of the sympathetic autonomic nervous system).

Women with beard & Men with breasts!

If there is an overgrowth of adrenal cortex in a mature woman, she develops certain male characteristics, such as, a beard, moustaches and deep male voice. The condition is known as **adrenal virilism** (Latin *Virilism* : maleness).

If the overgrowth occurs in mature men, they may develop some feminine characteristics, such as, enlargement of breasts.

Hyposecretion from adrenal cortex causes Addison's disease. Symptoms are loss of energy, skin pigmentation, loss of weight, nausea, hypoglycemia (low blood sugar), sensitivity to cold and pain, increased susceptibility to infections, etc.

Hypersecretion of adrenal cortex causes Cushing's syndrome. Symptoms are obesity, hyperglycemia (higher blood sugar), osteoporosis, weakness, salt and water retention.

2. PANCREAS

Pancreas is both a duct gland as well as a ductless gland. As a duct gland, its secretion (pancreatic juice) is poured into the duodenum for digestion. As a ductless gland, it has special groups of hormone-secreting cells called **Islets of Langerhans**, which are scattered in the entire gland (*islets :* little islands) (Fig. 10.3). The islet cells produce three hormones — *insulin*, *glucagon* and *somatostatin* from three different kinds of cells called beta, alpha and delta cells respectively. (*Note : Somatostatin from Delta cells is excluded from syllabus*).

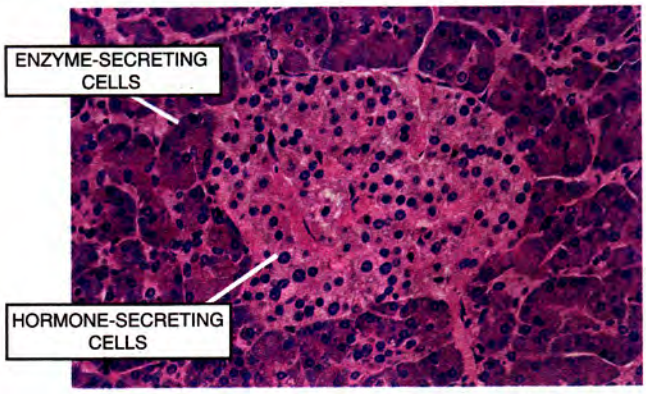


Fig. 10.3 : Section of pancreas tissue showing one islet (× 250)

(1) Insulin secreted by beta cells checks rise of sugar level in blood. This it does in two principal ways:

(i) It promotes **glucose utilisation** by the body cells.

(ii) It stimulates **deposition of extra glucose** of the blood as glycogen in liver and muscles.

Abnormalities in insulin — shortage and excess.

Insufficient secretion of insulin causes **diabetes** (more correctly **diabetes mellitus** or ***hyperglycemia*).** The word *"mellitus"* means honey, referring to the passage of sugar (glucose) in urine. A diabetic person:

- has **high concentration of sugar in blood** (hyperglycemia — *hyper* : excess, *glyce* : sugar (glucose), *emia* : blood.
- excretes a **great deal of urine** loaded **with sugar**.
- feels **thirsty** because of the loss of water through too much urination.
- **loses weight** and becomes weaker and weaker. In certain cases, the person loses eye sight or vision.

The usual treatment by administering insulin is not a cure, but only a method of supplying the hormone which is not being produced by the pancreas.

Over-secretion of insulin

- Sugar level in the blood is lowered (hypoglycemia, *hypo* : below) and
- Brain may enter a state of coma if the level becomes too low even for a few minutes.

A similar thing may happen to a diabetic patient if an overdose of insulin is given — the patient may become unconscious. This is called **insulin shock** or hypoglycemia and a prompt bite of sweet biscuits or sugar candy is helpful.

Caution in answering a question.

It is **wrong** to say "insulin converts glucose to glycogen."

Instead, "insulin enables the cells to absorb glucose and use it or convert it into glycogen."

(2) Glucagon is secreted from alpha cells. It stimulates the breakdown of glycogen in the liver to glucose, thus it raises sugar level in the blood.

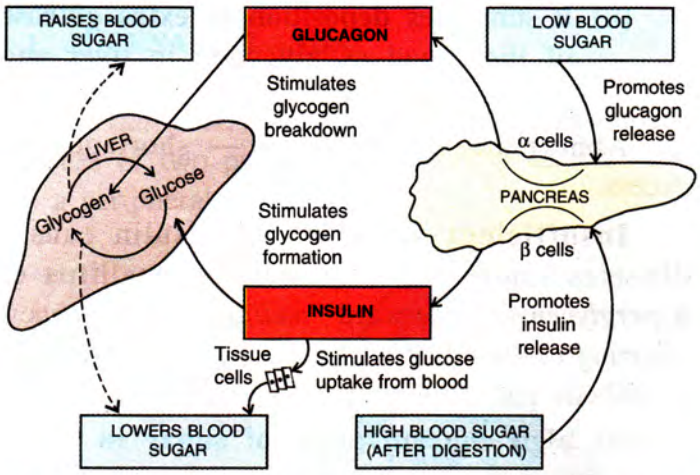


Fig. 10.4 : The role of pancreatic hormones (insulin and glucagon) in regulating blood sugar (glucose) level

HORMONES OF ISLETS OF LANGERHANS
(in Pancreas)

1. ***Insulin*** *(from beta cells)* – *Promotes glucose uptake by body cells*
   – *Stimulates deposition of extra glucose (as glycogen) in liver and muscles*

   Deficiency *causes diabetes mellitus (sugar diabetes)*

   Excess *causes nerve cell starvation & brain coma.*
2. ***Glucagon*** *(from alpha cells)* – *Stimulates liver to convert glycogen into glucose*
3. ***Somatostatin*** *(from delta cells)* (Not in syllabus) – *Inhibits secretion of insulin and glucagon.*

? PROGRESS CHECK

1. Mention against the three types of cells of the islets of Langerhans, the name of the hormone they secrete.
   (i) Alpha cells .....
   (ii) Beta cells .....
   (iii) Delta cells .....
2. Mention the two principal ways in which insulin acts :
   (i) .....
   (ii) .....
3. Name the following conditions :
   (i) Passage of much glucose in urine
   .....
   (ii) Overdose of insulin makes the diabetic patient unconscious .....
4. List any three symptoms of diabetes mellitus.
   (i) .....
   (ii) .....
   (iii) .....
5. List any two effects of adrenaline
   (i) .....
   (ii) .....
6. Name the two categories of hormones secreted by adrenal cortex.
   (i) .....
   (ii) .....

3. THYROID

The thyroid is a bilobed (butterfly-shaped) structure (Fig. 10.5) situated in front of the neck just below the larynx. The two lobes are joined by a narrow isthmus (interconnection). It secretes two hormones **thyroxine** and **calcitonin.** [*Note : Calcitonin is not included in the syllabus*].

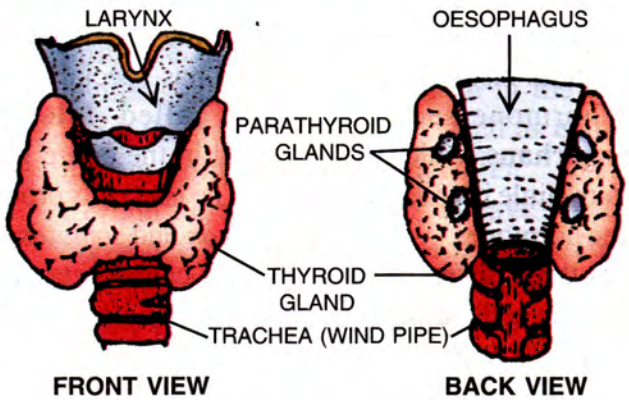


Fig. 10.5 : Thyroid gland

Thyroxine regulates the basal metabolism, *i.e.*, the rate of cellular oxidation resulting in heat production at rest. An increase in the secretion increases metabolism and a decrease in secretion lowers it. It also influences the general growth of the body, ossification of bones, body temperature, mental development, etc.

A. Undersecretion (Hypothyroidism) : Insufficient secretion of thyroxine may lead to three conditions – **simple goitre, cretinism** and **myxoedema**.

(i) **Simple goitre** is the enlargement of the thyroid and is visible as a **swelling in the neck** (Fig. 10.6). This is due to insufficient quantity of iodine in food. This condition is common in

the people living in hilly regions where iodine is deficient in soil and hence in the food grown there.

Fig. 10.6 A person suffering from simple goitre

Thyroid deficiencies are common in many parts of India. Use of iodised salt (containing iodine) in food is recommended because iodine is the active ingredient in the production of thyroxine.

(ii) **Cretinism** is a condition which affects the growth of children showing **dwarfism** and **mental retardation**. This is due to defective development, or early atrophy (degeneration) of the thyroid.

(iii) **Myxoedema** is a condition that affects an adult if his thyroid does not function properly; in this condition, the person becomes **sluggish** with **swelling of the face and hands**.

B. Oversecretion (Hyperthyroidism) : Excess of thyroxine secretion may also cause a kind of goitre called **exophthalmic goitre** (*exo* : outward, *ophthalmos* : eye).

A person having the problem of oversecretion shows

- a marked increase in metabolic rate,
- rapid heart beat,
- shortness of breath;
- eyes are protruded, and
- forms a goitre in the neck.

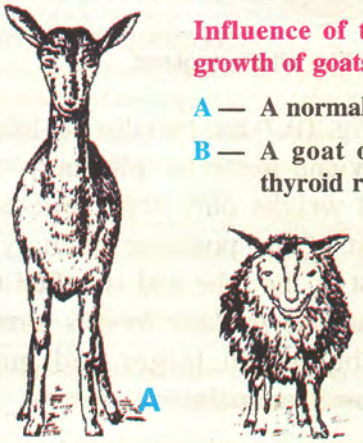
IMPROPER FUNCTIONING OF THYROID

Hypothyroidism (undersecretion)

1. ***Simple goitre*** *— enlargement of thyroid.*
2. ***Cretinism*** *— dwarfism and mental retardation.*
3. ***Myxoedema*** *— swelling of face and hands, sluggishness.*

Hyperthyroidism (oversecretion)

1. ***Exophthalmic goitre*** *— protruding eyes, increased metabolism, shortness of breath, restlessness.*



Influence of thyroid gland on the growth of goats.

A — A normal 4-month old goat;

B — A goat of the same age with thyroid removed.

? *PROGRESS CHECK*

Fill in the blanks with the correct alternative from those given for each :

(i) Thyroid is located close to ..... **(larynx/kidney).**

(ii) Cretinism is caused due to ..... of thyroxin **(undersecretion/oversecretion)**

(iii) Oversecretion of thyroxin causes ..... goitre. **(simple/exophthalmic)**

(iv) The condition showing swelling on face and hands and sluggishness due to hypothyroidism is called ..... **(cretinism/myxoedema)**

(v) The hormone concerned with facing dangers is ..... **(thyroxine/cortisone/adrenalin)**

(vi) Cortex and medulla are the two regions of .... **(thyroid/adrenal)**

(vii) One of the effects of increased secretion of adrenaline is ..... **(Dry mouth/slowing of heart beat/face flushed with blood)**

4. PITUITARY

The pituitary gland is a small projection (about the size of a pea) which hangs from the base of the mid-brain below hypothalamus (Fig. 9.6 page 111). It is popularly called the ***master gland*** because it seems to control practically all other endocrine glands.

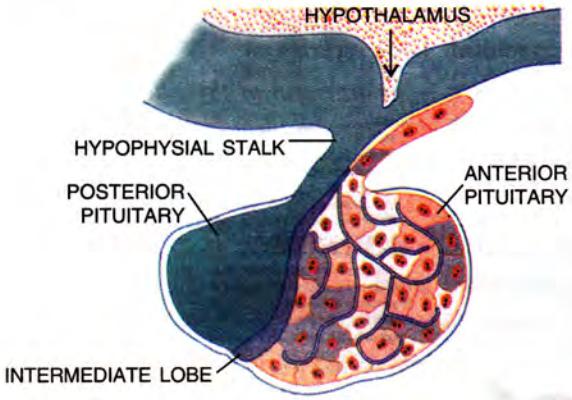


Fig. 10.7 : The pituitary gland

Pituitary gland (Fig. 10.7) has two distinct lobes, the **anterior pituitary** and **posterior pituitary** (the entire pituitary gland weighs only about **one-half gram).** The front part of the posterior pituitary is different from the rest of the lobe and is called the intermediate lobe. The *intermediate lobe* is almost absent in humans but much larger and more functional in some lower animals.

A. HORMONES FROM ANTERIOR PITUITARY

Some important hormones produced by the **anterior lobe** are as follows:

1. **Growth hormone** (GH) is essential for normal growth. It is also called ***somatotropin*** (*somatic:* body, *tropic:* stimulating).
   - The **deficiency** of GH in **childhood** results in **dwarfism**. [A **dwarf**, though fully developed, retains body proportions of a child.]

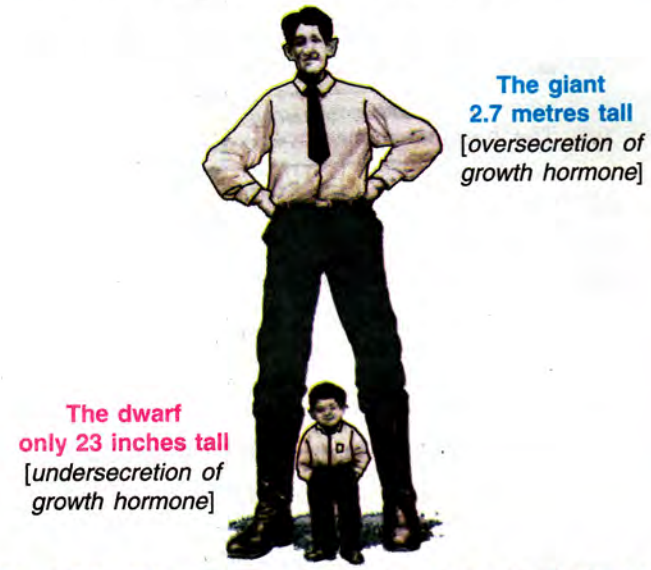


Fig. 10.8 : These two fully-grown men are victims of malfunctioning of the pituitary gland.

   - The **oversecretion in childhood** results in **gigantism**; the long bones lengthen beyond normal and human giants upto 2.7 metres in height are produced (Fig. 10.8).
   - If ***oversecretion*** of the growth hormone suddenly occurs ***in an adult***, there is an extra growth of bones in the face (particularly the jaws) and in the hands and feet. The person develops a large nose and thick lips. This condition is called **acromegaly** (*acro:* height/extremity, *megaly:* large).
2. **Thyroid stimulating hormone** (TSH) activates thyroid to secrete thyroxin.
3. **Gonad stimulating (Gonadotropic) hormones** regulate the activities of the testes and ovaries.
4. **Adrenocorticotropic hormone (ACTH)** regulates the activity of adrenal cortex.

> The term **tropic hormones** refers to such hormones which *stimulate other endocrine glands* to produce their specific hormone such as gonadotropic hormones secreted by anterior pituitary and also stimulate gonads to produce certain hormones. **"Tropic"** means ***influencing the activity*** of the named organ such as *thyrotropic* (for thyroid), adrenocorticotropic (for adrenal cortex), etc.

B. HORMONES FROM POSTERIOR PITUITARY

The **posterior lobe** produces two hormones named vasopressin and oxytocin.

1. **Antidiuretic hormone** (ADH), also called **vasopressin**, constricts blood vessels with rise in blood pressure. It also acts on the kidney increasing reabsorption of water from the kidney tubules.
   - Deficiency of ADH causes **diabetes insipidus** (water diabetes) in which urination is frequent and copious, resulting in loss of water from the body and the person becomes thirsty.

> **REMEMBER**
>
> **"Diabetes"** means passing out excessive amounts of urine.
> **The two types of "diabetes" :** In ***diabetes mellitus***, the urine contains sugar caused due to insufficient insulin, but in ***diabetes insipidus***, there is no sugar in urine. *"Insipid"* means tasteless (blank) referring to the absence of sugar in urine and *"melli"* means honey/sweet.

2. **Oxytocin** (Gk. *oxys* : sharp/quick, *tokos* : childbirth) stimulates vigorous contractions of the uterus in a pregnant mother, leading to the birth of the baby. Also, stimulates milk ejection.

Table 10.3 : Hormones of pituitary gland and their actions

Source	Hormones and their action	
ANTERIOR PITUITARY	**GROWTH HORMONE (GH)**	***Promotes growth of whole body, particularly of the skeleton*** Deficiency (–) In childhood = ***Dwarfism*** Excess : (+) In childhood = ***Gigantism*** In adult = ***Acromegaly***
	TROPIC HORMONES (Stimulate certain other endocrine glands)	***THYROID STIMULATING HORMONE (TSH)*** ***(Stimulates thyroid to secrete thyroxine)***
		ADRENOCORTICOTROPIC HORMONE (ACTH) (Stimulates adrenal cortex)
		GONADOTROPIC HORMONES ***(Regulate the activities of Gonads-testes and ovaries)*** ***These are mainly of three types*** (i) ***Follicle-Stimulating Hormone (FSH)*** *Stimulates egg formation in females and sperm formation in males* (ii) ***Luteinizing Hormone (LH)*** *Stimulates the formation of corpus luteum to produce the female hormone progesterone, and the testes to produce the male hormone testosterone* (iii) ***Prolactin*** - *Milk secretion*
POSTERIOR PITUITARY	**ANTIDIURETIC HORMONE (ADH)** or **Vasopressin**	***Increases reabsorption of water from kidney tubules*** *Deficiency :* ***Diabetes insipidus (water diabetes)***
	OXYTOCIN	***Uterus contractions during child birth, stimulates milk ejection***

Table 10.3 summarises all the main hormones secreted by the pituitary and their action.

? PROGRESS CHECK

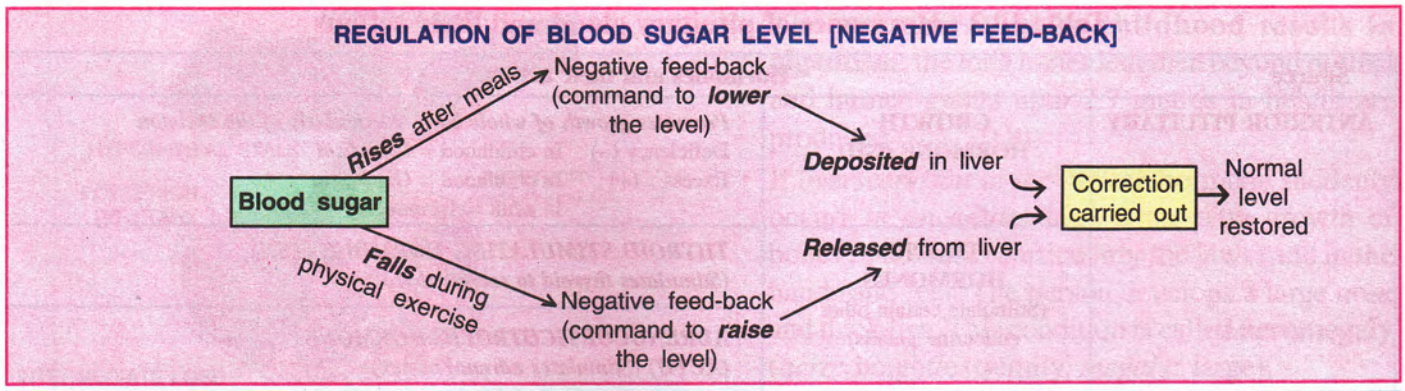
1. Mention if the following statements are true (T) or false (F). If false, rewrite the correct word (not words) striking out the single wrong one.
   (i) Pituitary is of the size of a lemon. T/F
   (ii) Pituitary has three lobes — anterior, posterior and intermediate. T/F
   (iii) Oversecretion of growth hormone in adult causes gigantism. T/F
   (iv) Vasopressin secreted by anterior lobe controls reabsorption of water form kidney tubules. T/F
2. Write the full forms of :
   (i) TSH .....
   (ii) LH .....
   (iii) ACTH .....
   (iv) ADH .....
3. What causes the following ?
   (i) Acromegaly .....
   (ii) Diabetes insipidus .....

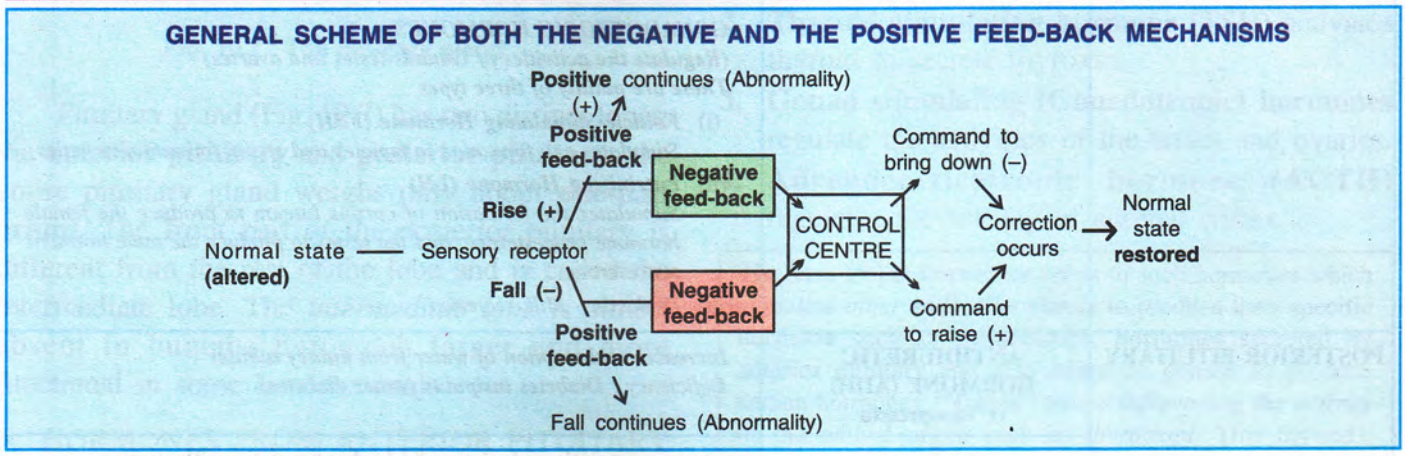
10.4 CONTROL OF HORMONAL SECRETIONS *[Feedback mechanism]*

[Commands like saying **"Too much, slow down"** or **"Too-little, speed up"**] – This is the feedback mechanism.

The body has mechanism to maintain a normal state. Whenever there is a change in this state there are "messages" through the body systems to "increase" if there is a fall below the normal, or to "decrease" if there is a rise above the normal. This kind of ordering for the opposite is **"negative feedback"**, to restore the normal state. Most feed-back mechanisms in our body are of this negative type. ***Example :*** Blood sugar level :

Positive feed-back mechanisms are very few. One example is that of uterine contractions during child birth. Normal state of uterus is uncontracted, one contraction instead of commanding to come to normal gives a message to continue to contract further (positive feed-back till delivery is completed).





10.5 THE HORMONES AT A GLANCE

Table 10.4 gives a consolidated general summary of the hormones from the four major endocrine glands, their actions and the disorders due to their undersecretion or oversecretion.

Table 10.4 Hormones from four major endocrine glands and their principal actions.

ENDOCRINE GLAND	HORMONES SECRETED	PRINCIPAL ACTIONS	DISORDERS	
			Undersecretion	Oversecretion
1. ADRENALS				
(i) Adrenal cortex	i. Mineralocorticosteroids (aldosterone)	Regulate plasma sodium and potassium concentrations,	Addison's disease	Adrenal virilism
	ii. Glucocorticoids (cortisol, corticosterone)	Regulate carbohydrate, lipid, and protein metabolism		
	iii. Sex corticoids (adrenal androgens)	Stimulate development of external sex characters in males		
(ii) Adrenal medulla	Adrenaline	Causes stimulation of sympathetic nervous system. Prepares body for any emergency.		
2. PANCREAS (Islets of Langerhans)				
(i) Beta cells	i. Insulin	Lowers blood sugar level	Diabetes mellitus	
(ii) Alpha cells	ii. Glucagon	Raises blood sugar level		
(iii) Delta cells	iii. Somatostatin *(not in syllabus)*	Inhibits the secretion of insulin and glucagon	—	—
3. THYROID	i. Thyroxine	Promotes tissue metabolism, growth and differentiation	Simple goitre, cretinism in children and myxoedema in adults	Exophthalmic goitre (Eye balls protrude, increased metabolism and restlessness)
	ii. Calcitonin *(not in syllabus)*	Promotes movement of calcium ions from blood to bones		

(Contd.)

4. PITUITARY				
(i) Anterior pituitary	**i. Growth hormone (somatotropin; GH)**	**Body growth**	**dwarfism**	**Gigantism in childhood, acromegaly in adulthood**
	ii. Prolactin	**Promotes lactation (milk formation and secretion)**		
	iii. Adreno-corticotropic hormone (ACTH)	**Stimulates secretion from adrenal cortex**		**Pigmentation in Addison's disease**
	iv. Thyroid-stimulating hormone (TSH)	**Stimulates thyroxine secretion**		
	v. Follicle stimulating hormone (FSH)	***In females*, growth of Graafian follicles and estrogen secretion *In males*, spermatogenesis.**		
	vi. Luteinizing hormone (LH)	***In females*, ovulation, maintenance of corpus luteum and secretion of progesterone *In males*, testosterone secretion.**		
(ii) Posterior pituitary	**i. Vasopressin (ADH)**	**Increases reabsorption of water from kidneys, contraction of blood vessels causing rise in blood pressure**	**Diabetes insipidus**	**Elevation of blood pressure**
	ii. Oxytocin	**Causes contraction of uterine muscle during childbirth**		

REVIEW QUESTIONS

A. MULTIPLE CHOICE TYPE

(Select the most appropriate option in each case)

1. A gland having endocrine as well as exocrine function is
   (a) pituitary (b) thyroid
   (c) pancreas (d) adrenal
2. Exophthalmic goitre is caused due to the overactivity of
   (a) thymus (b) thyroid
   (c) parathyroid (d) adrenal cortex.
3. The secretion of ADH (anti-diuretic hormone) is inhibited by
   (a) emotion and stress (b) nicotine
   (c) alcohol (d) morphine

B. VERY SHORT ANSWER TYPE

1. **Name** the following:
   (a) The three hormones produced by pancreas.
   (b) The hormone produced by adrenal medulla.
   (c) The condition caused by the oversecretion of insulin.
   (d) The hormone secreted by β (beta) cells of the islets of Langerhans.
   (e) The hormone which increases blood pressure.
   (f) The hormone causing more urine formation.
   (g) The hormone which stimulates the entire sympathetic nervous system.
2. **What** would a child suffer from, if there was hyposecretion from his thyroid ?
3. **Choose** the odd one out from each series
   (a) The glands – ***thyroid, adrenal, pituitary, prostate***
   .....
   (b) The conditions – ***cretinism, myxoedema, goitre, scurvy*** .....
   (c) The hormones – ***insulin, glucagon, cretinism, thyroxine*** .....
   (d) The hormonal sources – ***adrenal cortex, adrenal medulla, cortisone, pituitary*** .....
4. **Identify** the odd one in each of the following and mention what the rest are :
   (a) Larynx; glucagon; testosterone; prolactin. .....
   .....
   (b) Adrenaline; penicillin; insulin; thyroxin .....
   .....
   (c) Stomach; ileum; liver; adrenaline .....
   .....
   (d) TSH; GH; ADH; insulin. .....
   (e) Iodine, cretinism, goitre, myxoedema. .....
   .....

5. **Match** the items of column I with those of column II.

Column I	Column II
1. 'β' (beta) cells of islets of Langerhans	(a) Condition due to undersecretion of thyroxine in adults.
2. Thyroid	(b) Glucocorticoids
3. Cretinism	(c) Exophthalmic goitre
4. Addison's disease	(d) Increases heart beat
5. Hypothyroidism	(e) Thyroxine
6. Myxoedema	(f) Adrenal cortex
7. Adrenaline	(g) Insulin
8. Cortisone	(h) Undersecretion of thyroxine in a child.

6. **Match** the conditions in column A with the cause in column B

A (Condition)	B (Cause)
(a) Dwarfism and mental retardation.	(i) Shortage of glucose in blood.
(b) Diabetes mellitus	(ii) Oversecretion of growth hormone.
(c) Excess of glucose in blood.	(iii) Insulin shock.
(d) Gigantism	(iv) Oversecretion of thyroxine.
(e) Enlargement of breasts in adult males	(v) Hypothyroidism
(f) Exophthalmic goitre	(vi) Oversecretion of cortical hormones.

C. SHORT ANSWER TYPE

1. **Mention** which of the statements are ***true*** **(T)** and which are ***false*** **(F)**. Give reason in support of your answer.

(a) Adrenaline is often described as the emergency hormone. (T/F)

(b) There are two kinds of diabetes (mild and severe) related with two different hormones. (T/F)

(c) Simple goitre can be prevented by using iodised salt in food. (T/F)

(d) Pituitary is popularly called the master gland. (T/F)

(e) Hormones "obey" the commands like "enough, slow down or "two little, speed up". (T/F)

(f) Gigantism and dwarfism in humans basically depend on the quality and quantity of the food eaten during early growing age. (T/F)

2. **How** do endocrine glands differ from other glands ?

3. **Mention** any two differences between a hormone and an enzyme.

4. **Do you agree** with the statement – "All hormones are chemical signals"? Yes/No. Justify your answer.

5. **Why** is iodine as a nutrient, important to our body ?

6. If you stand to make your maiden speech before a large audience, your mouth dries up and heart rate increases. **What brings about** these changes?

7. If one adrenal gland is removed, the other one gets enlarged to some extent. **How do you explain** this change ?

8. **Name** the two kinds of diabetes ? **Mention** their symptoms and the causes.

9. People living in the low Himalayan hilly regions often suffer from goitre. **What could be** the possible reason for it ?

10. Given below is a table designed to give the names of the glands, the hormones produced, their chief functions, the effects of oversecretion and undersecretion in respect of thyroid, pituitary and pancreas. Fill up the blanks 1-13.

S.No.	Source Gland Cells	Hormone produced	Chief function	Effect of oversecretion	Effect of undersecretion
1.	(1)	Thyroxine	(2)	(3)	(4) .....
2.	Beta cells of Islets of Langerhans	(5)	Promotes glucose utilisation by the body cells	(6)	(7) .....
3.	(8)	Growth Hormone	(9)	(10)	Dwarfism
4.	(11)	Vasopressin	Increases reabsorption of water from kidney tubules	(12)	(13) .....

11. **Complete** the following table by filling in the blanks numbered 1 to 7

Gland	Hormone secreted	Effect on body
(1)	(2)	Regulates basal metabolism
Pancreas ("beta" cells)	(3)	Controls blood sugar.
(4)	(5)	Increases heart beat
(6)	Thyroid stimulating hormone	(7) .....

12. **Complete** the following table by filling in the blank spaces numbered 1 to 8.

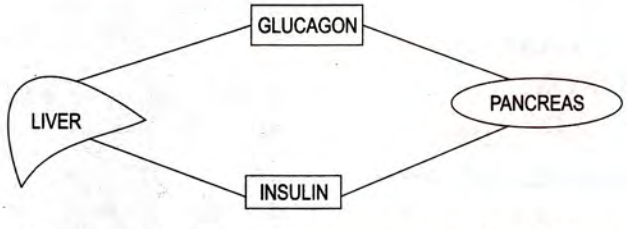
Gland	Secretions	Effect on body
(1)	Oestrogen	(2) .....
Alpha cells of Islets of Langerhans	(3)	(4) .....
(5)	(6)	Protruding eyes
(7)	(8)	Gigantism.

D. LONG ANSWER TYPE

1. **Compare** the hormonal response with the nervous response with respect to their speed, transmission and the general nature of changes brought about.
2. **Mention** three important differences between the action of hormones and that of nerves in the regulatory mechanism of our body.

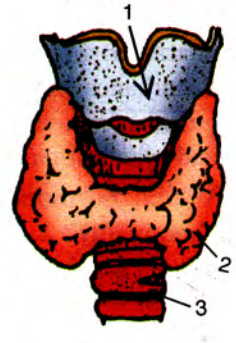
E. STRUCTURED/APPLICATION/SKILL TYPE

1. Study the diagram given below and then answer the questions that follow:



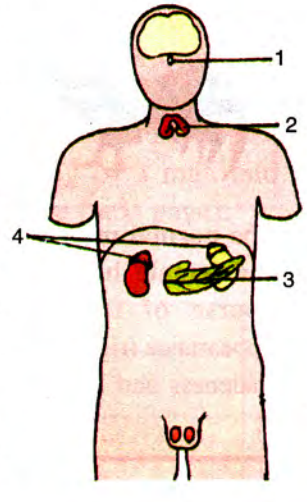
(a) **Name** the cells of the pancreas that produce (1) glucagon (2) insulin.
(b) **State** the main function of (1) glucagon and (2) insulin.
(c) **Why** is the pancreas referred to as an exo-endocrine gland?
(d) **Why** is insulin not given orally but is injected into the body?
(e) **What** is the technical term for the cells of the pancreas that produce endocrine hormones?
(f) **Where** in the body is the pancreas located?

2. Given alongside is a portion from the human body showing some important structure in ventral (front) view.



(a) **Where** is this portion located in the body ?
(b) **Name** the structures numbered 1-3.
(c) **State** one main function of each of the structures named above.
(d) Is there any duct to carry the secretions from the structure numbered 2? If so, give its name.

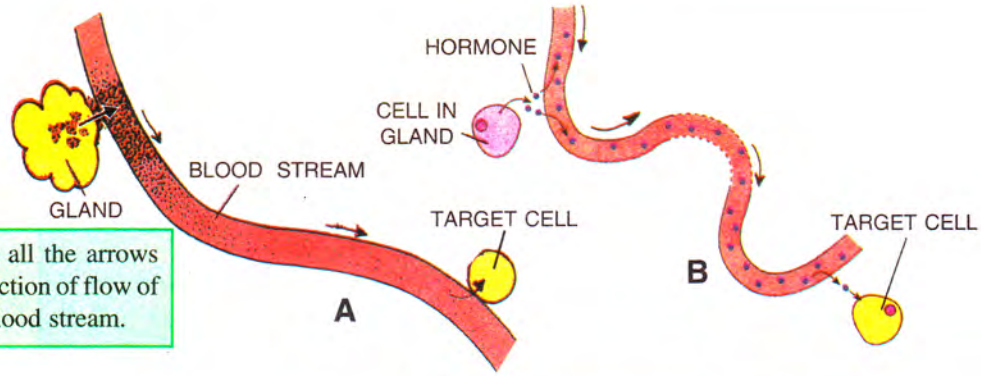
3. Given alongside is an outline diagram of human body showing position of certain organs.



(a) **Name** the parts numbered 1 to 4.
(b) **What** is common to all these parts in regard to the nature of their functions ?
(c) **Name** the nutrient element which is essential for the normal working of part 2.

4. Given below are two diagrams (one is correct, the other is somewhat incorrect) showing the transport of a hormone from its source gland/cell to the target organ/cell.

(a) **Which** one has the error — A or B? ..... (b) **What** is the error? .....



HINT : Look at all the arrows indicating the direction of flow of hormone inside blood stream.

JUST FOR CURIOSITY!

(But not in syllabus)

HE or SHE?

Given alongside is the picture of a **woman** with otherwise feminine characteristics. Hormonal disturbance has led to the growth of moustaches, beard and even hair on chest.

Which hormone you think is involved in this abnormality? .....

(Clue : Read the matter on page 137)

THE SHORTEST AND THE TALLEST

The short and long : He Pingping (2 feet 5 inches) of China and Sultan Kosen (8 feet 1 inch) of Turkey, in Istanbul. (Times of India, Jan. 15, 2010).

Such abnormalities are usually the result of respective undersecretion and oversecretion of growth hormone

THE "MAGIC" OF THE FEMALE SEX HORMONE!

The **normal male cock was injected with the female hormone oestrogen**. In due course of time, the changes in the appearance (right one) markedly reduced its maleness and brought in femaleness.

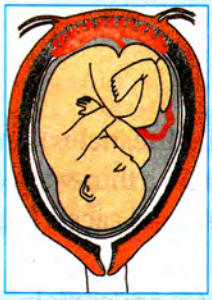
A CASE OF ACROMEGALY (7 FEET 3 INCHES TALL)

This could be due to a tumour in pituitary, causing excessive secretion of growth hormone.

11 The Reproductive System

Syllabus : *The Reproductive System : Organs, fertilisation and a general outline of nutrition and respiration of the embryo. Menstrual cycle : outline of menstrual cycle*

Scope of Syllabus : Functions of organs and accessory glands must be discussed. An idea of secondary sexual characters, structure and functions of the various parts of the sperm and an egg. Fertilization, implantation, placenta, foetal membranes, gestation and parturition, identical and fraternal twins to be explained briefly.



Reproduction is the key point of the **continuance of life** on earth. In a way, all other systems and processes in the body are for supporting the reproduction process. This chapter on the human reproductive system covers a wide range of information useful for even a common man. For our students, one or two long answer type questions and quite a few small ones always find a place in the question paper. For examination purpose, try to understand and memorise, in particular, the structures in the reproductive system, fertilisation and the functions of the placenta.

11 A. THE REPRODUCTIVE ORGANS

11.1 REPRODUCTION IN GENERAL

Reproduction is the formation of new individuals by sexual or asexual means, which can repeat the process in their own turn.

Many simpler organisms like bacteria and yeast reproduce by fission or budding, etc. Many plants reproduce vegetatively non-sexually by various methods. But in humans, reproduction is only sexual.

PATTERNS OF REPRODUCTION

(i) Asexual reproduction

The reproductive units may under asexual type of reproduction consist of any portion of the parent body. The size of the units may range from the whole to a small fragment of the parent body.

Example : A bud grows out of the body of hydra, gets separated and grows into a full hydra.

(ii) Sexual reproduction

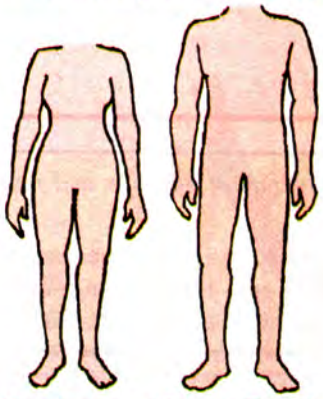
The gametes (sex cells - **egg** and **sperm**) are very small (microscopic in human beings). The gametes must normally unite (fertilisation) to produce a **zygote** which, through a process of development, finally becomes the offspring.

The gametes are usually produced in different sexes (male and female). These sexes often show outwardly differentiating features called **secondary sexual characters**. At least two features are apparent in a cartoonist's partial drawing of a man and a woman standing in a relaxed pose (next page).

Table 11.1 : Differences between asexual and sexual reproduction

Asexual reproduction	Sexual reproduction
1. No mixing of genetic material, therefore, no or less variation in offsprings.	1. Genetic mixing, increased variation.
2. No gametes are formed.	2. Gametes are formed.
3. Normally more offspring.	3. Fewer offspring.
4. Only one parent is involved.	4. Usually, two parents (male and female) are involved.
5. It is a rapid process during favourable conditions.	5. Slower process

Male or Female
(Some secondary sexual characters)



Hips large — Male or Female?
Lower arms projecting out from elbow—Male or female?

Think of sexual distinction in certain animals :
Lion and Lioness ...
Cow and Bull ...
Cock and Hen ...
Peacock and Peahen ...

Secondary sexual characters throughout the animal world serve to identify and attract sex partners. Odours (body smells), calling sounds, skin colouration, body contour, behavioural patterns, etc. are some such sex clues.

In humans, the secondary sexual characteristics include :

- Distribution of hair on body and face (beard and moustaches in males)
- Breasts in females
- Muscularity—stronger built in males
- Skeletal structure
- Psyche and behaviour
- Deeper voice in males

11.2 REPRODUCTION IN HUMANS

The organs of the reproductive system are divided into the primary and accessory parts:

(i) The **primary reproductive parts** include the ***gonads*** (testes in males and ovaries in females) which produce the sex cells (or ***gametes***) — the **sperms** and **eggs.**

(ii) The **accessory reproductive parts** include all those structures which help in the transfer and meeting of the two kinds of sex cells leading to fertilisation and in the growth and development of the egg up to the birth of the baby.

So, according to the above criteria, would you consider secondary sexual characters as given in the box above, as reproductive parts? **No.** These do not participate in reproduction.

11.2.1 Male Reproductive System

The male reproductive system (Fig. 11.1 A-C) consists of the following organs:

(1) **Testes** (one pair) to produce sperms,

(2) **Sperm duct (vas deferens)** from each testis to carry the **sperms**,

(3) **Accessory glands** (seminal vesicles, prostate and bulbo-urethral glands) to contribute to the seminal fluid, and

(4) **A penis** for transferring the sperms into the female.

(5) **Urethra** contained inside the penis, conveys the sperms received from sperm ducts.

1. TESTES (*sing. : testis*)

A. Location of testes

- The two **testes** (popularly called testicles) are oval organs which are contained in a thin-walled sac of skin called **scrotum** (or scrotal sacs) (Fig. 11.1 A, B & C).
- In the embryonic stage, the testes are contained within the abdomen. They descend into the scrotum shortly before birth. An abnormal condition results when they do not descend and it leads to sterility, i.e., incapability to produce sperms.
- The high temperature of the body does not permit maturation of sperms. But in the normal condition, being in a separate sac suspended from the body, the testes **escape too much body heat**.

Temperature regulation in the testes

Sperms are produced in the testes at a temperature 2 to 3°C lower than that of the body. This temperature is regulated in a strange manner through the movements of the scrotum wall.

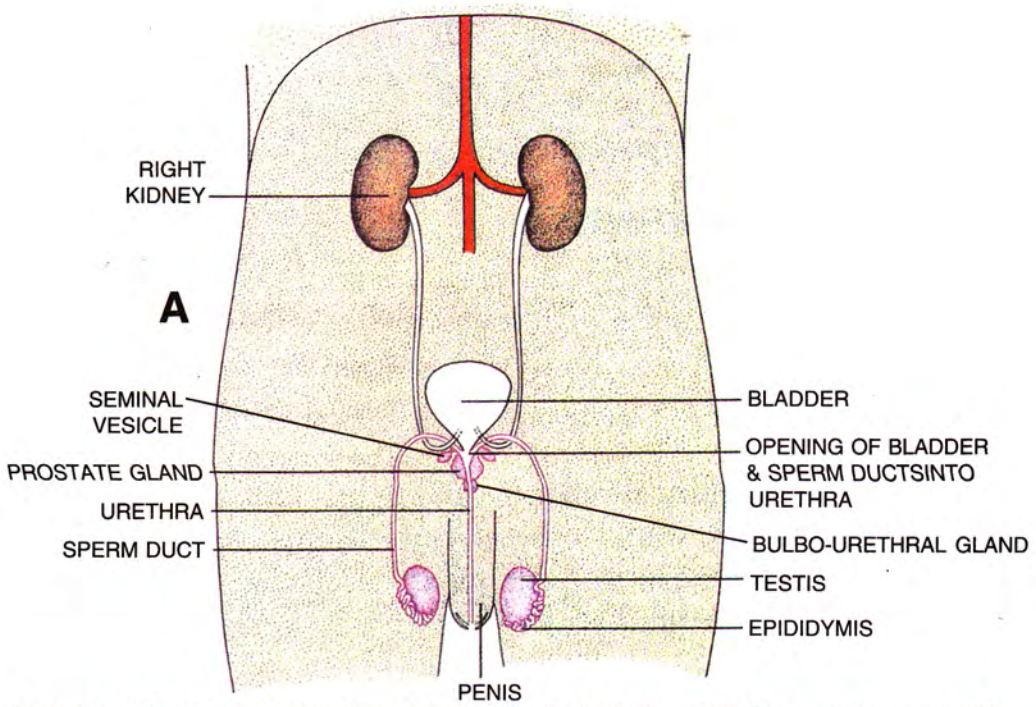
When it is too hot, the skin of the scrotum loosens so that the testes hang down away from the body. When it is cold, the skin contracts in a folded manner and draws the testes closer to the body for warmth.

B. Structure of testis

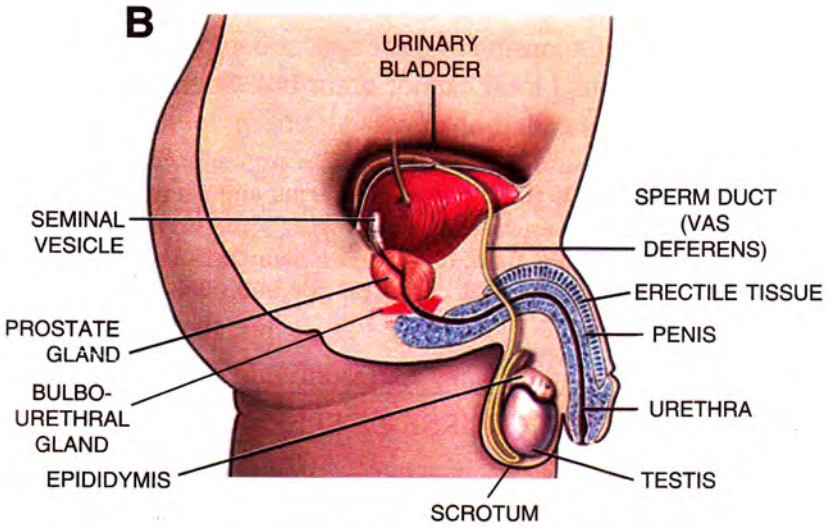
Each testis (Fig. 11.1 C) is encased in a capsule which is internally partitioned into 15-20 lobules (segments). Each lobule contains :

(i) **Seminiferous tubules** (*semini* : sperm, *ferous* : bearing) where the sperms are produced. The process is called **spermatogenesis**.

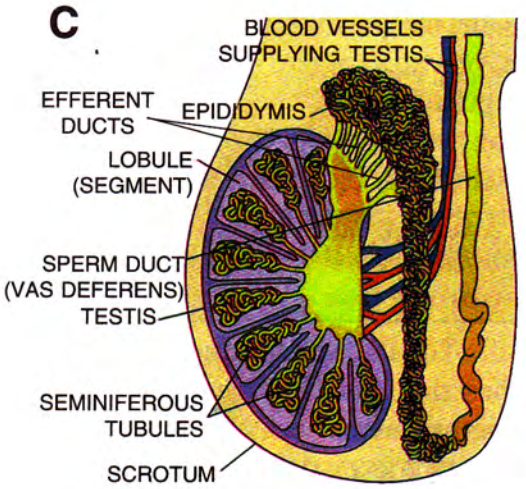
(ii) **Interstitial cells** (*interstitial* : filling in between) which are packing tissues between the coils of the



Arrangement of male reproductive organs in the body (highly simplified and diagrammatic).



Sectional view (diagrammatic) of male reproductive organs, showing passage of sperms from testis to urethral opening



Longitudinal section of testis

Fig. 11.1 : Human male reproductive system.

COMPONENTS OF HUMAN MALE REPRODUCTIVE SYSTEM

Male reproductive system

Testes	Ducts	Accessory glands	Supportive structure
1. Seminiferous tubules produce sperms 2. Interstitial cells produce Testosterone	(i) Epididymis (ii) Sperm duct (Vas deferens) (iii) Ejaculatory duct	(i) Seminal vesicle (ii) Prostate gland (iii) Cowper's gland.	Penis. Transfers sperms into the female organ (vagina)

seminiferous tubules. The **interstitial cells** also called **Leydig cells** produce the male hormone **testosterone**.

The sperm producing cells of the seminiferous tubules keep multiplying and produce sperms. The mature sperms pass into a small network of tubes (Fig. 11.1 C). From the network, arise 12-14 ducts **(efferent ducts)** which join a small tubular knot, the **epididymis** (*epi* : above, *didymos* : testicle) fitting like a cap on the upper pole of the testis. The epididymis is continued by the side of the testis upto its back from where a distinct tube **sperm duct (vas deferens)** arises. The epididymis internally contains a single coiled tube (actually about 6 metres long) which traverses from the upper part of the testis to its back and then it continues into the sperm duct. The epididymis stores the sperms for some days during which they mature and become motile (capable of moving).

2. SPERM DUCTS

The **sperm duct (vas deferens)** from each testis travels upward into the abdomen passing through an **inguinal canal**. The inguinal canal originally is the one which allows the descent of testes along with their ducts, blood vessels, nerves, etc.

*Sometimes, due to pressure in the abdomen, the intestine bulges into the scrotum through the inguinal canal and causes the most common type of **hernia**.*

The two **sperm ducts** loop over the ureters of their side, come together, and join the median duct, or **urethra**, at the back of the urinary bladder.

3. ACCESSORY GLANDS (Fig. 11.1 A & B)

Three male accessory glands are as follows :

(i) Seminal vesicles

- A pair of lobulated glands located between the posterior surface of the urinary bladder and the rectum.
- A duct from each seminal vesicle joins the corresponding sperm duct just before it unites with the urethra.
- Produce a secretion which serves as a **medium for the transportation of the sperms**. The mixture of this fluid and the sperms produces a milky fluid, the **semen**. In the sperm duct, the sperms are sluggish, but by the addition of this secretion, they become active.

(ii) Prostate gland

- A bilobed structure which surrounds the urethra close to its origin from the bladder.
- It pours an **alkaline secretion** into the semen as it passes through the urethra. It neutralises acid in female's vagina.

(iii) Bulbo-urethral glands

- These are two small ovoid glands which open into the urethra just before it enters the penis.
- The secretion serves as a lubricant.

4. PENIS

The **penis** lies in front of the scrotum, cylindrical in shape, serves for the passing out of both semen and urine (Fig. 11.1 C). It is a highly vascular organ, having erectile tissues and vascular spaces. Under the influence of sexual stimulation, blood flows in large amount into the penis and enters into the vascular spaces or sinuses, which makes it rigid and erect. Expansion of these spaces compresses the veins and thus blood cannot drain out. Such condition of penis is called erection.

Semen is the mixture of sperms and secretions from seminal vesicle, prostate, Cowper's and urethral glands. It is a milky fluid. Its average amount is 2–3 ml in a single ejaculation and contains 200,000,000–400,000,000 sperms.

THE COURSE OF SPERMS IN MALE

Seminiferous tubules
(produce sperms)
↓
Network of tubules
↓
Efferent ducts
↓
Upper part (head) of epididymis
↓
Middle part (body) of epididymis
↓
Hind part (tail) of epididymis
↓
Sperm duct (vas deferens)
↓
Urethra (in penis)

PROGRESS CHECK

1. Tick-mark the correct meaning of reproduction
   (a) increase in population
   (b) increase in the number of parents
   (c) production of new individuals
   (d) production of identical individuals
2. What is the significance of the testes being located in scrotal sacs?

   .....
3. State very briefly the chief function of each of the following :
   (i) Seminal vesicles .....
   (ii) Prostate gland .....
   (iii) Cowper's gland .....
   (iv) Sperm duct (vas deferens) .....

11.2.2 Female Reproductive System

The female reproductive system (Fig. 11.2 A, B, C, D and E) consist of the following reproductive organs.

1. A pair of **ovaries**,
2. A pair of **oviducts** (or Fallopian tubes) to convey the egg released from the ovary,
3. A sac-like or pear-shaped **uterus** for the growth and development of the embryo developed from the egg,
4. A **vagina**, and
5. **Vulva**, the outermost part.

1. OVARIES

The two **ovaries** are small ovoid bodies. Their peripheral part produces ova or the eggs. Normally, *only one egg matures in each ovary every alternate month*. A maturing egg contained in a cellular sac is called the **follicle**. As the egg grows larger, the follicle also enlarges and gets filled with a fluid and is now called the **Graafian follicle**. When ripe, the follicle bulges over the surface of the ovary. **Oogenesis** is the process in which the ova-producing cells give rise to the mature ovum.

Ovulation is the rupture of the follicle releasing the egg (page 157 Fig. 11.6). The released egg is picked up by **fimbrae** (cilia) of oviducal funnel of the oviduct. The remnant of the follicle persists for sometime to convert into a yellow mass

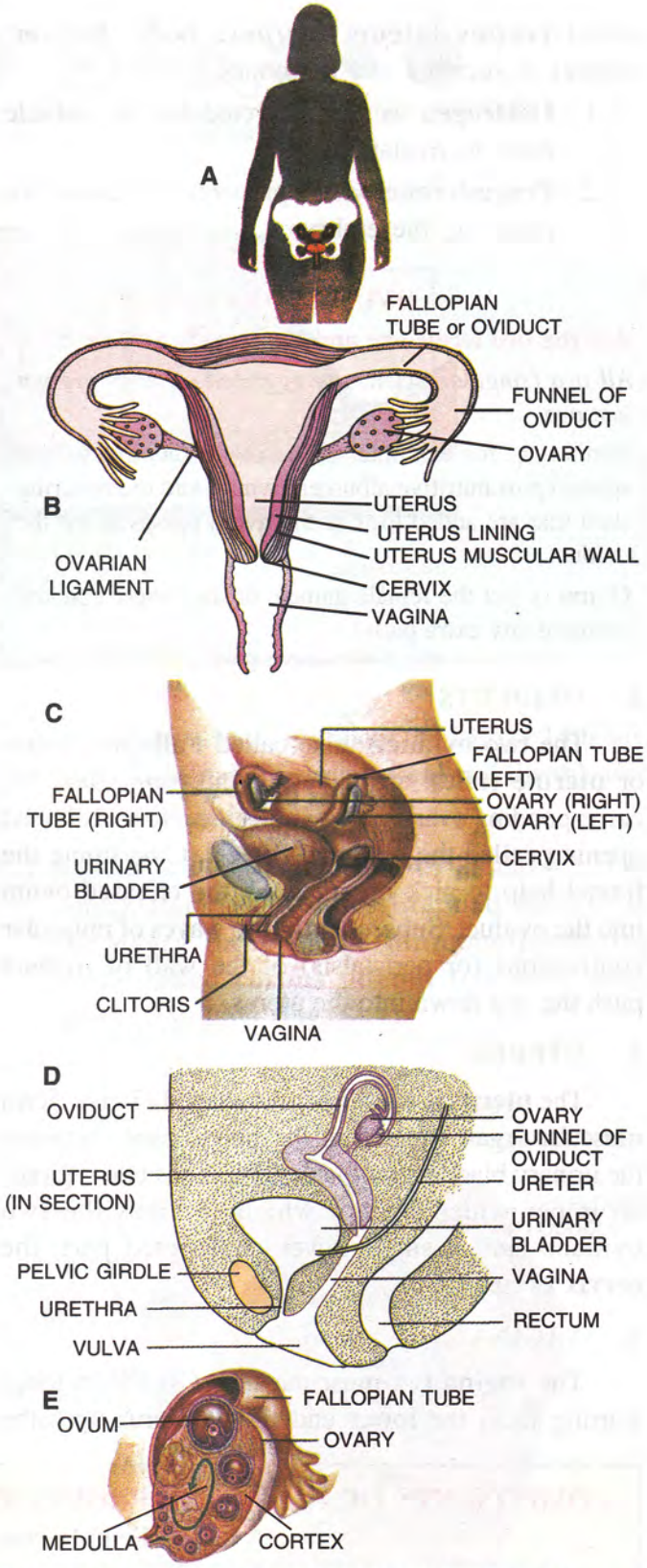


Fig. 11.2 : The human female reproducting organs : A–General position in the body; B–front sectional view (diagrammatic); C– Sectional side view, parts are differently coloured for better distinction. D– Sectional side view (diagrammatic); E–Stages of the growing egg inside the ovary

called **corpus luteum** (***corpus:*** body, ***luteum:*** yellow). It secretes two hormones :

1. **Oestrogen** as was secreted by the follicle prior to ovulation.
2. **Progesterone** which prepares the uterus for receiving the embryo.

OVUM & EGG

Are the two terms one and the same? .... "NO"

All ova (singular ovum) are eggs but all eggs are not just ova.

Hen's *egg*, for example, is the ovum (central yellow sphere) plus nutritive albumen (white) and the covering shell that are added to it as the ovum passes down the oviduct.

Ovum is just the female gamete or the proper egg cell (without any extra parts).

2. OVIDUCTS

The two **oviducts**, also called **Fallopian tubes** or **uterine tubes**, are about 12 cm long. Near the corresponding ovary, each oviduct has a funnel-shaped opening called the **oviducal funnel**. Cilia lining the funnel help to pick up and push the released ovum into the oviduct. Subsequently, the waves of muscular contractions (or peristalsis) of the wall of oviduct push the egg down into the uterus.

3. UTERUS

The **uterus** is a hollow pear-shaped (7cm × 5cm) muscular organ situated in the pelvic cavity between the urinary bladder and the rectum. It has two regions, an upper wider portion which receives the two oviducts and a small lower constricted part, the **cervix** or neck.

4. VAGINA

The **vagina** is a muscular tube (10-15 cm long) starting from the lower end of the uterus upto the outside. The vagina receives the male penis during copulation. The great elasticity of its wall also allows the passage of the baby during childbirth. The opening of the vagina in young females is partially closed by a thin membrane called **hymen** (or the virgin knot). The hymen is frequently ruptured in childhood due to strenuous physical exercise or disease.

5. VULVA

The external female genitalia is called the **vulva**. It contains independent openings of the urethra and vagina. The sides of the vulva have two small fleshy folds, the **labia minora** (lesser lips) which are hidden by larger hairy folds, the **labia majora** (greater lips). These folds are the equivalents of the male scrotum. In the uppermost angle of the vulva in front of the urethral opening is located, a small erectile **clitoris** which is highly sensitive and is the equivalent of male penis.

Puberty

Puberty is the period during which immature reproductive system of boys and girls mature and becomes capable of reproducing. At age 10 in girls, first sign is the enlargement of breasts. In boys at 11 years, the enlargement of testis is the first sign.

11.3 MENSTRUAL CYCLE

The reproductive period of the human female continues from about the age of 13 years to 45-50 years. This period is marked by a characteristic event repeated almost every month (28 days with minor variation) in the form of a menstrual flow. It may be temporarily stopped only by pregnancy.

MENARCHE and MENOPAUSE

Menarche ***is the onset of menstruation in a young female at about the age of 13 years*** **(arche : beginning).**
Menopause ***is the permanent stoppage of menstruation at about the age of 45 years*** **(pause : stop).**

COMPONENTS OF FEMALE REPRODUCTIVE SYSTEM

Female reproductive system

Ovaries	Oviducts	Uterus	Vagina	External organs
Follicle cells produce ova, oestrogen and progesterone	Transport ova into uterus	Protects and nourishes growing embryo	Receives the sperms	Vulva, . protects urethra and vagina.

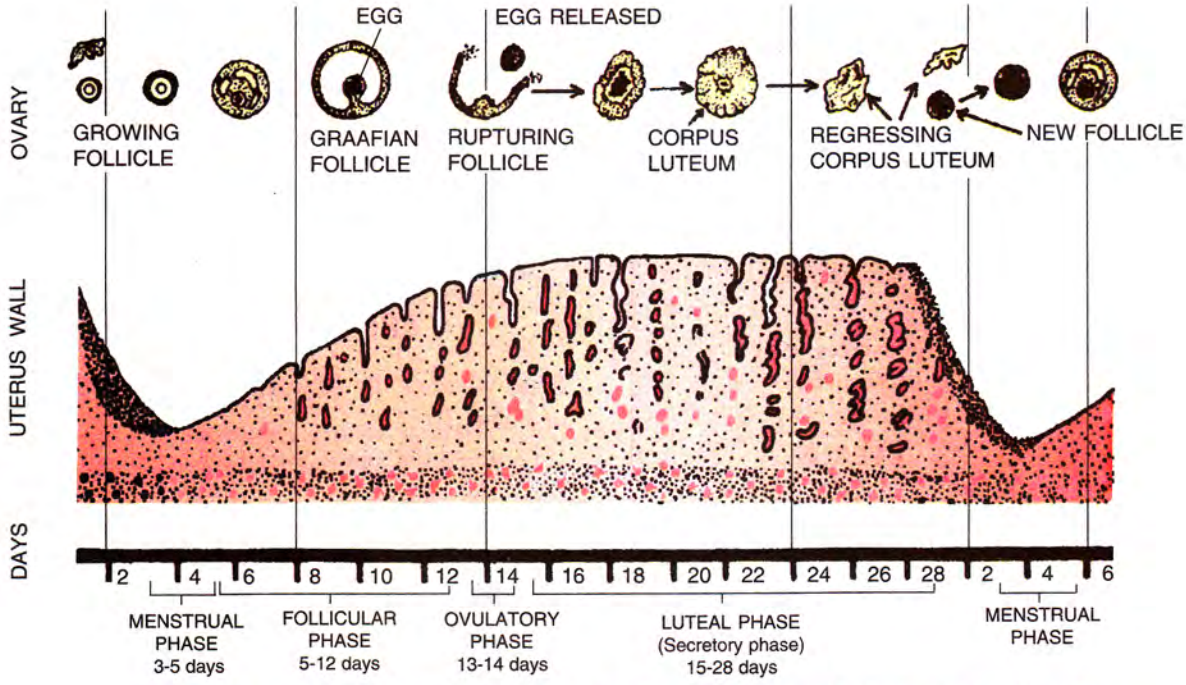


Fig. 11.3 : Uterine changes in relation to follicular changes during menstrual cycle

The period of a menstrual cycle is counted from the day of the onset of the flow to the next onset after 28 days (Fig. 11.3). This period can be divided into four main phases.

(1) Menstrual phase

(3) Follicular phase

(2) Ovulatory phase

(4) Luteal phase

(1) **Menstrual phase.** It lasts for 3-5 days during which blood is discharged. The bleeding is caused due to the shedding of the uterine lining rupturing the blood vessels.

Starting from the onset of the menstruation flow, the ovary begins to form a new egg in a follicle.

(2) **Follicular phase.** As the follicle grows, it produces certain hormones which reactivate the uterine wall to become thickened and to be supplied with a lot of blood. This change is a kind of preparation of the uterus to receive the fertilised egg and to provide for the development of the future embryo.

(3) **Ovulatory phase.** On about the 13th or 14th day, the follicle ruptures (**ovulation**) and the released egg travels down the oviduct.

(4) **Luteal phase.** It lasts from 15-28 days. Uterus lining thickens further. Emptied follicle in the ovary turns into a hormone-producing tissue called **corpus luteum** (*corpus* : body, *luteum* : yellow) (Fig. 11.4).

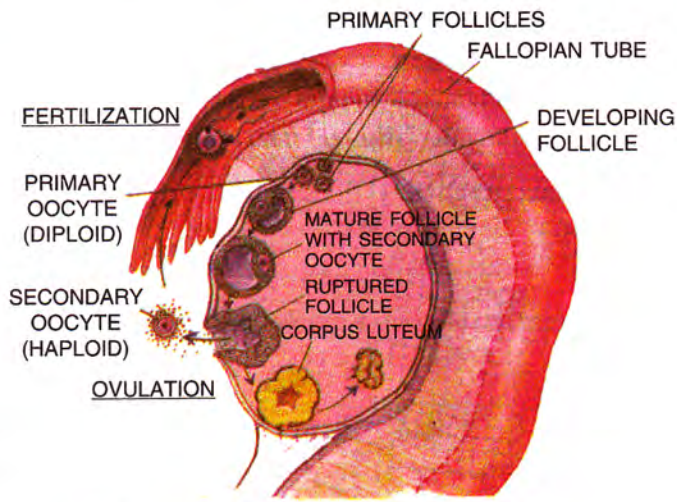


Fig. 11.4 : Maturation of egg, ovulation, and fertilization (diagrammatic)

THE COURSE AND FATE OF EGG INSIDE FEMALE BODY

OVARY
(Releases egg)
↓
FALLOPIAN TUBE

(If fertilised)	**(If unfertilised)**
↓	↓
Divides and becomes early embryo	**Degenerates (may get absorbed)**
↓	↓
UTERUS	**UTERUS**
↓	↓
Implantation (Pregnancy) Forms baby	**Degenerates & Passes out in menstrual discharge**

If there is no fertilisation, the egg disintegrates and the uterine lining restarts shedding on the 28th day. If on the other hand, the egg is fertilised, it gets **implanted** or fixed in the uterus wall and there is no menstrual discharge. This is because the level of the hormone **progesterone, secreted by the persistent corpus luteum**, is increased and it **prevents maturation of another follicle**.

If there is no implantation, the corpus luteum degenerates and the uterine wall cannot be maintained in its thickened state.

? *PROGRESS CHECK*

State whether the following statements are **True** (T) or **False** (F) :-

(i) Oviducts and fallopian tubes are one and the same thing. T/F

(ii) One egg is released from each of the two ovaries every month. T/F

(iii) The enlarged mature follicle bursts to release the egg. T/F

(iv) The egg is passed down through the oviduct by muscular contractions. T/F

(v) Clitoris is equivalent to the male penis. T/F

(vi) The vagina is a muscular tube. T/F

REVIEW QUESTIONS

A. MULTIPLE CHOICE TYPE

(Select the most appropriate option in each case)

1. Which one of the following is the correct route that a sperm follows when it leaves the testis of a mammal?
   (a) Vas deferens → epididymis → urethra
   (b) Urethra → epididymis → vas deferens
   (c) Epididymis → urethra → vas deferens
   (d) Epididymis → vas deferens → urethra

2. When pregnancy does not occur, the life of corpus luteum is about -
   (a) 4 days (b) 10 days (c) 14 days (d) 28 days

3. In female, after how much time after fertilisation, does the fertilised egg get implanted in the uterine wall?
   (a) few months (b) one month
   (c) three weeks (d) about seven days

B. VERY SHORT ANSWER TYPE

1. **Name** the following :
   (a) The body part in which the testes are present in a human male.
   (b) The part where the sperms are produced in the testes.
   (c) The fully developed part of the ovary containing a mature egg.
   (d) The accessory gland in human males whose secretion activates the sperms.
   (e) The tubular knot fitting like a cap on the upper side of the testis.

2. **Choose** the odd one in each of the following:
   (a) Oestrogen; progestrone; testosterone; prolactin.
   (b) Ovary; fallopian tube; ureter; uterus.
   (c) Seminiferous tubule; ovum; epididymis; sperm duct; urethra.
   (d) Sperm; implantation; fertilisation; ovum; after birth.

3. **Rewrite** the terms in the correct order so as to be in a logical sequence.
   (a) Sperm duct, penis, testes, sperms, semen.
   (b) Puberty, menopause, menstruals, menarche, reproductive age.
   (c) Graafian follicle, ostium, uterus, fallopian tube.

4. **Write** in sequence, the regions through which a mature sperm travels from the seminiferous tubules up to the urethral opening in the human male.

C. SHORT ANSWER TYPE

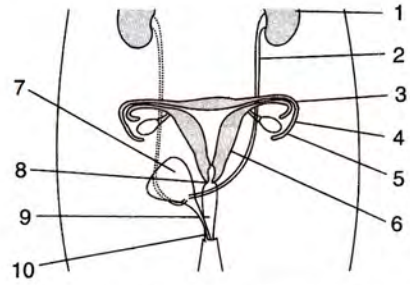
1. **What** is semen?
2. **Describe** the functions of the following :
   (a) Inguinal canal, (b) Prostate gland,
   (c) Testis, (d) Ovary
   (e) Oviduct.
3. **What** are the secondary sexual characteristics in the human male and female respectively ?
4. **What** are the accessory reproductive organs?
5. **Differentiate** between primary and accessory reproductive organs.
6. **What** is hymen?
7. **Define** the following terms :
   (a) Hernia (b) Ovulation (c) Puberty
8. **List** any two changes each in human male and female, which occur during puberty.
9. **Differentiate between the following pairs :**
   (a) Menarche and menopause
   (b) Bulbo-urethral gland and prostate gland.
   (c) Hymen and clitoris
   (d) Uterus and vagina
   (e) Efferent duct and sperm duct.

D. LONG ANSWER TYPE

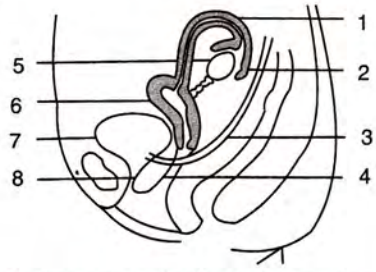
1. **What** is the significance of the testes being located in scrotal sacs outside the abdomen. **Can there be** any abnormal situation regarding their location? If so, what is that and what is the harm caused due to it?
2. Is it correct to say that the testes produce testosterone. **Discuss** ?
3. Suppose a normal woman has never borne a child. **How many** mature eggs would she have produced in her lifetime? Your calculation should be based on two clues —
   (a) Eggs are produced at the rate of 1 egg every 28 days (one menstrual cycle).
   (b) A woman's total reproductive period is 13-45 years.

E. STRUCTURED/APPLICATION/SKILL TYPE

1. Given below is a diagram of two systems together in the human body.
   (a) **Name** the systems.
   (b) **Name** the parts numbered 1-10.
   (c) **Describe** the functions of the parts 3, 4, 5 & 6.

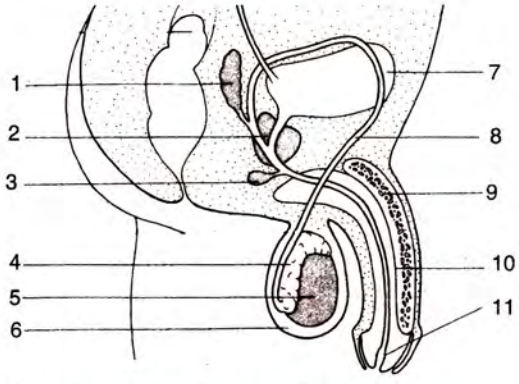


2. The following diagram represents the vertical sectional view of the human female reproductive system.



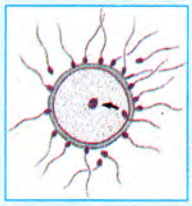
   (a) **Label** the parts indicated by the guidelines 1 to 8.
   (b) **How** does the uterus prepare for the reception of zygote?
   (c) **What happens** to the uterus, if fertilisation fails to take place?

3. Given below is the schematic diagram of the sectional view of the human male reproductive system.



   (a) Name the parts numbered 1-11.
   (b) State the functions of the parts numbered 1, 2, 3, 5, 8 and 11.

11 B. FROM FERTILISATION TO BIRTH



You have learnt about the different parts and their arrangement in the male and female reproductive systems in the Section A of this chapter. Here, you will study how a new individual is conceived and how it grows in the mother's womb and finally born as a baby.

11.4 FERTILISATION (Union of egg nucleus and sperm nucleus)

During copulation (*mating* or *coitus*), the **sperms** are released in the vagina near the cervix of the uterus. A single ejaculation by the human male contains about four hundred million sperms. These sperms actively swim with the help of their tails (Fig. 11.4A) and pass through the cervix into the cavity of the uterus progressing at a rate of approximately 1.5 mm per minute. From the uterus, they climb up, to reach the oviducts. If there happens to be an ovum (egg) in the oviduct, it gets fertilised by just one single sperm (Fig. 11.5).

Fertilisation : ***The fusion of the male gamete* (sperm) *and female gamete* (ovum) *to form zygote is called fertilisation.***

A few days, soon after ovulation (12th or 13th day after the onset of menstruation) are most favourable for conception (becoming pregnant).

Out of the millions of sperms released into the vagina, very few are able to climb up to the upper parts of the oviducts, the rest die on the way and are absorbed.

Functions of the main parts of a sperm (Fig. 11.4 A).

The **acrosome** at the top of the head of the sperm secretes an enzyme (hyaluronidase) which facilitates entry of the sperm into the egg by dissolving the wall of the ovum.

The **nucleus** contains genetic material (22 + X or 22 + Y chromosomes) which, during fertilisation, combines with the nucleus of the egg containing 22 + X chromosomes, and thus restoring the normal number of 23 pairs.

NEITHER THE "SUN" NOR THE "FULL MOON"

It is a microscopic view of human egg (or egg cell) surrounded by sperms

Microscopic view of sperms. Each sperm has a head, a middle piece and a tail

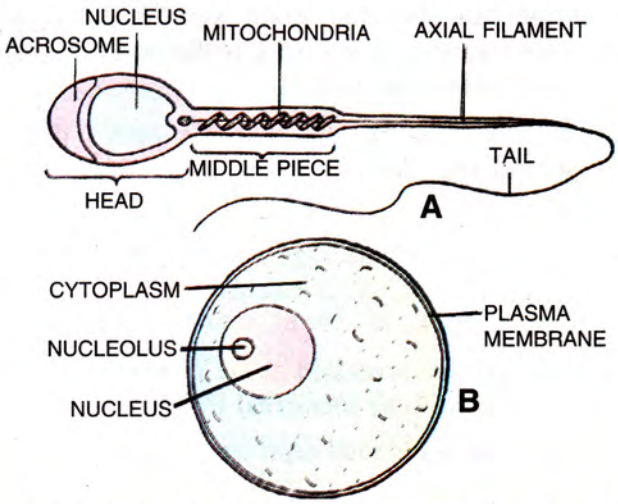


Fig. 11.4 : A–A single sperm (diagrammatic and highly magnified). B–Ovum (magnified and diagrammatic)

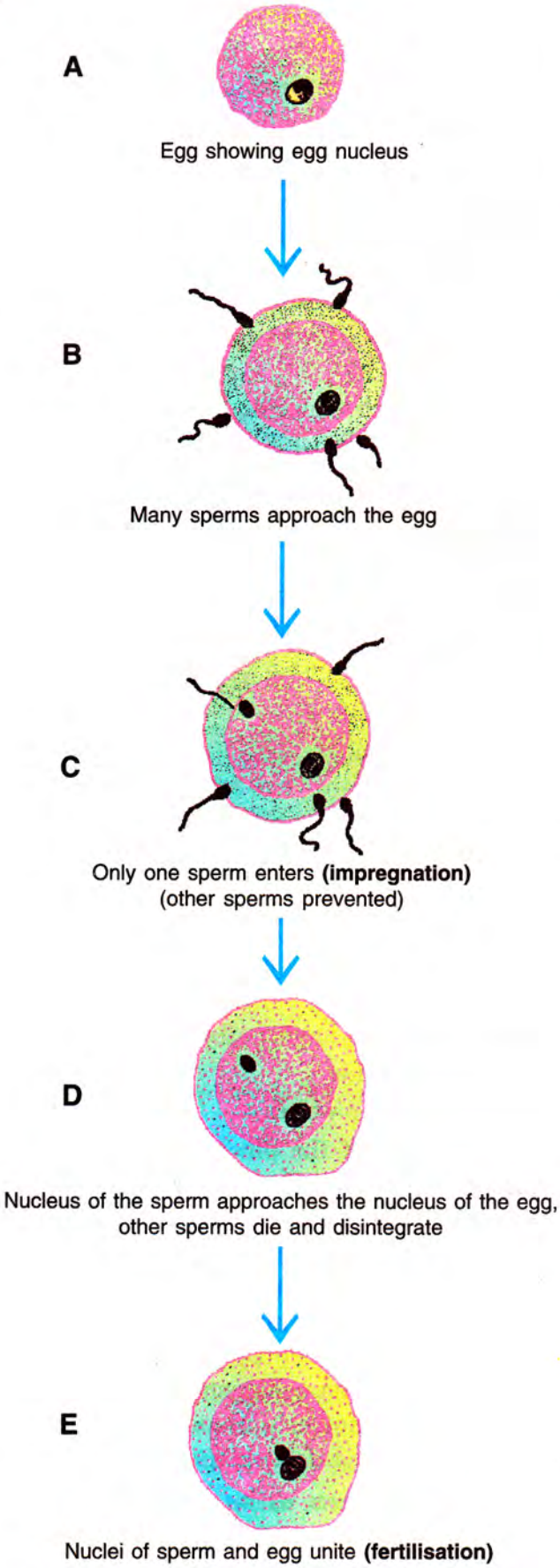


Fig. 11.5 : Stages in the fertilisation of an egg

The **mitochondria** contained in the middle piece, provide energy (ATP) for the activity of the sperm to swim.

The **tail** makes lashing movements for propulsion.

Sperms may remain alive in female genital passage for a few days, but their fertilising power is limited to one or two days only.

During fertilisation, several sperms may surround an egg, but only one sperm enters it. In doing so, the tail is left behind and only the head part (which contains nucleus) penetrates the egg. This sperm nucleus fuses with the nucleus of the egg.

As soon as one sperm enters the egg (ovum), the entry of other sperms is prevented by some chemical barrier.

11.5 IMPLANTATION (CONCEPTION) AND PREGNANCY

The fertilised egg **(zygote)** soon starts dividing **(cleavage)** into 2, 4, 8, 16 cells and so on. By the time it reaches the uterus, it has already formed a small hollow ball of numerous cells **(blastocyst)**. This is a kind of embryo which forms a pit in the wall (endometrium) of the uterus and gets fixed in it in about a week's (5-7 days) time after ovulation. This process is called **implantation** and it produces the state of **pregnancy**. The uterus continues to develop to take care of the developing embryo.

By the end of five weeks of pregnancy, the embryo is quite advanced. The heart and circulatory system have been formed. After two months, limbs have also been formed.

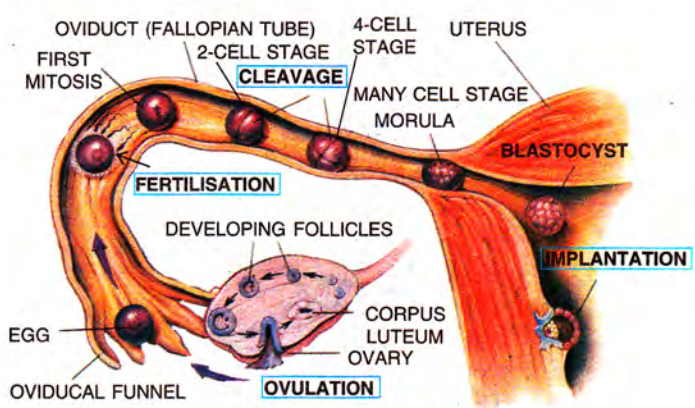


Fig. 11.6 : Maturation of egg, ovulation, fertilisation and implantation (diagrammatic)

Embryo – a growing egg after fertilisation until the main parts of the body and the internal organs have started to take shape.

Foetus – When embryo starts having a look of a baby (from 7 weeks of gestation onwards).

Pregnancy – The state of carrying the unborn young one inside the body.

Gestation – The full term of the development of an embryo in the uterus. In humans, it lasts for about 280 days.

11.6 PLACENTA

The growing **embryo** or the **foetus** (8 weeks old with human-like appearance) is a living organism. It **needs food and oxygen**. It **excretes nitrogenous wastes and carbon dioxide** which need to be continuously removed. These special functions are performed by a structure called **placenta**. Placenta is a disc-like structure attached to the uterine wall (Fig. 11.8). A cord containing blood vessels connects the placenta with the foetus; this is called **umbilical cord**.

The placenta is formed of two sets of minute finger-like processes, the **villi**. One set of villi are given out by the uterine wall and the other set by an extension (allantois) from the embryo. The two sets of villi get interlocked but they never open into each other (Fig. 11.7). Here, the blood of the embryo comes in close contact, but never mingles with the blood of the mother. The foetal (embryo's) blood brought to it by an artery contains carbon dioxide and urea, etc., excreted by the foetus. This blood flows through very fine capillaries of the placenta. Close to these are the capillaries and blood sinuses of the mother.

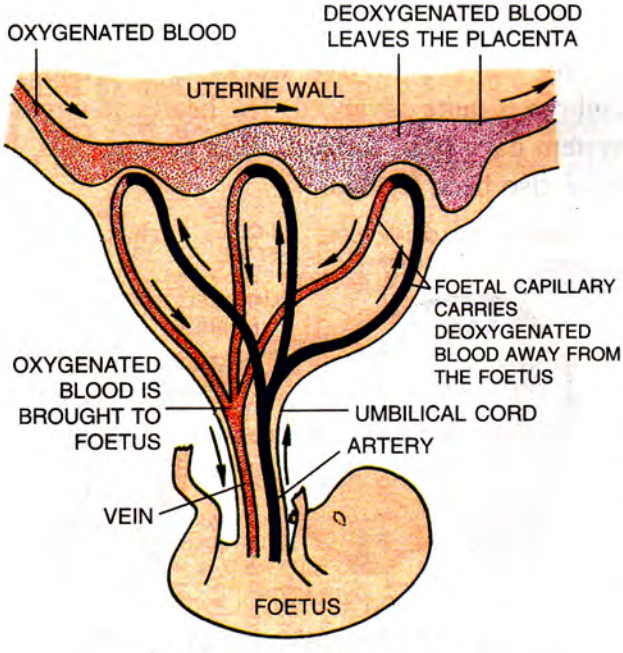


Fig. 11.7 : The Placenta

Functions of Placenta

The placenta allows diffusion of substance from the mother to the foetus and from foetus to the mother as follows.

A. From mother to foetus (for utilisation)

- **Oxygen**
- **Nutrients** such as glucose, amino acids, vitamins, mineral ions (Na, Cl, K, Ca, Fe etc.)

TABLE 11.3 : Materials that can pass through placenta

Mother to foetus ↓ (for utilisation)	Foetus to mother ↑ (for elimination)
1. Oxygen	1. Carbon dioxide
2. Glucose	2. Urea
3. Amino acids	3. Other waste products
4. Lipids, fatty acids & glycerol	
5. Vitamins	
6. Mineral ions such as Na, K, Ca, Cl, etc.	
7. Certain drugs	
8. Alcohol, nicotine	
9. Antibodies	
10. Viruses	

B. From foetus to mother (for elimination)

- **Carbon dioxide**
- **Urea** (& other wastes)

Permeability of the placenta. The placenta is permeable to respiratory gases, nutrients and also antibodies but it *does not allow* the passage of germs from the mother to the foetus. Certain viruses like the HIV of AIDS can pass through the placenta if the mother is already infected. Secondly, if there was a direct continuity of blood between the mother and the foetus without a placenta, the relatively high pressure of the mother's blood would seriously damage the soft and delicate tissues of the foetus.

Placenta also acts as an endocrine gland. It produces the hormones called oestrogens and progesterone. Presence of progesterone in urine provides for certain tests of pregnancy.

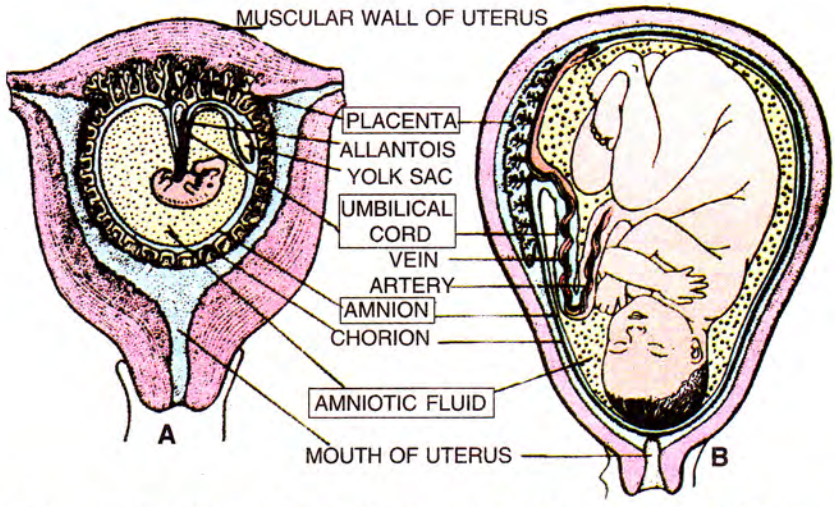


Fig. 11.8 : Growth of embryo (foetus) inside the uterus. A–About 8 week old, B–Almost fully formed

STAGES IN THE DEVELOPMENT OF HUMAN EMBRYO

	Egg (Ovum)	– Unfertilised stage, released from ovary
IN OVIDUCT	Zygote	– Fertilised egg, 1-cell state.
	Morula	– A **spherical mass** of cells, resulting from repeated division of zygote.
	Blastocyst	– Hollow sphere of cells with a surrounding single cellular layer (trophoblast) and an inner cell mass projecting from it centrally. Fixes into the uterine wall.
INSIDE UTERUS	Embryo (3 weeks)	– A tiny organism about the size of a large pea, **hardly resembles human being.**
	Advanced embryo (5 weeks)	– **Heart and blood vessels** have formed (but **no limbs**).
	Foetus (8 weeks)	– **Limbs have appeared.** Some resemblance with ultimate human being.
	Infant	– **Born** at the end of nearly 40 weeks.

AMNION

Amnion is a sac which develops around the embryo even before the formation of allantois (Fig. 11.8). A fluid (**amniotic fluid**) fills the space between the amnion and the embryo. Functions of amniotic fluid :

1. Protects the embryo from physical damage by jerks or mechanical shocks. For example, when the mother falls over.
2. Keeps even pressure all around the embryo.
3. Allows the foetus some restricted movement.
4. Prevents sticking of the foetus to the amnion.

11.7 PARTURITION (BIRTH)

The full term of the development of an embryo in the uterus is called **gestation**. In humans, it lasts for about 280 days. At the time of birth, the baby is pushed out by the powerful contractions of the muscles of the uterus, head first (Fig. 11.9). In a few minutes, the blood vessels in the umbilical cord shrink and can be tied and cut. After about 15 minutes, the placenta breaks from the uterus and is expelled out as "after-birth." Uterus contracts and gradually comes back to normal in a few days.

The new-born "announces" its arrival by letting out sharp cry. This cry is the nature's clearing process of the baby's respiratory passage.

The **gestation period** and the **number of young ones** normally produced at a time in some mammals are as follows :

	Gestation Period	Young ones produced
Rabbit	32 days	(6-8)
Cat and dog	65 days	(4-6)
Swine	114 days	(4-8)
Human and human-like apes	280 days	(1)
Cow	290 days	(1)
Horse	340 days	(1)
Elephant	600 days	(1)

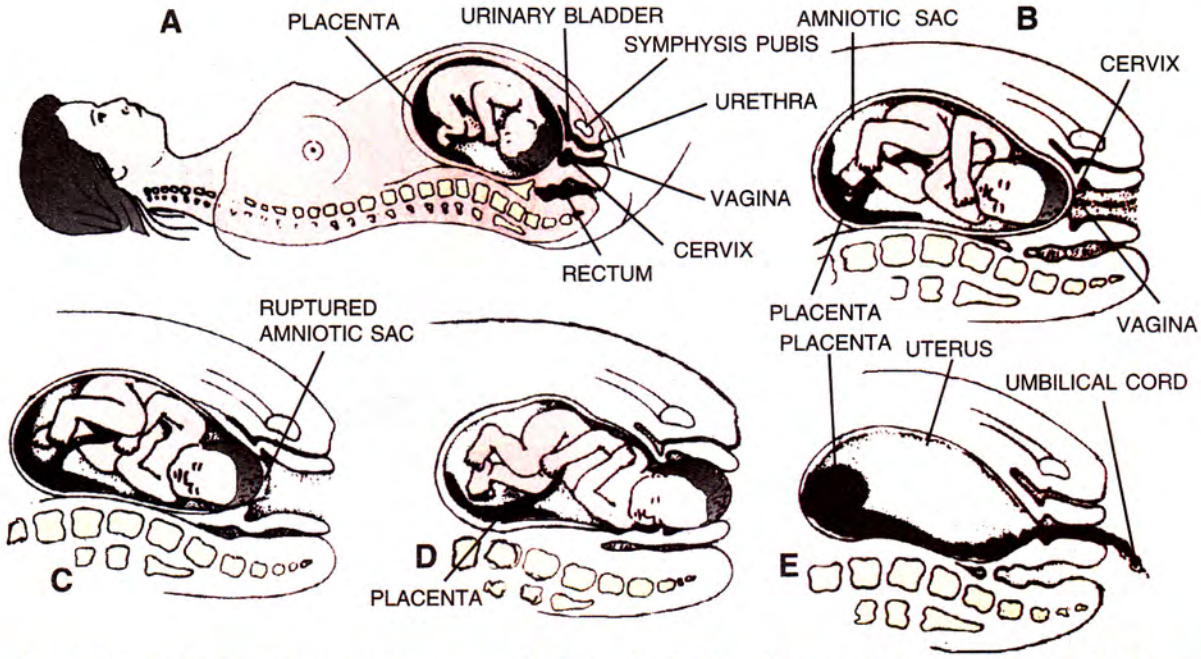


Fig. 11.9 : Stages in Birth (A-D) – Uterus contracts, cervix dilates, baby's head passes through cervix, amniotic sac ruptures at this time and released fluid passes out through vagina. A baby is born and the afterbirth (placenta) is discharged (E)

? *PROGRESS CHECK*

1. Name the three main regions of the human sperm, and briefly mention the function of each.

   (i) Part ..... Function .....

   (ii) Part ..... Function .....

   (iii) Part ..... Function .....

2. Fill in the blanks :

   (i) Implantation is the process of fixing of the ..... in a pit in the wall of .....

   (ii) Heart and circulatory system are formed in the embryo by the end of ..... months of pregnancy.

   (iii) A cord containing ..... vessels connects the ..... with the foetus.

3. List the substances which the foetus receives from the mother through placenta.

   .....

4. How are carbon dioxide and urea, excreted by the foetus, removed?

   .....

5. Does the foetus inside the mother's uterus breathe ? Yes/No

6. Write one sentence each using the following terms pertaining to reproduction in humans.

   (i) Gestation .....

   (ii) 280 days .....

   (iii) Head first .....

   (iv) Placenta .....

   (v) After-birth .....

   (vi) Tied and cut .....

7. Mention if the following statements are **True (T)** or **False (F)** :

   (i) Placenta produces certain hormones. ..... T/F

   (ii) Amniotic fluid serves to provide oxygen to the foetus ..... T/F

   (iii) Heart and blood vessels have been formed by the end of five weeks of pregnancy. ..... T/F

   (iv) Mother's blood flows into the foetus through placenta ..... T/F

USEFUL INFORMATION

TWINS – FRATERNAL & IDENTICAL

1. **FRATERNAL TWINS (Produced from two eggs)**
   Sometimes, two eggs are released from ovaries at a time and both may get fertilised to produce two individuals. Such twins produced from two eggs are called *fraternal twins*. Fraternal twins may be either **both boys**, or **both girls**, or **one boy and one girl**. Fraternal twins in all respects are like the normal sisters and brothers, but here they are of the same age having been born within a few minutes of each other. About 75 per cent of all cases of twins belong to this type. Fraternal twins are biologically known as : **Diovular** (meaning produced from two ova), or **Dizygotic** (meaning produced from two zygotes, that is, two fertilised eggs).
2. **IDENTICAL TWINS (Produced from one egg)**
   Sometimes, a single fertilised egg may get split and separated into two parts during its early stages of cell division. Each of these two split parts then behaves like an independent egg and produces one complete individual each. Identical twins being produced from a single egg are either **both boys** or **both girls**; and for the same reason, they are very similar (identical) to each other. Yet, all is not similar in identical twins, for example **fingerprints**, **birth marks** and even **handwritings** are not similar.

MORE THAN TWO – THE TRIPLETS, QUADRUPLETS, ETC.

Sometimes, three, four or even more babies are born from a single pregnancy. Such births may arise due to a variety of conditions, for example :-

Triplets (three born at a time) may be produced **either** from one single zygote, splitting into two, and one of the split parts again splitting into two, or the triplets may be produced from two eggs in which one zygote produces a pair of identical twins and the other develops normally into one baby.

Quadruplets (four born at a time) may be produced as two pairs of identical twins from two eggs or in other combinations of identical and fraternal twins.

The chances of survival of all the children in multiple birth decrease with the increase in their number. Rare cases of six or seven babies produced are known but only a fewer number survives.

FIRST TEST-TUBE BABY OF THE WORLD

Born on July 25, 1978. Her mother's fallopian tubes were blocked. The same one when grown up as a complete woman is this, here driving the car. →

And now, she herself is the mother of a normal baby son. ↓

TEST-TUBE BABIES

Sometimes, the mothers are incapable of conceiving for some reason. In them, the mature ovum is taken from their ovary and it is made to fertilise in a petri dish (*in vitro* fertilisation, "vitro" means "glass", referring to fertilisation in glass containers) and allowed to develop upto a certain stage. Thereafter, it is placed back in the uterus for further natural growth and the children thus born are called "***test-tube***" babies. (The word "test-tube" is symbolic with laboratory). Thousands of such babies have already been produced in India.

TWO UNLUCKY CONJOINED TWINS

Just a few years ago, two Iranian twin sisters 29 years old Ledan and Laleh were fed up of the difficult life they were leading with their joined skulls. They decided to undergo surgery — if successful, they would lead a happy life, if not, they would be freed forever. Sad, the luck did not favour.

SURROGATE MOTHER is any such woman who offers to carry any one else's fertilised egg/embryo in her own womb till completion of pregnancy and delivers the baby.

SIAMESE TWINS — A developmental abnormality

These are conjoined twins produced from a single egg, who have failed to separate completely. The place and the extent of the joint between the two varies considerably (two such examples are shown here). In some rare cases the two conjoined twins have been successfully separated surgically. One such case, was reported in August 1996, in which two seven-month old twin girls, joined at the abdominal region, were successfully separated at Christian Medical College, Ludhiana; some more surgery will be required at puberty after which they would be expected to become complete women (anatomically).

Sita and Gita successfully separated at Delhi's Batra Hospital in April, 2010.

Why is the name Siamese Twins?

The first case becoming world famous was that of two twin boys born to a Chinese mother in Siam (now Thailand) in 1811 who were joined at the thoracic region and lived upto the age of 63 years. They were married to twin sisters (non-conjoined).

- The world's first live octuplets were born in 1967 but all babies died within 14 hours
- The world's first surviving octuplets were born on December 20, 1998 but the tiniest infant died of heart and lung failure a week after being born. The 5 daughters and 2 sons celebrated their 10th birthday on December 20, 2008. →→→→→→→
- Second surviving octuplets were born in Dec. 2008, to a mother in U.S.A.

— Times of India, 28 Jan, 2009.

REVIEW QUESTIONS

A. MULTIPLE CHOICE TYPE

(Select the most appropriate option in each)

1. In humans, the fertilisation takes place in :
   (a) uterus (b) oviducal funnel
   (c) fallopian tube (d) vagina
2. The middle piece of sperm provides :
   (a) energy (b) food
   (c) gene (d) chromosomes
3. The normal gestation period in humans is :
   (a) 270 days (b) 290 days
   (c) 280 days (d) 295 days

B. VERY SHORT ANSWER TYPE

1. **Name** the following :
   (a) The fluid surrounding the developing embryo.
   (b) The body part in which the embryo develops.
   (c) The membrane which protects the foetus and encloses a fluid.
   (d) The canal through which the testes descend into the scrotum just before birth in human male child.
2. **Choose** the odd one in each of the following:
   (a) Sperm; implantation; fertilisation; ovum; afterbirth.
   (b) Relaxin; cervix dilates; amniotic sac ruptures; child birth; follicle.
3. **Rewrite** the terms in the correct order so as to be in a logical sequence.
   (a) Implantation, ovulation, child birth, gestation, fertilisation.
   (b) Coitus, ovum, sperm, sperm duct, urethra, vagina.
4. **Give appropriate terms** for each of the following :
   (a) The onset of reproductive phase in a female.
   (b) Rupture of follicle and release of ovum from the ovary.

(c) Monthly discharge of blood and disintegrated tissues in human female.

(d) Process of fusion of ovum and sperm.

(e) Fixing of developing zygote (blastocyst) on the uterine wall.

5. **Match** the items in column I with those in column II and write down the matching pairs (some may not match)

Column I	Column II
(a) Acrosome	(i) An embryo which looks like human baby
(b) Gestation	(ii) Luteinizing hormone
(c) Menopause	(iii) Ovum producing cells
(d) Foetus	(iv) Semen
(e) Oogenesis	(v) Spermatozoa
(f) Ovulation	(vi) Complete stoppage of menstrual cycle
	(vii) Time taken by a fertilised egg till the delivery of baby.

C. SHORT ANSWER TYPE

1. (a) **State** whether the following statements are **TRUE (T)** or **FALSE (F)** :

(i) Fertilisation occurs in vagina. (T/F)

(ii) Uterus is also known as birth canal. (T/F)

(iii) Nutrition and oxygen diffuse from the mother's blood into the foetus's blood through amnion. (T/F)

(iv) Gestation period in humans is about 380 days. (T/F)

(b) **Rewrite** any two of the wrong statements by correcting only one word either at the beginning or at the end of the sentence.

2. **Complete** the following table by writing the name of the structure or the function of the given structure :

Structure	Function
1. Corpus luteum	1. .....
2.	2. Produces male gametes in mass.
3. Placental disc	3. .....
4.	4. Increases the force in uterine contraction
5. Umbilical cord.	5. .....
6. Fallopian tube	6. .....

3. **Given** below are the names of certain stages/substances related to reproduction and found in human body. Answer the questions related to them,

(a) **Foetus.**
- Where is it contained?
- How does it differ from embryo?

(b) **Hyaluronidase.**
- Is it an enzyme or simply a protein?
- What is its function?

(c) **Morula.**
- What is this stage?
- Name the stage which comes next to it?

(d) **Amniotic fluid.**
- Where is it found?
- What are its functions?

(e) **Gestation.**
- What is its meaning?
- How long does it normally last ?

(f) **Placenta.**
- What are the two sources that form placenta?
- Name any two main substances which pass from foetus to mother through placenta.
- Name any two hormones it produces.

(g) **Implantation.**
- The development stage that undergoes this process.
- The approximate time after fertilisation, when it occurs.

D. LONG ANSWER TYPE

1. **Differentiate** between :

(a) semen and sperm

(b) implantation and pregnancy

(c) follicle and corpus luteum

(d) amnion and allantois

(e) impotency and sterility

(f) prostate gland and Cowper's gland (the nature of secretion)

(g) identical twins and fraternal twins

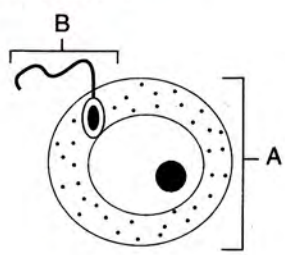
2. **Name** and describe very briefly, the stages in the development of human embryo.

3. **Describe** the functions of

(a) amnion (b) placenta

F. STRUCTURED/APPLICATION/SKILL TYPE

1. The diagram below represents two reproductive cells A and B. Study the same and then answer the questions that follow :



(a) Identify the reproductive cells A and B.

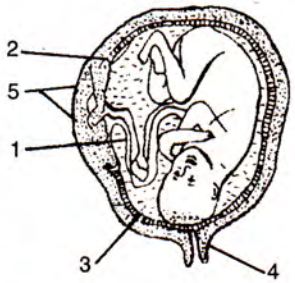
(b) Name the specific part of the reproductive system where the above cells are produced.

(c) Where in the female reproductive system do these cells unite?

(d) Name the main hormones secreted by the (1) ovary (2) testes.

(e) Name an accessory gland found in the male reproductive system and state the function of its secretion.

2. The diagram given alongside is that of a developing human foetus in the womb. Study the same and answer the questions that follow :



(a) **Name** the parts '1' to '5' indicated by guidelines.

(b) **What term** is given to the period of development of the foetus in the womb?

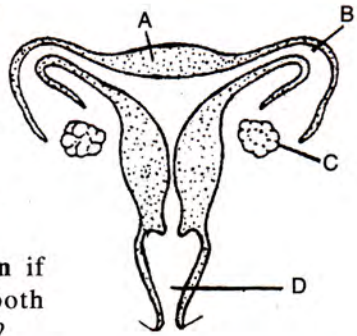
(c) **How many days** does the foetus take to be fully developed?

(d) **Mention** two functions of the parts labelled '2' other than its endocrine function.

(e) **Name** any one hormone produced by the part labelled '2'.

3. **Given** below is a portion of the diagram to show the diagrammatic highly magnified view of a single human sperm. Complete the diagram to show its normal structure.

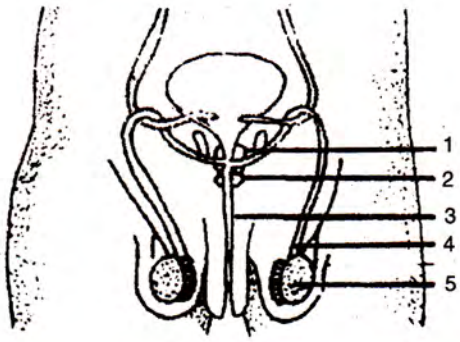
4. The figure given alongside represents the female reproductive system of a mammal.



(a) **Name** the parts labelled A - D.

(b) **What will happen** if the part B on both sides gets blocked?

5. **Given** below is the outline of the male reproductive system. Name the parts labelled 1 to 5.



WHAT IS IT ?

Just a **fancy** or a **superstition** !

DAY → **12-12-12** at **12:12 NOON** ← TIME

A few caesarian births on this day and at this time at the request of the parents!

SIMILARLY

(Horoscopes as you want)

Some people have been getting caesarians done on the same day and time as that of the birth of certain worshipped "Gods" or on particular Zodiacs.

Positive feed-back mechanisms are very few. One example is that of uterine contractions during child birth. Normal state of uterus is uncontracted, one contraction instead of commanding to come to normal gives a message to continue to contract further (positive feed-back till delivery is completed).

12 Population — The Increasing Numbers and Rising Problems

Syllabus : Population : Problems posed by the increase in population in India; need for adopting control measures – Population control.

Scope of Syllabus : Main reasons for the sharp rise in human population in India and in the world. The terms demography, population density, birth rate, death rate and growth rate of population should be explained. With population growth, increased consumption and urbanisation there is a need to keep a check on demands of urban areas over rural areas of exploitative use of resources rather than sustainable use. Methods of population control to be taught.

Human population throughout the world and in India, in particular, has been rising at an alarming rate. This is by far the most serious problem the world is facing today, and if not solved, will lead to grave consequences in future. What all this problem of rising world population embodies and what steps may help to solve it, are the topics covered here.

12.1 RISING POPULATION — A GLOBAL THREAT

Today, we hear a lot about population problem in the developing countries including India. All the media of mass communication — radio, television, stage, press, etc. — are trying their best to educate people about the grave dangers of rising population. It is becoming a serious threat, not for any one country in particular, but for the world as a whole.

12.2 WORLD POPULATION THROUGH THE AGES

It is estimated that the total world population about 50,000 years ago would have been around one million (1,000,000). At that time, man lived a very primitive life. He knew nothing about farming, but he had begun to use tools which he made from stones, sticks and bones (Fig. 12.1.) He was a wanderer and took shelter in caves. He used to kill animals and eat them raw or roast them on fire. He used to catch fish from waters. He collected eggs from birds' nests or gathered fruits, roots and leaves from wild plants. Meanwhile, due to safety reason, he had learnt to live in groups and to use his intellect in many ways as in hunting large animals like the mammoths. He had improved his tools which were still mainly of stones **(stone age)**. This **tool-making revolution** thus helped man to improve his life.

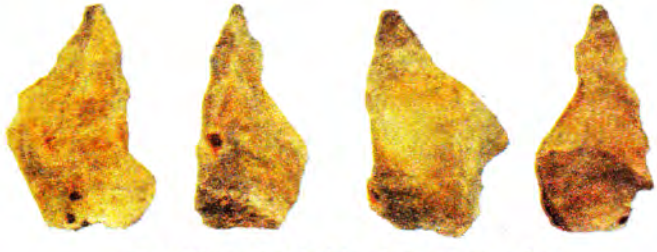


Fig. 12.1 : A primitive human species (*Homo erectus*), of the stone age (about 1 million years before) who lived in caves and hunted animals, and some of the stone tools which he used for hunting and for scraping flesh from the killed animals

Fig. 12.2 : An artist's perception of a late stone age family

About 10,000 years ago, the total world population had reached approximately 5.3 million. At that time, the human way of life was undergoing a remarkable change — a kind of revolution.

- He started living in **settled communities** in primitive huts.
- He had **started domesticating animals — dog being the first**.
- He learnt to sow crops and store food. This was the beginning of **agriculture**.
- His primitive stone tools and weapons were now gradually replaced by those of bronze and iron. He had thus stepped into the **metal age**.

As a result of all the above progress, the human population began to grow faster.

WORLD POPULATION
- Some important dates and figures -

- World population crossed the 5.0 billion mark on July 11, 1987.
- World population in 1995 was nearly 5.6 billion.
- Number of babies born every day is more than 1,00,000.
- October 12, 1999, The World Population crossed the 6,000,000,000 (six billion) figure. The six billionth member of the world population was born in Sarajevo (Yugoslavia).

According to one estimate the total world population will reach 10 billion around the year 2050.

With the present trend of population growth, India is overtaking China to becoming World's "TOP MOST" in population by the year 2025 or so.

JULY 11 IS OBSERVED AS WORLD POPULATION DAY

12.3 RAPID RISE IN POPULATION

(i) Industrial revolution

A major phase in the growth of human population started with the **scientific** and **industrial revolution**, which began around the seventeenth century. Rapidly growing industries made human life more and more comfortable, with greater opportunities of jobs and with more production of food. All this favoured population rise. However, there was one drawback. As the community groups were increasing, there were **widespread outbreaks of infectious diseases** due to close contact of the people. **Nutritional diseases** also appeared due to unbalanced diets.

(ii) New Discoveries in Medical Science

The twentieth century (1901-2000) witnessed remarkable discoveries in medical science, specially the **antibiotics** and the prophylactic **vaccinations** against many diseases ("prophylactic" means guarding beforehand). This resulted in a sharp reduction in the number of deaths of all age groups, specially the infants and the old. ***More children per family began to reach the reproductive age*** and as they reproduced, the rate of growth of population began to rise very rapidly.

The two big question marks (??). Figure 12.3 depicts a diagrammatic curve of the growth of human population where three main revolutions in human culture have been indicated : (1) **Tool making revolution** (2) **Agricultural revolution** (3) **Scientific industrial revolution**.

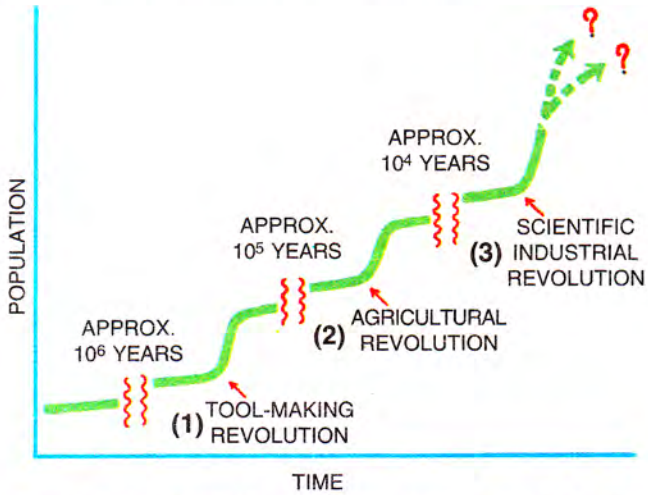


Fig. 12.3 : Three great cultural revolutions, each of which favoured steep rise in human population

Each cultural revolution was followed by a rapid rise in population till it became somewhat stabilised or rose very slowly (flattened curve) for a long period (shown by wavy gaps). The next revolution provided further improved means of livelihood and the human population again moved upward rapidly, and so on.

The modern period is marked by the end of the solid curve; we do not know exactly whether the population would continue to rise rapidly or slowly, or would soon tend to stabilise, and hence the two big question marks.

? ***PROGRESS CHECK***

1. Name the three great cultural revolutions that favoured a steep rise in population.

   .....

2. Mention two areas of medical sciences which have indirectly contributed to high growth in human population.

   .....

3. Is the present day human population growth following a J-shaped curve or S-shaped curve?

   .....

12.4 POPULATION EXPLOSION — A SERIOUS GLOBAL CONCERN

According to demographers, about one-third of the total number of all the people who have ever lived on earth are alive today, is termed as population explosion that began in the middle of the nineteenth century. Two-thirds of the present world population belong to the developing nations where more than half the people live below poverty line. India and China make one-third of the total world population. Figure 12.4 represents the profile of human population growth in the world from the earliest times, particularly during the last 12,000 years. In earlier years, the human population remained fairly constant. The sharp dip shortly after 1000 A.D. is due to severe epidemics, specially the Black Death (Plague, caused by a bacterium spread by the ratflea bite). Later, the scientific and industrial age gave a fresh momentum to the population rise. Today, the rate of growth of population has reached a point such that the **population more than doubles in about 35 years**. The total world population reached 7 billion on 31 October 2011. According to the present rate of population grown, it is likely to reach 50 billion by the end of this century (more than seven times the present number)

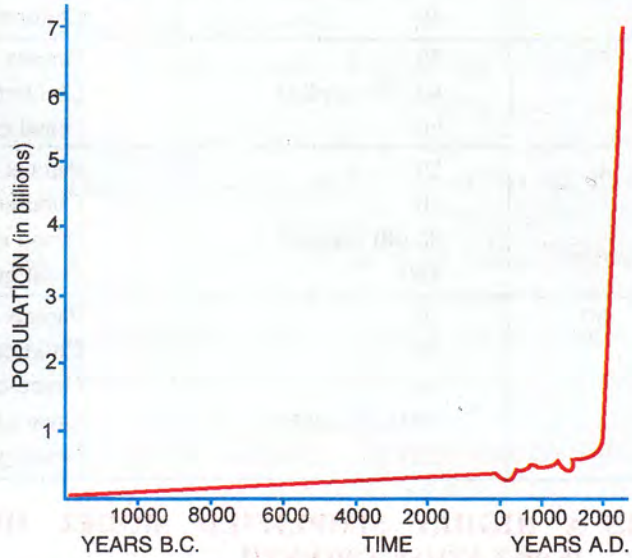


Fig. 12.4 : The world population during the last twelve thousand years

Six main reasons for sharp rise in WORLD HUMAN POPULATION in the recent past.

1. **Better health care**, for all age groups. There are more health care centres, hospitals, and practising doctors available for help.
2. **Fewer deaths** due to better medical aid. This is for two reasons : there are regular vaccination programmes, many diseases have been controlled or even wiped out and secondly, more patients get cured and live longer.
3. **Food shortages minimised** and green revolution. More food is produced and stored. There are very few starvation deaths.
4. **Improved nutrition** (due to consciousness) specially for growing children. They keep healthy, suffer less from diseases and live longer.
5. **Large scale immunisation** against fatal diseases.
6. **Fewer infant deaths**. In older times, an average family used to get 4-6 children out of which, 1 or more would not survive due to certain diseases. Today, most new born babies survive due to better health care. Maternity homes provide safety for both the child as well as the mother.

   As a result of all the above factors, even if a couple produced only 2-3 children, the total population rises sharply.

   More and more children are reaching the reproductive age and they contribute to population growth.

Table 12.1 : A model of population growth
[In about half a century the population tends to grow 10 times]

Year	Number of individuals	Generation	Age (years)	Total population
1	20 (10 couples)	Parents	20-30	60
	40	Children	0-10	
20	20	Parents	40-50	
	40 (20 couples)	Children	20-30	140
	80	Grand children	0-10	
40	20	Parents	60-70	
	40	Children	40-50	300
	80 (40 couples)	Grand-children	20-30	
	160	Great grand-children	0-10	
60	20	Parents	dead	
	40	Children	60-70	
	80	Grand-children	40-50	600
	160 (80 couples)	Great grand-children	20-30	
	320	Great, great, grand-children	0-10	

12.5 A HIGHLY SIMPLIFIED MODEL OF POPULATION GROWTH

The table above (Table 12.1) gives a model of growth of population. We have imagined a population of 20 (10 couples) who have an average of 4 children. When they grow up and reach the reproductive age of 20-30 years, they too pair off and again have four children, and so on in each generation. The total population after the fourth generation at the end of 60 years, has multiplied ten times.

At this rate, we in India have already numbered more than 1.21 billion and would overtake China in the year 2025 or so, to become TOP MOST in population — something not to be proud of at all. Can we afford such a rise in population ? Can our resources — food and other requirements of life — keep pace with rising population ?

1 square foot of earth per person !

If there are no further checks or controls, the population in the next 700 years would become so much that only 1 sq. foot of earth per person would be available. Can this situation really come ? If not, what would be the cause of this? No one can answer at present.

Need for adopting control measures

With the fast increasing world population there are numerous problems which are serious threats, for example :

1. Decreasing open spaces,
2. Shrinking of forests,
3. Increasing industrialisation causing air, water and soil pollution,
4. Rapid and intense shortage of drinking water and other resources,
5. Increasing pollution is a health hazard.

In order to reduce the above threats, it is urgently required to control population growth. And this can be achieved only by taking population control measures primarily in the form of methods of contraception.

12.6 POPULATION IN INDIA

The trend of rise of population in India is as alarming as in the rest of the world. Except for a slight fall in 1911-21, the population of India has been steadily increasing for the last 100 years. Since 1951, the growth rate has been very high. The ten-year interval statistics during the last 110 years is as follows :

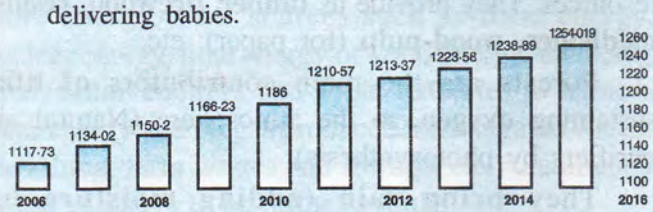
Year	Approximate population of India (in millions)	Year	Approximate population of India (in millions)
1901	238	1961	439
1911	252	1971	548
1921	251	1981	685
1931	279	1991	846
1941	318	2001	1027
1951	369	2011	1210

A few years ago, it was estimated that India's population in 2001 A.D. would be around 760 million; but now, we find, it has already crossed one billion (1000 million) mark.

Some latest figures about population in India are as follows :

Current Indian population is a little more than 1·32 billion and is growing rapidly :

- 52 per minute
- 3,120 per hour
- 74,480 per day
- 2·7 crore per year
- At least, 35 out of every 1,000 babies born die at birth.
- 45 out of 1,000 babies born do not survive beyond the age of five.
- More than 100 pregnant women per 1,00,000 die while delivering babies.



THE BILLIONTH INDIAN

Officially designated billionth Indian, "Aastha" was born on Thursday, May 11, 2000 at 11.40 A.M. at Safdarjung Hospital, New Delhi. This is the picture of the newly born Astha.

Astha — when six years old. She aspires to become a doctor.

The Seven Billionth World Baby of India

Hundreds of children are born every day and every hour in the world. One *seven billionth baby* born in India is Nargis, born in a village near Lucknow (U.P.) at 7.20 A.M., on 31 October, 2011. Internationaly, the population milestone is the baby born in Manila (Phillipines) where the sun rises almost earliest in the world related to International Date Line.

The 23 years old Vinita Yadav holding the world's 7 billionth girl Indian child Nargis born on 31 October, 2011.

12.7 FACTORS RESPONSIBLE FOR POPULATION EXPLOSION IN INDIA

(1) **Illiteracy.** Most of the rural population which forms the bulk of our society are still illiterate, ignorant and superstitious. They also do not know the functioning of the human reproductive system.

(2) **Traditional beliefs.** Among the people from lower strata of society, children are regarded as a gift of God and a sign of prosperity. Therefore, they make no effort to avoid pregnancy.

(3) **Mortality rate.** Due to high infant mortality rate in our country, people from the economically weaker section think it safer to produce more children so that at least some may survive.

(4) **Economic reasons.** Children are considered to be helping hands to increase the family income.

(5) **Religious and social customs.** India is a centre of various religious and social customs, and as such most people do not accept family planning norms.

(6) **Desire for a male child.** Most Indian families still hold the view that a male child is essential for keeping up the name of the family. Further, a male child is usually a great help to the aged parents. These two reasons often contribute to getting several children before getting one son or sometimes not even that.

(7) **Lack of recreation.** Poor standard of living and poverty provide no recreation other than sex.

World-wide population trends

1. **Birth rates are falling**

	World	China	India	U.S.
1970-1975	4.7	5.8	5.4	2.5
2005-2010	2.6	1.4	2.8	2.1

Which one of the three countries mentioned above has reduced the birth rate maximally ?

2. **People are living longer**
   — Better nutrition
   — Better healthcare

   Once an adult has reached the age of 60, he/she can expect the following more years of full health.
   - 13 years in **India**
   - 15 years in **China**
   - 19 years in **U.S.**

PROGRESS CHECK

1. Write any six factors which have contributed to a rapid rise of human population in recent times in the world.
2. Give the approximate figures for the population in India in million at (a) the beginning and (b) the end of twentieth century.
   (a) ..... (b).....
3. List any four reasons for the population explosion in India.
   .....

12.8 RISING POPULATION — PRESSURE ON NATURAL RESOURCES

What is a resource ?
Resource is any substance (natural or artificial), energy or organism which is used by humans for their welfare.

In the context of rising human population, the six main resources under pressure are as follows :-

1. Food
2. Water
3 Land
4. Forests
5. Energy
6. Minerals

With the rise in population, their production falls far short of the demand.

1. FOOD

One most important need of humans (or any living organism) is food. It is true that humans have been discovering better and better methods to produce more food, but it cannot be in the same proportion as the rise in population. If unchecked, the number of people are increasing in **geometrical progression**, more or less in a pattern of 1, 2, 4, 8, 16, ... *i.e.*, the numbers at each step are being **multiplied**. Compare this with the growth in food production. By bringing more land under cultivation and by using better farming methods, food production rises in **arithmetic progression** in a pattern of 1, 2, 3, 4, 5, ..., *i.e.* by adding up at each step. This indicates that *food would be running short for the unchecked rising population.*

Production of food rises by arithmetic progression. Population grows by geometrical progression.

2. WATER

Availability of clean and germ-free water for drinking purpose would be more and more scarce with the increase in population; the reason would be mainly, the pollution of rivers, ponds, lakes, etc.

3. LAND

Man is bringing more and more land under **cultivation** and also using up land for **building more residential colonies, factories and industries**. Usable land would thus become less and less available.

4. FORESTS

Forests are in a way, the most important natural resources. They provide us **timber, firewood, resins, medicines, wood-pulp** (for paper), etc.

Forests are the main contributors of life-sustaining **oxygen,** to the atmosphere (Natural air purifiers by photosynthesis).

They **bring rain (adding moisture by transpiration)** and at the same time, **prevent floods** (by holding soil particles firmly).

They **stabilise climatic conditions** including atmospheric temperature (by absorbing CO_2).

Forests are *natural homes* for the immense variety of large and small wild animals.

Deforestation (cutting down of forests) has been one of the most serious outcomes of rising population – to get land for cultivation and housing and to obtain timber and wood. Deforestation has led to numerous other problems such as :

— Droughts, — Flash floods,
— Soil erosion,
— Extinction of several wild animals and a threat of extinction of hundreds of species,
— Global warming.

Forests are one of our *renewable resources*. By careful management and by **afforestation** (planting more trees), we can maintain and even improve the existing forests.

Shrinking of forest cover over the world has to be stopped without delay to maintain the habitability of our planet earth.

5. ENERGY

We need energy for cooking in homes, for running factories, for transportation, and so on. Two major sources of energy at present are coal and petroleum — these are termed **fossil fuels** and their reserves underground are fast depleting. It is estimated that at the current rates of consumption, which are still rising,

- the reserves of petroleum may be exhausted within 150 years.
- coal may last a bit longer.

Once finished, petroleum and coal cannot be formed again during a lifetime.

Coal and petroleum are categorised as conventional sources of energy because these have been in use since long.

Non-Conventional Sources of Energy

Increasing population would need more and more energy. New sources such as solar energy, nuclear energy, tidal energy or wind energy, are being used. **Solar cookers** and **solar batteries** to harness solar energy and biogas produced from organic wastes (cowdung, farm wastes and sewage, etc.) are already in use and have to be further popularised.

6. MINERAL RESOURCES

More population means more requirements, more industries, more means of transportation and all of them utilise minerals such as iron, copper, etc.

Minerals are a non-renewable resource. Once finished, they can never be replaced

12.9 POPULATION GROWTH AND URBANISATION CAUSING SERIOUS PRESSURE ON RESOURCES

12.9.1 Changing Face of the Earth

The human population is growing very fast throughout the world. The villages are turning into towns, towns into cities and cities into megacities or the metropols — a process covered under what we call **urbanisation.** Some of the major changes occurring in the process of urbanisation are as follows :

- More and more residential **buildings, markets, schools, hospitals,** etc.
- More **streets** and **roads**, more **highways, railway lines** and **airports**.
- More **industrial installations, godowns** and **reservoirs**, and so on.

All such developmental activities are encroaching upon the open land, as well as on the neighbouring agricultural land. There is encroachment even on the forests. Thus, overall, there is a loss of natural vegetation which also is degrading the environment specially the climatic conditions.

12.9.2 Rising Living Standards of Growing Population

Living standards of the people are rising very fast.

- More and more household equipment – the furniture, the crockery, electric gadgets, the decoration articles, and so on.
- More clothes : just think of how many shirts and suits, how many sarees, and how many pairs of shoes per person, and so on.
- Some means of personal conveyance – a cycle, a motor cycle, a motor car (some people may have several of each of these for a single family), and then there are taxis, and other means of transport.

12.9.3 Need to Check Exploitative Use of Resources

As you have learnt, the increasing numbers in population, and even more than that, the increasing standards of modern living are causing very rapid depletion of natural resources. Among these, there are some resources which are non-renewable *i.e.* once lost are lost for ever (never regained) and there are others which take very long time to get renewed. Therefore, it is absolutely necessary that every citizen becomes conscious and contributes to the sustainable use of natural resources.

Sustainable means which can be continued with no ill effect on the availability of the required items.

Sustainable development means the kind of development that meets the need of the present without compromising the ability of the future generations to meet their own needs.

Sustainable development can be achieved mainly by :–

- **Reduction of excessive use** of natural resources.
- **Recycling** and **reuse** of resources wherever possible.
- **More use of renewable resources** such as solar energy, wind power, etc.

? *PROGRESS CHECK*

1. Mention whether the following statements are **True** (T) or **False** (F).
   (i) Urbanisation is the enlargement of towns covering a very large area together with modern facilities. (T/F)
   (ii) Rising population is leading to an increased coverage of land for raising forests. (T/F)
   (iii) Coal and iron are inexhaustible resources. (T/F)

2. Fill up the blanks by choosing the right option.

(i) Public conveyances like buses and railways are ..... (necessities/luxuries).

(ii) Many sets of garments per member in a family are ..... (necessities/fashions).

(iii) Petroleum is a resource of the same category as that of ..... (copper/ground water).

12.10 RATE OF POPULATION GROWTH MUST BE REDUCED

For a better future of mankind, the rate of growth of human population must be reduced. That will mean (i) less burden on depleting resources, (ii) better health care, (iii) better education, and so on. How it can be done is engaging the attention of all governments and social organisations.

Before describing a few major steps being taken in this direction, let us first understand a **few terms** and some of their applications in the study of human population.

A FEW STATISTICAL TERMS

- **Demography** (*demos* : people + *graphos*: measurement). Statistical study of human population. This is specially with reference to size and density, distribution and other vital statistics (which are given below).
- **Population density** is the number of individuals **per square kilometre (km²)** at any given time.

  Towns and larger cities have a greater population density than the rural areas. Countrywise density in 2016,

  Netherlands — about 407 persons/km² the highest population density,

  Japan — about 348 persons/km²,

  India — about 392 persons/km² and

  US — only about 33 persons/km².
- **Birth rate** or **natality** is the number of **live births per 1000 people of population per year**.

  For example, if there were 440 live births in a population of 20,000, the birth rate would be $440 \div 20 = 22$.
- **Death rate** or **Mortality** is the number of **deaths per 1000 of population per year**.

  [Registration of births and deaths is compulsory in our country].
- **Growth rate of population** is the difference between the birth rate and the death rate.

  As long as the birth rate exceeds the death rate, the population grows. If the birth rate is lower than the death rate, the population declines.

In India, the birth : death ratio in 1901 was 46 : 44 and in 1973, it was 37 : 14. It is apparent that both birth and death rates have fallen, but the fall in death rate is much sharper which is on account of better medical care, both for infants and the old. The result is, sharper rise in population. The current rate of growth (2006) of population is about 2.07%, which is very high when we compare it with that of the world (a little less than 2%). In 2016 India's population is about 1·32 billion.

12.11 NEED FOR ADOPTING CONTROL MEASURES

As the population density increases in a country beyond its means, it brings many problems, for example :

— per capita *income comes down*

— *natural resources* like land, minerals, wood, fuel, etc. *decrease*

— general *health goes down*

Overall, the large population of a country is the result of having **large families** and the quality of life goes down. Therefore, there is pressing need for adopting population control measures.

? PROGRESS CHECK

1. Give the technical terms for the following :

   (i) Statistical study of human population

   .....

   (ii) Number of deaths per 1000 people per year

   .....

   (iii) Number of individuals per sq. km. at any given time

   .....

   (iv) Difference between birth rate and death rate

   .....

2. List any three consequences of high population density .....

   .....

12.12 POPULATION EDUCATION AND POPULATION CONTROL

It is necessary that the people should be educated about the need to limit the population and about the steps which can be taken in this direction.

1. The message about population problem should reach as many people as possible including those living in very remote areas.
2. People should be made aware of the advantages of having small families and, at the same time, the disadvantages of having many children.

   China is almost reaching the norm of 1 child per family, whereas India has to strive hard even to reach the 2 children per family norm.
3. The orthodox view, to have at least one son specially in Indian society, should be modified by education.
4. Marriageable age should be higher. ***[The age restriction of at least 18 years for girls and 21 years for boys under the law must be followed strictly].***
5. The married couples should be educated to ***delay the birth of their first child, to space the second with a sufficient interval*** for proper upbringing and to ***stop the third***.
6. People should be advised to adopt family planning methods by which they can prevent pregnancy **(contraception)**. These include devices for both men and women, for example: **Condoms** (such as 'Nirodh'), **intrauterine** devices (such as Copper-T), **oral pills** (such as Mala-D). Various methods of contraception are being described in the next section 12·13 below in more detail.

FAMILY WELFARE

The inverted **red triangle** has become a popular sign in India for family welfare. It is prominently displayed at all such offices and hospitals where any help or advice about family planning is available free of cost. These are known as family welfare centres.

The term FAMILY WELFARE has three aspects :

1. **Family planning in terms of having a small family.**
2. **Total welfare of the small family, including the diet and nutrition of the child and of the pregnant mother.**
3. **Subsequent care of the children, e.g., immunisation and oral rehydration therapy, etc. to ensure survival of the young ones.**

? *PROGRESS CHECK*

1. List any five major disadvantages of having large families .....
   .....
2. What are the age restrictions for marriage for boys and girls respectively in India ?
   .....
3. What are the three aspects covered under family welfare ?
   .....

12.13 METHODS OF CONTRACEPTION

The common methods of contraception are as follows :

1. **Hormonal Methods (Pills) :** Various hormonal preparations come in the form of tablets or pills (commonly called contraceptive pills). These hormones prevent the release of the egg from the ovary.
2. **Barrier Methods :**

   (a) **Condom (e.g. Nirodh) :** It is used by men only. It is made of latex (rubber sheath). It prevents the sperms from being deposited in the vagina.

   (b) **Diaphragms :** These are round latex caps with coil spring. These caps can be fitted deep in the vagina on the mouth of the uterus (cervix). These caps prevent the entry of sperms into the uterus.

   (c) **Sperm-killing (spermicidal) agents:** These are chemicals placed in the vagina near the cervix, which kill the sperms if they are there.

3. **Intra-Uterine Devices (IUDs) :** The two devices commonly used in India are Lippe's Loop and Copper-T. These are fitted inside the uterus. These do not stop fertilisation but prevent implantation of the blastocyst (embryo).

4. **Surgical methods :**

(a) **Tubectomy** (for female) : In this, the abdomen is opened and the fallopian tubes (oviducts) are cut or ligated i.e. tied with nylon thread to close the passage of the egg (Fig. 12.5).

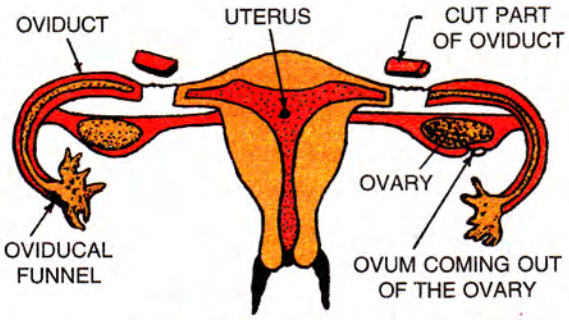


Fig. 12.5 : Tubectomy

(b) **Vasectomy** (in male) (*vasa* = vessel; *tomy*: cutting) : In this surgery, a small cut is made in the scrotum, vas deferens (sperm duct) from each testes is ligated and a small piece between the two ligatures is removed (Fig. 12.6). This surgery is easier, quicker and safer. So, it is recommended that between the couple, it is better if the husband gets operated. This operation has no harmful effect on manliness of any kind nor it reduces the pleasure of intercourse or libido.

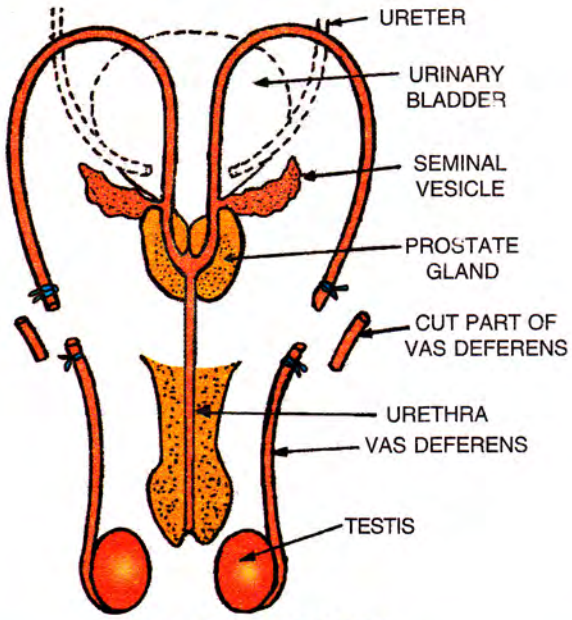


Fig. 12.6 : Vasectomy

5. **Induced Abortion or Medical Termination of Pregnancy (MTP) :** If the woman has somehow become pregnant and the couple does not want to have the child or if there is definite evidence of any serious genetic disease in the embryo based on a special test, then the foetus can be removed. This method should not be considered a contraceptive method, but as a last step that can be taken. This operation (forced abortion) should be performed only by a trained doctor at a hospital. Abortion is legally permitted (only within 5 months of pregnancy) and can be requested by any desirous female at any government hospital at no cost. For this, even husband's consent is not necessary.

? *PROGRESS CHECK*

1. State whether the following statements are True (T) or False (F). If false, write the correct word for the one which is wrong.

Statement	T/F	Correct
(i) Some vitamin preparations prevent the release of the egg from the ovary.	.....	.....
(ii) Use of a condom for contraception is a barrier method.	.....	.....
(iii) IUDs prevent implantation of embryo in vagina.	.....	.....
(iv) Tubectomy is performed on females.	.....	.....

2. Write the full form of MTP. In what circumstances is it recommended ?

MTP .....

Circumstances .....

.....

.....

.....

.....

.....

REVIEW QUESTIONS

A. MULTIPLE CHOICE TYPE

(Select the most appropriate option in each case)

1. What was directly responsible for the rapid rise of world population in the twentieth century?
   (a) Increased food production
   (b) Better transport facilities
   (c) Better education and job prospects
   (d) Use of antibiotics and prophylactic vaccinations
2. Birth rate is the number of live births
   (a) per 1000 people per year
   (b) per 100 people per decade
   (c) per 1000 people per decade
   (d) per 100 people per year

B. VERY SHORT ANSWER TYPE

1. **Give the technical term** for the statistical study of human population of a region.
2. **Name** two surgical techniques (one for the human male and another for the human female) that can be used to prevent pregnancy.

C. SHORT ANSWER TYPE

1. **Write** *true* (T) or *false* (F) for the following :
   (a) Vasectomy is the surgical method of sterilisation in human males. .....
   (b) Tubectomy is the placing of a diaphragm on the cervix. .....
2. **What** is the total world population at present ?
3. **Define** the following terms :
   (a) Birth rate
   (b) Death rate.
   (c) Rate of growth of population.
   (d) Population density.
   (e) Exhaustible resource
4. **Mention** whether the following statements are ***true*** (T) or ***false*** (F). Give reason in support of your answer.
   (a) Cow was the first domesticated animal. (T/F)
   (b) Rapidly growing industries favoured population rise. (T/F)
   (c) Present human population growth is following arithmetic progression. (T/F)
   (d) Birth rate (natality) is the number of live births per hundred people of population per decade. (T/F)
   (e) Tubectomy is a popular surgical method of contraception in human males. (T/F)
5. **What** is the present rate of growth of population of the world and of our own country ?
6. **What** are the age restrictions for marriage by law for boys and girls in India?
7. **Give** two advantages of a small family.
8. **Mention** two reasons for the rapid increase of population in India.
9. Some great author has said that a population explosion is far more dangerous than an atomic explosion. **Justify** his statement ?
10. **Explain** briefly the relationship between poverty and population and how one affects the other.
11. **List** three major landmarks in human history which contributed to the sudden rise in population of the world.
12. **What** was the approximate Indian population according to the 1981 census ? What was it in 1991 ?
13. Sterilisation in men means preventing the flow of sperms into the seminal vesicles by cutting or ligaturing the vas deferens. **Can** there be a corresponding operation made in women ? If yes, **where** ?
14. **What is meant by** family welfare centres ? **What** is the symbol of family welfare in our country ?
15. **List** the advantages of having small families.

D. LONG ANSWER TYPE

1. Our resources cannot keep pace with the rising population. **Give** three examples in support of this statement.
2. **How** can the knowledge of processes of reproduction help people in limiting the size of their families ? Give **two** concrete examples.
3. **What** is the idea behind the phrase "population explosion" ?

E. STRUCTURED/APPLICATION/SKILL TYPE

1. Given below are hypothetical figures in regard to population (in crores) of two countries A and B during the last three decades.

Country	1971	1981	1991
A	6.4	9.6	10.6
B	15.7	15.7	15.3

Fill in the blanks :

(a) Rate of growth of population of country ..... has declined between years ..... and .....
(b) The country ..... shows negative population growth between years ..... and .....
(c) The country ..... shows zero population growth between years ..... and .....

13 Aids to Health

Syllabus : *Aids to health : an understanding of the use and action of the following – vaccination; immunisation; antitoxin; serum; antiseptics; disinfectants; penicillin; sulphonamide drugs; First Aid.*

Scope of Syllabus : An idea of local defence system and their merits, active and passive immunity, difference between antiseptics and disinfectants to be discussed. Basic principles of first aid to be taught.

To be healthy, we need personal care as well as community involvement. This chapter on Aids to Health is intended to familiarise you with various (natural and artificial) ways of protection from diseases. Apart from the importance of the topic for examination, the information given here is very helpful for leading a healthy life.

13.1 NEED TO KEEP HEALTHY

Every individual wishes to keep healthy and disease-free. This requires several things — some at personal level and some at community level. At **personal level**, one has to keep his body clean by washing, bathing, brushing teeth, regular physical exercise, and proper diet and proper rest and sleep. At **community level**, our surroundings should be kept clean with no accumulation of garbage or stagnant water, *etc.*, so that the disease-spreading insects and pests do not thrive.

WORLD HEALTH DAY
APRIL, 7

This day is celebrated to create consciousness about keeping healthy and disseminate the message at all levels.

13.2 IMMUNITY

Immunity means **body's defence against disease**. Our body is all the time invaded by various harmful substances like pollutants (poisonous chemicals) and germs. They may enter our body in the following four ways :

1. Directly through the **skin**,
2. Through **mucous membranes** of eyes, nose, urinary or genital tracts,
3. Through **food** or **water** intake,
4. Through the **air we breathe in**.

Our body system first tends to **prevent their entry** into the body. Secondly, if somehow they do enter, the body fights with them, so that they cause no harm **(rendered harmless)**.

The defence system in our body works at two levels:

A. **Local defence system (Prevention of entry of germs).** This is a kind of barrier system which tackles the germs at their possible entry points. It includes :
   (1) protective mechanical **barriers**
   (2) **thrown out**, if entered by sneezing etc.
   (3) germ-killing **secretions**, and
   (4) germ-fighting **WBCs**.

B. **Immune system.** It deals with the germs after they have entered into the body tissues.

13.2.1 Local Defence System

1. **Protective mechanical barriers**. These include the skin, hair, mucus, etc.

   (i) **Skin** – Skin has an outer tough layer made of a protein **keratin** and it is **almost impermeable to germs**. At any given time, there are lots of germs settled on the outer surface of the skin, which have come through the air or through **direct contact** with contaminated objects. *Even a handshake or a kiss on the cheeks of a baby transfers germs from one individual to another*. Washing with

soap and water removes the germs. Any **scratch** or **cut** in the skin opens the way for germs to get in. Should there be any cut in the skin, the **clotting of blood plugs the cut ends of blood vessels** at the wound to prevent entry of germs.

(ii) **Hairs** – Hairs intercept the germ's journey inwards or upto the skin. Hairs inside the nostrils trap dust containing the germs.

(iii) **Mucus** – Mucus is a slimy secretion of the epithelial lining of various organs. For example:

- the mucus secreted in the nasal passage and the wind pipe, **traps many bacteria** and prevents their entry into the body tissues.
- Cilia of the wind-pipe throw out the bacteria trapped in the mucus.

2. **Thrown out, if entered**

Coughing, sneezing and **vomiting** are direct methods to throw out the germs or any foreign unwanted objects which get into the respiratory and digestive systems. Even diarrhoea (loose motions) helps in throwing out the germs if the infection persists in the digestive tract.

3. **Germ-killing secretions**

(i) **Saliva, sweat, tears** and **nasal secretions** contain germ-killing substances.

(ii) **Hydrochloric acid** secreted by the stomach kills germs that gain entry along with the food.

4. **Germ-fighting white blood cells (WBCs).**

Should any microbe enter the body systems, the white blood cells (phagocytes) are ready to fight them. They squeeze out of the walls of the blood capillaries (by **diapedesis**) and engulf the bacteria or the germs and destroy them **(phagocytosis)** (Figs. 13.1 and 13.2). Pus in a wound, for example, is a mixture of destroyed germs, killed WBCs and damaged tissue cells.

MERITS OF LOCAL DEFENCE SYSTEMS

1. They start working **instantaneously**.
2. They are **not dependent on previous exposure** to infections.
3. They are effective against **a wide range** of potentially infectious agents.

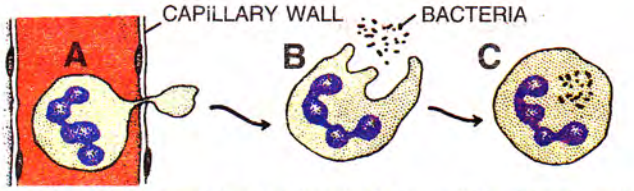


Fig. 13.1 : The engulfing of bacteria by white blood cells (phagocytosis). A-Cell forcing its way across capillary wall (diapedesis), B-White cell attracted towards bacteria, C-Bacteria are engulfed by the white cell. (The W.B.C. shown here is neutrophil with 4-lobed nucleus)

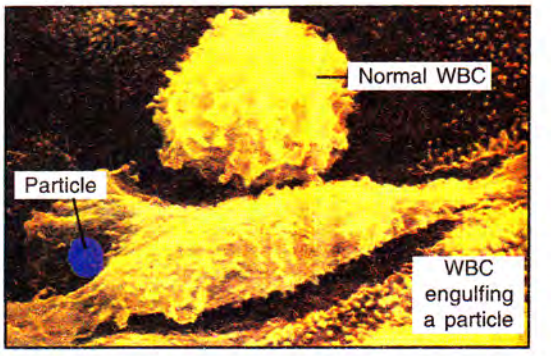
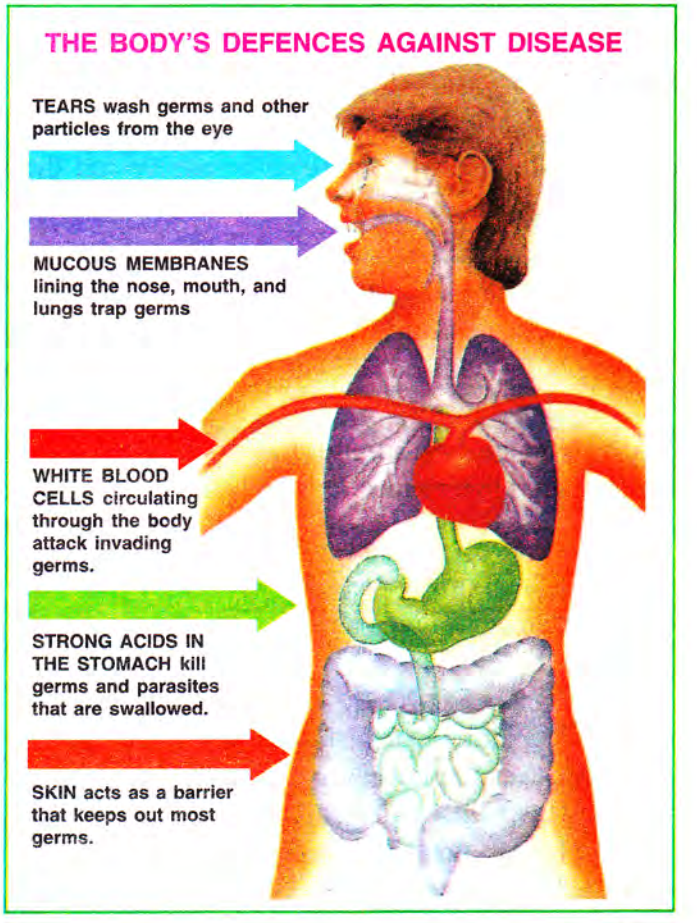


Fig. 13.2 : Two white blood cells patrolling the alveoli in a human lung. The spherical one is in its normal shape. Below it is an elongated white cell, about to engulf the round particle on the left. (Scanning electron microscopic view, highly magnified about × 5,000)



13.2.2 Immune System

The local defence systems are not effective in all cases and circumstances. Certain microbes (germs) or their poisonous secretions (**toxins**) do enter the deeper tissues and various organ-systems, by their special mechanisms of entry or through any breaches in the protective barriers.

At this stage, the blood and other body fluids start fighting against the germs or any other unacceptable foreign substance. The body fluids contain special proteins called **antibodies** which react with the invading germs, and **antitoxins** which react with their poisons (toxins) to destroy them, and thus they provide protection against disease (immunity).

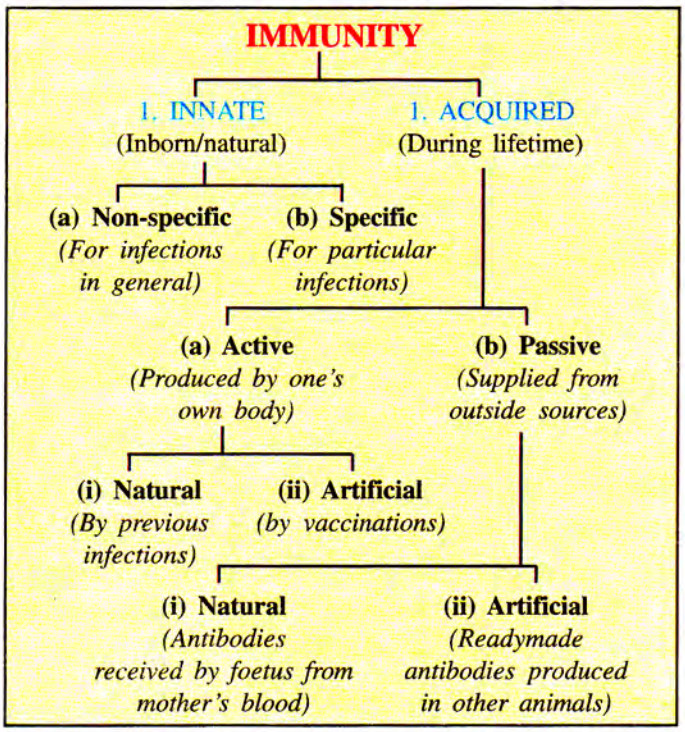
Immunity is the body's resistance to the onset of a disease after infection by harmful germs.

To define more elaborately – Immunity is the **"capacity of our body to deal with foreign substances, e.g., bacteria, viruses, toxins, etc. that enter our body and to render them harmless."** or simply, "it provides resistance against disease–causing germs."

KINDS OF IMMUNITY

Immunity can be classified into two main categories-**innate** and **acquired** immunity and their different subcategories are as follows :

1. INNATE IMMUNITY, also called natural or native immunity. This immunity is by **virtue of genetic constitutional make-up**. It is there in the body without any external stimulation or a previous infection.
   (a) **Non-specific innate immunity.** A degree of natural resistance to all infections in general. *For example*, humans do not suffer from the plants' highly infectious diseases, or even certain diseases of animals.
   (b) **Specific innate immunity.** This is a natural resistance to a particular kind of germ only. Some races or some individuals do not suffer from certain infectious diseases. *For example*, human beings are immune to a highly infectious disease of dogs (known as 'Distemper'), which kills about 50% of all infested dogs.
2. ACQUIRED IMMUNITY — **Resistance to a disease which an individual acquires during his life-time**. It may be the result of :



EITHER

A previous infection **(actively acquired immunity)**, *e.g.*, a person having once suffered from "measles" will not normally suffer from it again.

OR

"Ready-made" antibodies supplied from outside **(passively acquired immunity)**, *e.g.* a person bitten by a poisonous snake is given anti-venin injection (*venom* : poison) which contains antibodies for the poison that were produced in the body of a horse.

(a) **Actively acquired immunity.** This is the resistance developed by an individual due to a previous infection or antigen (chemical found on the surface of the disease-causing germ cell) which enters his body naturally leading to **(i) naturally acquired active immunity)** or is introduced artificially, as in vaccinations leading to **(ii) artificially acquired active immunity).** In either case, the body lymphocytes react in two ways:

– They produce **antibodies** which freely circulate in the blood & lymph, and which bind to the microorganism to kill it.
– They produce **killer cells** carrying specific

receptors for foreign antigens found on invading germs.

The actively acquired immunities are usually **long-lasting** carried out through 'memory' lymphocytes.

(b) **Passively acquired immunity.** This is the immunity provided to an individual not by his own body but from an outside source in the form of "ready-made" antibodies. The passively acquired immunity again can be of two types :

(i) ***Naturally acquired passive immunity.*** In it, the readymade or the "pre-prepared" **mother's antibodies** may reach the foetus (developing embryo) through the placenta.

(ii) ***Artificially acquired passive immunity.*** In this, the antibodies are produced in the **blood of a horse or some other animal** by injecting germs into its body. **Antiserum** injections are prepared from the serum (containing antibodies) of such animals' blood and are injected into the body of the patient, e.g. in the treatment of snake-bite by **antivenin** or that of a diphtheria patient by anti-diphtheria injections. Haffkine's Institute in Bombay and another institute at Kasauli are preparing several such anti-sera. Antivenin for treating snake-bite is also based on the same principle.

For the sake of simplicity, let us just take the active and passive immunities and summarise the differences between them as given in table 13.1 given below.

13.2.3 Antibodies

These are special chemicals found in the blood which act against the **germs** or their secretions. Some of the characteristics of the antibodies are as follows :

1. The antibodies are **proteins** (they belong to the class of immunoglobulins).
2. Antibodies are produced by a type of specialised lymphocytes **on exposure** to ***antigens*** (chemical substances found on the germs' cells) (Fig. 13.3). These special lymphocytes particularly concentrate in the lymph nodes and spleen and also in the circulating blood and lymph.

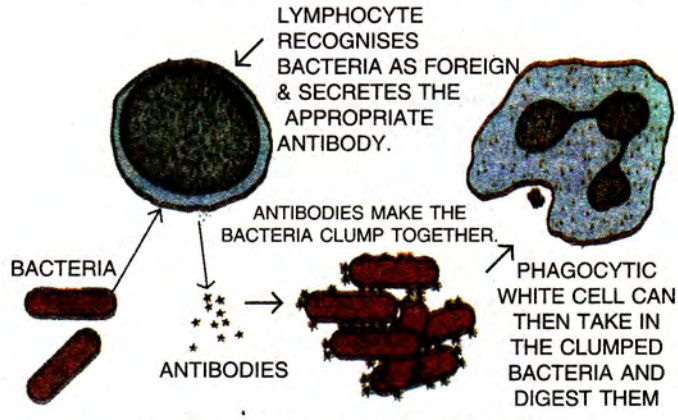


Fig. 13.3 : Antibodies attack bacteria

3. Our body can make an **unlimited variety** of different antibodies.
4. Antibodies are **specific** which means that one kind of antibody acts against only one particular type of antigen.
5. An antibody **recognises** its particular antigen and binds to it rendering it harmless, which is subsequently destroyed and eliminated by the body.
6. Some antibodies are present in the blood of some people **from the very birth.** Such people having these particular antibodies in their blood do not suffer from those particular diseases

Table 13.1 : Differences between active and passive immunity

Active Immunity	*Passive Immunity*
1. Produced by **one's own** body.	1. **Received from outside,** i.e.not developed by one's own body.
2. **Induced by infection** or by contact with immunogens (immunity-producing agents such as vaccines, allergens, etc.).	2. Provided by **readymade antibodies.**
3. Provides effective and long-lasting protection.	3. Protection is less effective and does not ensure against a subsequent infection.
4. Immunity **effective** only **after a certain time** gap (time required for production of antibodies).	4. **Immediately effective.**

even if the germs for them have crossed the barriers and escaped the phagocytes.

7. Immunity produced by the antibodies on exposure to antigens may be *either* for a **short period** (as in common cold, cholera), *or* for a **longer period** (as in small pox, measles, *etc.*).

SUMMARY OF OUR BODY'S DEFENCE AGAINST DISEASE GERMS

A. BARRIERS (Prevent entry of germs)

A1. Prevent entry **mechanically**
- Tough outermost layer of skin
- Hairs on skin and in nose
- Blood clot plug at any cut
- Cilia in wind pipe

A2. Prevent entry by **killing**
- Sweat
- HCl in stomach
- Tears
- Nasal secretion
- Saliva
- Mucus in wind pipe and food canal

A3. **Thrown out** if entering
- Coughing
- Sneezing
- Vomiting
- Diarrhoea

B. FIGHT TO KILL GERMS ON ENTRY INTO THE BODY (Immune Response)

B1. At entry point ***(non-specific)***
Phagocytes (WBCs) engulf pathogens in general (Inflammation increases blood supply, WBCs engulf debris).

B2. In the deeper parts (***specific***, by **recognising the pathogen**)
- By antibodies (*humoral immunity humor* : body fluid)
- Killer cells invade the pathogen or even kill an infected body cell (*cell-mediated immunity*)

A CONDITION IN WHICH THE IMMUNE SYSTEM FAILS
— AIDS —
(Acquired immuno-deficiency syndrome)

This feared disease (with no cure as yet) is caused by the infection of HIV (Human Immunodeficiency Virus). It is transmitted through sexual contact, contaminated syringe needles, and through blood transfusion. The virus attacks the cells of the immune system and causes a marked reduction in T-cells of the thymus. These are the cells which activate lymphocytes that produce immunity. With the collapse of immunity in full-blown AIDS cases, other severe infections develop unchecked to ultimately cause death.

A detailed account of AIDS, its germ, mode of infection, symptoms etc. have been given in *Concise Biology Part I* of Class IX.

Dec. 1 — WORLD AIDS DAY
(Awareness for its severity and protection)

? ***PROGRESS CHECK***

1. Give one example of each of the following:
   (i) Germ killing body secretion .....
   (ii) Germ trapping body secretion .....
   (iii) Mechanical barrier that prevents entry of germs into the body .....
2. Mention if the following statements are **True (T)** or **False (F)**
   (i) Immune system deals with the germs after they have entered the body. T/F
   (ii) Antibodies eat up the germs T/F
   (iii) Human beings can suffer from all those diseases which attack dogs. T/F
   (iv) Anti-venine injection against snake bite is an example of artificially acquired passive immunity. T/F
   (v) Mother's antibodies may reach the foetus through placenta. T/F
   (vi) A person having once suffered from measles usually gets repeated attacks. T/F

13.3 VACCINATION AND IMMUNISATION

Vaccination is the practice of **artificially introducing the preparation of weakened germs or the germ substance into the body for developing resistance** to particular diseases. Scientifically, this practice is called **prophylaxis** and the material introduced into the body is called the **vaccine**.

The vaccine or germ substance is introduced into the body usually by injection and sometimes orally (e.g. polio drops). Inside the body, the vaccine stimulates the WBCs to produce antibodies against germs for that particular disease.

The terms "vaccine" and vaccination" were originally used for vaccination against small pox, but now these are used in a general sense.

FOUR CATEGORIES OF VACCINES :

(1) **Killed germs,** as **TAB vaccine** for **typhoid**, **Salk's vaccine** for **poliomyelitis,** and the vaccine for **rabies** (dog-bite).

(2) **Living weakened germs,** as the vaccine for **measles,** and the freezed-dried BCG vaccine for **tuberculosis.** Full form of BCG is "Bacillus of Calmette and Guerin" after the names of two

French workers who developed this strain for vaccination.

(3) **Living fully poisonous germs**, as for smallpox. In this vaccination, a person is inoculated with cowpox virus which is very similar to smallpox virus. Cowpox virus causes only a single pustule to develop rather than multiple pustules of smallpox all over the body. Vaccination by cowpox vaccine protects from smallpox as well. **The smallpox vaccinations are no more given, because the disease has been totally eradicated according to present-day records.**

(4) **Toxoids** (inactivated toxin secreted by bacteria), as for diphtheria and tetanus. These toxins (poisons) are **made harmless by the addition of dilute formalin**, yet retaining the capacity to produce antibodies (antitoxins). Attempts are being made to develop a vaccine against AIDS also, let us pray we succeed in it.

VACCINATION — *Vaccination is the introduction of any kind of dead or weakened germs into the body of a living being to develop immunity (resistance) against the respective disease or diseases.*

VACCINE — *A preparaton consisting of weakened germs or the germ substances to develop immunity against the germs of a particular disease.*

IMMUNISATION — *Developing resistance to disease-producing germs or their toxins by introducing killed germs or germ substance to induce the production of specific antibodies.*

Immunisation against some common infectious diseases has been taken up in India on a mass scale with an attempt to cover the entire population. The National Immunisation Schedule is as follows :-

NATIONAL IMMUNISATION SCHEDULE

Age	*Vaccinations*
3-12 months	**DTP** : 3 doses at intervals of 4-6 weeks **Polio** (oral) : 3 doses at intervals of 4-6 weeks **BCG** (Intradermal)
9-15 months	**Measles vaccine** : one dose
18-24 months	**DTP** : booster dose **Polio** (oral) booster dose
5-6 years	**DT** against diphtheria and tetanus, booster dose **Typhoid (TAB)** vaccine : 2 doses at an interval of 1-2 months
10 years	**Tetanus** toxoid — booster dose **Typhoid** vaccine — booster dose
16 years	**Tetanus** toxoid — booster dose **Typhoid** vaccine — booster dose
Mothers (during pregnancy)	(a) *Immunised previously.* One booster dose of **tetanus** toxoid, preferably 4 weeks before the expected date of delivery. (b) *Non-immunised :* **Two doses of tetanus** toxoid, the first dose between 16 and 24 weeks and the second dose between 24 and 32 weeks of pregnancy.

Abbreviations :

DTP = Diphtheria, Tetanus and Pertussis (whooping cough)

DT = Diphtheria and Tetanus;

BCG = (Bacillus of Calmette and Guerin) Tuberculosis.

? ***PROGRESS CHECK***

1. Define the term prophylaxis.
   .....
2. Name the four categories of materials for preparing vaccines.
   .....
3. Name the diseases prevented by :
   (i) Salk's vaccine .....
   (ii) BCG vaccine .....
   (iii) DTP vaccine .....

13.4 ANTITOXINS (More appropriately called ANTIBODIES)

The terms "Toxin" and "Antitoxin"

Toxin is a general term used for any poisonous substance produced by an animal or a plant or a bacterium. *Example* : Snake venom, sting poisons of scorpion, insects, etc., or even poisonous chemicals released by pathogens growing inside the body.

"Antitoxin" was the name given to any chemical substance produced inside the body in response to the entry of foreign posionous substance. **"Antivenins"** for snake bites are produced inside animals like horses. Presently, the more general term "antibody" is used instead of "antitoxin".

"Antibody" is a blood serum protein produced in response to the injected antigens.

Suppose, someone has actually got a disease such as diphtheria, in such a case, injecting pre-prepared

antibodies from some other source is helpful. For this, an antibody-containing serum (popularly called **anti-serum**) is obtained from the blood of horses, rabbits, etc., in which the disease is artificially produced in a mild form. Treatment with such antibodies is called **passive immunisation**. Haffkine's Institute in Bombay and another institute at Kasauli are preparing several such anti-sera. Antivenine for treating snake-bite is also based on the same principle.

13.5 ANTISEPTICS AND DISINFECTANTS PREVENT CATCHING DISEASES

13.5.1 Antiseptics

These are mild chemical substances which, **when applied on the body, kill germs**. These substances are in such mild concentration that they cause no harm to the skin and body. **Lysol, carbolic acid (phenol), iodine, benzoic acid, mercurochrome, boric acid,** etc., in dilute solution are good antiseptics. Certain antibiotic creams also serve the same purpose.

A CAUTION

Do not use commercial names as examples of antiseptics in your examination answers.

Names like Dettol, Savlon, Listerine, Soframycin are all commercial names. They may have one or the other active ingredient individually or in combination. It is these active ingredients which actually serve as antiseptics.

13.5.2 Disinfectants

These are strong chemical substances **that are applied on spots and places where germs thrive and multiply**. Commonly used disinfectants are cresol, phenol, lysol, 40% formalin, lime, bordeaux mixture, DDT, *etc. Precaution :* All disinfectants are strong and should not come in contact with the human skin.

Strong heat and boiling also destroy germs and may be called physical disinfectants.

Deodorants are neither antiseptics nor disinfectants. They only serve to mask a bad smell.

Table 13.2 : Differences between antiseptics and disinfectants

Antiseptics	Disinfectants
1. Mild germ-killing chemicals.	1. Strong germ-killing substances.
2. Cause no harm to skin and body.	2. May cause harm to skin and body.
3. Applied on body. *Example* : Iodine tincture	3. Applied on spots. *Example* : Phenol

13.6 ANTIBIOTICS – PENICILLIN AND OTHERS

Antibiotics are chemical substances produced by some microorganisms, and can kill or inhibit the growth of other microorganisms.

The term ANTIBIOTICS

The first antibiotic Penicillin was discovered in 1929, but its first use for treating any human disease was tried in the 1940s. The term "Antibiotics" for such category of drugs was coined much later, by Selman Waksman in 1942.

DISCOVERY OF PENICILLIN

Alexander Fleming (1881-1955) working in a hospital in London, was growing laboratory cultures of a bacterium *Staphylococcus* (round bacteria growing in clusters). In 1928 he found that a certain unwanted mould *Penicillium* had grown in one of the cultures in a petri dish and this had inhibited the growth of the bacteria for some distance. Obviously, some substance must have spread from the mould, which killed the bacteria upto that distance. Fleming named this bacteria-killing substance released from the mould as Penicillin in 1929. In the expectation of this substance to become an effective killer of disease bacteria, it was tried on laboratory animals and showed positive results without harming the animals.

On humans, the substance penicillin was first tried in the early 1940s and was found to be quite effective against several infections. In particular, it yielded very good results in treating gonorrhea, a **sexually transmitted disease** (STD). Sometimes, the physicians in those early days recommended using a combination of penicillin and sulpha drugs under the name "pentidsulph". Thereafter, a whole lot of antibiotics such as streptomycin, chloromycetin, aureomycin, ampicillin, etc. have been discovered and are being effectively used against many infectious diseases.

Antibiotics are also being used for the prevention of infections after surgical operations.

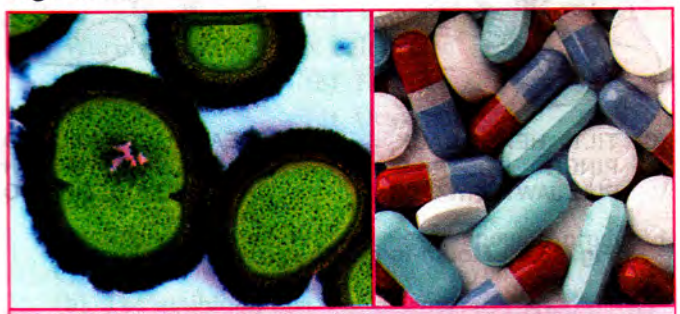
SOURCES OF ANTIBIOTICS

The mould which produced penicillin in the findings by Fleming, was found to be *Pencillium notatum*. This mould is somewhat similar to the one that often grows on oranges, lemon and other citrus fruits. The commercial production of penicillin has

been largely done from a related species *P. chrysogenum*, but it is also being produced synthetically.

Streptomycin is one of the very widely used antibiotics. This is obtained from a bacterium *Streptomyces*.

A large number of antibiotics are now made synthetically rather than from culturing micro-organisms.



Antibiotics like penicillin are made by fungi and other microbes. They play a very important part in medical treatment of illnesses.

USES OF ANTIBIOTICS

1. Primarily, the antibiotics find a wide use in medicine to **fight infections**.
2. Certain antibiotics are used as **food preservatives**, specially fresh meat and fish.
3. Some are used in **treating animal feed** to prevent internal infections.
4. Some antibiotics are used for **controlling plant pathogens**.

HOW IS IT ?

You may be curious to know how the antibiotics kill the germs. Here are two examples.
***Penicillin* interferes with the cell wall formation and hence the bacteria are unable to grow and multiply.**
***Streptomycin* binds to bacterial ribosomes which are then unable to synthesise proteins and the bacteria are unable to grow and multiply.**

13.7 SULPHONAMIDE GROUP OF MEDICINES

Since ancient times, man has been trying to discover newer and newer medicines to cure diseases. He tried a variety of plant and animal products, many of which worked well. He also tried various chemical substances, and some of these yielded good results. This is how the kind of treatment *chemotherapy* (treatment by the use of chemicals) was developed.

In 1910, a drug called *salvarson* (based on an arsenic compound) was produced. It killed the germs of syphilis as well as of sleeping sickness. But frequently, it proved poisonous to the patient as well.

In the 1930s, a group of chemicals known as ***sulphonamides*** were discovered which proved effective in many types of bacterial diseases. Sulphadiazine and sulphanilamide are two such sulpha drugs. These are synthetic drugs and they interfere with the metabolism of bacteria which are thus killed.

Sulphonamides are now rarely used, and that too, in combination with antibiotics, for certain ailments.

PROGRESS CHECK

1. Correct the following statements if they are false (without changing the first word).
   (i) DDT is an antiseptic.
   .....
   (ii) Penicillin is a disinfectant.
   .....
   (iii) Disinfectants are applied on the body.
   .....
   (iv) Deodorants are both antiseptic as well as disinfectants.
   .....
   (v) Alexander Fleming discovered the first sulphonamide.
   .....
   (vi) Antibiotics cannot be made synthetically.
   .....
   (vii) Sulphonamides are now rarely used.
   .....
2. List any three uses of antibiotics.
   .....

13.8 FIRST AID

Health emergencies may sometimes suddenly arise in numerous ways. Some such situations could be as follows :-

1. **Serious cuts on the body**
2. **Breaking of a bone**
3. **A particle falling in the eye**
4. **Sudden unconsciousness**
5. **A heart attack**
6. **Burns of various kinds**
7. **Swallowing a poisonous substance**
8. **Drowning accident.**
9. **Bitten or stung** by poisonous animals or insects.
10. **An electric shock**

In all such cases, whatever is needed to be done **before the doctor arrives** or **the patient is taken to the nearest available hospital** or a dispensary. comes under First Aid. Some such treatments can be as follows :

1. **Bleeding :** In the case of bleeding, raise the affected part to minimise gravitational outflow of blood. Wash the cut surface with clean water, press the area with a piece of clean cotton wool, and if possible, apply some mild antiseptic.
2. **Fractures :** In the case of fractures, lay the victim comfortably, loosen or remove the clothes from the affected part. Do not move the part/parts fractured. If the fractured part is an arm, tie a sling to rest the arm in it.
3. **Eye :** Should anything fall in the eyes, do not rub. Wash gently with clean water by sprinkling it into the eye.
4. **Unconsciousness :** If someone falls unconscious, immediately lay the person comfortably on the bed. Loosen the clothes. Let fresh air come into the room.
5. **Heart attack :** In the case of heart attack, immediately lay the person straight horizontally, allow fresh air to come in and get medical help immediately.
6. **Burns :** In the case of minor burns, immediately wash the part with sufficiently cold water for a few minutes. Do not rub the part. Apply cream/ ointment specially recommended for burns, in case they are readily available.
7. **Swallowing poison :** In case some poisonous substance has been swallowed, make the patient drink as much salt water as possible, even forcibly, and try to induce vomiting.
8. **Snake bite :** In case of a snake bite, immediately squeeze out some blood from the wound, tie a tourniquet above the site to prevent spreading of venom into the body.
9. **Stinging :** In case of a sting by a bee, or a wasp, pull out the sting if still in the wound, squeeze out some blood to force out the venom. Apply some alkali, like baking soda or lime.

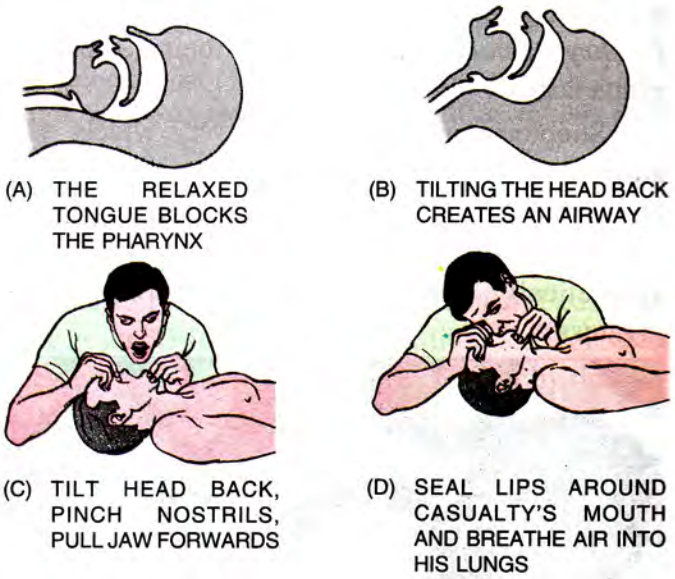


Fig. 13.4 : Mouth-to-mouth resuscitation (revival)

10. **Artificial Breathing :** A person may stop breathing in accidents such as drowning, **electric shock**, or due to head injury. Breathing must immediately be restored to save life. This is done by inducing breathing by artificial means. One such method is shown in Fig. 13.4.

In drowning, if the victim has drunk much water, some even goes into the lungs, immediately lay the victim with his back facing upward and the head tilted towards one side. Press the back repeatedly to force the water out. When all the water has gone out, start giving artificial breathing immediately.

The following steps should be followed while giving artificial breathing :

— Lay the victim flat on his back and put a pillow or folded towel under his shoulders in a way that his chest is raised and the head thrown back.

— Sit just near the victim's head and hold his arms. Draw the arms upwards and backwards. This will cause his chest to expand and draw the air.

— Next, fold the victim's arms and press them against the ribs. The air will now be expelled.

— Repeat the two steps at the rate of about 15 times per minute. Continue till the victim starts breathing without any extra help or till the doctor arrives.

REVIEW QUESTIONS

A. MULTIPLE CHOICE TYPE

(Select the most appropriate option in each case)

1. Penicillin is
   (a) an antiseptic (b) a disinfectant
   (c) an antibiotic (d) an anti-toxin
2. "T" in DTP vaccination stands for
   (a) Tuberculosis (b) Typhoid
   (c) Tetanus (d) Tonsilitis
3. World Health Day is celebrated on
   (a) January 15 (b) February 21
   (c) April 7 (d) October 10

B. VERY SHORT ANSWER TYPE

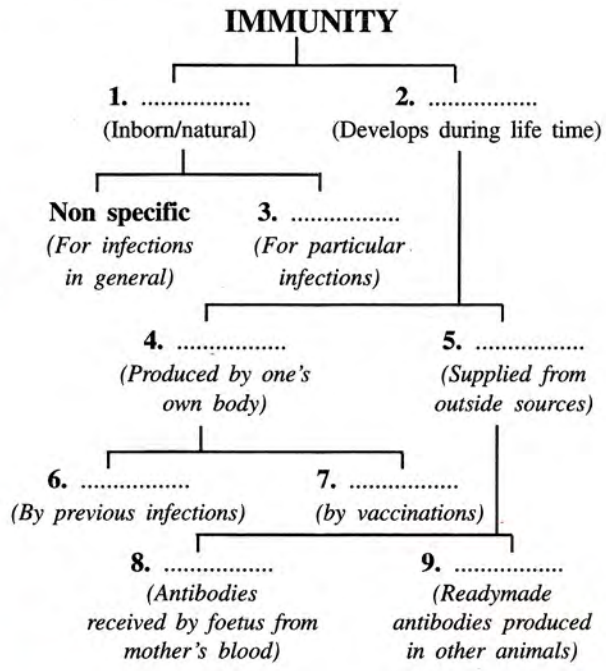
1. **Name** the following :
   (a) The drug based on arsenic compound, produced in 1910 which killed germs of syphilis.
   (b) The antibiotic that was discovered first.
   (c) The category of immunity required in the treatment of snake-bite.
   (d) Any four antiseptics, any two disinfectants and any two antibiotics.
   (e) The vaccine that helps to produce immunity against Polio.
2. **Write** the full forms of : (i) AIDS (ii) BCG (iii) DPT vaccine (iv) WHO
3. Give the **technical term** for the kind of proteins produced in the blood to fight and destroy harmful microbes.
4. **Name** the following :
   (a) Device used to check bleeding.
   (b) Support tied to arm in case of fracture.
   (c) A substance to neutralise the effect of poison.
   (d) Chemical substance which destroy microorganisms and prevent their further growth.
   (e) The treatment given to a person who has stopped breathing.

C. SHORT ANSWER TYPE

1. **Mention** if the following statements are ***true*** (T) or ***false*** (F).
   (a) Lysol is an antibiotic. (T/F)
   (b) Sweat and tears contain germs-killing substances. (T/F)
   (c) Our body can make only a limited variety of different antibodies. (T/F)
   (d) Salk vaccine is used against tuberculosis. (T/F)
   (e) Treatment by the use of chemicals is known as allopathy. (T/F)
   (f) Alexander Fleming coined the term "antibiotic" for substances like penicillin. (T/F)
2. **Differentiate** between :
   (a) Antiseptic and antibiotic,
   (b) Antiseptic and disinfectant,
   (c) Disinfectant and deodorant,
   (d) Vaccination and sterilisation
   (e) Active immunity and passive immunity,
   (f) Innate immunity and acquired immunity.
3. **Name** any three vaccines and the diseases for which they provide immunity.
4. **Given** below is a table of certain vaccines, the diseases against which they are used and the nature of vaccine. Fill up the gaps 1 - 10.

Vaccine	Disease(s)	The nature of vaccine
TAB	1.	2. .....
Salk's vaccine	3	4. .....
BCG	5.	Living weakend germs
Vaccine for measles	Measles	6. .....
Cowpox virus	7.	8. .....
Toxoids	9.	Extracts of toxins
	10.	secreted by bacteria

5. **Given** below is a scheme of classifying immunity against human diseases. Fill up the **types of immunity** in the blanks 1 - 9.



6. **Given** below are the groups of certain substances of particular categories. Mention the category of each group and identify the one **wrong** example in it giving reason.
   (a) Lysol, benzoic acid, DDT, mercurochrome.
   (b) Formalin, iodine, lysol, phenol.
   (c) BCG, DTP, ATP.
   (d) Tears, skin, nasal secretion, HCl (in stomach).
7. **List** any four ways in which antibiotics are being used.
8. **List** the merits of local defence systems.
9. Suppose a person develops the disease diphtheria. **Comment** upon the principle of the treatment he should receive.
10. **What** first aid steps would you take in the following cases of accident?
    (a) Bleeding from a cut in the skin.
    (b) A fractured arm.
    (c) Stoppage of breathing due to electrical shock.

D. LONG ANSWER TYPE

1. The principle of vaccination is to produce immunity against a disease. **Explain**.
2. "Abnormally, large number of WBCs in the blood are usually an indication of some infection in our body." **Comment** on the statement.
3. **Explain briefly**, the role of the following health aids:
   (a) Antiseptics (b) Disinfectants (c) Vaccines
4. Define first aid.
5. Describe briefly the first aid treatment you would carry out in the following cases:
   (a) Little toe in the foot is pierced by a thorn and is bleeding.
   (b) An elderly woman walking on the footpath during a hot mid-day has fallen unconscious.
   (c) A young boy has burnt his finger tip while firing crackers.
   (d) Your gardener has been bitten by a snake while digging soil in the flower bed.
   (e) Your friend has received an electric shock.
   (f) Your little brother has swallowed a poisonous liquid.
6. Name any **five** antibiotics. State their source and the disease against which they are used.

AN EXAMPLE OF SCIENTIFIC REASONING

An idea : Hello little brother! Can you hear me ?
A lovely ice cream waiting for you!

?

Science : Can a baby in the mother's womb hear what we speak??
&
Does the unborn baby understand the language one speaks English, Hindi, Tamil, Chinese or any other language ?

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14 Health Organisations

Syllabus : *Health organisations : Red Cross, WHO; common health problems in India.*

Scope of Syllabus : Major activities of Red Cross and WHO should be discussed. Common health problems in India.

Health is one of the primary concerns of all the governments of the world. They strive to take steps individually at the national level as well as collectively at the global level to safeguard the health interests of their people. This chapter is aimed at familiarising the students with two main organisations, namely the Red Cross and WHO.

14.1 COMMON HEALTH PROBLEMS IN INDIA

India is a vast country. It has highly diverse geographical and climatic conditions. Its population is distributed in broadly five types of habitations :

1. **Big cities.** These have multi-storeyed buildings, too many vehicles, heavily burdened water supply and sewage systems, some with lots of industries, either inside the township or outside.
2. **Small towns.** Not so crowded.
3. **Villages.** Small population, agriculture based; dairies, poultry farming, cottage industries, etc. are the main sources of livelihood.
4. **Remote areas.** Tribal people, mostly thriving on forests and forest products; neither proper drinking water nor any medical facility is available.
5. **Slum-dwellings.** Slums and Jhuggi-Jhompris are a common sight at all places specially on the outskirts of big cities. Unhealthy, unhygienic conditions prevail in them.

Health problems. The health problems differ in each kind of habitation. However, we may generalise them as follows :-

(A) Food and water borne diseases.

Several diseases specially **diarrhoea, gastroenteritis, typhoid, dysentery**, are very common in areas deficient in proper water supply. At many places, water from hand-pumps and other sources is contaminated.

At certain places, harmful mineral contents in water obtained through wells or hand-pumps cause health problems.

Untreated sewage or effluents from industries poured into rivers and other water bodies harm the people living alongside.

(B) Insect and air-borne diseases.

The public in general, and specially the uneducated village folk, are not conscious of the flies which alight on exposed food stuff and contaminate them.

Lack of general cleanliness leads to breeding of houseflies, mosquitoes, and other insects which cause diseases.

Some common insect and air-borne diseases:

Insect-borne diseases

Houseflies : Dysentery, Cholera, Diarrhoea, Typhoid. (All due to contamination of food by the flies sitting on it)

Mosquitoes : Malaria, Dengue fever, Filariasis (Pathogen transferred by mosquito bite)

Rat flea : Plague (Through rat flea bite)

Air borne diseases

1. Tuberculosis
2. Whooping cough
3. Pneumonia

} By inhaling the droplets, dust particles into the lungs.

4. Diarrhoea (Air coming in contact with food)

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(C) Lack of Medical facilities.

Preventive immunisation is catching up, but still needs to be carried out more effectively.

Lack of medical facilities, specially in the rural areas, often leads to avoidable deaths and damage to health.

Lack of knowledge and superstitious beliefs delay the timely treatment which leads to serious consequences.

(D) Professional hazards.

Certain health problems are related with child labour which is rampant in the carpet industry, fireworks industry, glass bangles manufacturing units, etc. The real cause lies in the economic compulsion.

? ***PROGRESS CHECK***

1. Name any two common water-borne diseases :
   .....
2. Mention any two health problems of each of the following :
   (i) Villagers .....
   (ii) Slum dwellers .....
   (iii) Forest tribal people .....

14.2 CATEGORIES OF HEALTH ORGANISATIONS

Every country is concerned about the health and well being of its people. For achieving this goal, several kinds of organisations have been working at different levels. We can broadly classify them into three categories on the basis of the level at which they work :

A. Local bodies
B. National organisations
C. International organisations

14.3 LOCAL BODIES

All cities, towns and even the larger villages have some kind of a local body to look after the health and sanitation of their people. These include **Municipal Corporations, Municipalities, Town Area Committees**, etc. They have regular staff and equipment for looking after the following :

1. **Sanitation :** Removal and proper disposal of garbage, sewage and other wastes, elimination of breeding places of flies, mosquitoes, etc.
2. **Supply of safe drinking water**
3. **Vaccinations :** Immunisation (developing resistance to diseases) of the infants and others to protect them from several infectious diseases such as tetanus, pertussis (whooping cough), diphtheria, tuberculosis, poliomyelitis, measles, etc. These programmes are intensified whenever there is a risk of an epidemic breaking out.
4. **Keeping statistical records :** Apart from compulsory registration of births and deaths, every other kind of information about the health and diseases of the people in their area is to be regularly maintained.

14.4 NATIONAL BODIES

In India, several agencies, Institutes and Research Centres are actively engaged in studying the health problems of the country. These centres are in particular working on the following diseases :

1. Malaria
2. Dengue
3. Tuberculosis
4. Leprosy
5. Cholera

For each such disease, they undertake a regular survey, identification of the transmitting agent and its breeding places, arranging prophylactic immunisation, and any other kind of steps to be taken to fight against the respective diseases.

National Institute of Communicable Diseases (NICD) (earlier known as Malaria Institute) located at Delhi is seriously engaged in doing research on infectious diseases.

An extensive national programme under "Pulse Polio" has been launched to fully eradicate poliomyelitis.

14.5 INTERNATIONAL BODIES

Two most important International bodies concerned with people's health are:

1. Red Cross
2. WHO (World Health Organisation)

14.5.1 Red Cross

The Red Cross is a national as well as an International agency. The main function of Red Cross Society is to perform activities which should prevent or remove human sufferings in peace time as well as

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at the time of war. It was formally founded in 1864. The emblem of the Red Cross Society is a red-coloured cross painted on a white background.

Fig. 14.1 : The emblem of the Red Cross

People belonging to the Red Cross can go to battlefields and take care of the wounded soldiers whether friends or enemies. Major activities of Red Cross Societies are as follows:

1. To extend relief and help to the victims of any calamity — flood, fire, famine, earthquakes, etc.
2. To procure and supply blood for the needy victims of war or other calamities.
3. To extend all possible first-aid in any accident.
4. To educate people in accident prevention.
5. To arrange for ambulance service in all emergencies.
6. To look after maternal and child welfare centres.
7. The Indian Red Cross Society has also been engaged in training midwives.

Red Cross Day
8, May

WRONG USE OF RED CROSS

This Red Cross emblem is very often used by hospitals, ambulances, doctors and nurses for quick identification but legally, it is wrong. Only the Red Cross Society units can use it.

14.5.2 WHO (World Health Organisation)

The World Health Organisation (WHO) established in 1948, is a specialised agency of the United Nations Organisation (UNO).

Reasons for the formation of WHO

Member countries of the UNO focused on the need for creating an international body to look after the health problems of people of the world. This was particularly felt in the field of research on the causes and cures of diseases. The combined efforts in this direction were to give better and faster results. The poor and developing countries were to benefit quickly.

WHO has six regional offices in the world including one in Delhi. Each regional office works for its member countries. Its headquarters are located in Geneva. Member states of WHO are bound by the International Sanitary Regulations to send in all relevant information about the Internationally notifiable diseases. Malaria and small-pox are two such notifiable diseases.

Main activities of WHO are as follows :

1. To **collect** and **supply information** about the occurrence of diseases of epidemic nature (such as cholera, plague, typhus, yellow fever, small pox, etc.).
2. To promote and support **projects for research** on diseases.
3. To supply information on **latest developments about the use of vaccines**, cancer research, nutritional discoveries, control of drug addiction and about health hazards of nuclear radiation.
4. To suggest **quarantine measures** (isolation of patient) to prevent spread of disease to others.
5. To lay **pharmaceutical standards** for important drugs, to ensure purity and size of the dose.
6. To **organise campaigns** for the control of epidemic (widespread) and endemic (local) diseases. [One example of an endemic disease is the simple goitre due to iodine deficiency].

? ***PROGRESS CHECK***

1. In which year was WHO established ?

   .....

2. Name the world organisations concerned with the following :

   (i) Campaigning for control of endemic goitre

   .....

   (ii) Supplying food and other facilities to children in schools

   .....

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REVIEW QUESTIONS

A. MULTIPLE CHOICE TYPE

(Select the most appropriate option in each case)

1. Red Cross Day is celebrated on
   (a) May 8 (b) June 23
   (c) September 17 (d) November 21
2. WHO headquarters are located in
   (a) Paris (b) Berlin
   (c) Geneva (d) New York

B. VERY SHORT ANSWER TYPE

1. **Name** the organisation responsible for the following :
   (i) To extend relief to victims of earthquake
   .....
   (ii) To lay pharmaceutical standards for important drugs
   .....
   (iii) Arranging ambulance in emergencies
   .....
   (iv) To suggest quarantine measures
   .....
   (v) Training of midwives
   .....
   (vi) Procuring and supplying blood for transfusion.
   .....
2. **Name** any two habitation based health problems.
3. **What** do the following abbreviations stand for ?
   (a) WHO (b) UNO
4. **Mention** if the diseases listed below **are** correctly matched (True or False). Write the **correct alternative for the wrongly matched**.

Disease	Agent	T/F	Correct alternative, if wrong
Malaria	Housefly	.....	.....
Typhoid	Housefly	.....	.....
Cholera	Droplets in air	.....	.....
Tuberculosis	Mosquito	.....	.....
Whooping cough	Air borne	.....	.....
Pneumonia	Houseflies	.....	.....
Dengue fever	Rat flea	.....	.....

C. SHORT ANSWER TYPE

1. **List** any three responsibilities of City Municipalities in caring for people's health.
2. **List** any three **health problems** in India.
3. **State** two functions of WHO.
4. **State** the main functions of Red Cross.
5. **State** the main functions of World Health Organisation.
6. **List** four major activities of the Red Cross.

D. LONG ANSWER TYPE

1. **Describe** the reasons for the formation of WHO.

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15 Pollution — A Rising Environmental Problem

Syllabus : *(i) Types of pollution – air, water (fresh and marine), soil, radiation and noise.* **Self explanatory.**

(ii) Sources of pollution and major pollutants.

(iii) Effects of pollution on climate, environment, human health and other organisms and its abatement. Greenhouse effect and global warming, Acid rain, Ozone layer depletion.

Meaning of the terms, causes, effect on life on earth, idea about setting standards - ***Euro/Bharat stage vehicular standards.***

Scope of Syllabus : Sources of pollution and major pollutants.

Air : Vehicular, industrial, burning garbage, brick kilns.

Water : Household detergents, sewage, industrial waste, oil spills, thermal pollution.

Soil : Industrial waste, urban commercial and domestic waste, chemical fertilizers, biomedical waste like needles, syringes, soiled bandages etc., biodegradable waste like paper vegetable peels, etc., non-biodegradable waste like plastics, glass, styrofoam, etc, pesticides like DDT etc.

Radiation : X-rays, radioactive fall out from nuclear plants.

Pollution is a serious problem of the modern times due to very rapid advancement in several areas such as industries, transport, agriculture, residential set-ups, thermal and nuclear power generation plants. It is causing deterioration and even poisoning of the environment including air, water and soil. It is posing a serious threat to human health as well as to almost all kinds of our surroundings.

15.1 POLLUTION

POLLUTION

Pollution is the addition of any such constituent to air, water or land which deteriorates the natural quality of the environment.

AND

Pollutant is any such constituent which causes pollution.

Types of pollution

There are *five* major types of pollution :

1. Air pollution
2. Water pollution
3. Soil pollution
4. Radiation
5. Noise

15.2 AIR POLLUTION

Air pollution means degradation of the air quality harmfully affecting the living organisms as well as certain objects.

Types of air pollution

The air pollution is basically of *two* types :

1. **Gaseous pollution :** Harmful gases given out from a variety of sources.
2. **Particulate pollution :** Particles such as those of dust, smoke, mining, stone drilling, wearing of rubber tyres of motor vehicles.

Sources of air pollution

1. **Natural sources**

   Examples : Ash from burning volcanoes, dust from storms and forest fires.

   These pollutions are beyond human control and will continue to occur.

2. **Man-made sources**

   Examples : Vehicular (automobiles), industries, garbage, brick kilns. These are the four major sources which, to a great extent, are under human control and the methods for controlling them are being developed.

15.2.1 Vehicular Air Pollution

There are various kinds of vehicles — the motor cars, trucks, buses, scooters, tractors, motor cycles, railway engines, etc. They are mostly running on petrol and diesel. The exhaust given out contain three main **gaseous pollutants** : CO_2, SO_2 and CO. Simultaneously, there is the wearing of rubber tyres of the automobiles releasing **rubber particles** and furthermore, the speeding vehicles also raise the **road dust particles** into the air. You must have also experienced a lot of dust raised when the road cleaners sweep the roads every morning.

GASES (Exhaust)

TYRE PARTICULATE AND DUST

Fig. 15.1 Particulate and gaseous emissions from an automobile.

Control : Efficient engines, good quality automobile fuels, lead-free petrol, greater use of compressed natural gas (CNG).

15.2.2 Industrial Air Pollution

The whole world is undergoing extensive industrial revolution. It ranges from small scale pottery and carpet weaving units to huge sugar factories, cloth factories, metal factories, automobile manufacturing units, drug manufacturers, oil refineries and so on. They give out all kinds of pollutants.

The chief industrial **gaseous pollutants** again consist of CO_2, SO_2 and CO and also oxides of nitrogen.

The smoke released by the factory chimneys into the air contains lot of **particulate pollutants**.

Fig. 15.2 Smoke from factory chimneys

Stone drilling and mining (coal, metals, etc.) produce fine particles which pose serious health hazards to the labourers involved.

SMOG (Smoke plus Fog)

The smoke released from various sources may get mixed with dust particles and small drops of fog to produce what is called **smog**. Smog is harmful to plants and, if inhaled, may cause asthma and allergies is humans.

15.2.3 Burning Garbage

The garbage mainly consists of items such as peelings of vegetables and fruits, shells taken off from dry fruits, washings of pulses, rice, etc., and also the leftovers in food dishes. Such waste is either used in composting (making manure for agricultural use) or burnt in special enclosures. On **burning**, the garbage releases CO_2 and some other **harmful gases** too. The smoke given out adds to the **particulate** air pollution.

15.2.4 Brick Kilns

Brick kilns (**Hindi :** *"eenton ke bhatte"*)

The brick kilns are fire-heated enclosures for making construction bricks. Raw moist clay bricks are arranged in heaps with fire-wood in between and then covered by layer of some special mud mixture to contain the burning flames inside. This set-up is left for a few days. The smoke collecting inside is released through a hole. On opening, the original mud-coloured bricks are found to be red, and there is a huge quantity of ash. The wastes produced are large quantities of ash and broken brick bits. These are all pollutants, which are either somehow reused or just dumped. Lot of smoke and heat given out are the pollutants.

? ***PROGRESS CHECK***

1. Mention whether the following statements are ***true*** (T) or ***false*** (F)
   (i) Pollution and pollutant are one and the same thing. (T/F)
   (ii) Rubber tyres of motor vehicles contribute to particulate pollution. (T/F)
   (iii) The chief gaseous air pollutants are CO_2 and SO_2. (T/F)
   (iv) Kitchen garbage and leftovers in food dishes can be used for making manure (compost). (T/F)
   (v) Brick kilns give out both gaseous and particulate pollutants. (T/F)

2. Name any *four* ways to control vehicular air pollution.
3. Name any *two* small scale industries that can be the source of particulate air pollution.
4. Give *two* examples of gaseous air pollutants.

15.3 WATER POLLUTION

Water pollution means any change in the water quality which makes it unsuitable for use by humans and by other living organisms.

Sources of water pollution

The five major sources of water pollution are as follows :

1. Household detergents
2. Sewage
3. Industrial wastes
4. Oil spills
5. Thermal pollution

15.3.1 Household Detergents

Every home uses some detergents (cleansing agents) to wash and clean the soiled or worn garments, crockery, utensils, etc. The dirty water flows down the drains.

15.3.2 Sewage

Sewage is the liquid waste from domestic activities. It consists of kitchen wastes, toilet and other household waste water. Most cities have sewage treatment plants to remove the dirty part and release the cleaned fluid water into nearby water bodies or rivers. Small towns and villages may still be releasing their fluid wastes directly into some nearby large water body (river/lake).

[At some places, people are still following the practice of disposing off the dead bodies into the rivers, specially in India. If not the dead bodies, the ashes after cremation are very commonly immersed into rivers like Ganga at many places. We like it or not, such practices are sources of water pollution].

15.3.3 Industrial Waste

A large number of industries (small scale as well as large scale) produce waste water which contains various types of chemical pollutants. Such wastes are commonly discharged into the rivers. Fish processing industries set up near sea coasts release toxic wastes into the sea causing pollution.

15.3.4 Oil Spills

Oil spills are the accidential discharges of petroleum in oceans or estuaries. The sources of spills are the overturned oil tankers, offshore oil mining, oil refineries. Oil pollution kills a lot of marine life (fish, birds, etc.). Fig. 15.3 below shows a duck coated with oil.

Fig. 15.3 Oil spill affected duck.

15.3.5 Thermal Pollution

Many industries (thermal power plants, oil refineries and even nuclear power plants) use water for cooling their machinery. This hot waste water may be 8–10°C warmer than the intake water, and is released into the nearby streams, rivers or the sea and causes warming. This warming of water harmfully affects the animals (even killing the fish), and harms the plant life growing in it.

? ***PROGRESS CHECK***

1. Mention whether the following statements are ***true*** (T) or ***false*** (F)
   (i) Liquid kitchen waste alone constitutes the sewage. (T/F)
   (ii) Household detergents are safe and non-contributors to water pollution. (T/F)
   (iii) Industrial wastes mainly consist of chemical pollutants. (T/F)
   (iv) Thermal power plants give out a lot of hot waste water. (T/F)
   (v) Hot water discharged into water bodies hardly affects the fish and other aquatic life. (T/F)

15.4 SOIL POLLUTION

The soil pollution is largely localised whereas the air and water pollutions can spread to long distances. The major sources of soil pollution are :

1. Industrial wastes

2. Urban commercial and domestic waste
3. Chemical fertilizers
4. Biomedical waste
5. Pesticides

15.4.1 Industrial waste

In addition to releasing gaseous air pollutants and chemical-laden water, industries also give out much solid wastes. These wastes are in the form of **chemical residues, flyash, metallic ash,** etc.

15.4.2 Urban Commercial and Domestic Wastes ("Urban": Relating to Cities)

The cities and towns have a variety of markets — food grains, vegetables and fruits. They have tailors, restaurants, banquet halls giving out lot of solid waste in different forms. At home, we produce wastes in the form of plastic bags, glass bottles, electric bulbs, kitchen waste, paper-packaging, etc. All this is **solid waste**. It is collected by municipal workers and dumped for proper disposal — part of this can be converted into manure, and the rest can be dumped in sanitary landfills.

Sanitary landfills are the places where the wastes are dumped in a ground depression and covered with dirt every day.

15.4.3 Chemical Fertilizers

Chemical fertilizers (nitrates, phosphates, ammonium salts) help in faster and increased crop yield. But their excessive use is harmful. These fertilisers are slowly washed away by the rain water, to reach lakes and ponds. This leads to **faster growth of bacteria** which **consume lot of oxygen** in water resulting in the **death of fish and other water animals**.

15.4.4 Biomedical Waste

There are numerous items under this category:

- needles, syringes, dirty dressings, etc.
- unused discarded medicinal tablets and powders.
- discarded biological research materials carelessly disposed off in the municipal garbage.

Such waste often reaches the soil and may cause harm to soil organisms, and also to humans indirectly through some agents.

15.4.5 Pesticides

Several pesticides such as DDT were much used to kill pests in agricultural farms, godowns and even at homes. Most of these persisted (undegraded) in the environment as pollutants causing much harm to life indirectly. Presently, milder pesticides are being used, but even these are pollutants.

Pesticides such as DDT (dichloro-diphenyl-trichloroethane), used in agriculture to destroy pests alter the basic structure of soil, kill microorganisms in it and may even reach the human body through food grown in such soils. The killed microorganisms are mostly those that recycle the nutrients in the soil.

The wastes generated from the various sources described above can be categorised into two types :

(i) **Biodegradable waste.** Material which can be degraded (broken down) by microorganisms into relatively harmless compounds.
Examples : Paper, vegetable peels, food left-overs, sewage, cow dung, dried leaves, hay, etc.

(ii) **Non-biodegradable waste.** Material which cannot be degraded.
Examples : Plastic, glass, styrofoam (a kind of packing material) and pesticides like DDT.

? *PROGRESS CHECK*

1. Mention whether the following statements are ***true*** (T) or ***false*** (F)
   (i) Soil pollution is largely localised. (T/F)
   (ii) Flyash and metallic ash are examples of urban domestic waste. (T/F)
   (iii) Chemical fertilisers may reach the rivers but do not harm the fish. (T/F)
   (iv) Biomedical waste may consist of both biodegradable and non-biodegradable waste. (T/F)
2. List any *two* degradable and any *two* non-degradable medical wastes released from hospitals.

15.5 RADIATION

Radiation is a form of energy consisting of high energy particles. It is being used extensively in the fields of **medicine** (X-rays, etc.) and in generating electricity in the **nuclear power plants**.

X-rays contain a great deal of energy (measured in **photons**, the units of energy). They damage the body cells. Too frequent and too many X-ray exposures may cause serious health hazards (damaged chromosomes, genetic variations, bone cancer, etc.). X-ray machine operators have to take very special care to avoid exposure as much as possible.

Nuclear power plants can be the sources of leak of nuclear radiations either through the negligent disposal of wastes or by any accidental explosion of the plant. Two very serious nuclear plant explosions have occurred — one in Chernobyl (Ukraine) in 1986 and the other in Japan (Fukushima Daiichi Nuclear Plant) on 11, March 2011. So many people died and many more suffered radiation exposure causing health problems such as haemorrhaging and even cancers. The chief radiation pollutant was **Iodine 131**, which raises the risk of thyroid cancer. Radiation even leaked into the sea and reached humans passively through sea food.

Fig. 15.4 Recording radioactivity levels at a village, about 40 km from the Fukushima Daiichi nuclear power plant in Japan

Carelessly discarded radioactive material may cause severe damage as it happened in Mayapuri Delhi in 2010. The radioactive waste (Cobalt 60) from a research centre somehow reached the market streets through "kabaris". Several exposed people are still suffering and had even died. A Delhi resident sufferer from nuclear (Cobalt 60) radiation had ignorantly kept Cobalt 60 pencils in his back pocket, and suffered serious burns (Fig. 15.5).

Fig. 15.5 A cobalt 60 radiation sufferer from Delhi.

15.6 NOISE POLLUTION

Noise is defined as any unpleasant/loud undesired sound interfering with one's hearing and concentration.

Major sources of noise are the industrial machines, workshops, trains, automobiles on the streets, jet aircrafts landing and taking off in the air, loud conversation and the radio or television inside houses, the loudspeakers and musical bands in public places, and so on.

— If you are reading something seriously or solving a mathematical problem, even a mild conversation in the room becomes noise.

— But, if you are doing some light reading in a running train, you may not get disturbed.

Fig. 15.6 Noise pollution

Harmful effects of noise pollution :

1. **Interferes in communication.**
2. **Interrupts concentration of thought** and disturbs peace of mind.
3. **Lowers efficiency** of work.
4. **Disturbs sleep** and leads to nervous **irritability**.
5. A sudden loud sound can **damage ear drum**. **Prolonged noise** can even **lead to deafness**.
6. **Bird life** gets **disturbed** by aircrafts landing or taking off from airports.

Measures to minimise noise pollution :

— Prohibiting blowing of horns.

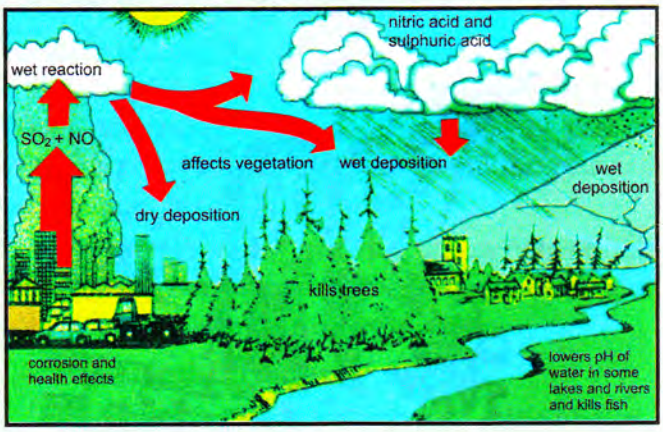
— Restriction on loud speakers, specially during night.

— Planting trees by the road side and keeping doors closed in the houses reduce noise reaching our ears.

— Not to burn fire crackers.

? PROGRESS CHECK

1. Mention whether the following statements are ***true*** (T) or ***false*** (F)
   (i) X-rays are a potential source of radiation pollution. (T/F)
   (ii) Unwanted disturbing sound, even if it is music next door, is noise. (T/F)
   (iii) People routinely working in noisy places are not much affected by noise. (T/F)
2. List any *three* common places which are potentially major noise producers.
3. Can you make out the pollutions shown below ?



15.7 EFFECTS OF VARIOUS TYPES OF POLLUTION

Pollution affects the environment, humans and other life in numerous ways. The more significant ones are as follows :

A. Effects on human health

- *Air pollution* causes respiratory problems, lung disorders. **Particulate lead** may cause blood cell shortage. **Smog** (smoke + fog) leads to asthma and poor visibility. The **exhaust gas SO_2** causes serious damage to the air passages in lungs (the disease bronchitis).
- *Water pollution* may lead to several diseases like cholera, jaundice and typhoid.
- *Soil pollution* may indirectly affect human health. The pesticides used in agricultural farming may cause health problems.

B. Effects on climate and environment

Pollution affects the climate and environment in several ways but the three most significant ones are : *(i)* Acid rain, *(ii)* Greenhouse effect and global warming and *(iii)* Ozone layer deplection

1. Acid rain

Normally the clean rain is only slightly acidic (pH of about 6) because of some CO_2 naturally present in the atmosphere. Due to increasing industrialisation there is lot of emission of CO_2, and sulphur dioxide (SO_2) and oxides of nitrogen which get dissolved in the rain drops falling on earth as rain. This is the **acid rain**.

Harmful effects of acid rain :

- Damage to vegetation by pollution of the soil.
- Decay of building material and paints.
- Erosion of ancient monuments, statues and sculpture by the acid reacting with the calcium.
- The fine particles (sulphates, nitrates) degrade visibility and harm the human health.
- Fish and other aquatic animals are harmed due to increased acidity of the water in such lakes/ rivers, *etc.*

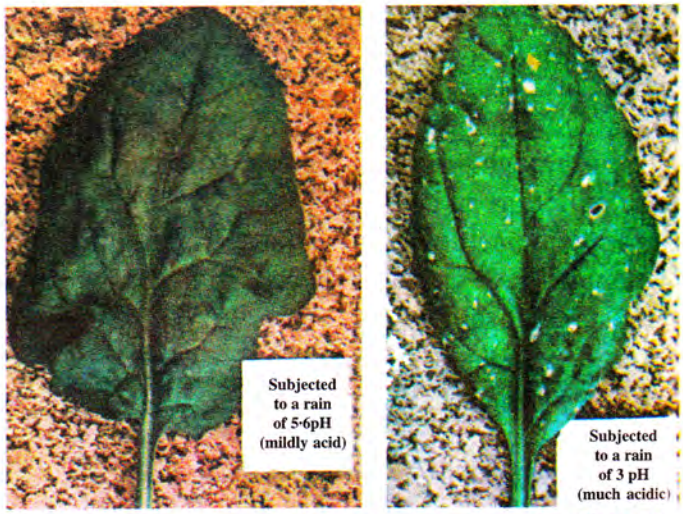


Fig. 15.7 : Result of an experiment to show the effect of acid rain on spinach leaves

2. Greenhouse effect and global warming

- *What is a greenhouse.* Greenhouses are small glass houses specially constructed to grow plants particularly during cold winters. The glass panel all around lets the sunlight enter but *does not*

allow the heat to escape. (You experience the same thing inside a car parked in sun for a few hours).

- Certain gases *specially* CO_2 and methane (CH_4) accumulating in the atmosphere prevent the escape of heat, thus *warming the air* (Greenhouse effect).
- With increased industrialisation, burning of fuels in homes, and rising population **more CO_2 is released**. On the other hand, the decreasing vegetation and deforestation is leading to **less CO_2 utilisation in photosynthesis**. Thus overall rise in CO_2 is leading to greater retention of the solar radiation in the atmosphere causing **global warming**.

  During the last three decades the temperature of the Earth atmosphere has increased by about 0·5°C. This is causing melting of snow caps, rise in sea level, as well as decline in food production in agricultural fields and in fishery resources in the oceans.

3. Ozone layer depletion

Ozone (O_3) is an allotropic form of oxygen (O_2). It forms a sort of sunscreen high up in the atmosphere. It prevents the harmful type of ultra-violet rays (UV-B) coming down from the sun. Certain gaseous compounds such as CFCs (chlorofluorocarbons) released from refrigerators, aerosol-sprayers and packing material styrofoam, rise into the atmosphere. There they break down into chlorine atoms which in turn breakdown **ozone** (O_3) **into oxygen** (O_2) and O. The reduced ozone cannot prevent the entry or harmful UV-B rays to the earth, which cause sun burn, genetic disorders, skin cancers and reduced productivity of forests and sea.

INTERNATIONAL OZONE DAY
September 16
[Do not disturb ozone layer].

15.8 ABATEMENT OF POLLUTION (*abatement : diminishing or nullifying*)

Pollution cannot be totally stopped but several steps can be taken to curtail it.

- Use of unleaded petrol and of CNG (Compressed Natural Gas) in automobiles.
- Switching of the automobile engines at red lights and when not in use.
- Installation of tall chimneys in factories, and fitting them with filters and, electrostatic precipitators.
- Treating industrial effluents before discharging them into water bodies.
- Not to throw food wastes into open ground or in the drains.
- Setting up of **sewage treatment plants** in larger habitations, and **septic tanks** in houses.
- Greater use of compost (organic matter) instead of chemical fertilisers, and judicious use of pesticides.
- Recycling of plastic, metal and glass material and incineration (burning) of non-recyclable waste.
- Planting of trees along roadside, waste land and mountainous slopes reduces soil erosion as well as improves the air quality (reduction of the amount of CO_2 in the atmosphere).

VEHICULAR STANDARDS :

Certain norms have been laid down under the title **Euro/Bharat norms** which are applicable to all automobiles, on the levels of emissions given out — stricter controls to be maintained in most large cities. Government of India has adopted auto fuel policy to effectively **cut down sulphur and nitrogen oxides** in the automobile exhausts.

? ***PROGRESS CHECK***

1. Mention whether the following statements are ***true*** (T) or ***false*** (F)
   (i) Diseases like cholera and jaundice are the results of **soil pollution**. (T/F)
   (ii) CO_2 and methane are **directly** contributing to global warming. (T/F)
   (iii) Erosion of ancient monuments and statues is caused by acid rain which itself is the result of gaseous pollution. (T/F)
   (iv) Use of unleaded petrol and compressed Natural Gas (CNG) in automobiles is one of the methods of abatement of gaseous and particulate air pollution. (T/F)

REVIEW QUESTIONS

A. MULTIPLE CHOICE TYPE

(Select the most appropriate option in each case)

1. Which one the following is an example of **pollutant** ?
   (a) A rat entering your kitchen.
   (b) CO_2 given out by the respiring organisms.
   (c) The heat given out while cooking food.
   (d) The dust raised during road-cleaning
2. Which one of the following is a "dirty" practice contributing to pollution and seriously needs stoppage by educating the public ?
   (a) Too loud marriage musical bands
   (b) Disposing of corpses in rivers
   (c) Floating lighted earthen lamps ("deeyas") in rivers
   (d) Wearing scented/perfumed clothes
3. One of the examples of radiation pollutants is
   (a) Sulphur dioxide
   (b) Ozone
   (c) Iodine – 131
   (d) Discarded fused electric bulbs

B. VERY SHORT ANSWER TYPE

1. Name the following pollutants :
   (i) A pollutant which is mainly responsible for causing acid rain
   (ii) Any two chemicals leading to the formation of ozone holes.
   (iii) The chemical element which caused minimata disease in Japan.
2. Match the items in column I with the closely related ones in column II.

Column I	Column II
(i) Chlorofluocarbons (CFCs)	(a) Global warming
(ii) Flyash	(b) Biodegradable
(iii) Cow dung	(c) Nuclear radiation pollutant
(iv) CO_2 and methane	(d) Acid rain
(v) Sulphur dioxide	(e) Industrial waste
(vi) Iodine – 131	(f) Ozone depletion

3. Fill in the blanks :
   (i) Rubber particles and dust raised by running motor vehicles are examples of ..... pollutants.
   (ii) Too frequent exposure to ..... in a medical diagnostic technique may damage chromosomes.
   (iii) Thermal power plants give out a lot of ..... waste water.
   (iv) Sewage is a liquid waste from ..... .

C. SHORT ANSWER TYPE

1. List two major harmful effects of each of the following :
   (i) Rivers contaminated with sewage.
   (ii) Too much gaseous exhausts containing CO_2 and SO_2.
   (iii) Pesticides such as DDT used in agriculture.
   (iv) Prolonged noise such as the one produced by crackers throughout night.
2. List the three major constituents of sewage.
3. What are the common sources of oil spills, and how do they affect sea life.
4. Mention any two measures to minimise noise pollution.

D. STRUCTURED/APPLICATION/SKILL TYPE

1. A lot of fish are dying near a sea shore. Describe any two possible causes.
2. Look at a cartoonist's presentation of a kind of pollution given below.
   (i) Name the kind of pollution.
   (ii) List the sources of pollution.
   (iii) Mention any two harmful effects of this pollution.