4

314en04

CELL – STRUCTURE AND FUNCTION

INTRODUCTION

All organisms are composed of structural and functional units of life called 'cells'. The body of some organisms like bacteria, protozoans and some algae is made up of a single cell whereas the body of higher fungi, plants and animals are composed of many cells. Human body is built of about one trillion cells.

Cells vary in size and structure as they are specialized to perform different functions. But the basic components of the cell are common to all biological cells. This lesson deals with the structure common to all types of the cells. You will also learn about the kinds of cell division and the processes involved therein in this lesson.

OBJECTIVES

After completing this lesson, you will be able to :

- *justify that cell is the basic structural and functional unit of all organisms;*
- *list the components of the cell and state cell theory;*
- *differentiate between prokaryotic and eukaryotic cells;*
- *differentiate between plant and animal cells;*
- *illustrate the structure of plant and animal cells by drawing labelled diagrams;*
- *describe the structure and functions of plasma membrane, cell wall, endoplasmic reticulum (ER), cilia, flagella, nucleus, ribosomes, mitochondria, chloroplasts, golgi body, peroxisome, glyoxysome and lysosome;*
- *describe the general importance of the cell molecules-water, mineral ions, carbohydrates, lipids, amino acids, proteins, nucleotides, nucleic acids, enzymes, vitamins, hormones, steroids and alkaloids;*
- *justify the need for cell division;*
- *describe various phases of cell cycle;*
- *explain the term karyotype and mention the karyotype analysis and its significance.*

4.1 THE CELL AND CELL THEORY

4.1.1 Landmarks in the study of a cell

Soon after Anton Van Leeuwenhoek invented the microscope, Robert Hooke in 1665 observed a piece of cork under the microscope and found it to be made of small compartments which he called "cells" (Latin cell = small room). In 1672, Leeuwenhoek observed bacteria, sperms and red blood corpuscles, all of which were cells. Much later, in 1831, Robert Brown, an Englishman observed that all cells had a centrally positioned body which he termed the **nucleus**.

4.1.2 The cell theory

In 1838 M.J. Schleiden and Theodore Schwann formulated the "cell theory." Which maintains that:

- all organisms are composed of cells.
- cell is the structural and functional unit of life, and
- cells arise from pre-existing cells.

The cells vary considerably, in shapes and sizes (Fig.4.1). Nerve cells of animals have long extensions. They can be several centimeter in length. Muscle cells are elongated in shape. Egg of the ostrich is the largest cell (75 mm). Some plant cells have thick walls. There is also wide variation in the number of cells in different organisms.

4.1.3 The Cell

A cell may be defined as a unit of **protoplasm** bound by a plasma or cell membrane and possessing a nucleus. Protoplasm is the life giving substance and includes the cytoplasm and the nucleus. The cytoplasm has in it **organelles** such as ribosomes, mitochondria, golgi bodies, plastids, lysosomes and endoplasmic reticulum. Plant cells have in their cytoplasm, large vacuoles containing non-living inclusions like crystals, and pigments. The bacteria have neither defined cell organelles nor a well formed nucleus. But every cell has three major components:

- plasma membrane
- cytoplasm
- DNA (naked in bacteria) and enclosed by a nuclear membrane in all other organisms

Two basic types of cells

Cytologists recognize two basic types of cells (Fig. 4.1). Their differences have been tabulated below in Table 4.1. Organisms which do not possess a well formed nucleus are **prokaryotes** such as the bacteria. All others possess a well defined nucleus, covered by a nuclear membrane. They are **eukaryotes**.

Table 4.1 Differences between Eukaryotic and Prokaryotic cells

Eukaryotic cell (eu = true, karyon = nucleus)	**Prokaryotic cell** (Pro = early/primitive)
1. Nucleus distinct, with well formed nuclear membrane.	1. Nucleus not distinct, it is in the form of a nuclear zone 'nucleoid'. Nuclear membrane absent.
2. Double-membraned cell organelles (Chloroplasts, mitochondria, nucleus) and single membraned (Golgi apparatus, lysosomes, vacuole, endoplasm reticulum) are present	2. Single-membraned cell bodies like mesosomes present. Endoplasmic reticulum, plastids, nitochondria microbodies like lysosomes, and Golgi body absent.
3. Ribosomes - 80 S	3. Ribosomes - 70 S
4. Distinct compartments in the cell i.e. the cytoplasm and the nucleus	4. No compartments.
5. Depending upon the species number of chromosomes per nucleus varies from two to many.	5. There is only one chromosome per cell.
6. Each chromosome is linear with its two ends free.	6. The chromosome is circular and remains attached to cell membrane at one point.
7. Each chromosome has one linear double-stranded DNA complexed with histones	7. The chromosome has single double-stranded circular DNA molecule and is not associated with histones.
8. Each chromosome has one centromere that divides a chromosome into two arms. However, if the centromere is terminal, the chromosome would have only one arm	8. The chromosome lacks a centromere.

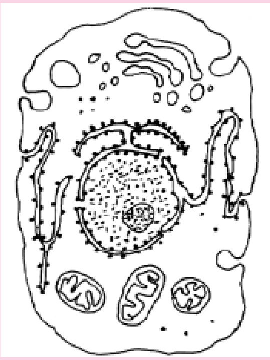


Fig. 4.1a Eukaryotic Cell

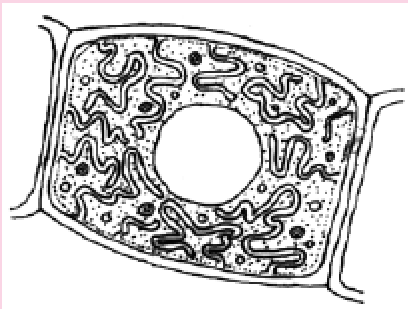


Fig. 4.1b Prokaryotic Cell

(As seen in an electron micrograph.)

Svedberg unit

When the cell is fractionated or broken down into its components by rotating in an ultracentrifuge at different speeds the ribosomes of eukaryotic and prokaryotic cells sediment (settle down) at different speeds. The coefficient of sedimentation is represented in Svedberg unit and is depicted as S.

The plant cell and the animal cell also differ in several respects as given in Table 4.2 and shown in Fig. 4.2.

Table: 4.2 Differences between plant cell and animal cell

Plant cell	Animal cell
1. Cellulose cell wall present external to cell membrane. 2. Vacuoles are usually large. 3. Plastids present. 4. Golgi body present in the form of units known as dictyosomes. 5. Centriole absent.	1. No cell wall, outermost structure is cell membrane or plasma membrane 2. Generally vacuoles are absent and if present, are usually small.. 3. Plastids absent. 4. Golgi body well developed having 2 cisternae 5. Centriole present.

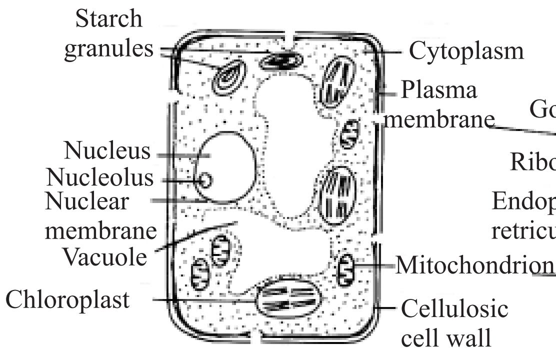


Fig. 4.2a Generalised plant cell

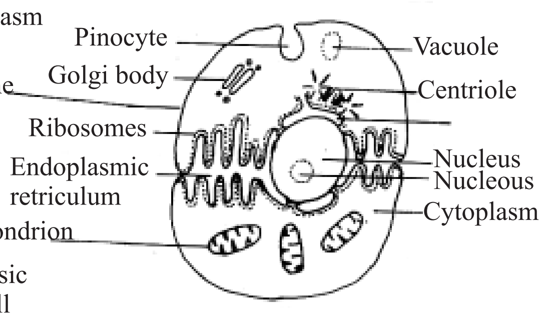


Fig. 4.2b Generalised animal cell

INTEXT QUESTIONS 4.1

1. From where do new cells arise?

   ....

2. Name the scientists who proposed the 'cell theory'.

   ....

3. Name an organelle which a plant cell has but an animal cell does not.

   ....

4. Give two points of difference between a prokaryotic cell and a eukaryotic cell

   ....

4.2 COMPONENTS OF THE CELL

The major components of the cell are (1) cell membrane, (2) cytoplasm, and (3) nucleus.

4.2.1 Cell membrane (Plasma membrane)

Each cell has a limiting boundary, the cell membrane, plasma membrane or plasmalemma. It is a living membrane, outermost in animal cells but internal to cell wall in plant cells.

It is flexible and can fold in (as in food vacuoles of *Amoeba*) or fold out (as in the formation of pseudopodia of *Amoeba*)

The plasma membrane is made of proteins and lipids and several models were proposed regarding the arrangement of proteins and lipids. The **fluid mosaic model** proposed by Singer and Nicholson (1972) is widely accepted. It is represented in Fig 4.3.

According to the fluid mosaic model,

(i) The plasma membrane is composed of a lipid bilayer of phospholipid molecules into which a variety of globular proteins are embedded.

(ii) Each phospholipid molecule has two ends, an outer head hydrophilic i.e. water attracting, and the inner tail pointing centrally hydrophobic, i.e. water repelling

(iii) The protein molecules are arranged in two different ways:

  (a) Peripheral proteins or extrinsic proteins: these proteins are present on the outer and inner surfaces of lipid bilayer.

  (b) Integral proteins or intrinsic proteins: These proteins penetrate the lipid bilayer partially or wholly.

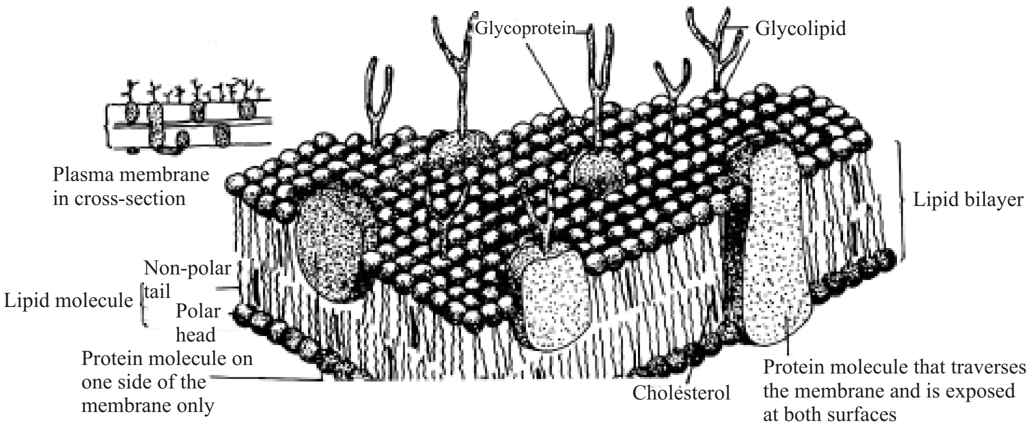


Fig. 4.3 The fluid mosaic model of cell membrane.

Functions

(i) The plasma membrane encloses the cell contents.

(ii) It provides cell shape (in animal cells) e.g. the characteristic shape of red blood cells, nerve cells, and bone cells.

(iii) It allows transport of certain substances into and out of the cell but not all substances so much it is termed '**selectively permeable**'.

Transport of small molecules (such as glucose, amino acids, water, mineral ions etc).

Small molecules can be transported across the plasma membrane by any one of the following three methods:

(i) **Diffusion** : molecules of substances move from their region of higher concentration to the regions of lower concentration. This does not require energy. Example : absorption of glucose in a cell.

(ii) **Osmosis:** movement of water molecules from the region of their higher concentration to the region of their lower concentration through a semipermeable membrane. There is no expenditure of energy in osmosis. This kind of movement is along concentration gradient.

(iii) **Active Transport:** When the direction of movement of a certain molecule is opposite to that of diffusion i.e. from region of their lower concentration towards the region of their higher concentration, it would require an "active effort" by the cell for which energy is needed. This energy is provided by ATP (adenosine triphosphate). The active transport may also be through a carrier molecule.

Transport of large molecules (bulk transport)

During bulk transport the membrane changes its form and shape. It occurs in two ways:

(i) endocytosis (taking the substance in)

(ii) exocytosis (passing the substance out)

Endocytosis is of two types :

Endocytosis

Phagocytosis	Pinocytosis
1. intake of solid particles 2. membrane folds out going round the particle, forming a cavity and thus engulfing the particle (Fig. 4.4a)	1. intake of fluid droplets 2. membrane folds in and forms a cup-like structure and sucks in the droplets (Fig. 4.4b)

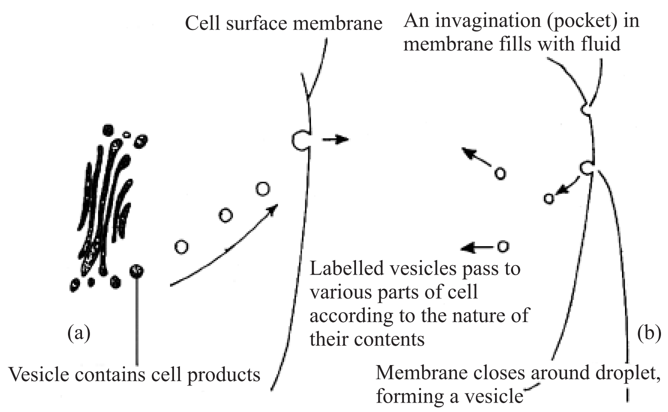


Fig. 4.4 Diagrammatic representation of (a) phagocytosis; (b) pinocytosis

Cell membrane regulates movement of substance into and out of the cell. If the cell membrane fails to function normally, the cell dies.

Cell wall

In bacteria and plant cells the outermost cell cover, present outside the plasma membrane is the **cell wall** about which we shall study now.

Bacterial cell wall is made up of peptidoglycan. Given below is the structure and function of the plant cell wall.

(a) Structure

- Outermost non-living layer present in all plant cells.
- Secreted by the cell itself.
- In most plants, it is chiefly made up of cellulose but may also contain other chemical substances such as pectin and lignin.
- The substance constituting the cell wall is not simply homogeneous but it consists of fine threads or fibres called microfibrils.
- It may be thin (1 micron) and transparent as in the cells of onion peel. In some cases it is very thick as in the cells of wood.

(b) Functions

- The cell wall protects the delicate inner parts of the cell.
- Being rigid, it gives shape to the cell.
- As it is rigid, it does not allow distension of the cell, thus leading to turgidity of the cell that is useful in many ways
- It freely allows the passage of water and other chemicals into and out of the cells
- There are breaks in the primary wall of the adjacent cells through which cytoplasm of one cell remains connected with the other. These cytoplasmic strands which connect one cell to the other one are known as **plasmodesmata**.
- Walls of two adjacent cells are firmly joined by a cementing material called **middle lamella** made of calcium pectinate.

INTEXT QUESTIONS 4.2

1. Define diffusion and osmosis.

   ....

2. What does active transport mean?

   ....

3. Give one point of difference between phagocytosis and pinocytosis.

   ....

4. Match the following :

(i)	hydrophilic end	(a)	cell wall
(ii)	microfibrils	(b)	inner ends of lipids
(iii)	fluid-mosaic model	(c)	fluid droplets
(iv)	hydrophobic end	(d)	outer ends of lipids
(v)	pinocytosis	(e)	Nicholson and Singer

5. Give two functions of the plant cell wall.
   (i) .... (ii) ....

4.3 THE CYTOPLASM AND THE CELL ORGANELLES

The cytoplasm contains many cell organelles of which we shall learn about :

1. those that trap and release energy e.g. mitochondria and chloroplasts;
2. those that are secretory or involved in synthesis and transport e.g. Golgi, ribosomes and endoplasmic reticulum
3. the organelles for motilily - cilia and flagella
4. the suicidal bags i.e. lysosomes
5. the nucleus which controls all activities of the cell, and carries the hereditary material

4.3.1 Mitochondria and chloroplast - the energy transformers

Mitochondria (found in plant and animal cells) are the energy releasers and the chloroplasts (found only in green plant cells) are the energy trappers.

Mitochondria (Singular = mitochondrion)

Appear as tiny thread like structures under light microscope. Approximately 0.5 - 1.00 μm (micrometer)

Number usually a few hundred to a few thousand per cell (smallest number is just one as in an alga, **Micromonas**.

Structure: The general plan of the internal structure of a mitochondrion observed by means of electron microscope is shown in Fig. 4.5. Note the following parts.

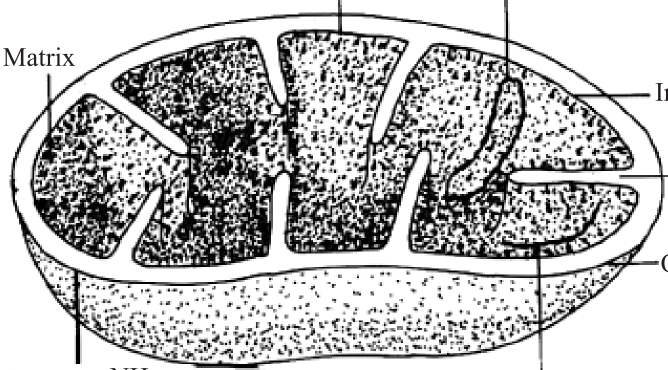


Fig. 4.5 Structure of a mitochondrion

- Wall made up of double membrane
- The inner membrane is folded inside to form projections called '*cristae*' which project into the inner compartment called the 'matrix'.

Function : Oxidises pyruvic acid (breakdown product of glucose) to release energy which gets stored in the from of ATP for ready use. This process is also called **cellular respiration**. That is why mitochondria are called the 'power house' of a cell.

A highly simplified flow-chart of the fate of glucose to release energy is shown below :

In cytoplasm. glucose enters cells (containing 6 atoms of carbon) — Broken into two Pyruvic acid molecules (containing 3 atoms of carbon) — In mitochondria Acetyl-Co-A is Oxidised into CO_2, H_2O and ATP

Plastids

Plastids are found only in a plant cell. These may be colourless or coloured. Based on this fact, there are three types of plastids.

(i) Leucoplast - white or colourless

(ii) Chromoplast – blue, red, yellow etc.

(iii) Chloroplast – green

4.3.2 Chloroplast

- Found in all green plant cells in the cytoplasm.
- Number 1 to 1008 (how so definite)
- Shape: Usually disc-shaped or laminate as in most plants around you. In some ribbon - shaped as in an alga *Spirogyra* or cup-shaped as in another alga *Chlamydomonas*.
- Structure: the general plan of the structure of a single chloroplast has been shown in Fig. 4.6.

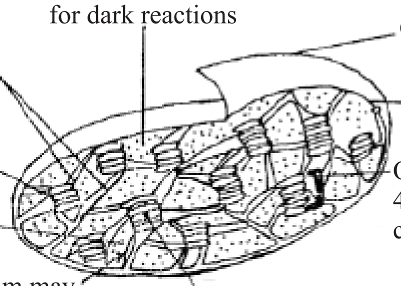


Fig. 4.6 Structure of a single chloroplast

Note the following parts :

- Wall made up of double membrane i.e. outer membrane and inner membrane numerous stack-like (piles) groups or *grana* (singular = granum) are interconnected by *lamellae*.
- Sac-like structures called thylakoids placed one above the other constitute a granum.

- Inside of the chloroplast is filled with a fluid medium called stroma.
- Function: chloroplasts are the site of photosynthesis (production of sugar, from carbon dioxide and water in the presence of sunlight).

Chloroplast versus mitochondria

Can you now visualize how these two organelles are opposite to each other, one traps the solar energy locking it in a complex molecule (by photosynthesis), the other releases the energy by breaking the complex molecule (by respiration).

Similarities between mitochondria and chloroplasts : both contain their own DNA (the genetic material) as well as their own RNA (for protein synthesis). Thus, they can self-duplicate to produce more of their own kind without the help of nucleus.

Thought the chloroplasts and mitochondria contain their own DNA the hereditary molecule and also their own ribosomes, they are termed as semi-autonomous only because they are incapable of independent existence outside the cytoplasm for a long time. Since most of their proteins are synthesised witht he help of the nuclear DNA.

INTEXT QUESTIONS 4.3

1. What is a cell organelle?

   ....

2. Name the chemical which provides energy trapped in its bonds to the cell.

   ....

3. Which part of the chloroplasts is the site of light reaction?

   ....

4. Name the sac like–structure which form the grana?

   ....

5. Why is mitochondrion called the "power house" of the cell?

   ....

6. Which organelle contains enzymes for cellular respiration?

   ....

7. State two similarities between mitochondria and chloroplasts.

   ....

8. Which plastid imparts colour to flower petals?

   ....

9. Which plastid is green in colour?

   ....

10. Why are mitochondria and chloroplast called semi-autonomous?

    ....

4.3.3 Endoplasmic reticulum (ER), golgi body and ribosomes

The Endoplasmic reticulum (ER) and Golgi body are single membrane bound structures. The membrane has the same structure (lipid-protein) as the plasma membrane but ribosomes do not have membranes. Ribosomes are involved in synthesis of proteins in the cell, Golgi bodies in secreting and the ER in transporting and storing the products. These three organelles operate together.

Fig. 4.7 and Fig. 4.8 show the diagram of ER and Golgi body as seen under an electron microscope. Note the ribosomes present in the ER.

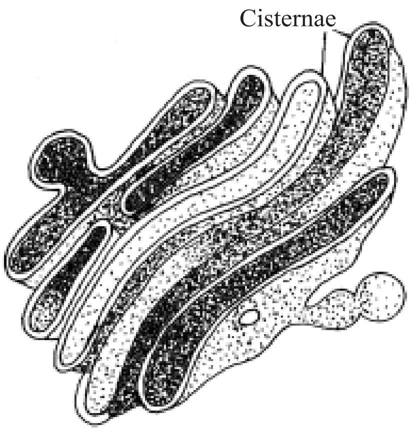


Fig. 4.7 Golgi body

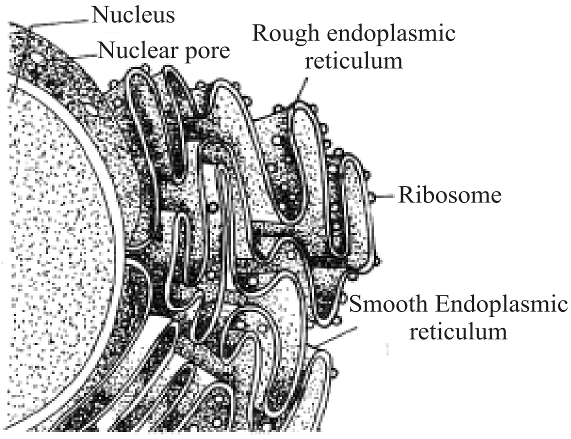


Fig. 4.8 Endoplasmic reticulum

Endoplasmic reticulum (ER)	Golgi body	Ribosomes
Structure		
A network of membranes with thickness between 50 - 60A°. It is of two types– rough endoplasmic reticulum (RER) i.e. when ribosomes are attached to it and Smooth endo-plasmic reticulum (SER) when no ribosomes are present.	Is a stack of membranous sacs of the same thickness as ER. Exhibit great diversity in size and shape.	Spherical about 150 - 250 Å in diameter, made up of large molecules of RNA and proteins (ribonucleo proteins)
Distributed hroughout the cytoplasm and is in contact with the cell membrane as well as the nuclear membrane.	In animal cells present around the nucleus, 3 to 7 in number. In plant cells, many in number of and present scattered throughout the cell called dictyosomes.	Present either as free particles in cytoplasm or attached to ER. Also found stored in nucleolus inside the nucleus. 80S types found in eukaryotes and 70S in prokaryotes (S-svedberg unit of measuring ribosomes).
Function		
Provides internal framework, compartment and reaction surfaces, transports enzymes and other materials through out the cell. RER is the site for protein synthesis and SER for steroid synthesis, stores carbohydrates.	Synthesis and secretion as enzymes, participates in transformation of membranes to give rise to other membrane structure such as lysosome, acrosome, and dictyosomes, synthesize wall element like pectin, mucilage.	Site for protein synthesis.

INTEXT QUESTIONS 4.4

1. Given below is a list of functions, relate them to their respective organelles:
   (a) synthesis of some enzymes ....
   (b) synthesis of steroids ....
   (c) storage of carbohydrates ....
   (d) Intracellular transport ....
   (e) Synthesis of proteins ....
2. Name the equivalent structure of Golgi body in plants. Mention two differences between their structures.
   (i) ………………………...…. (ii) ………….................…………
3. Mention any two advantages of the extensive network of endoplasmic reticulum.
   (i) …………………………….. (ii) ………………....………………
4. What are the three places where ribosomes occur in a cell?
   ....
5. Name the membrane system that connects the nuclear membrane with the cell membrane?
   ....

4.3.4 The microbodies (tiny but important)

These are small sac-like structures bounded by the single membranes. These are of different kinds of which we will take up three, viz. lysosomes, peroxisomes and glyoxysomes.

1. Lysosomes (lysis = breaking down; soma = body)

Lysosomes are present in almost all animal cells and some non-green plant cells (Fig 4.9). They perform intracellular digestion.

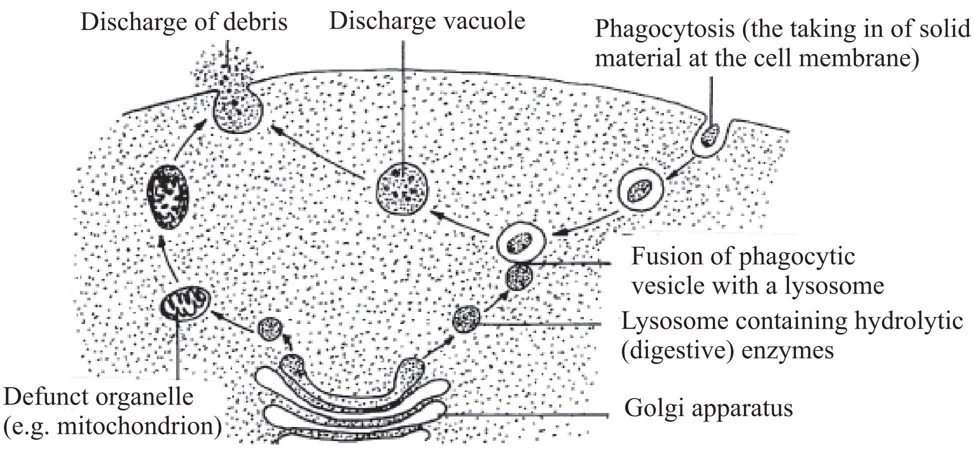


Fig. 4.9 Lysosomes

The main features of lysosomes are as follows :

(i) Membranous sacs budded off from Golgi body.

(ii) May be in hundreds in a single cell.

(iii) Contain several enzymes (about 40 in number)

(iv) Materials to be acted upon by enzymes enter the lysosomes.

(v) Lysosomes are called "suicidal bags" as enzymes contained in them can digest the cell's own material when damaged or dead.

Importance of intracellular digestion by the lysosomes

(i) help in nutrition of the cell by digesting food, as they are rich in various hydrolysing enzymes which enable them to digest almost all major chemical constituents of the living cell.

(ii) Help in defence by digesting germs, as in white blood cells.

(iii) Help in cleaning up the cell by digesting damaged material of the cell.

(iv) Provide energy during cell starvation by digestion of the own parts of the cells (autophagic, auto : self; phagos: eat up).

(v) Help sperm cells in entering the egg by breaking through (digesting) the egg membrane.

(vi) In plant cells, mature xylem cells lose all cellular contents by lysosome activity.

(vii) When cells are old, diseased or injured, lysosomes attack their cell organelles and digest them. In other words lysosomes are autophagic, i.e. self devouring.

2. Peroxisomes

Found both in plant and animal cells. Found in the green leaves of higher plants. They participate in oxidation of substrates resulting in the formation of hydrogen peroxide.

- They often contain a central core of crystalline material called nucleoid composed of urate oxidase crystals.
- These bodies are mostly spherical or ovoid and about the size of mitochondria and lysosomes.
- They are usually closely associated with ER.
- They are involved in photorespiration in plant cells.
- They bring about fat metabolism in cells.

3. Glyoxysomes

- The microbodies present in plant cells and morphologically similar to peroxisomes.
- Found in the cell of yeast and certain fungi and oil rich seeds in plants.
- Functionally they contain enzymes of fatty acid metabolism involved in the conversion of lipids to carbohydrates during germination.

INTEXT QUESTIONS 4.5

1. Why are lysosomes called suicidal bags?

   ....

2. List the usefulness of intracellular digestion by lysosomes

   ....

3. What is the function of peroxisomes in plant cells

   ....

4.3.5 Cilia and flagella (the organelles for motility)

(i) Some unicellular organisms like *Paramecium* and *Euglena* swim in water with the help of cilia and flagella respectively.

(ii) In multicellular organisms some living tissues (epithelial tissues) have cilia. They beat and create a current in the fluid in order to move in a given direction e.g. in the wind pipe (trachea) to push out the mucus and dust particles.

(iii) Cilia beat like tiny oars or pedals (as in a boat) and flagella bring about whiplash like movement.

(iv) Both are made up of contractile protein tubulin in the form of microtubules.

(v) The arrangement of the microtubules is termed as 9 + 2, that is, two central microtubules and nine duplet sets surrounding them.

Cilia	Flagella
shorter (5 to 10 µm)	longer (15 µm)
several 100 per cell structure : protoplasmic projection and membrane bound	usually 1 or 2 in most cells
consist of 9 sets of peripheral duplet microtubules and 1 set of two singlet tubules in the centre	same as in cilia

Centriole

It is present in all the animal cells (but not in *Amoeba*), located just outside the nucleus. It is cylindrical, 0.5 µm in length and without a membrane. It has 9 sets of peripheral triplet tubules but none in the centre (9 + 0). Each set has three tubules arranged at definite angles (Fig. 4.10). It has its own DNA and RNA and therefore it is self duplicating.

Function : Centrioles are involved in cell division. They give orientation to the 'mitotic spindle' which forms during cell division

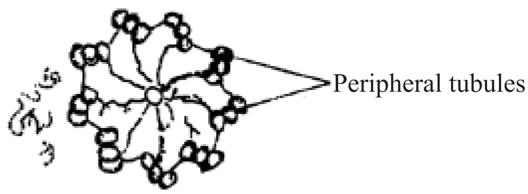


Fig. 4.10 Centriole (showing 9 + 0 structure)

Basal bodies

These are structures similar to centrioles. They have the same nine sets of triplet organization (9 + 0), as in the centrioles. The cilia and flagella appear to arise from the basal bodies.

4.4 NUCLEUS (THE HEREDITARY ORGANELLE)

General structure of the nucleus :

(i) It is the largest organelle seen clearly when the cell is not dividing.

(ii) It stains deeply, is mostly spherical, WBC have lobed nuclei.

(iii) It is mostly one in each cell (uninucleate, some cells have many nuclei; (multinucleate).

(v) Double layered nuclear membrane having fine nuclear pores encloses nucleoplasm which contains chromatin network and a nucleolus.

Functions

- Maintains the cell in a working order.
- Co-ordinates the activities of other cell organelles.
- Takes care of repair work.
- Participates directly in cell division to produce genetically identical daughter cells. This division is called mitotic cell division.
- Participates in production of meio-gametes and meiospores through another type of cell division called meiotic cell divisioin.

The parts of a nucleus are given here :

4.4.1 Nuclear membrane

- Double layered membrane is interrupted by large number of nuclear pores.
- Membrane is made up of lipids and proteins (like plasma membrane) and has ribosomes attached on the outer membrane which make the outer membrane rough.
- The pores allow the transport of large molecules in and out of nucleus, and the membranes keep the hereditary material in contact with the rest of the cell.

4.4.2 Chromatin

- Within the nuclear membrane there is jelly like substance (karyolymph or nucleoplasm) rich in proteins.
- In the karyolymph, fibrillar structures form a network called *chromatin fibrils*, which gets condensed to form distinct bodies called **chromosomes** during cell division. On staining the chromosomes, two regions can be identified in the chromatin material heterochromatin, dark and euchromaticn (light). Heterochromatin has highly coiled DNA and genetically less active than euchromatin which has highly uncoiled DNA and genetically more active.

- The number of chromosomes is fixed in an organism. During mitotic cell division chromosomes divide in a manner that the daughter cells receive identical amounts of hereditary matter.

4.4.3 Nucleolus

- Membraneless, spheroidal bodies present in all eukaryotic cells except in sperms and in some algae.
- Their number varies from one to few, they stain uniformly and deeply.
- It has DNA, RNA and proteins.
- Store house for RNA and proteins; it disappears during early phase of cell cycle and reappears after telophase in the newly formed daughter nuclei.
- Regulates the synthetic activity of the nucleus.
- Thus nucleus and cytoplasm are interdependent, and this process is equal to nucleo–cytopalsmic interaction.

INTEXT QUESTIONS 4.6

1. Why cannot the cell survive without the nucleus?

   ....

2. Explain the following terms:

   (a) chromatin network...... ....

   (b) chromosomes ....

3. What is the function of the nucleolus in the cell?

   ....

4.5 MOLECULES OF THE CELL

The cell and its organelles are made of organic chemicals such as proteins, carbohydrates, nucleic acid and fats. These are aptly termed biomolecules. Inorganic molecules such as water and minerals are also present in a cell.

A. Water

- Water with unique physical and chemical properties has made life possible on earth.
- It is a major constituent of protoplasm.
- It is a medium in which all the metabolic reactions occur.
- It is a universal solvent in which most substances remain dissolved sparingly or completely.
- It is responsible for turgidity of cells.

B. Elements necessary for life

Elements	Functions
Hydrogen, Carbon, Oxygen, Nitrogen, Calcium, Potassium, Sodium, Magnesium, Phosphorous, Sulphur, Chlorine, Iron, Boron, Silicon, Manganese, Copper, Zinc, Cobalt, Molybdenum, Iodine	1. Required for organic compounds of the cell and present as major constituents. (Ca in plant cell wall, C, H, O, N as organic compounds) 2. Act as major cations (Na, K) and anions (Cl) in most physiological processes. 3. As cofactor of enzymes participate in most of the biochemical reactions of a cell (Fe, Cu, Mo, Zn, B) 4. Involved in energy transfer reactions (P in ATP). 5. Green pigment chlorophyll in plants have magnesium in the centre of tetrapyrrole ring.

C. Biomolecules

(i) Carbohydrate

Structure	Functions
1. Composed of C, H and O	1. Most abundant organic substance present in nature which occurs in the form of cellulose in plant cell wall.
2. Simple six carbon sugar (glucose) is called a monosaccharide.	2. In both plants and animals it is used as a source of energy (sugar).
3. Two molecules or units join together to form disaccharide (sucrose).	3. An important storage form in plants is starch and in animals it is glycogen.
4. More than ten units of monosaccharides join in a chain to form a polysaccharide e.g. starch and cellulose.	4. Present in nucleic acids as five carbon sugar (Ribose in RNA, and deoxyribose in DNA).
(ii) Amino acid	
1. Basic amino acid structure shows that the central carbon atom is attached with an amino group ($–NH_2$), a carboxylic acid group (–COOH), one hydrogen and one side group (R).	1. Plants have the ability to utilize inorganic nitrogen and synthesize amino acid.
2. There are 20 different side groups which give 20 different amino acids.	2. In an animal, principal source of amino acids is provided by the plants or animals that it consumes in its diet (pulses are rich in protein).
(iii) Proteins	
1. Composed of C, H, O and N.	1. Structurally proteins form integral part of the membranes

2. Amino acids join together by "peptide" bonds to form protein molecules.	2. Functionally in the form of enzymes they play a vital role in metabolic reactions.
3. Twenty different amino acids make numerous simple and complex proteins.	3. Synthesis of DNA is regulated by proteins (enzymes).
4. Based on the complexity of structure the proteins can have primary, secondary, tertiary and quaternary structures.	4. Proteins are so important that nucleic acids directly regulate protein synthesis
5. When proteins exist with other molecules they are known as conjugated proteins e.g. glycoprotein, lipoprotein and chromoprotein.	
(iv) Nucleic Acids	
1. They are of two types : Deoxyribose nucleic acid (DNA) and Ribose nucleic acid (RNA)	1. DNA is the main genetic material for almost all organisms except certain viruses.
2. They are long chain polymers composed of units called **nucleotides**. as purines (Adenine and Guanine) and pyrimidines as (Thymine, Cytosine and Uracil)	2. RNA molecules are involved in information transfer and protein synthesis; and RNA acts as genetic material in some viruses e.g. TMV (Tobacco Mosaic Virus)
3. Each nucleotide has pentose sugar, nitrogen base and phosphate group.	
4. DNA has one oxygen less in its sugar molecule.	
(v) Lipids	
1. Composed of C, H, O. Amount of oxygen is very less.	1. Due to their low oxygen content, and higher number of C-H bonds they store higher amount of energy and release more energy during their oxidation
2. They are synthesized from fatty acids and glycerol. Simple lipids are called glycerides.	2. A molecule of fat can yield twice as much energy as from carbohydrate.
3. Fats can be saturated or unsaturated.	3. Phospholipids are important components of cell membranes.
4. Fats are solid at room temperature, those that remain liquid at room temperature are called oils.	
(vi) Vitamins	
1. Vitamins are organic compounds required in the diet of animals for their healthy growth.	1. Vitamins (from plant) are essential nutrients in animals diet as animals can not synthesise such compounds.
2. Vitamins are classified according to their solubility into two groups : Water soluble e.g. vitamin B and ascorbic acid and fat soluble vitamins (viz. A,D, E, K)	2. Their deficiency causes various diseases in animal, like deficiency of vitamin B causes "beri-beri" and that of vitamin C causes scurvy.

3. Plants have the ability to synthesize vitamins from CO_2, NH_3 and H_2S.	3. Vitamin A present in the carotene pigment of carrot. Vitamin D can be produced by man with the help of sunlight. Vitamin K is produced by bacteria in the human intestine.
(vii) **Hormones**	
1. Hormones are specific organic substances effective in low concentrations, synthesized by cells in one part of the organism and then transported to another part of the organism, where it produces characteristic physiological responses.	1. In animals hormones are produced in ductless glands called endocrine glands which control all the biochemical activities of the organism 2. In animals hormones may be proteins, peptides or steroids. 3. In plants hormones (growth regulators) are generally produced in metabolically active cells and control the vegetitive and reproductive growth of the entire plant. Proteinaceous hormones are not found in plants.
(viii) **Alkaloids**	
1. Alkaloids are complex organic compounds made of C, H, O and N.	1. The active principles of drugs from medicinal plants are generally alkaloids e.g. Quinine from the *Cinchona*. Ephedrine from and Morphine from *Papaver* species
2. Alkaloids in plants are produced from amino acids.	
(ix) **Steroids**	
1. These are fat soluble lipid compounds synthesized from cholesterol.	
2. They are produced by the reproductive organs like ovaries, testes and placenta and also by adrenal glands.	Most of the steroids act as life-saving drugs, and others act as hormones which are effective in performing specific functions in specific organs of animal body.
3. They include testosterone, estrogen, and cortisol	

INTEXT QUESTIONS 4.7

1. What is the importance of water in a living cell.

....

2. Which is the basic molecule in starch?

....

3. What is a peptide bond and where will you find it?

....

4. Which is the most energy rich biomolecule in living organisms?

....

5. What are nucleotides?

....

4.7 CELL DIVISION

A single cell divides many times and forms a multicelled organism. Unicellular bacteria and protozoa divide and increase in number. The injured tissues are replaced by new cells through cell division. Thus cell division is one of the most important activities in all organisms. In this lesson you will study about the two kinds of cell division and the processes involved in them.

Majority of cells in a multicellular organism grow and then can divide. However, the cells like the nerve and muscle cells of animals and guard cells of plants do not divide.

The process of cell division is almost same in all organisms. A cell passes through phases of growth after which are able to duplicate their chromosomes before they divide. These phases in the life of a cell constitute the **cell cycle.**

4.7.1 The cell cycle

You can use the term mother or parent cell for the cell that undergoes division and the daughter cells for the ones that are the result of this division. Before each daughter cell undergoes division, it must grow to the same size as its mother cell. We can distinguish two main phases in the life of a cell.

(i) Interphase - Non-dividing period (Growth phase)

(ii) Dividing phase - Also called M-phase (M for mitosis or meiosis)

(i) **Interphase - (Inter = in between)**

The interval between two successive cell divisions is termed interphase (phase at which the cell is not dividing). It is the longest period in the cell cycle (Fig.4.11). The interphase is subdivided into three main periods - G_1, S and G_2.

G_1 (Gap-1) Phase i.e. **First phase of growth** – This is the longest phase. Lot of protein and RNA are synthesised during this phase.

S or synthetic Phase - It comes next. Lot of DNA is (synthesised). A chromosome contains a single double helical strand of DNA molecule. After S-phase each chromosome becomes longitudinally double except at centromere, and thus, it has two molecules of DNA and two chromatids. Thus each chromatid contains one molecule of DNA. The two chromatids are joined by a centromere (which does not divide at this stage) to form a single chromosome.

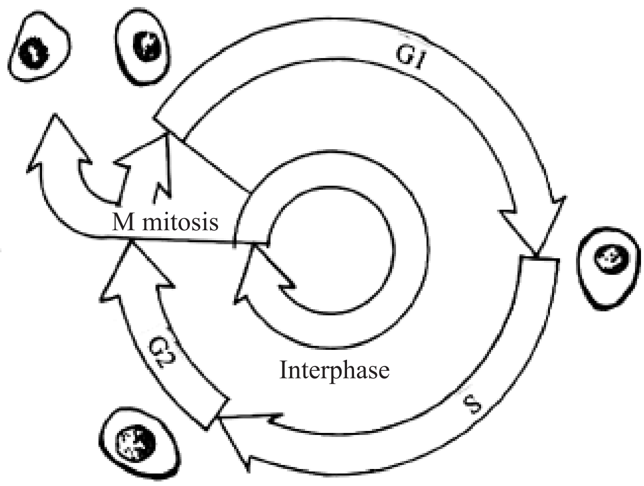


Fig. 4.11 The cell cycle consists of various stages (G_1, S, G_2 and M)

G_2 (GAP 2) phase - More protein including the histones are synthesised in this phase. Cytoplasmic organelles such as mitochondria and golgi bodies get duplicated. Centriole also divides into two centrioles contained in a single centrosome.

(ii) **M-phase or dividing phase** - Represented by the symbol M (Mitosis or meiosis) (Fig. 4.11). Mitosis occurs so that during this period the chromatids separate and form daughter chromosomes. The daughter chromosomes go to daughter nuclei and cytoplasm divides forming two identical daughter cells.

INTEXT QUESTIONS 4.8

1. Explain in one sentence
   (i) Interphase ....
   (ii) Synthetic-phase ....
   (iii) Dividing-phase ....
2. What is the full form of the following in the cell cycle?
   (i) G_1 ....
   (ii) S ....
   (iii) G_2 ....
   (iv) M-Phase ....

4.7.2 Kinds of cell division

There are two kinds of cell division- mitotic cell division and meiotic cell division.

1. Mitotic : Cell division is for growth and replacement of older cells by new cells wherein the two daugher cells are identical and similar to mother cell in all respects. Mitotic cell division occurs in haploid as well as diploid cells.
2. Meiotic cell division occurs in the gonads for sexual reproduction to produce gametes. The resultant cells, egg (in female) and sperms (in male), possess half the chromosome number of that present in the parent cell. Meiotic cell division takes place only in diploid cells responsible for production of haploid spores or gametes.

1. **Mitosis (mitos = thread)** Mitosis is divided into 4 phases or stages termed as

   (i) Prophase (ii) Metaphase

   (iii) Anaphase (iv) Telophase

   These phases refer to the changes taking place in the nucleus (Fig. 4.12).

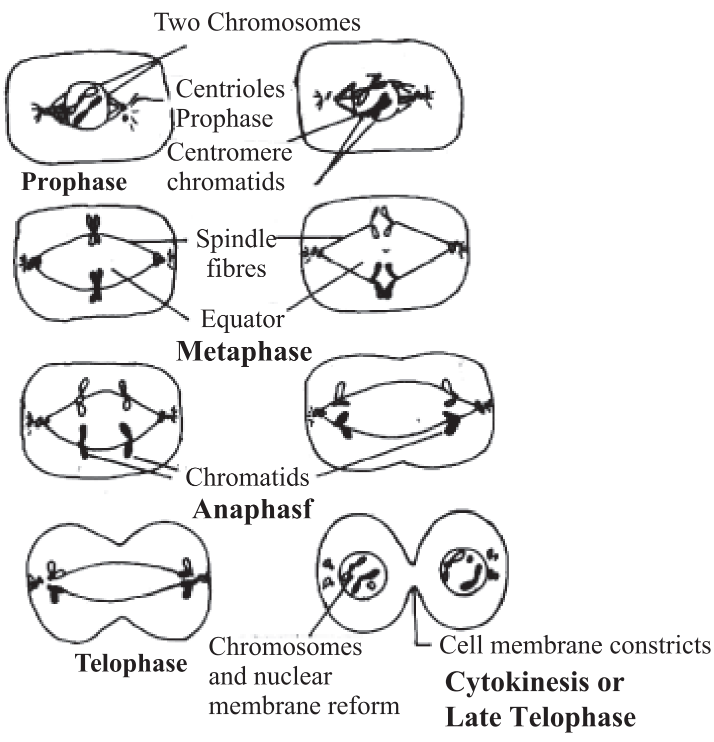


Fig. 4.12 Stages of Mitosis in an animal cell presuming there is just one pair of chromosome in the dividing cell

The nucleus divides first and then the whole cell divides. Division of one nucleus to produce two daughter nuclei a is called (**karyokinesis**). Division of cytoplasm to give two daughter cells is called **cytokinesis**.

Prophase : It shows three subphases :

(i) **Early prophase**

(a) Centriole divides and each of the two centrioles start moving towards opposite poles of the nucleus of the dividing cell.

(b) Chromosomes appear as long threads, and start coiling.

(c) Nucleus enlarges and becomes less distinct (Fig. 4.13a)

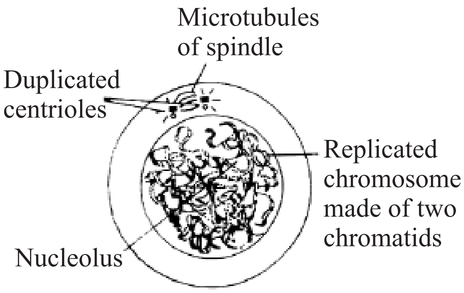


Fig. 4.13a Prophase

(ii) **Middle prophase**

(a) Chromosome condensation is complete and they become short and thick

(b) Each chromosome is made up of two chromatids held together at their centromeres.

(c) Each chromatid contains newly replicated daughter DNA molecule.

(iii) **Late Prophase**

(a) Centrioles reach the opposite poles of the dividing cell.

(b) Some spindle fibres extend from pole to the equator of the dividing cell.

(c) Nuclear membrane disappears

(d) Nucleolus is not visible.

Metaphase

(a) chromosomes are brought towards the equator of the cell, with the help of spindle fibres.

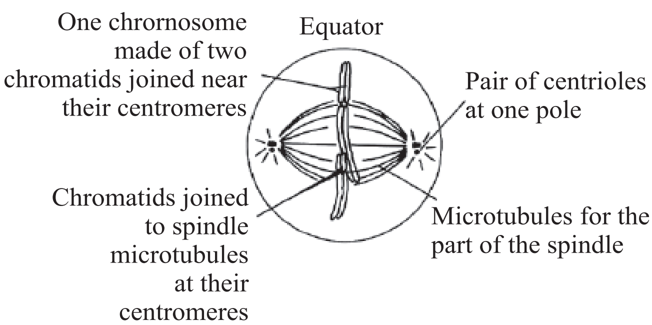


Fig. 4.13b Metaphase

(b) Each chromosome becomes attached to the two spindle fibres by centromere. Whereas each centromere is joined to the opposite poles.

(c) The sister chromatids are not yet separated. (Fig. 4.13b) because the centromere has not divided

Anaphase

(a) Centromeres of all the chromosomes divide and then each chromatid becomes a chromosome.

(b) Spindle fibres contract and pull the centromeres to the opposite poles.

(c) As the chromosomes are pulled by spindle fibres to opposite poles by their centromeres, they acquire various shapes such as V, J or I depending upon the position of centromere.

(d) Half the number of chromosomes move towards one pole and the other half to the opposite pole.

(e) Cytokinesis begins as the cleavage furrow starts from the periphery towards the centre in animal cells, and in plants, cell plate appears in the centre that grows centrifugally towards periphery.

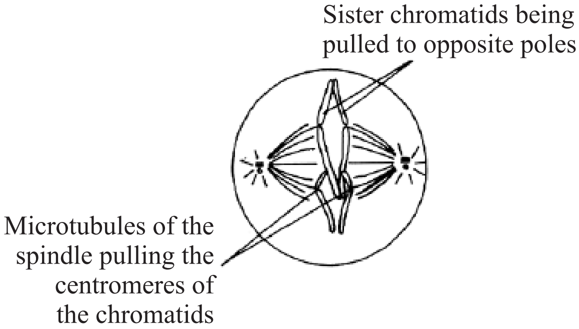


Fig. 4.13c Anaphase

Telophase

(a) Chromosomes uncoil to form a chromatin network as in the parent nucleus.

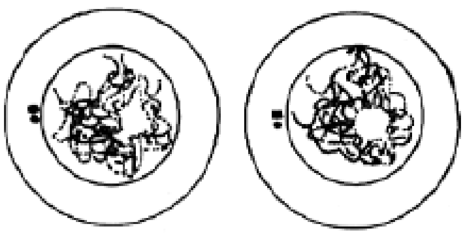


Fig. 4.13d Telophase

(b) New nuclear membrane is formed around each daughter nucleus

(c) Nucleolus reappears again in each newly formed daughter nucleus.

Cytokinesis

It is the process of the division of cytoplasm of a dividing cell into two. It is initiated in the beginning of telophase and is completed by the end of telophase. The mechanism of cytokinesis is different in plant and animal cells. In an animal cell, invagination of plasma membrane proceeds from the periphery of the cell towards the interior. In plant cell phragmoplast (cell plate) begins to form in the centre of cell and then expands towards the periphery (Fig. 4.13e).

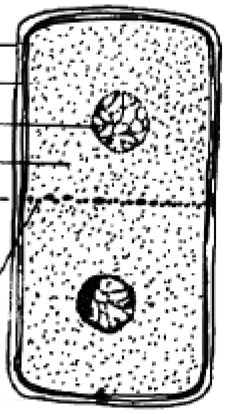


Fig. 4.13e Cytokinesis

Siginificance of Mitosis

It is an equational division, and the two newly formed daughter cells are identical in all respects. They receive the same number and kind of chromosomes as were in the mother cells.

- It is the only mode of reproduction in unicellular organisms.
- It is the process by which growth takes place in multicellular animals and plants by constantly adding more and more cells.
- It also plays a role in repair during growth, for example in wound healing, regeneration of damaged parts (as in the tail of lizard), and replacement of cells lost during normal wear and tear (as the surface cells of the skin or the red blood cells).

Mitotic Cell Division (Limited or unlimited)

Growth by mitosis occurs in a limited or controlled manner to the extent it is required in the body. But at times due to some special cases the number of cells may increase abnormally which may cause **Cancer**.

In plant tissue culture, a cell from a plant can be grown in a nutrient medium, where it divides repeatedly by mitosis to give an undifferentiated cell mass called **callus** capable of differentiating into a plant in the presence of nutrients and specific growth hormones. In animals, stem cell culture is also based on the ability of a cell to divide and give rise to cells of specific type.

INTEXT QUESTIONS 4.9

1. Name the stage of cell cycle during which chromatin material is duplicated.

   ....

2. Is the number of chromosomes reduced in the daughter cells during mitosis? yes/no?

   ....

3. Name the stage in nuclear division described by each of the following sentences:

   (i) disappearance of the nuclear membrane

   ....

   (ii) The nuclear membrane and nucleolus reappear

   ....

   (iii) The centromere divides and the chromatids move to opposite poles due to the shortening of spindle fibres

   ....

   (iv) The chromosomes arrange themselves at the equatorial plane of the spindle with the spindle fibres attached to the centromeres.

   ....

---

2. Meiotic Cell Division (GK meioun = make smaller, sis = action)

This division is also known as '**reduction division**'. But why this name? This is because, in this kind of cell division the normal **chromosome number of the mother cell is reduced to half in daughter cells.** The normal chromosome number in human being is 46 (23 pairs), but as a result of meiosis in ovary and testes this number is halved to 23 in daughter cells (called sperms or the egg).

Where does it occur? It occurs in reproductive cells, e.g. in the testes of male and in the ovaries of female animals; and in plants, in the pollen mother cell of the anthers (male organs) and in the megaspore mother cells of the ovary (female organ) of the flowers.

Why does it occur? In meiosis the chromosome number is reduced to half so that when doubled at fertilisation (zygote formation) during the reproduction it once again becomes ristored to the deploid state.

- The number of chromosomes remains constant in a species generation after generation.
- Cells divide mitotically in the organisms that reproduce vegetatively/asexually. Thus, there is no change in the number of chromosomes, but sexually reproducing organisms form gametes such as sperms in males and ova in females. The male and female gametes fuse to form the zygote which develops into a new individual. .
- If these gametes were, produced by mitosis, the offspring developing from zygote then would have double the number of chromosomes in the next generation.
- Every living organism has a definite number of chromosomes in its body cells. e.g. onion cell-16; potato-48; horse-64; man-46. Therefore to keep the chromosome number constant the reproductive cells of the parents (ovaries and testis in animals, and pollen mother cells in anthers and megaspore mother cells in the ovules inside the ovary in plants) divide through meiosis.

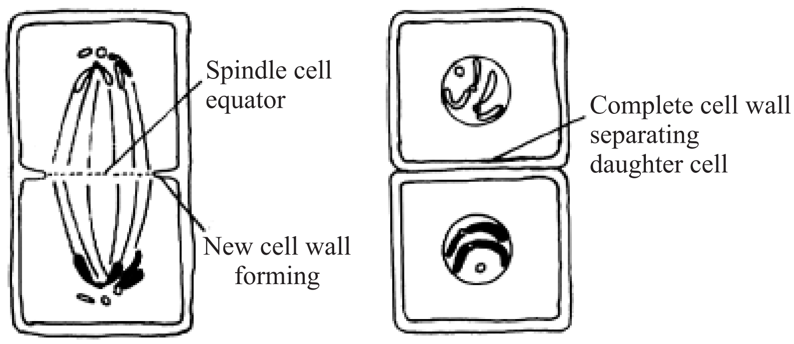
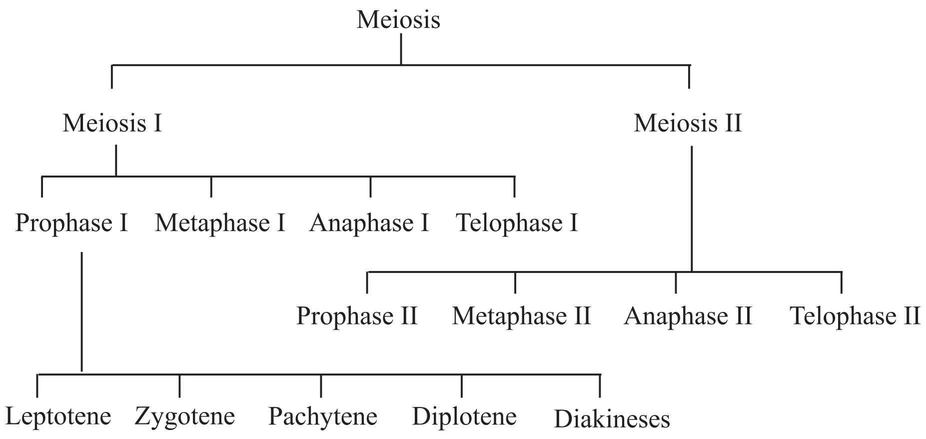


Fig. 4.14 : Cell wall formation after mitosis in a plant cell

How does meiosis occur?

Meiosis is characterized by two successive divisions of the nucleus (meiosis I and II) and cytoplasm, whereas the chromosomes divide only once. The phases of meiotic division are given in the flow-chart drawn here.

– **The interphase** which precedes the onset of meiosis is similar to the interphase which precedes mitosis. At S-phase, the DNA molecule of each chromosome duplicates to give rise to two DNA molecules and hence two chromatids are found in one chromosome attached to a single centromere.



– Meiosis-I and meiosis-II are continuous and have been divided into sub-stages only only for convenience to study the process of nuclear division.

Meiosis-I

Like mitosis, meiosis-I also consists of four stages; prophase-I, metaphase-I, anaphase-I and telophase-I.

Prophase-I

The prophase-I of meiosis-I is much longer as compared to the prophase of mitosis.

- It is further sub-divided into the following five sub-stages :

(i) **Leptotene** (GK 'leptos' - thin; 'tene - thread) (Fig. 4.15a)

  - The chromosomes become distinct and appear as long and thin threads bearing fine beads due to condensation (coiling of DNA) at specific points called chromomeres.
  - Each chromosome consists of two chromatids held together by a centromere but these are not easily visible.
  - Nuclear membrane and nucleolus are distinct.

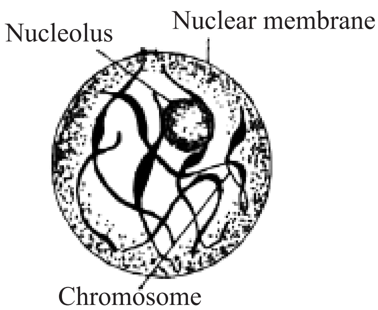


Fig. 4.15a Leptotene

(ii) **Zygotene** (GK. 'Zygos'-pairing) (Fig. 4.15b)

  - Chromosomes continue coiling and become shorter and thicker
  - Similar or homologous chromosomes start pairing from one end. This pairing is known as **synapsis.**
  - Each pair of homologous chromosomes is called a **bivalent**.
  - Nuclear membrane and nucleolus are distinct.

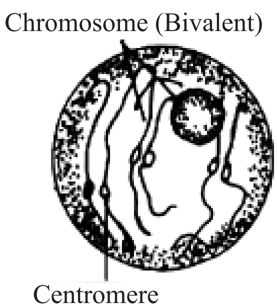


Fig. 4.15b Zygotene

(iii) **Pachytene** (GK. 'pachus' - thick) : (Fig. 4.15c)

- The chromosomes become shorter and thicker due to further coiling.
- Each paired unit called a 'bivalent' shows four chromatids hence bivalents are also known as **tetravalents**.

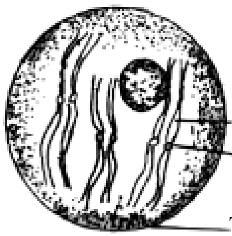


Fig. 4.15c Pachytene

- Crossing-over occurs at the end of pachytene i.e. break and exchange of parts (genes) occurs between non-sister chromatids (chromatids of a homologous pair)

  The point of interchange and rejoining appears X-shaped and is known as chiasma (plural-chiasmata) or the point of **crossing over**.

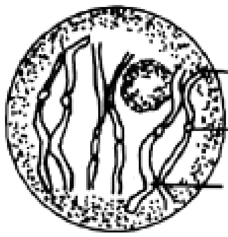


Fig. 4.15d Diplotene

(iv) **Diplotene** ('Diplous'-double) (Fig. 4.15d)

- Chromosomes continue coiling further and become shorter.
- The centromeres of homologous chromosomes start repelling each other
- The two non-sister chromatids of a homologous pair of chromosomes remain, attached at one or two points, the **chiasmata**.
- Nucleolus and nuclear membrane become indistinct.
- It is at the chiasmata that exchange of segments of nonsister chromatids (genes) between homologous chromosomes has taken place. The process of gene exchange is known as **genetic recombination**.

(v) **Diakinesis** (GK dia = through, in different directions, kinesis = motion; Fig. 4.15e)

- The bivalents become the shortest and thickest due to maximum coiling.
- The centromeres and non-homologous parts of homologous chromosomes of a bivalent move apart due to repulsion from each other.

- Consequently, the bivalents acquire various configurations such as O, X or 8, depending upon the number of chiasmata per bivalent.
- Nuclear membrane and nucleolus disappear.
- Spindle formation is completed.

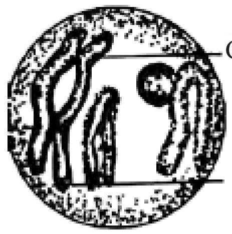


Fig. 4.15e Diakinesis

(vi) **Metaphase-I** (Fig. 4.15f)

- The bivalents arrange themselves at the equatororial plate.
- The homologous chromosomes arrange in such a way that all maternal or all paternal chromosomes do not get attached to same pole. In other words, some maternal and some paternal chromosomes are joined to each pole.
- The spindle fibres are attached at the centromere of the chromosomes.
- One centromere of a bivalent is joined to one pole and second centromere is joined to the opposite pole by the separate spindle fibres.

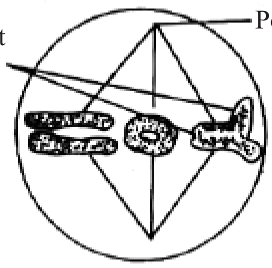


Fig. 4.15f Metaphase

(vii) **Anaphase-I** (Fig. 4.15g)

- The spindle fibres shorten.
- The centromeres of homologous chromosomes are pulled along by the spindle fibres towards the opposite poles (no division of centromere)
- Thus, half of the number chromosomes (each with two chromatids) of the parent cell go to one pole and the remaining half to the opposite pole.
- Each set of chromosomes that moves to one pole consists of a mixture of paternal and maternal chromosome parts (new gene combination). This is the basic reason for mixing of maternal and paternal genes in the products of meiosis.

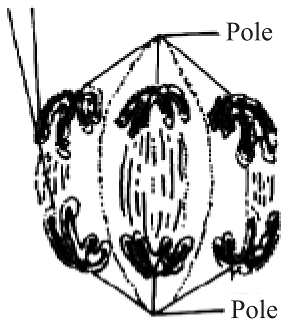


Fig. 4.15g Anaphase

(viii) **Telophase-I** (Fig. 4.15h)

- The separated chromosomes uncoil in the newly formed daughter nuclei.
- The daughter nuclei have half the number of centromeres as compared to that in the parent nucleus. But, since each centromere has two chromatids, amount of DNA at the two poles at telophase-I is same i.e. 2n (diploid as in the parent nucleus wherein the chromosomes had duplicated at S-phase, thus amount of DNA in the dividing cell upto anaphase I was 4n)
- The daughter cells now have half the amount of DNA as compared to that at Anaphase-I, that is 2n.
- The nucleous reappears and nuclear membrane forms
- The daughter nuclei enter into the second meiotic division.,

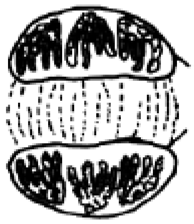


Fig. 4.15h Telophase

Fig. 4.15i Prophase II

Second Meiotic Division has the same four stages;

(i) Prophase II (ii) Metaphase II

(iii) Anaphase II (iv) Telophase II

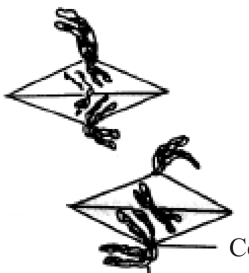


Fig. 4.15j Metaphase II

(i) **Prophase II** (Fig. 4.15i)

- The chromosomes shorten and chromatids become distinct. The two chromatids of each chromosome are attached to the single centromere.
- Formation of spindle starts.
- Nucleolus and nuclear membrane begin to disappear.

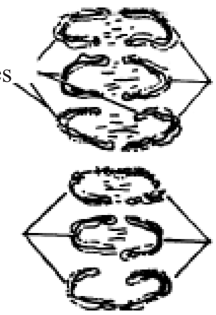


Fig. 4.15k Anaphase II

(ii) **Metaphase II** (Fig. 4.15j)

- The chromosomes arrange themselves along the equator.
- Formation of spindle apparatus is completed.
- The centromere of each chromosome is attached by two spindle fibres to the opposite poles.

(iii) **Anaphase II** (Fig. 4.15k)

- The centromere in each chromosome divides so that each chromatid has its own centromere and each chromatid is now a complete chromosome.

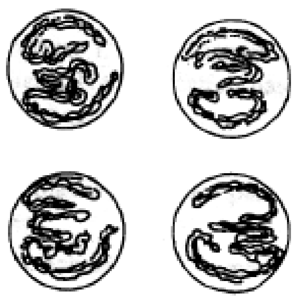


Fig. 4.15l Telophase II

- The chromatids get their respective centromere and become daughter chromosomes and begin to move towards the opposite poles due to contraction of spindle fibres.

(iv) **Telophase II** (Fig. 4.15l)

- On reaching the poles, the chromosomes organize themselves into haploid daughter nuclei.
- The nucleolus and the nuclear membrane reappear.
- Each of the four daughter nuclei has half the number of chromosomes (n) as well as half the amount of DNA as compared to the parent nucleus (2n).

Cytokinesis

- This may occur in two successive stages, once after meiosis I and then after meiosis II, or in some instances it occurs only after meiosis II.
- Thus after meiotic cell division four haploid cells are formed.

Significance of Meiosis

(i) It helps to maintain constant number of chromosomes in different generations of a species undergoing sexual reproduction.

(ii) Meiosis occurs during gamete formation (gametogenesis) and reduces the number of chromosomes from diploid (2n) to haploid (n) in the gametes. These haploid gametes fuse to form diploid zygote during fertilization. The diploid zygote develops into a normal diploid individual.

(iii) Meiosis establishes new combination of characters due to (i) mixing of paternal and maternal chromosomes and (ii) crossing over during prophase I. As a result the progeny inherits the traits of both the mother and the father in new gene combinations.

Comparison of Mitosis and Meiosis

Mitosis	Meiosis
1. Cell divides only once	There are two cell divisions. First meiotic division and the second meiotic division.
2. Takes place in somatic cells as well as in reproductive cells which may be haploid or diploid or polyploid	Takes place only in diploid germ cells.
4. Duration of prophase is short (few hours)	Prophase-I, is compartively longer. (takes many days).
5. Prophase simple.	Prophase I is complicated having five sub-stages namely leptotene, zygotene, pachytene, diplotene and diakinesis.
7. Synapsis does not occur.	Synapsis of homologous chromosomes takes place during prophase-I.
8. No exchange of segments during prophase between two nonsister chromatids of chromosomes.	Exchange of segments during crossing over between non sister chromatids of two homologous chromosomes takes place.
9. Each chromosome consists of two chromatids united by a centromere.	Each bivalent has four chromatids and two centromeres.

10. Chromosomes are duplicated at the beginning of prophase.	In prophase I, chromosomes appear single although DNA replication has taken place in interphase I.
11. In metaphase all the centromeres line up in the same plane.	In metaphase I, the centromeres are lined up in two planes which are parallel to one another.
12. The metaphasic plate is made up of duplicated chromosome.	The metaphasic plate is made up of paired chromosomes.
13. Centromere division takes place during anaphase.	No centromere divisions during Anaphase I, centromeres divide only during Anaphase II.
14. Spindle fibres disappear completely in telophase.	Spindle fibres do not disappear completely during telophase I.
15. Reappearance of nucleoli at telophase.	Nucleoli do not appear in telophase I.
16. The chromosome number does not change at the end of mitosis.	There is reduction in the chromosome number from diploid to haploid.
17. The genetic constitution of chromosomes daughter cells is absolutely identical to that of parent cells.	The genetic constitution of chromosomes in daughter cells is different as compared to the parent cells. The daughter cell chromosomes contain a mixture of maternal and paternal genes.
18. Mitosis is of shorter duration.	Meiosis is of longer duration.
19. It is the basis of growth and repair and reproduction in vegetatively or asexually reproducing organisms.	It is basis of maintaining same chromosome number in different generations of a species reproducing sexually as well as for providing genetic variation in the progeny.

What is a karyotype

Chromosomes can be seen distinctly only at metaphase. They are then photographed, cut and arranged in pairs according to size. Such an arrangement of homologous chromosomes of an individual in descending order according to size, is termed as a karyotype (see human karyotype in lesson 21).

INTEXT QUESTIONS 4.10

1. Name the sub-stage of meiosis-I in which the :

   (i) Homologous chromosomes pair

   ....

   (ii) Tetrads are formed.

   ....

   (iii) Homologous chromosomes begin to move away from each other.

   ....

2. Sites of meiosis in flowering plants, are :

....

3. Rearrange the following stages of meiosis I in their proper sequence :

zygotene, pachytene, leptotene, metaphase-I diakinesis, anaphase-I, telophase-I.

....

4. Mention two major points in which meiosis I differs from meiosis II

....

WHAT YOU HAVE LEARNT

- A living cell is a self-sufficient unit of the body of a living plant or animal.
- Important cell organelles are mitochondria, Golgi complex, ER, ribosomes, peroxisomes, chloroplast, glyoxisomes, nucleus.
- With the exception of centrioles, ribosomes and nucleolus, all other organelles are membrane-bound.
- Although a cell fails to live, grow and reproduce in the absence of a nucleus, nucleus all by itself without cytoplasm is also ineffective.
- Some organelles like mitochondria and chloroplast have the capacity to duplicate themselves to some extent without the help of the nucleus i.e. they are termed semi-autonomous.
- The living cells divide by mitotic cell division to produce new cells.
- Growth in body occurs due to increase in the number of cells.
- The continuity of the chromosomal set is maintained by cell division.
- The life cycle of a cell includes interphase (G_1, S & G_2) and M-phase (mitosis or meiosis)
- Mitotic cell division occurs in somatic cells or reproductive cells that results in the formation of identical cells, both qualitatively and quantitively.
- Meiosis occurs in germ cells only i.e. testis and ovary. This is a reduction division where the chromosome number becomes half.
- The significance of mitosis is growth, and reproduction where the product of reproduction is identical.
- The Significance of meiosis is in sexual reproduction where ova and sperm both have half the number of chromosomes i.e. 23 each in human gametes (but normal number of chromosome of human is 46 or 23 pair) and on fertilization the chromosome number becomes normal.
- Meiosis also helps in mixing the paternal and maternal characters.

TERMINAL EXERCISES

1. Justify the statement that cell wall although a dead material, influences living processes inside the cell.
2. Differentiate between cell wall and cell membrane.
3. Draw Singer and Nicholson's model of cell membrane.
4. Why is cell membrane vital for the cell?
5. Draw structure of mitochondria and chloroplast as seen by electron microscope.
6. List functions of mitochondria and chloroplast.
7. Name the self–duplicating cell organelles? Why are they called so?
8. Differentiate between functions of ER, ribosomes and Golgi bodies.
9. Most organelles are membrane – bound. What is the advantage of such arrangement.
10. Differentiate between the structure and function of centriole and cilia/flagella.
11. Why are lysosomes known as "suicidal bags"?
12. What are the functions of nucleus?
13. List the cell organelles. Write in one line each, about their functions and explain the division of labour.
14. Give the points of difference between
    (i) prokaryotic and eukaryotic cell.
    (ii) plant and animal cell.
15. Why is the cell termed the structural and functional unit of living organisms?
16. Name the following :
    (i) The condition in which a cell has the normal paired chromosomes.
    (ii) The condition in which a cell contains only one member of each pair of chromosomes.
    (iii) The pairing of maternal and paternal chromosomes during meiosis.
    (v) The exchange of parts in homologous (maternal and paternal) chromosomes during prophase-I of meiosis.
    (vi) The point by which a chromosome is attached to the spindle fibre.
    (vii) The type of cell division that results in growth.
17. What are the sites of meiosis in a flowering plant and in a sexually reproducing animal?

18. List the sub-stages of prophase-I.
19. What is the significance of meiosis?
20. Draw a schematic diagram of various stages of the life-cycle of a cell.
21. Draw labelled diagrams of various stages of mitosis.
22. Tabulate the main differences between mitosis and meiosis.
23. Why is prophase of meiosis so prolonged and elaborate?
24. What is the difference between cytokinesis in animal cell and cytokinesis in plant cell?

ANSWERS TO INTEXT QUESTIONS

4.1 1. Pre-existing cells

2. Schleiden and Schwann

3. Chloroplast/plastid

4. Prokaryote - naked nucleus, no membrane bound cell organelles

Eukaryote - distinct nucleus with a cell membrane, membrane bound cell organelles present

4.2 1. Diffusion : Movement of molecules from region of their higher concentration to region of their lower concentration.

Osmosis : Movement of water molecules across a semipermeable membrane from region of their higher concentration to the region of their lower concentration.

2. Movement of molecules against concentration gradient that is region of lower to higher concentration by expending energy.

3. Intake of solid particles (phagocytosis)

Intake of fluid droplets (pinocytosis)

4. (i) – d (ii) – a (iii) – e

(iv) – b (v) – c

5. (i) Protection/shape

(ii) Provide communication between cells through plasmodesmata

4.3 1. Membrane bound bodies in the cytoplasm

2. ATP

3. Grana

4. Thylakoids

5. Because energy as ATP is generated and stored in mitochondria

6. Mitochondria

7. (i) both are semiautonomous
   (ii) both contain DNA or both contain ribosomes
8. Chromoplasts
9. Chloroplast
10. They have their own DNA for production of more copies of themselves by self duplication but cannot lead independent life, outside the cell/ cytoplasm.

4.4 1. (a) Golgi body (b) ER, (c) amyloplasts (d) ER, (e) ribosomes
2. refer text
3. (i) internal framework, (ii) transport of cellular substances
4. cytoplasm, ER, Nucleolus; chloroplasts, mitochondria
5. ER

4.5 1. Because the lysosome can devour organelles of the same cell
2. They help in cleaning up the cell by digesting useless matter
3. Fat metabolism

4.6 1. Nucleus controls all the functions of the cell as it has the hereditary information
2. (a) Chromosomes are present as a network when not dividing, that is, at early interphase or Go-stage (Differentiation stage during development)
   (b) Bearers of hereditary information as genes on them
3. Site of RNA synthesis

4.7 1. (i) It is a universal solvent and most chemical reactions of the cell occur in aqueous medium
   (ii) It is a constituent of protoplasm
2. glucose
3. –NHCO–, between amino acids in a polypeptide, found in proteins
4. ATP
5. building blocks of nucleic acids, each containing a pentose sugar, nitrogenous base and phosphate

4.8 1. (i) Interphase - stage between two successive cell divisions;
   (ii) Synthetic phase - DNA is synthesised;
   (iii) Dividing phase - Mitosis in somatic cells or meiosis in the germ cells takes place.

2. (i) First growth phase; (ii) Synthetic phase;
   (iii) Second growth phase; (iv) Mitosis/meiotic phase.

4.9 1. S-shape of Interphase;

2. No;

3. (i) Late Prophase; (ii) Late Telophase; (iii) Anaphase; (iv) Metaphase

4.10 1. (i) zygotene (prophase I); (ii) Pachytene; (iii) Diplotene

2. Microspore/pollen mother cell in anthers and megaspore mother cell in the ovule.

3. Leptotene, zygotene, pachytene, diplotene, diakinesis, metaphase I, telophase I.

4. Reduction in chromosome number to half in Meiosis-II; exchange of genetic material in meiosis I.