UNIT 1 INTRODUCTION TO THE CELL

Structure

1.1 INTRODUCTION

This is the first unit of the block **"Introduction to Cell Biology"**. In this unit you will study about the evolution of the cell that involves two processes:

i) Occurrence of genetic variations which are passed on from one generation to another; and

ii) Selection of those genetic changes which are useful for the survival and propagation of the organism.

Discovery of the cell as a structural unit of life was possible with the development of the microscope. It is interesting to learn as to how the present day cell evolved from smaller components and then became a building block for larger structures. You will study that molecules which were capable of self-replication and carrying genetic information were evolved first. These molecules then got enclosed in a membrane, to give rise to the first ancestral cell which could propagate its own self. The development of mechanisms for photosynthesis and respiration in the early cells led to the evolution of procaryotes (e.g. bacteria) first and then to eucaryotes (higher animals and plants). Although the basic structure of plant and animals cells is similar, they differ in certain aspects such as the absence of large vacuoles and cell wall in animal cell. You will study about the differences between plant and animal cells in this unit.

It would be easier to understand this unit if you know the basic principles of biochemistry.

Objectives

After studying this unit, you will be able to:

- outline the stages in the evolution of the cell from simple molecules,
- list the distinctive features of organelles of procaryotic and eucaryotic cell,
- compare a plant cell with an animal cell,
- state the importance of chloroplast and mitochondria.

1.2 HISTORY OF CELL BIOLOGY

Scientific knowledge grows with the development of new tools and techniques for studying various physical and biological processes. This is true also of the origin of the concept of cell as a basic unit of life. By 1800 A.D., good microscopes were developed and consequently plants and animals were found to be made up of small units, later known as 'cells'. However, it was only in 1838, that the cell theory was proposed. According to this theory, the cell is both the structural and the functional unit of all living organisms. Cell theory gave a great impetus to study of the cell. It was established that the cell is a mass of protoplasm limited by a cell membrane and possessing a nucleus. Another important observation was that cells come only from pre-existing cells as a result of cell division. Details of cell division were soon worked out. It became apparent that mitosis is the formation of nuclear filaments (chromosomes) and their equal division between the daughter cells. It was also observed that organisms generally develop from the fusion of two sex cells, the spermatozoon (male sex cell) and ovum (female sex cell). In 1892, cytology (cyto = cell, logos = study) was established as a separate branch of biology. Study of cells with electron microscope gave a new dimension to the study of cell. Detailed morphological studies of the cell helped to relate the structure with function of cellular organelles.

Interaction between various branches of scientific enquiry leads to their overall growth. The interaction between cytology and genetics on one hand and between physiology and biochemistry on the other gave rise to a more comprehensive discipline, Cell Biology, which embodies all that should be known about the cell (Fig. 1.1).

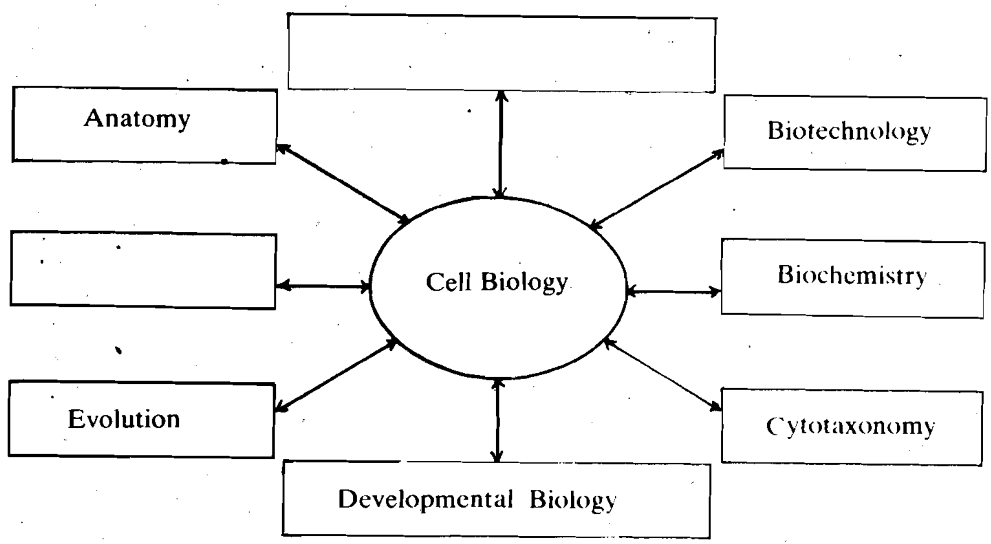


Fig. 1.1: Relationship between Cell Biology and other biological disciplines.

For example, when in 1865 Mendel put forward the fundamental laws of heredity, the cytological changes that occur during meiosis resulting in the formation of sex cells, were not known. Hence the distribution of factors, later on called as '**genes**', could not be understood as proposed by Mendel. With the understanding of the processes that take place in meiosis, the importance of Mendel's work became evident. Consequently, the **chromosome theory of heredity** was finally established and genes were assigned definite places called **loci**, on the chromosomes. Later, sex determination was related to some special chromosomes. A biochemical analysis of various components of cell made a great impact on the understanding of the cellular function. Although the nucleic acids were isolated in 1869, their basic role in heredity and protein synthesis was realised only in 1950 and even later. Cell organelles like mitochondria were isolated by employing certain techniques about which you will study in detail in Unit 4. The role of mitochondria in cellular respiration was also established.

X-ray diffraction and several other physico-chemical methods helped scientists to understand the structure and function of the macromolecules in cell. Further studies on the cell revealed that cell is both a morphological and a physiological unit of the life.

SAQ 1
Fill in the blanks.

a) The invention of .... can be considered as a landmark in the study of cell biology.

b) Cell theory states that ....

....

c) New cells arise by ....

d) .... is the type of cell division that results in the equal distribution of chromosomes in daughter cells.

1.3 EVOLUTION OF THE CELL

All the living organisms are made up of cells. A living cell may be defined as a compartment enclosed by a membrane that consists of several chemical constituents and is capable of propagating itself by division. Activity of an organism is dependent on the activities of its cells, individually and collectively. Basic structures and functions are common in all cells with certain differences according to their specific needs.

As you have already studied in Unit 12 of the Foundation Course in Science and Technology, there are two stages in evolution of the cell; **chemical evolution** and **biological evolution**. Chemical evolution started with the formation of organic molecules on the earth which had no life until then. We call it **prebiotic earth**. Some of these early molecules developed the ability of producing an exact copy of their ownself by self-replication. We can mark this event as the origin of life. Later on, during the course of biological evolution, molecular aggregates organised and formed the cell which was different from the cell as it exists today. We shall trace these events which are based partly on speculation and partly on experimental evidence.

1.3.1 From Molecules to the First Cell

You may recall from Unit 12 of Foundation Course in Science and Technology that the prebiotic conditions on the earth in all probability were volcanic eruptions, lightning and heavy rains. There was no trace of free oxygen or an ozone layer in the atmosphere to absorb ultraviolet radiations from the sun. It is assumed that organic molecules would have originated in such climatic conditions. This is described as their abiotic origin. Laboratory experiments from 1953 onwards prove that organic molecules like amino acids, proteins, nucleotides, nucleic acids, lipids and ATP can be formed in similar conditions on the earth. Stanley Miller's experiment described below is one such experiment (Fig. 1.2). It is possible that such organic molecules similar to those synthesised in Miller's experiment would have got accumulated at several places in high concentration, giving rise to a kind of liquid soup, the prebiotic soup. A spherical pre-life form or **protobiont** may have been formed in such a soup.

Protobiont a spherical globule filled with large organic molecules, carrying out the functions of a living being, that ultimately evolved into a true life form, i.e. eubiont.

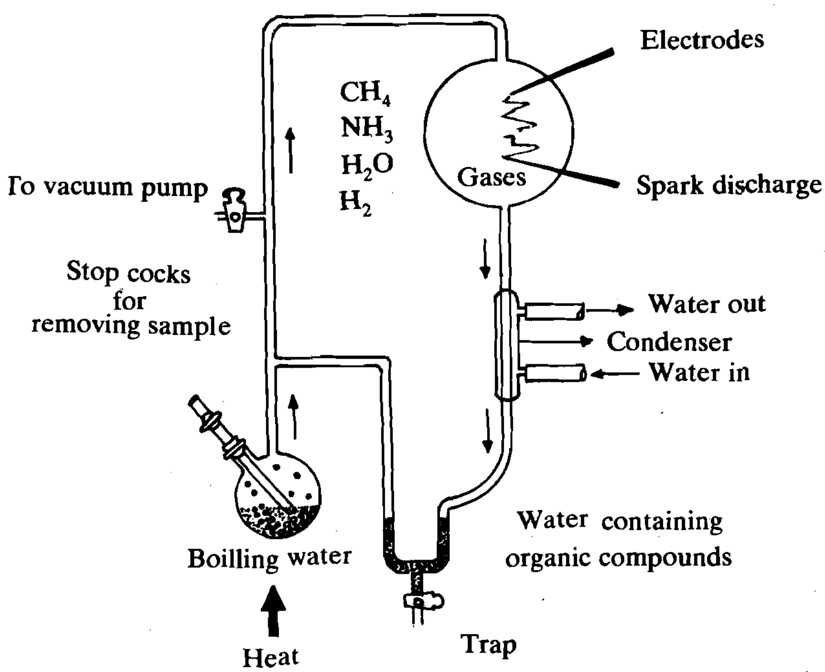


Fig. 1.2 : Apparatus used by Stanley Miller in experiments on the synthesis of organic compounds from abiotic components. In the flask, water is added and the entire apparatus is made free of air. Then hydrogen, methane and ammonia gases are introduced through a valve. When water in the flask is heated to boiling these gases circulate clockwise in the steam. Gases and steam enter the sparking chamber and are subjected to spark discharges. When the molecules move through the vicinity of water cooled condenser, condensation occurs. Gaseous substances continue to circulate in the apparatus until the experiment is concluded, which takes usually a week or so. Non-gaseous substances accumulate in the trap, and are analysed.

Scientists have three different speculations about the composition of a protobiont. Some consider it as an aggregate of electrically charged molecules with water around them acting as a boundary and this is called as **coacervate model** (Fig. 1.3). This model was proposed

Polymerisation : The process of linking together of many simple units (e.g. amino acids) to form larger and more complex molecules (e.g. proteins) is known as polymerisation and the product is called as polymer.

Coacervate is a fluid filled droplet formed in dilute aqueous solutions, whose boundary develops as a film of bound water molecules.

by Alexander Oparin. Sidney Fox proposed another model for protobiont formation called **protenoid microsphere model**. According to this model when water free mixtures of amino acids are heated at high temperature, they polymerise to form protein-like molecules, called **proteinoids**. These can persist only if cooled quickly. According to a third model called as the **lipid bilayer model** of Richard Goldacre, an abiotically synthesised phospholipid bilayer was formed around a central space containing organic molecules. All such models are without any experimental or theoretical evidence. However, the supporters of each model try to explain how some life-processes like osmosis and budding, can be carried out by such **protobionts**.

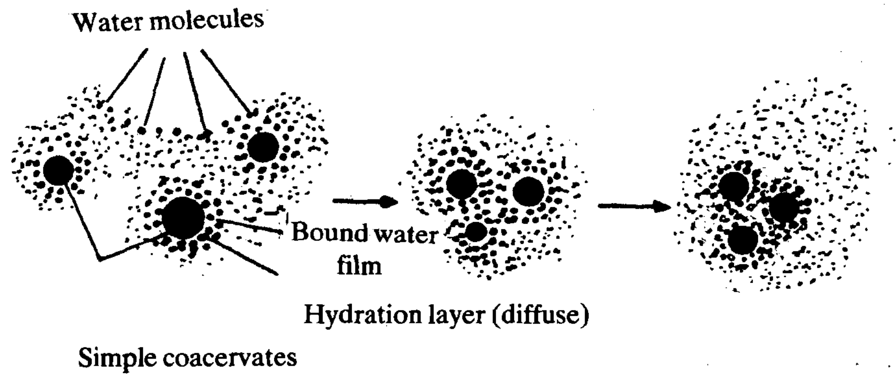


Fig. 1.3 : Coacervate model of protobiont. Water molecules become tightly bound to an electrically charged molecule to form simple coacervate droplets. Attractions between the electrically charged systems may lead to the fusion of two or more simple coacervates to form complex coacervate.

The origin of a true life form, eubiont from a protobiont involves the acquisition of three major features:

1) assembly of phospholipids and proteins into a cell membrane forms the boundary of the cell,

2) development of protein-directed metabolic pathways to utilise the organic molecules for energy needs, and

3) formation of nucleic acid molecules that are not only capable of self-replication but are also capable of storing genetic information for the synthesis of proteins.

Since we have no definite idea of the structure of a protobiont, it is difficult to speculate the manner in which a eubiont evolved from a protobiont. All the same, it is certain that a eubiont comparable to the simplest living cell today must have originated first.

Genetic Information : Information related with the ways in which characteristics are passed on from parents to offspring.

Metabolic Pathways : Processes by which food is built up into living matter or by which living matter is broken down into simple substances.

It is quite likely that the formation of a boundary membrane would have taken place before the acquisition of a genetic information system and metabolic pathways. A separation of the cell interior from the outside, would permit sufficient interaction of molecules inside the cell.

Let us sum up in a tabular form what we have learnt so far regarding the evolution of cell.

Table 1.1: The Origin of the Cell

			First Multicellular Organisms	
			↑	
	Post Cellular		First Eucaryote	0.9×10^9 years ago
			↑	
Biological Evolution			First Procaryote	3.5 and 3.0×10^9 years ago
			↑	
		Metabolic pathways	Plasma membrane	Genetic information system
			↑	
	Pre Cellular	Proteins, Nucleic acids, lipids, polysaccharides, ATP		
			↑	
Chemical Evolution		Amino acids, nucleotides, sugars		
			↑	
		Prebiotic Molecules, Ammonia, Methane, Water, Formaldehyde etc. 4.6×10^9 years ago (solar system)		Electic discharge, U.V.

SAQ 2

a) Which stage of the evolution is characterised by the organisation of molecular aggregates?

....

b) Give the names of three protobiont models.

....

....

....

1.3.2 Procaryotic Structure and Diversity

The first organisms which did not have well defined nucleus, called procaryotes, (pro = earlier, caryon = nucleus) were probably **anaerobic** and **heterotrophic**. It is believed that at that time there was no free oxygen available in the atmosphere, and the autotrophs had a complex metabolism to prepare their own food. You can observe the difference between autotrophism and heterotrophism in Fig. 1.4.

Anaerobic: Conditions in which oxygen is absent, reactions that proceed in the absence of oxygen or cells that function in the absence of oxygen.

Autotroph: An organism that can prepare its food on its own.

Heterotroph: An organism that cannot prepare its food on its own.

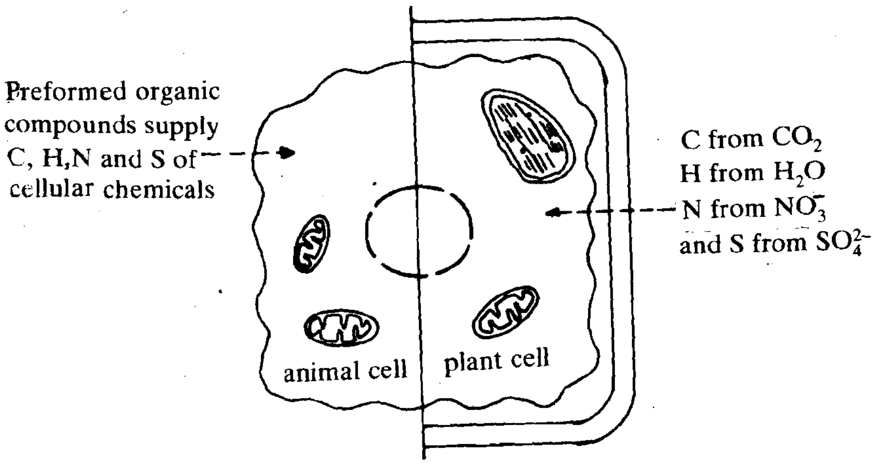


Fig. 1.4 : Sources of few main elements from which all chemicals are synthesised in autotrophic and heterotrophic organisms.

We will now discuss different types of procaryotes and their evolutionary relationship to draw an outline of organic evolution.

The 'group of procaryotes' is known as **Monera**. This group includes eubacteria, archaebacteria, green bacteria, purple bacteria, virus, prochlorophyta, cyanophyta and mycoplasma. Here we will describe the structure of two procaryotes viz. bacteria and virus.

Bacteria: Bacteria have a protective covering called 'cell wall'. Beneath this, there is a plasma membrane which encloses protoplasm of the bacterium containing various types of RNA, DNA, proteins and organic molecules. In bacteria, DNA molecule and enzymes involved in oxidation of food are found associated with the plasma membrane (Fig. 1.5).

Bacteria, though simple in their structure, are the most abundant of all the life forms on earth today. This is due to their rapid rate of multiplication and the ability to adapt to any nutrient and environment.

Viruses: Viruses are on the borderline of life between non-living and the living organisms. They have some characteristics of a living organism such as the ability to reproduce while some of non-living objects, like the absence of metabolic processes and ability to crystallise.

Viruses are very simple organisms with a circular nucleic acid molecule (DNA or RNA) surrounded by a protein coat (Fig. 1.6).

Viruses are organisms which live only as parasites and can reproduce themselves only in a host cell such as bacteria, animals or plants at the expense of the metabolic machinery of the host cell.

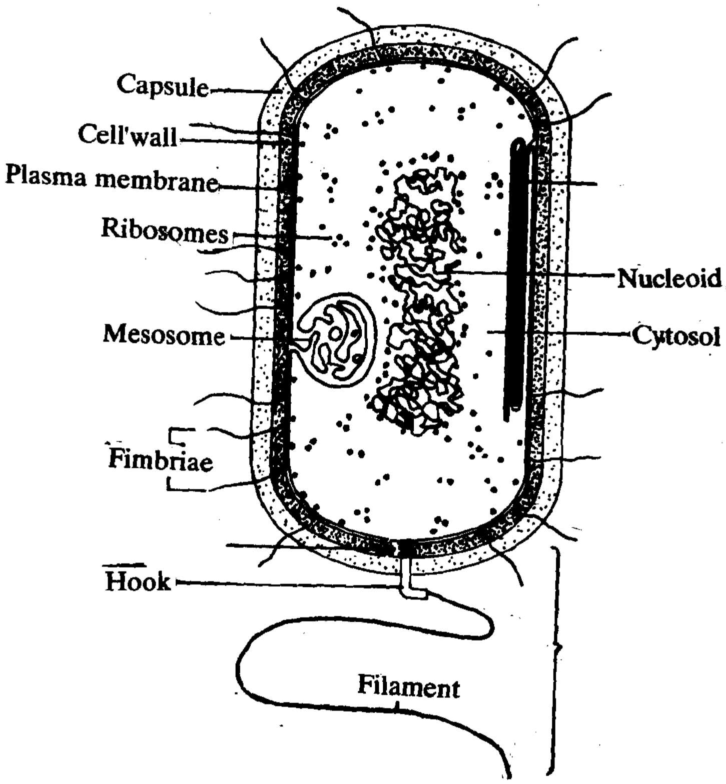


Fig. 1.5 : Structure of a bacterium. The bacterial cell is enclosed by a cell wall, which is further surrounded by capsule. Infolding of plasma membrane forms mesosomes. The nuclear material is concentrated in a specific region of the cell called nucleoid. One or more flagella may be present for locomotion. Small appendages that are called fimbriae arise from the cytosol and help the bacterium in getting attached to a surface.

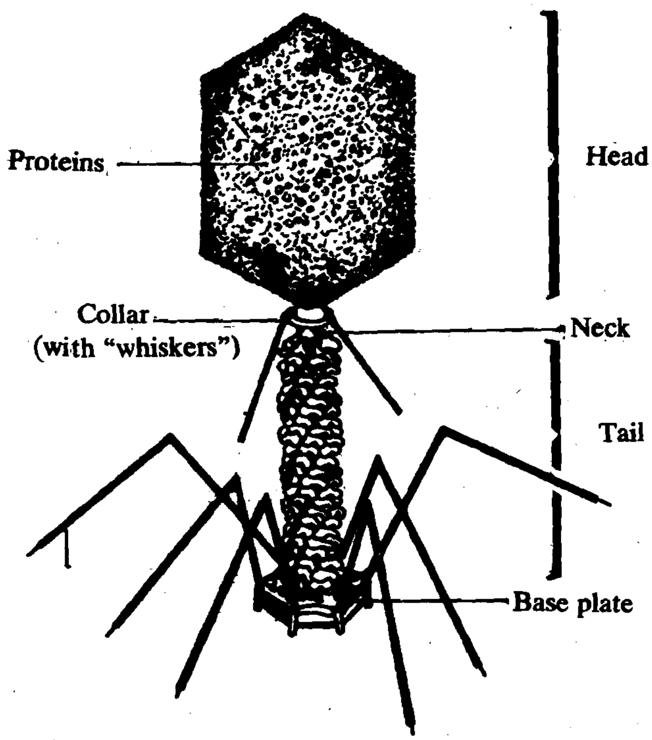


Fig. 1.6 : T_4 bacteriophage (bacteriophage is a specific type of virus which kills bacteria). Six tail fibres and collar whiskers are shown in the diagram.

The earlier living organisms must have existed independently, must have had their own metabolic machinery and capability of reproduction. It is, therefore, certain, that viruses are not in the direct line of evolution of life from non-living matter, because they are all parasites and have no metabolic machinery of their own. They are probably degenerated forms of life whose origin is a mystery.

1.3.3 Evolution of Photosynthesis and Aerobic Respiration

Bacteriochlorophyll is the chlorophyll present in bacteria which is different from that found in higher plants..

It is assumed that the earlier form of the bacteria utilised H_2S for the preparation of food. The following reaction shows this process

$$CO_2 + H_2S \xrightarrow[\text{Bacteriochlorophyll}]{\text{light energy}} \underset{\text{(food)}}{\text{Sugar } (CH_2O)_n} + \text{Sulphur (S)}$$

Since this reaction takes place in the presence of sunlight, it is called as photosynthesis. In this type of photosynthesis H_2S is used. Fig. 1.7 shows different types of metabolic pathways in bacteria.

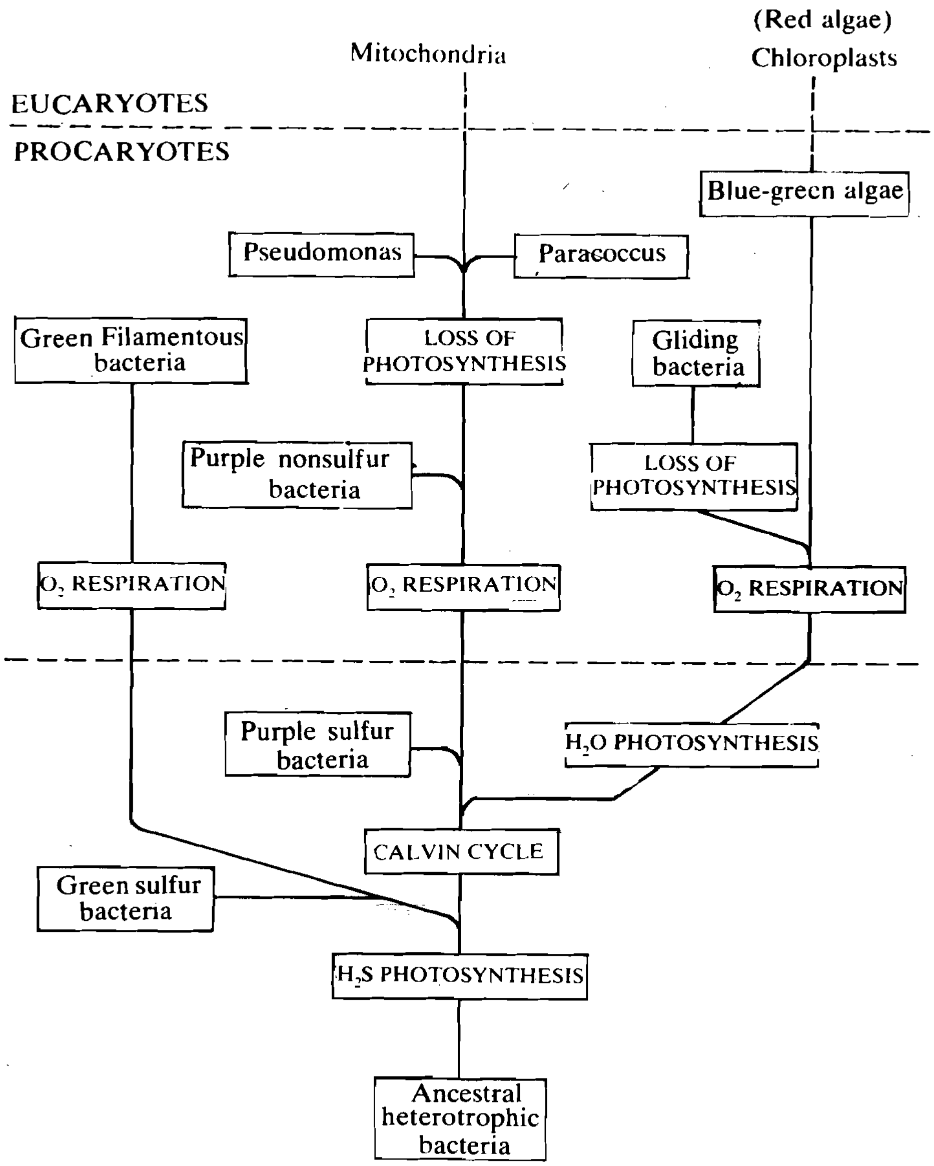


Fig. 1.7 : An evolutionary tree showing possible ways by which anaerobic and autotrophic bacteria (photosynthesisers) developed from the early anaerobic and heterophic bacteria. Likewise, aerobic form of bacteria also developed independently. Photosynthesis was retained in some forms of bacteria whereas it was lost in others.

Later, a more efficient photosynthetic system evolved in which H_2O instead of H_2S was used as an electron donor. This led to the release of free oxygen (O_2). This is the usual form of photosynthesis with which you are familiar.

$$CO_2 + H_2O \xrightarrow[\text{Chlorophyll}]{\text{+ Solar energy}} \text{Sugar } (CH_2O)_n + O_2$$

The photosynthesis which takes place by utilising water, helped in the evolution of autotrophic mode of nutrition and release of free oxygen in the atmosphere. The release of free oxygen made possible a far more efficient method of getting energy from glucose by respiration. The free oxygen got converted into ozone (O_3) in the presence of ultraviolet radiation and formed an ozone layer in the upper atmosphere. The formation of this layer prevented the incoming ultraviolet rays which otherwise could have broken down the proteins, nucleic acids etc. Thus, the formation of ozone layer made existence of various forms of life on earth possible.

Glycolysis: A pathway for glucose catabolism that does not require oxygen.

The free O_2 generated by photosynthesis was perhaps more like a poison to anaerobic bacteria initially. But some bacteria soon developed a metabolic system in which oxygen was used for the oxidation of food (respiration). This was a much more efficient system for the release of energy from organic molecules, compared with the earlier system of respiration, that is glycolysis. Some of these aerobic bacteria lost the ability of H_2S photosynthesis and became perhaps the ancestor of another class of organisms, that used the mitochondria for respiration. In mitochondria, the energy released by respiration is stored in the form of ATP molecules for further use.

SAQ 3
Arrange the following structures and processes in the order in which they are believed to have evolved.

a) aerobic respiration
b) polymers
c) photosynthesis
d) organic monomers
e) acquisition of intracellular organelles

....

....

1.4 PROCARYOTES TO EUCARYOTES

Procaryotes are the simple, unicellular organisms which do not have well defined nucleus, whereas eucaryotes are the complex, multicellular organisms with well defined nucleus. Procaryotes were originated about three and a half billion years ago, whereas eucaryotes originated about one and a half billion years ago. Thus, it appears that eucaryotes evolved later than the procaryotes. But in biochemical details the procaryotes and eucaryotes are very similar. Therefore, we can say that they have a common origin.

Eucaryotes, like procaryotes, have the same biochemical pathways for respiration both anaerobic and aerobic and for photosynthesis. The eucaryotes not only attained larger size and complex structure but also developed into multicellular organisms. Earlier each form of cell which was thought as an autonomous and self-sufficient unit, gradually became dependent on each other in larger organisms leading to division of labour within organisms. This type of cooperation between cells eventually led to the development of higher forms of life as they exist today.

Procaryotes and eucaryotes are compared in Table 1.2.

Table 1.2 : Comparison of Procaryotic and Eucaryotic Cell

	Procaryote (Monera)	Eucaryote
Differences		
Organisms	Monera, eubacteria, archaebacteria, cyanobacteria (= cyanophyta = blue-green bacteria, purple bacteria).	Plants, animals, protists and fungi
Nucleus	Absent	Present
Chromosomes	Single	Multiple
DNA	Circular molecule naked (nucleoid)	Long DNA chain bound by histones
Cell Division	Binary Fission	Mitosis or meiosis
Organelle	None except ribosomes. Plasmalemma is perhaps infolded as mesosome in green bacteria and concentrically infolded in cyanobacteria.	Mitochondria, chloroplast (in plants only), Golgi bodies, lysosomes, endoplasmic reticulum, etc.
Cell wall	Peptidoglycans, Absent in mycoplasma	Cellulose (in plants only); Absent in Animals

Exocytosis and Endocytosis	Absent	Present
Cytoskeleton	Absent	Present, composed of protein filaments.
Compartments in cells	Absent	Present due to membrane system
Cellular Organisation	Mainly unicellular	Mainly multicellular with differentiation
Metabolism	Anaerobic or aerobic	Aerobic
Cell size	1-10 μm linearly	10-100 μm linearly

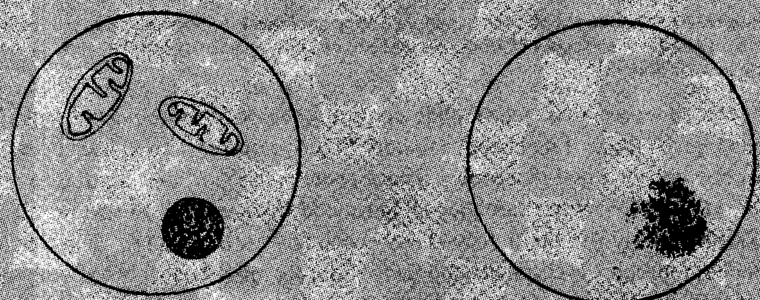
Similarities : Procaryotes and eucaryotes have many kinds of molecules in common such as DNA, ribosomal machinery, enzymes, various similar metabolic pathways and membranes of similar organisation.

SAQ 4

a) Name the organelle common to both procaryotes and eucaryotes.

....

b) Two figures are given below. Identify the procaryotic and eucaryotic cell and give one important feature of identification.



(i) (ii)

....

....

....

....

c) State one important difference between eucaryotic and procaryotic DNA.

....

....

....

1.4.1 Eucaryotic Cell Organelles

A eucaryotic cell has excessive foldings of intracellular membrane as compared to procaryotic cell. The eucaryotic cell has a number of **organelles** such as endoplasmic reticulum, Golgi apparatus, nucleus, mitochondria etc. Organelles have the same relation to a cell, as organs have with an organism. The **endoplasmic reticulum** is a complex system of membranous sacs, chambers, and tubular canals. It is the site for synthesis of proteins. The **Golgi apparatus** (or complex) which is a stack of flattened sacs sorts out and processes proteins, besides, it helps in secretion. Membranes also enclose **lysosomes**, the organelles that contain enzymes necessary for degrading foreign materials thereby help in defence mechanisms. Likewise, membranes surround **peroxisomes** (microbodies) in which highly reactive hydrogen peroxide is synthesised and degraded. Peroxisomes are also the sites where a variety of biochemical reactions cause conversion of lipids into proteins and vice-a-versa. In plants, the membranes surround large liquid filled **vacuoles**. The remaining cytoplasm which is not bound by these organelles is referred to as the cytosol. A detailed account of these organelles is given in Unit 3.

The extensive intracellular membrane system of a eucaryotic cell is much larger in size than a procaryotic cell. It provides enough surface area for the exchange of materials and other important cellular reactions which take place on the membrane surface.

It is assumed that membranous organelles have been formed by infolding of plasma membrane through a process called endocytosis (Fig. 1.8). In endocytosis portions of cell membrane along with the contents of the external medium invaginate and pinch off in the form of cytoplasmic vesicles. Exocytosis is just a reverse process.

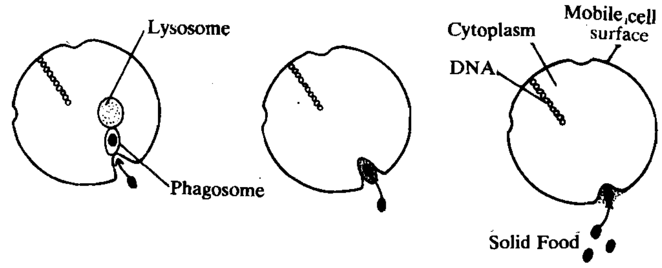


Fig. 1.8 : Showing evolution of the earliest membranous organelle, the lysosomes.

a) **Endocytosis was the possible mechanism for ingestion of food to prevent damage to internal cell components. Endocytotic pockets were located on the outer surface of the cell.**

b) **In later stages of evolution, food was packaged in the membranous vesicles formed at the cell surface which also induced the digestive enzymes. The food was digested outside the cell in specialised enclosures.**

c) **In the last stages of evolution, the digestive enzymes were packaged in lysosomes located internally and food was digested by the fusion of lysosome and phagosome vesicles, a physiological process, well known in the present day cell.**

All eucaryotic cells have a cytoskeleton made up of a network of protein filaments (Fig. 1.9). This network gives the cell its shape, capacity to move and ability to transport organelles from one part of a cell to another. These protein filaments are similar in all eucaryotes. The important protein filaments are actin and myosin in muscles and tubulin in microtubules. Actin and myosin are involved in muscle contraction and in the formation of microfilaments. Microtubules are hollow and form cilia, flagella, centriole and mitotic spindle. This kind of cytoskeleton is absent in the procaryotes.

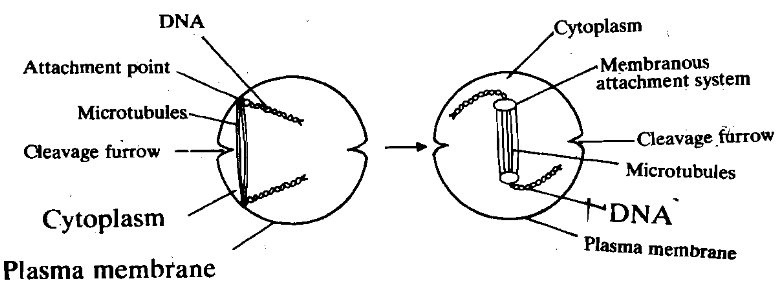


Fig. 1.9 : For the evolution of eucaryotic cell, the detachment of DNA from plasma membrane (in procaryotes DNA is attached to plasma membrane) is necessary. The orderly separation of replicated DNA molecules during cell division required system of attachment. Later, in the course of evolution, this system got detached from the mobile plasma membrane. Presence of microtubules in all eucaryotes indicates that they appeared early in eucaryotic evolution and were retained in all the later generations. Therefore, between the points of attachment, a system having tubular apparatus developed.

In procaryotes the DNA molecule lies freely in the cytoplasm attached to the cell membrane (Fig 1.5). In eucaryotes it is enclosed inside the nucleus. This kind of formation of compartment protects DNA from many chemical changes that occur in the cytoplasm (Fig. 1.10).

The DNA found in eucaryote is not only large (human cells contain DNA thousand times larger than that in a typical bacteria) but is also packed together with histones into chromosomes. Histones are the proteins which are basic in nature, found in eucaryotes. They bind to DNA and wrap it up into compact chromosomes. Histones also control the expression of the characters called gene expression, about which you will study in detail in Units 12 and 13. Histones are important proteins which have not undergone any change during evolution and are identical in all plant and animal cells studied so far. Division of the nucleus by mitosis is another characteristic of the eucaryotes which permits proper and equal distribution of the genetic material to the daugher cells. Ribosomes which are the granular structures consisting of RNA and proteins are necessary for protein synthesis. These are the only organelles that are common to both procaryotes and eucaryotes. However, there are some minor differences between procaryotic and eucaryotic ribosomes.

1.4.2 Mitochondria and Chloroplast

Mitochondria are commonly known as the "power house" of cells. These are the distinct organelles of all eucaryotic cells, plants, fungi and some protists. In the cell, mitochondria are the sites of aerobic respiration. They are enclosed by a double membrane. The inner membrane is thrown into folds which are called as 'cristae'. Oxidative enzymes are located on these cristae. Mitochondria contain circular and naked DNA. They reproduce by fission, like bacteria. In the absence of mitochondria, eucaryotic cells would have to respire anaerobically and they will have to depend on an inefficient process, like glycolysis for their energy needs. It is interesting that mitochondria resemble an aerobic and non-photosynthetic bacterium like **Paracoccus**. In fact, in one of the eucaryotes like **Pleomyxa palustris**, there are no mitochondria. In this organism, in place of mitochondria there are aerobic bacteria which help the organism in respiration. The association of bacteria with the organism shows a kind of symbiotic (mutual advantage) relationship, wherein bacteria help the organism in respiration and in turn bacteria are benefitted by living at the expense of the organism permanently.

This relationship suggests that mitochondria are procaryotes which have entered the "eucaryotic" cell as endosymbionts, i.e., they have association inside the cell even before the entry of chloroplasts in the cell. In other words, we can say that mitochondria have evolved earlier than the chloroplasts.

Like mitochondria, chloroplasts are also distinctive organelles of eucaryotic cell. But they are found only in plant cells. Chloroplasts contain membranes forming a system of thin sacs or lamellae stacked on top of each other. These membranes contain the pigment chlorophyll whose function is to trap light energy required to make organic molecules particularly sugars. This process is called **photosynthesis**. It is worth mentioning that chloroplasts resemble the present day cyanobacteria in size and structural organisation of chlorophyll bearing membranes. Chloroplasts also contain DNA and reproduce by self-replication. In fact a number of present day eucaryotic cells do contain cyanobacteria in them (Fig. 1.11).

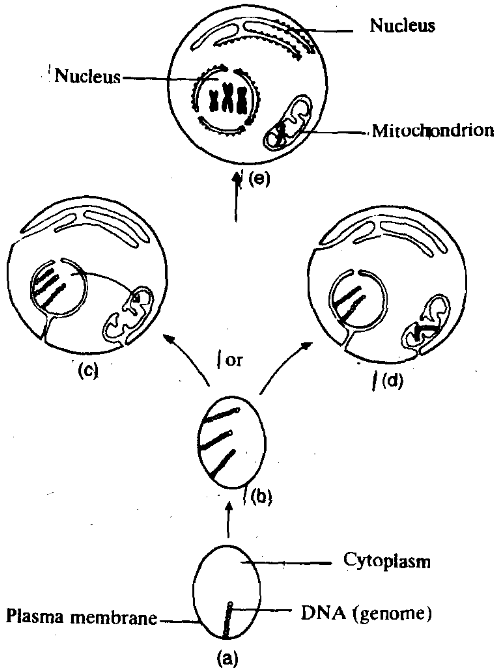


Fig. 1.11 : Evolutionary origin of mitochondria and other membranous system.

a) **Procaryotic cell with one molecule of DNA (genome) is assumed to have undergone genome duplication.**

b) **Multiple copies of genome (DNA) are formed.**

c) **There occurs internalisation of plasma membrane and its differentiation to nuclear, endoplasmic reticulum (ER), mitochondrial and other systems in eucaryotic cells. Later on some DNA that was originally enclosed in nuclear envelope was transferred to mitochondria.**

d) **During partition bulk of the DNA was retained in the nucleus while some of the DNA was transferred to mitochondria.**

e) **Modern eucaryotic cells have numerous internal membrane systems in which main portion of DNA is present in nucleus whereas a small portion remains in mitochondria.**

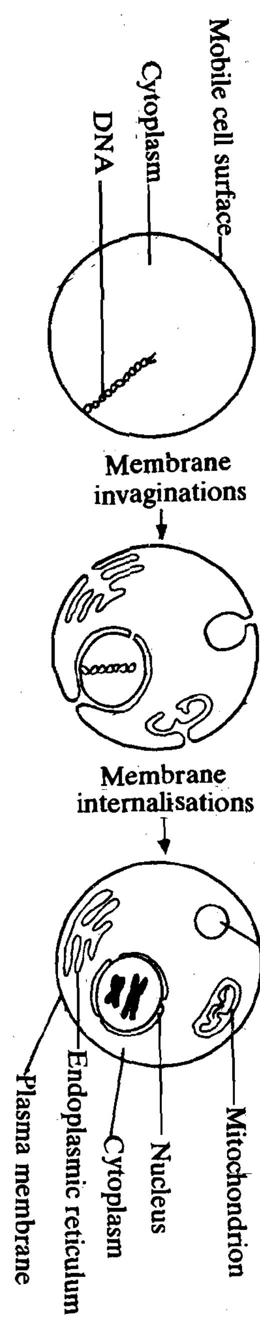


Fig. 1.10 : The process of invaginations and internalisations of membrane is proposed as an evolutionary phenomenon in which procaryotic cells with a mobile cell surface would have undergone endocytotic invaginations of certain regions of plasma membrane. These infoldings were established in eucaryotic cells as internal membrane systems independently, consequently, these remained without having any relation with plasma membrane.

It is from this symbiotic relationship that we can trace the origin of eucaryotic forms and divergence of plant and animal cells (Fig. 1.12).

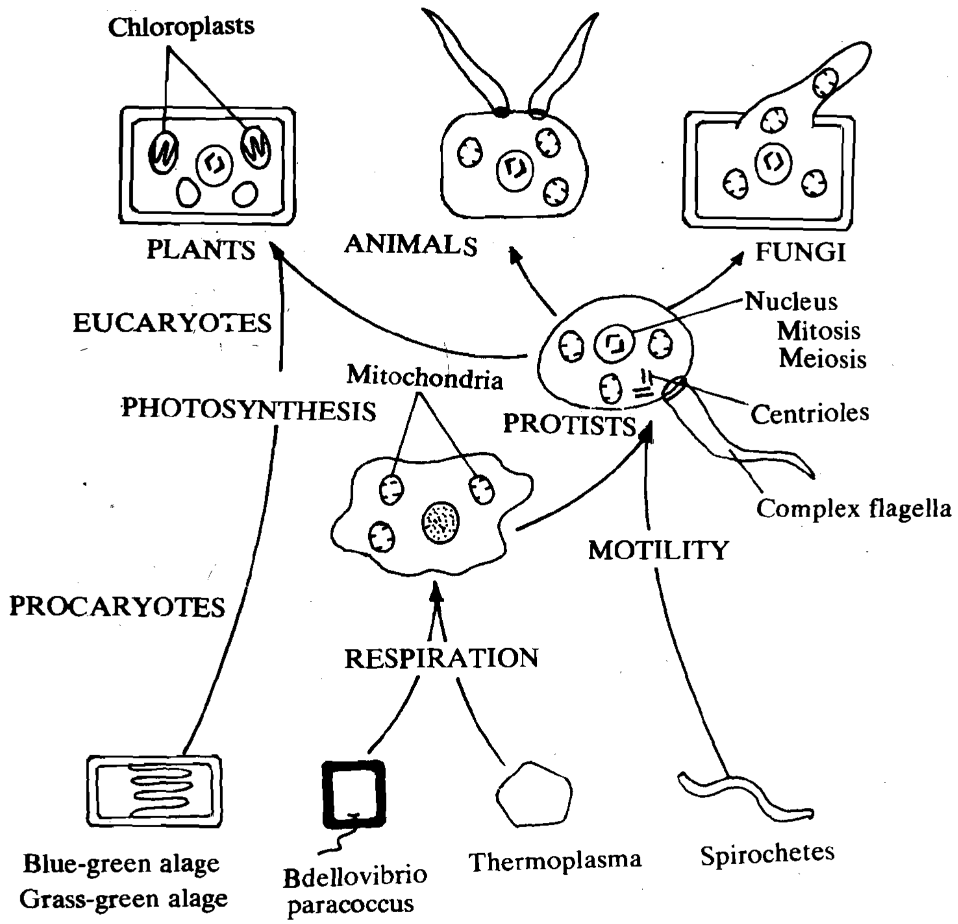


Fig. 1.12 : Schematic diagram showing the endosymbiont theory regarding origin of organelles in eucaryotes. The early procaryotic and anaerobic cell could ingest solid food through mobile cell surface. Such a cell might have engulfed respiring procaryotic cells like Paracoccus, leading to the development of symbiotic endosymbionts. The endosymbionts which were dependent on the host for their nutrients and protection, developed into cell organelles like mitochondria, flagella and chloroplast.These organelles were advantageous in respiration, motility and photosynthesis to host. The symbiotic relationships helped to trace the origin of eucaryotic forms and divergence of plants and animal cells.

1.4.3 Animal and Plant Cells

The internal structural organisation and information related with hereditary characters and metabolic pathways are similar in all eucaryotic cells whether they are of plants, fungi, animals or protists. On the other hand plant and animal cells differ in some respects. Cell wall in plant cells is unique. It provides mechanical support and protection. Besides, the cell wall helps to balance osmotic pressure of the cell with the surrounding medium. It consists of a network of cellulose and a gel-like matrix. Plant cells also contain pigment containing organelles called plastids such as chloroplasts (green colour), chromoplasts (red colour) and leucoplasts (no colour). Chloroplasts help the plants to synthesise their own food in presence of sunlight (autotrophs). Presence of large vacuoles is another important feature which distinguishes the plant cells from the animal cells. Endoplasmic reticulum (ER) plays a significant role in the formation of vacuoles. Glyoxysomes, the microbodies found in some plant cells, are involved in lipid metabolism. Golgi complexes found in plant cells are called as dictyosomes. The animal cells, often contain flagella and cilia for movement, and centrioles for cell division. On the other hand, these organelles are generally absent in plant cells. The difference between plant and animal cells are listed in the Table 1.3 and illustrated in the Fig. 1.13 for your ready comparison.

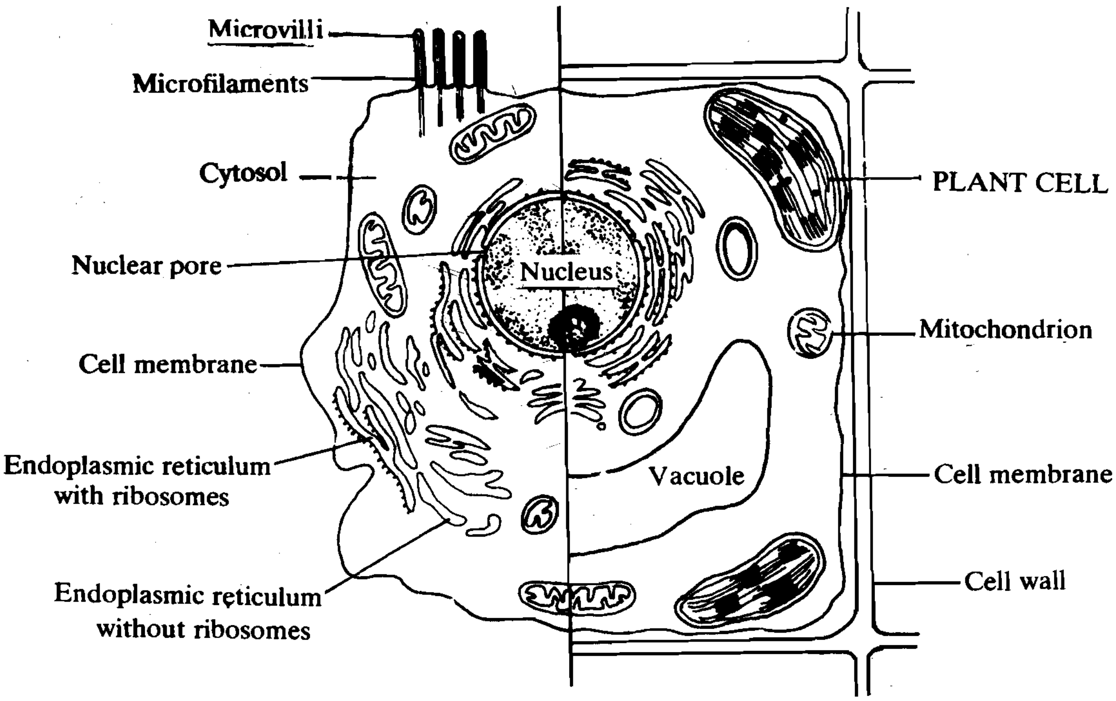


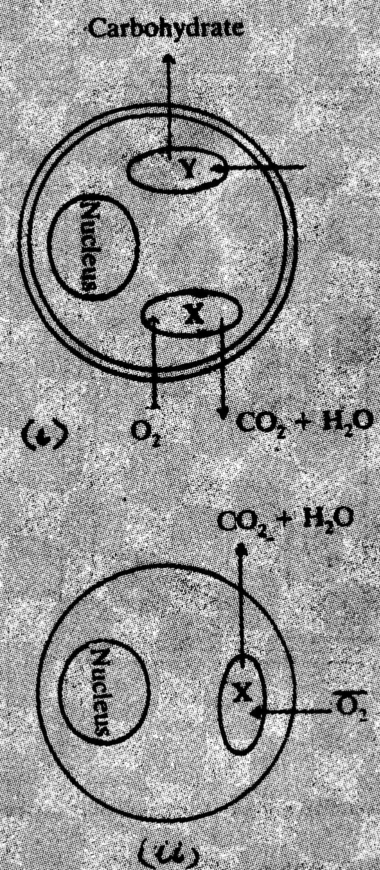
Fig. 1.13 : Generalised structure of eucaryotic cell showing the difference between plant cell and animal cell.

Table 1.3 : A Comparison of Animal and Plant Cells

	Animal Cell	Plant Cell
Exterior Structure		
Cell wall	Absent	Present (cellulose)
Cell membrane	Present	Present
Flagella	May be present	Absent except in sperm of a few species
Interior Structure		
Endoplasmic reticulum (ER)	Usually present	Usually present
Microtubules	Present	Present
Centrioles	Present	Absent
Golgi bodies	Present	Present
Organelles		
Nucleus	Present	Present
Mitochondria	Present	Present
Chloroplast	Absent	Present
Chromosomes	Multiple units, DNA associated with protein	Multiple units, DNA associated with protein
Ribosomes	Present	Present
Lysosomes	Usually present	Equivalent structures called "spherosomes"
Vacuoles	Absent or small	Usually a single large vacuole in mature cell

SAQ 5

Look at the following figures and answer the questions:



a) Name the organelles X and Y.

....

....

b) Identify the animal and plant cell and give reasons for identification.

....

....

....

....

c) Which major process occurs in organelle X ?

....

d) Which major process occurs in organelle Y ?

....

1.5 SUMMARY

Let us sum up whatever we have said so far.

- Although there are different species of living organisms, there is a unique master plan of organisation at the cellular and molecular levels. The rapid processes in the field of cell and molecular biology in the present century is due to the development of microscopes and various physico-chemical methods used to analyse the cell, such as X-ray diffraction and cell fractionation.
- **The evolution of life, from simple to complex, took place in two stages— chemical evolution and biological evolution. Three possible models for protobiont formation are coacervate model, proteinoid microsphere model and lipid bilayer model.**

- Protobionts could become eubionts only with the development of self-replicating genetic system. Scarcity of nutrients favoured the selection of those which could obtain the nutrient from a precursor. Hence, more complex metabolic pathways such as glycolysis developed which consequently led to the development of autotrophs.
- From an evolutionary viewpoint, procaryotes are considered to be the ancestors of eucaryotes. Procaryotes and eucaryotes resemble as well as differ from one another in many respects. The complex multicellular eucaryotes like plant and animal cell differ from each other in many respects.

1.6 TERMINAL QUESTIONS

1) How did the primordial cell originate?

....

....

....

2) List two changes in the environment that resulted from evolution of water splitting photosynthesis.

....

....

3) Name the organelle(s) responsible for the following function in a eucaryotic cell.

   a) Production of ATP by the oxidation of food:...

   b) Protein synthesis: ....

   c) Secretion:...

   d) Synthesis of food in the presence of sunlight:..

4) Symbiotic relationships of mitochondria with procaryotic cells helped in tracing the evolution of eucaryotic cells. Explain it.

....

....

....

....

....

....

....

....

1.7 ANSWERS

Self-assessment Questions

1) a) Microscope
   b) Cell is the structural and functional unit of organisation
   c) The division of pre-existing cells
   d) Mitosis

2) a) Biological evolution
   b) Coacervate model, proteinoid microsphere model, lipid bilayer model

3) d, b, e, c, a.

4) a) Ribosomes
   b) (i) is eucaryotic cell, and (ii) is procaryotic cell because in (i) nucleus is well defined with nuclear membrane whereas in (ii) nucleus is not clearly demarcated.

c) In procaryote, DNA molecule is circular and naked whereas in eucaryote DNA is long chain bound by histones.

5) a) Organelle 'X' is mitochondria and organelle 'Y' is chloroplast.
   b) (i) is plant cell because of presence of cell wall and chloroplast, and (ii) is animal cell because of their absence.
   c) Respiration.
   d) Photosynthesis.

Terminal Questions

1) The assemblage of phospholipid molecules to form membrane was the first step for the formation of primordial cell.

2) a) Release of free oxygen in atmosphere
   b) Autotrophic mode of nutrition

3) a) Mitochondria
   b) Ribosomes
   c) Golgi complex
   d) Chloroplast

4) Mitochondria, the power house of the cell resemble aerobic, nonphotosynthetic bacteria. It was found that some eucaryotic organisms which lacked mitochondria were in permanent symbiotic relationship with aerobic bacteria (procaryote) for respiration. Thus, symbiotic relationship suggested that mitochondria are procaryotes which entered the eucaryotic cell as endosymbionts.