MODULE 3: MOLECULAR BASIS OF CELL STRUCTURE AND DEVELOPMENT

UNIT 1: PROKARYOTIC CELL STRUCTURE

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1.0 INTRODUCTION

Cells are the fundamental structural and functional units that the plant body and animal body is composed of. In this unit we shall examine the structure of prokaryote cell in some detail and then study other cells in the next few units.

2.0 A: OBJECTIVES

By the end of this unit, you should be able to:

- Clearly outline and label bacterial cell;
- Write on the current understanding of the prokaryotic cell structure;
- Illustrate some of the structures disclosed in the diagrams.

2. 0 B: HOW TO STUDY THIS UNIT

1. You are expected to read carefully through this unit twice before attempting to answer the activity questions. Do not look at the solution or guides provided at the end of the unit until you are satisfied that you have done your best to get all the answers.
2. Share your difficulties in understanding the unit with your mates, facilitators and by consulting other relevant materials or internet.
3. Ensure that you only check correct answers to the activities as a way of

confirming what you have done.

4. Note that if you follow these instructions strictly, you will feel fulfilled at the end that you have achieved your aim and could stimulate you to do more.

3.0 MAIN CONTENTS

3.1 Details of Prokaryotic Cellular Components

An example of prokaryotic organism-*Escherichia coli*. It is a simple single cell, rod-shaped and bacillus

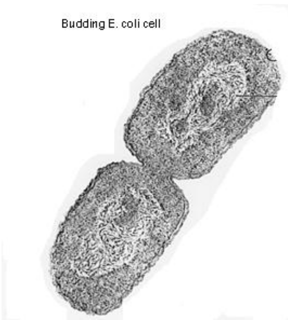


Fig. 28. Budding Escherichia coli
©Wilbur H. Campbell, 1995

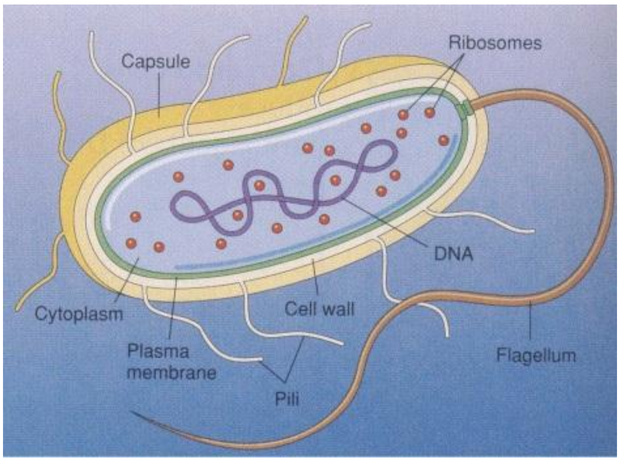


Fig. 29. A typical bacterial cell
Morayeel.louisiana.edu

E. coli grows in human intestine; it has a single, circular chromosome and also contains DNA as plasmids - Plasmids are extra-chromosomal DNA.

3.2 Prokaryotic Cell Wall

The cell wall is a very rigid structure (Fig. 29) that gives shape to the cell. Its main function is to prevent the cell from expanding and eventual bursting because of uptake of water, since most bacteria live in hypotonic environments (i.e., environments having a lower osmotic pressure that exists.

Bacterial cell wall is usually essential for bacterial growth and division. Cells whose walls have been completely removed are incapable of normal growth and division. Some bacteria have extra-cellular wall structures such as flagella, pili, slime and others outside the cell wall.

Species of bacteria can be divided into two major groups called Gram-positive and Gram-negative. The distinction between Gram-positive and Gram-negative bacteria is based on their Gram stain reaction. The staining reactions are located in the cell wall region of the bacterium.

However, some bacteria do not have cell walls. Although most prokaryotes cannot survive in nature without their cell walls, some are able to do so. These include the mycoplasmas, a group of pathogenic bacteria that causes a variety of infectious diseases in humans and other animals. The *Thermoplasma* groups, species of Archaea also naturally lack cell walls. These prokaryotes are essentially free-living protoplasts, and they are able to survive without cell walls either because they have unusually tough cytoplasmic membranes or because they live in osmotically protected habitats such as the animal body.

3.3 Prokaryotic Cytoplasmic Membrane

Immediately beneath the cell wall is the cytoplasmic membrane (Fig. 29). This structure is composed primarily of phospholipids and proteins. The phospholipids form a bilayer in which most of the proteins are tenaciously held (Fig. 30). This membrane is a semi-permeable due to its structure of proteins and phospholipid. It is a selective membrane.

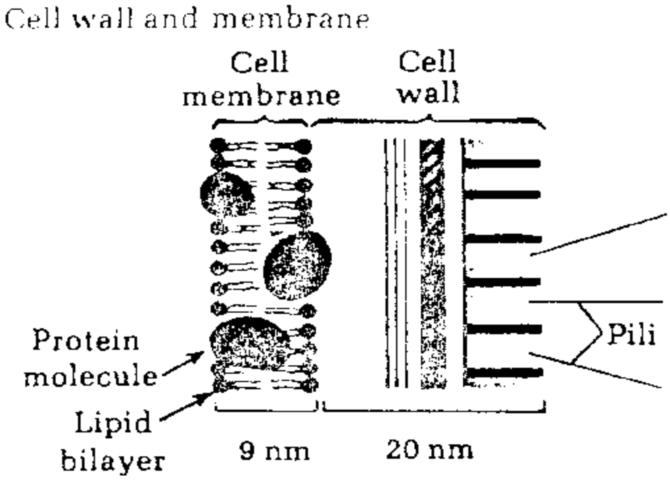


Fig. 30.Prokaryotic Cell Wall and Membrane.
(Modified from Lehninger, Biochemistry, ©Wilbur H. Campbell, 1995)

3.4 Nuclear Material

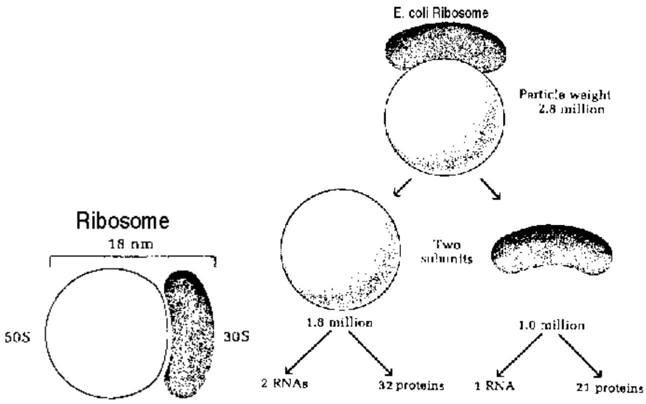
In contrast to eukaryotic ells, bacterial cells contain neither a distinct membrane-enclosed nucleus nor a mitotic apparatus. However, they do contain an area near the centre of the cell that is regarded as a nuclear structure, and the DNA of the cell is confined to this area (Fig. 29). Because it is not a discrete nucleus, this indistinct structure has been designated by such terms as the nucleoid; the chromatin body; the nuclear equivalent; and even the bacterial chromosome. It consists of a single, circular DNA molecule in which all the genes are linked.

3.5 Cytosol

The cell membrane encloses the cytoplasm called cytosol (Fig. 29). The cytosol bounded by the cytoplasmic membrane may be divided into: (a) cytoplasmic area, granular in appearance and rich in the macromolecular RNA-protein bodies known as ribosomes, on which proteins are synthesized; (b) the chromatinic area, rich in DNA; and (c) the fluid portion with dissolved substances. Unlike animal and plants cells, there is no endoplasmic reticulum to which ribosomes are bound. Some of the ribosomes are free in the cytoplasm, and others, especially those involved in the synthesis of proteins to be transported out of the cell, are associated with the inner surface of the cytoplasmic membrane. Intracellular granules of polyphosphate may be found in certain microorganisms. Such storage granules appear as a deep violet colour when the cells are stained with dilute methylene blue. Mitochondria, which are about the same size as bacterial cells are absent in prokaryotic cells.

3.6 Prokaryotic Ribosome

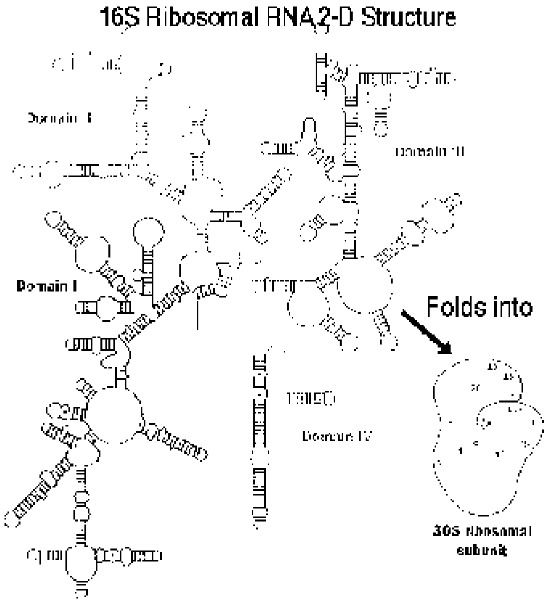
The ribosome - a cytoplasmic structural unit is made up of RNA and protein which is the site of protein synthesis. When the ribosomes of prokaryotes undergo sedimentation in a centrifuge, they have a sedimentation coefficient of 70 Svedberg units (70S) and are composed of two subunits, a 50S and a 30S subunit. This is in contrast to the ribosomes of eukaryotic organisms, which has a sedimentation coefficient of 80S and are composed of a 60S and a 40S subunits. The Svedberg unit is the unit used in expressing the sedimentation coefficient: the greater a particle's Svedberg value, the faster it travels in a centrifuge.



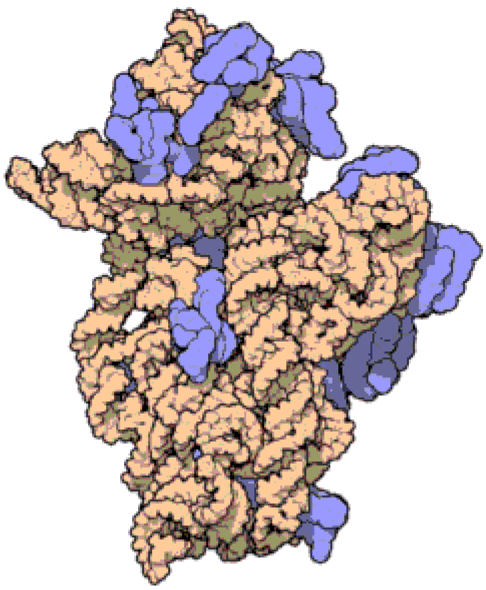
(A) (B)

Fig. 31: (A), Prokaryotic Ribosome; (B) Two Dimensional (2-D) Model of E. coli Ribosomes
Modified from Lehninger, Biochemistry, ©Wilbur H. Campbell, 1995

The structures of each subunit can be further revealed as shown in Fig. 32. The 30S subunit is segmented into different fractions as shown in the Figure.



(a)



(b)

Fig. 32: Structure of 16S rRNA of 30S Subunit of (a) E. coli Ribosome and (b) Thermusthermophillus

(Source: Voet and Voet Biochemistry, ©1990 John Wiley and Sons)

4.0 CONCLUSION

The cells of prokaryotes are relativelythe various structures that coordinate the activities and functions of the cells.

Bacterial cells differ from one another not only in their physical features but also in their chemical characteristics and in their functions.

5.0 SUMMARY

In this unit we have learnt that:

- Cytoplasmic membrane is composed of phospholipids and proteins.
- Bacterial cells contain neither a distinct membrane-enclosed nucleus nor a mitotic apparatus.
- Bacterial cells have no endoplasmic reticulum to which ribosomes are bound.
- Ribosome is the site of protein synthesis.
- Prokaryotes ribosomes are composed of two subunits, a 50S subunit and a 30S subunit.
- The cell wall is a rigid and protective structure
- Some prokaryotes lack the cell walls in their cells

6.0 TUTOR MARKED ASSIGNMENT

- Why do bacterial cells need cell walls? Do all bacteria have cell walls?
- Write a short account of each of the parts of a prokaryotic cell.
- Is it proper to refer to bacterial cells as containing a typical nucleus? Explain.

7.0 FURTHER READING AND OTHER RESOURCES

Madigan, M.T., Martinko, J.M., Dunlap, P.V. & Clark, D.P. (2009).Brock Biology of Microorganisms.12th edition.Pearson International Edition.

Pelczar, M.J., Chan, E.C.S. & Krieg, N.R. (1986).Microbiology, International edition, McGraw Hill International editions.Pages 73-98.ISBN 0-07-Y66494-3.

Snyder, L. &Champness, W. (2003). Molecular Genetics of Bacteria, Second Edition, Washington, D.C. pages 566.

UNIT 2: PLANT CELL STRUCTURE

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1.0 INTRODUCTION

As far back as 1665, plant cells were discovered. Since then important concepts on the structures of plant cells have been established. The cell wall being the prominent part of the plant cell was noticed. In this unit we shall discuss the current understanding of the structures that make up plant cell.

2.0 A: OBJECTIVES

By the end of this unit, you should be able to:

- Diagrammatically outline and label plant cell structure;
- Write on the current understanding of plant cell structure;
- Illustrate some of the structures disclosed in the diagrams.

2.0 B: HOW TO STUDY THIS UNIT

1. You are expected to read carefully through this unit twice before attempting to answer the activity questions. Do not look at the solution or guides provided at the end of the unit until you are satisfied that you have done your best to get all the answers.
2. Share your difficulties in understanding the unit with your mates, facilitators and by consulting other relevant materials or internet.
3. Ensure that you only check correct answers to the activities as a way of confirming what you have done.
4. Note that if you follow these instructions strictly, you will feel fulfilled at the end that you have achieved your aim and could stimulate you to do more.

3.0 MAIN CONTENTS

3.1 The Nucleic Acids - DNA and RNA

3.1.1 Deoxyribo Nucleic Acid (DNA)

The DNA is the genetic material of most living systems, including eukaryotes and prokaryotes. Double stranded DNA is found only in natural form. Chromosomes of eukaryotes and prokaryotes are double stranded DNA

3.1.2 Ribonucleic Acid (RNA)

RNA is single stranded. It is genetic material in some viruses. The RNA exists in 3 basic forms: tRNA (transfer RNA) = adapter in protein synthesis - matches codon to amino acid; rRNA (ribosomal RNA) = structural RNA in ribosomes and mRNA (messenger RNA) = contains information for protein synthesis

3.2 Comparison between Plant and Animal cells.

1. Plant cells have cell wall, but animal cells do not.
2. Plant cells have chloroplasts, but animal cells do not.
3. Plant cells generally have a more rectangular shape because the cell wall is rigid. Animal cells have a round or irregular shape because they do not have a cell wall.
4. Plant cells usually have one or more large vacuole(s), while animal cells have smaller vacuoles, if they are present (Fig. 21).

In a typical plant cell, the following structures are usually present: cell wall, cell memberane, endoplasmic reticulum, Golgi apparatus, mitochondria, cytoplasm, vacuoles, nucleolus, nucleus, chloroplast

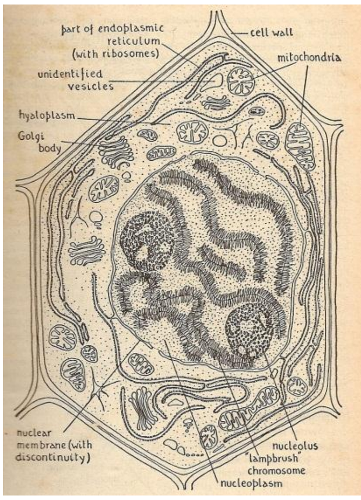

Fig. 21 Plant cell

(Source: Vines and Rees, Plant and Animal Biology, Vol. 2.)

3.3 Plant cell wall

A plant cell as a unit or independent structure is made up of tiny or microscopic mass of protoplasm enclosing in it a denser spherical or oval body, called the nucleus, and bounded by a distinct wall, called cell wall. Cytoplasm and nucleus are living, while the cell wall is non-living, the latter having been formed by the protoplasm during cell division, primarily for its own protection. A plant cell thus consists of a protoplast (cytoplasm and nucleus) representing the living parts and a cell wall. The cell wall is a non-living rigid structure that protects the cell.

Plant cells have almost the same components as animal cells, but there are three basic differences between them. One difference is the cell wall. Plant cell walls are reinforced structures containing cellulose and lignin to make them rigid.

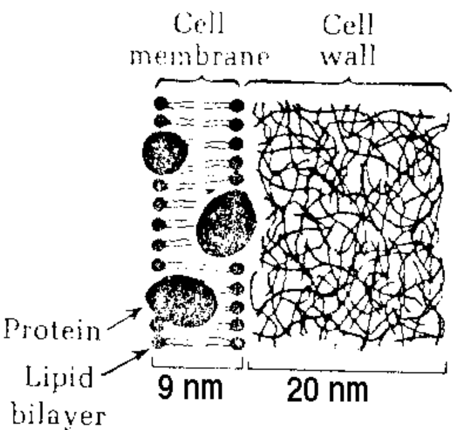

Fig. 22 Relative Thickness of Plant Cell Membrane and Cell Wall.
(©Wilbur H. Campbell, 1995, 1996)

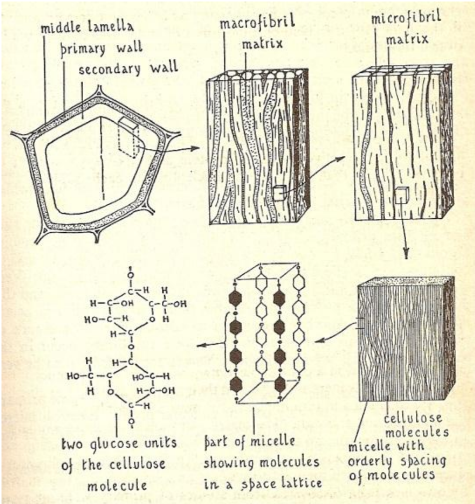

Fig. 23 Primary and Secondary Plant cell Wall In Increasing Detail
(Source: Vines and Rees, Plant and Animal Biology, Vol. 2.)

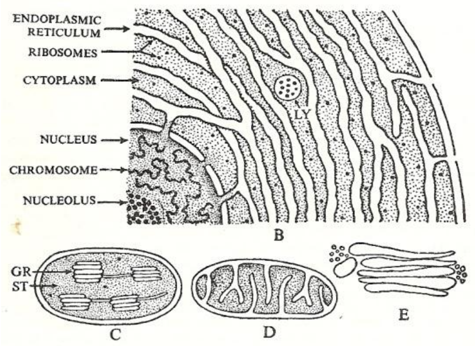

Fig. 26 Parts of a cell. (A) as seen under a compound microscope; (B-E) as seen under an electron microscope; (B), a portion of the cell (LY, Lysosome); (C), a chloroplast (GR, granum; ST, stroma); (D), mitochondrion; (E), Golgi body.
(Source: Dutta, A.C. 1981 Botany 5th edition)

3.4 Plant Cell Organelles

3.4.1 Chloroplasts

Chloroplasts are examples of plastids (Fig. 24 and 25). They are green. Plants are autotrophic in nature (energetically self supporting) by using the chloroplasts to manufacture food during the process of photosynthesis. This is the second difference between plant and animal cells. Animal cells lack chloroplasts.

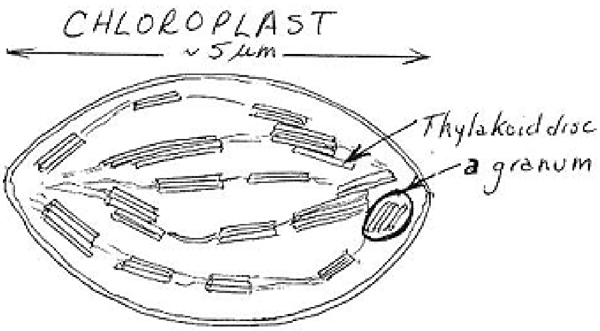

Fig.25. A detached Chloroplast
(Source: Wilbur H. Campbell, 1995, 1996)

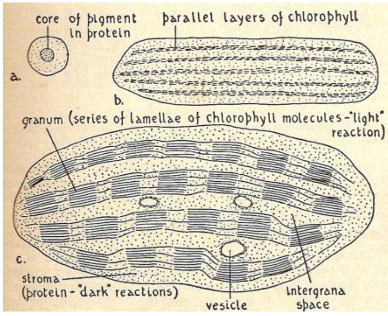

Fig. 25 Diagrams representing: (a) pigment-carrier of bacteria and blue-green algae, (b) lamellar chloroplast of some green algae, (c) chloroplasts of higher plant.
(Source: Vines and Rees, Plant and Animal Biology, Vol. 2.)

Plants utilize light energy and chloroplasts contain the chlorophyll and enzymes for carrying out photosynthesis (Fig. 24 and 25). Chloroplasts are green plastids which make plants generally green in colour. They work only in the presence of sunlight and perform some very important functions with the help of their chlorophyll.

3.4.2 Endoplasmic Reticulum, Mitochondria and Golgi body

Other important plant cell organelles include the endoplasmic reticulum, mitochondrion and Golgi body (Fig. 26). In the next unit, Unit 3, we shall discuss in details on their structures and functions.

3.5 Plant Vacuoles

The third difference between plant and animal cells is that, plant cells have a large vacuole. The plant vacuole is a single membrane organelle for storing organic acids, salts, etc. When the cell is very young it remains completely filled with cytoplasm (cell sap), but as the cell grows a large number of small non-protoplasmic but fluid-filled cavities of varying sizes, apparently like little bubbles, called vacuoles appear in the cytoplasm. As the cell enlarges all these small vacuoles begin to fuse together, and finally in the mature cell they form one large central vacuole which occupies the major part of the cell-cavity (Fig. 27).

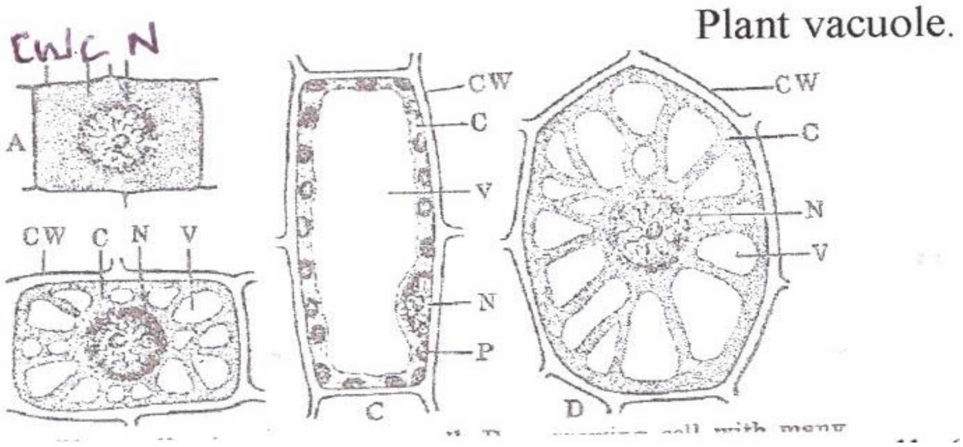

Fig. 27 Plant cells. (A), a very young cell; (B), a growing cell with many small vacuoles; (C) a mature cell with a large vacuole; (D), a mature cell with many vacuoles, CW, cell wall; C, cytoplasm; N, nucleus; V, vacuole; P, plastid (chloroplast) *(Source: Dutta AC 1981 Botany 5th edition)*

4.0 CONCLUSION

The presence of the cell wall, chloroplast and vacuole in the plant cell distinguish it from the animal cell.

5.0 SUMMARY

In this unit we have learnt that:

- Plant cells have a cell wall and usually contain chloroplasts (these are green structures which give plants their green colour). These are absent in animal cells.
- Plant cell walls are reinforced structures containing cellulose and lignin that make them rigid.
- Plants utilize light energy with chloroplasts that contain the chlorophyll and enzymes in carrying out photosynthesis.
- The plant vacuole is a single membrane organelle for storing organic acids, salts, etc.

6.0 TUTOR MARKED ASSIGNMENT

1. What are the distinguishing features of a plant cell?
2. Draw and label the plant cell.
3. Relate the structures of the plant cell to their functions.

7.0 FURTHER READING AND OTHER RESOURCES

Madigan, M.T., Martinko, J.M., Dunlap, P.V. & Clark, D.P. (2009).Brock Biology of microorganisms.12th edition.Pearson International edition.

Pelczar, M.J., Chan, E.C.S. & Krieg, N.R. (1986) Microbiology, International edition, McGraw Hill International editions.Pages 73-98.ISBN 0-07-Y66494-3.

Vines, A.E. & Rees, N. (1984).Plant and Animal Biology, Vol. 2, 4th edition.Pitman.

UNIT 3: EUKARYOTIC CELL STRUCTURE

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1.0 INTRODUCTION

In this unit we now discuss the typical eukaryotic cell structures. The eukaryotes include algae, fungi, protozoa, plants and animals. Their cells are more complex than those of the prokaryotes.

2.0 A: OBJECTIVES

By the end of this unit, you should be able to:

- Diagrammatically outline and label eukaryotic cell structure;
- Write on the current understanding of eukaryotic cell structure
- Discuss the functions of the various cell constituents

2.0 B : HOW TO STUDY THIS UNIT

1. You are expected to read carefully through this unit twice before attempting to answer the activity questions. Do not look at the solution or guides provided at the end of the unit until you are satisfied that you have done your best to get all the answers.
2. Share your difficulties in understanding the unit with your mates, facilitators and by consulting other relevant materials or internet.
3. Ensure that you only check correct answers to the activities as a way of

confirming what you have done.

4. Note that if you follow these instructions strictly, you will feel fulfilled at the end that you have achieved your aim and could stimulate you to do more.

3.0 MAIN CONTENTS

3.1 Eukaryotic Cell Membrane or Plasma Membrane

The typical eukaryotic cell usually has the cell membrane, cytoplasm, endoplasmic reticulum, Golgi body, mitochondria, nucleus, nucleoplasm, nucleolus, lysosomes, peroxisomes. Flagella and cilia may be present especially in the lower eukaryotes. The cell or plasma membrane contains equal amounts of lipids and proteins, which are arranged in a bilayer (Fig. 33). Plasma membrane is semi-permeable and contains transport systems for ions, sugars, and amino acids.

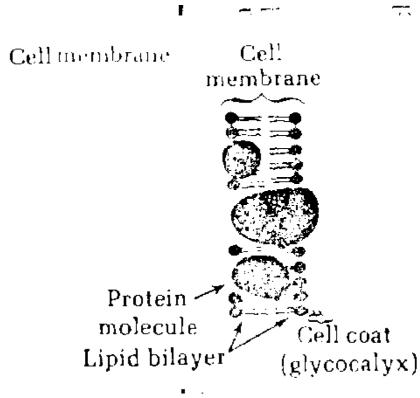

Fig. 33. Eukaryotic Cell Membrane or Plasma Membrane
(Source: Modified from Lehninger, Biochemistry, ©Wilbur H. Campbell, 1995)

3.2 Structure of a Eukaryotic Nucleus

A eukaryotic nucleus as seen with the electron microscope is illustrated below (Fig. 34). This nucleus is not engaging in mitosis and is thus called an interphase nucleus. The chromosomes in an interphase nucleus cannot be distinguished as individual entities but instead appear as an amorphous network; for this reason, interphase chromosomal material is commonly referred to as chromatin. The most prominent landmark of an interphase nucleus is its nucleolus - a large, deeply stained spherical body that contains RNA and protein and represents the site of synthesis and storage of the cell's cytoplasmic ribosomes (Fig. 34). These ribosomes are the structures that are involved in protein synthesis.

The chromatin in an interphase nucleus is surrounded by a membrane that folds back on it to form an envelope. At intervals the envelope is perforated into pores, at other intervals the envelope extends out into the cytoplasm as a network of channels and large cisternae known as the endoplasmic reticulum (Fig. 34). The cell's ribosomes are often bound to the outer surface of the endoplasmic reticulum, forming what is known as “rough” endoplasmic reticulum.

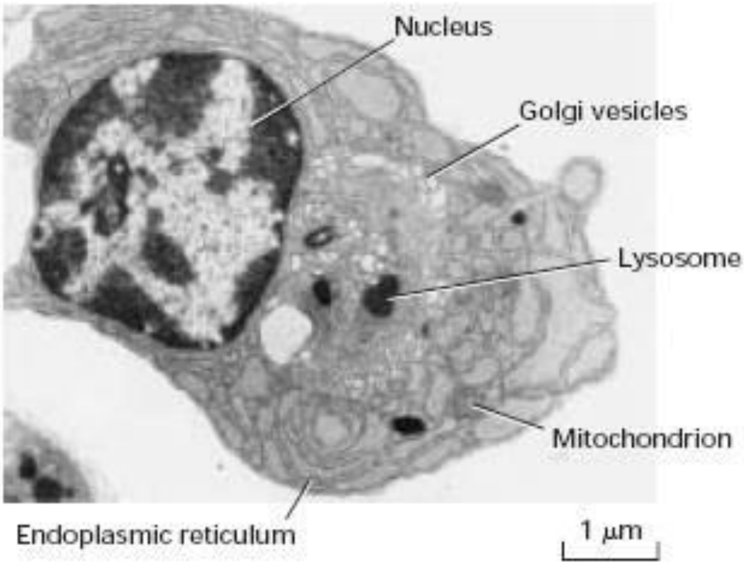

Fig. 34 Structure of a Eukaryotic cell, Chlamydomonasreinhardi. Arrow point to nuclear pores.
(Source: Ursula Goodenough, 1978, Genetic, 2nd edition)

3.3 Eukaryotic Cell Organelles

The cytoplasm contains structures called cell organelles. In addition the cytoplasm contains soluble enzymes, free ribosomes, and additional systems of membranes which serve to divide the cell into a number of compartments called organelles. Such organelles include endoplasmic reticulum, mitochondria, and chloroplasts - Chloroplasts are the sites of photosynthetic energy production and CO_2 fixation in eukaryotic phototrophs to produce manufactured food.

3.3.1 The Endoplasmic Reticulum

The endoplasmic reticulum (E.R.) is a single membrane system with an inner compartment which forms channels throughout the cytoplasm of the cell. The endoplasmic reticulum is a network of tubules and cisternae. The E.R. can be smooth or rough (Fig. 35).

Smooth endoplasmic reticulum (E.R.) provides the cell an organic phase in its membranes and unsaturated fatty acids and cholesterol are synthesized here. Foreign organic compounds are hydroxylated here to make them easier to digest.

Rough endoplasmic reticulum is a single membrane system covered with ribosomes for the synthesis of proteins to be exported from the cell. Eukaryotic ribosomes are very similar to prokaryotic ribosomes.

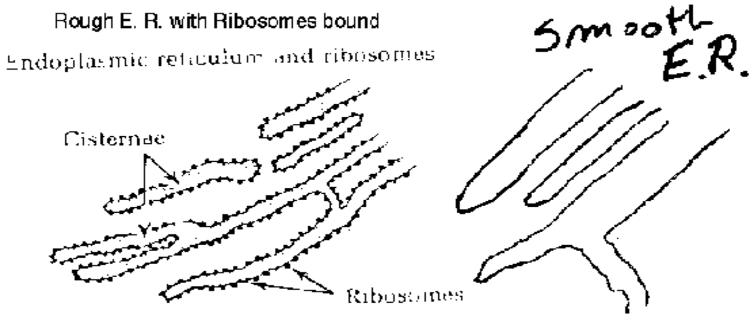

Fig. 35. Eukaryotic cell Endoplasmic Reticulum
Modified from Lehninger, Biochemistry, ©Wilbur H. Campbell, 1995

3.3.2 The Golgi Body

The Golgi body or apparatus is a membraneous organelle composed of flattened, sac-like cisternae stacked on each other (Fig. 36). The Golgi bodies (membranes) like the smooth E.R. lack bound ribosomes. However, rough ER is connected to the Golgi complex which is the system used for exporting proteins from the cell and into the plasma membrane.

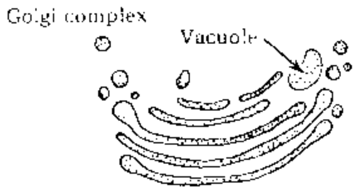

Fig. 36. Eukaryotic Cell Golgi Complex
Source: Modified from Lehninger, Biochemistry, ©Wilbur H. Campbell, 1995

3.4 The Cytoplasm/cytosol

The non-nuclear portion of a eukaryotic cell is called cytoplasm where the various cell organelles are embedded. The cytoplasm contains many enzymes and other compounds of the major aqueous phase of the cell. There are ribosomes floating freely in the cytoplasm which are for synthesizing soluble proteins (Fig. 37). The cytoplasm is dispersed among the organelles and also contains the cytoskeleton which helps the cell keep its shape. The cytoplasm is also called the cytosol.

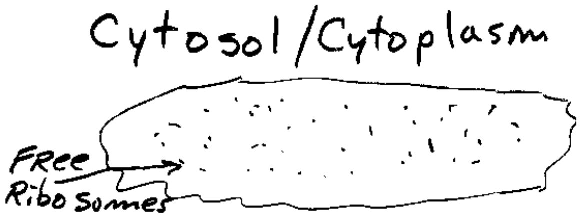

Fig. 37 Eukaryotic Cell Cytosol
Source: Modified from Lehninger, Biochemistry, ©Wilbur H. Campbell, 1995

3.4.1 Eukaryotic Cell Lysosomes

Lysosomes are membrane-enclosed compartments made from proteins and lipids transported from the Golgi complex. Lysosome allows for lytic activities to be partitioned away from the cytoplasm proper. Lysosomes are synthesized by Golgi apparatus and endoplasmic reticulum. They are involved in intracellular digestion and types of macromolecules.

3.4.2 Eukaryotic Cell Peroxisomes

The peroxisome is a specialized membrane-enclosed metabolic compartment. Peroxisomes originate in the cell by incorporating proteins and lipids from the cytoplasm, eventually becoming membrane-enclosed entities that can enlarge and divide in synchrony with the cell.

3.5 Eukaryotic Cell Flagella and Cilia

Flagella and cilia (Fig 38) are present on many eukaryotic microorganisms. Flagella and cilia are organelles of motility, allowing cells to move by swimming. Cilia are essentially shorter and more numerous than the flagella that beat in synchrony to propel the cell - usually quite rapidly – through the medium. Flagella are long appendages present singly or in groups that propel the cell along- typically more slowly than by cilia –through a whiplike motion. The flagella of eukaryotic cells are structurally quite distinct from the flagella of prokaryotes and do not rotate.

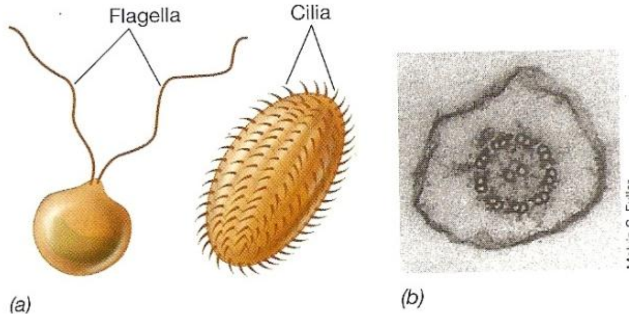

Fig. 38. Eukaryotic Flagella and Cillia

(Source: Madigan MT, et al., 2009 Brock Biology of Microorganisms. 12th edition).

4.0 CONCLUSION

The eukaryotic cell structure is made up of the cell membrane, nucleus, cytoplasm and a network of organelles while external locomotory appendages may be found on the cell membrane or cell wall.

5.0 SUMMARY

In this unit we have learnt that:

- Eukaryotic cell contain several different organelles and other important structures in the cytoplasm;
- The organelles include the endoplasmic reticulum, the Golgi complex, lysosomes, and the peroxisome.
- Flagella and cilia are organelles of motility.

6.0 TUTOR MARKED ASSIGNMENT

1. Give an account of the structures and functions of endoplasmic reticulum, Golgi complex and cytosol in eukaryotic cells
2. How does smooth endoplasmic reticulum differ from rough endoplasmic reticulum?

7.0 FURTHER READING AND OTHER RESOURCES

Cavalier-Smith, T (1975). The origin of nuclei and of eukaryotic cells.*Nature*, 256: 463-466.

Vines, A.E. & Rees, N. (1984).*Plant and Animal Biology*, Vol. 2, 4th edition. Pitman.

UNIT 4: THE ANIMAL CELL

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1.0 INTRODUCTION

In this unit, we shall discuss the major components that make up an animal cell. In unit 3, remember that the eukaryotic cell structure was discussed. Cells are a constant feature of all living organisms because cells are basic and functional units of all organisms. We therefore need to understand the structures of the variety of cells.

2.0 A: OBJECTIVES

By the end of this unit, you should be able to:

- Diagrammatically outline and label animal cell structure as seen from different perspective;
- Write on the current understanding of animal cell structure
- Thoroughly discuss the various animal cell components.

2.0 B: HOW TO STUDY THIS UNIT

1. You are expected to read carefully through this unit twice before attempting to answer the activity questions. Do not look at the solution or guides provided at the end of the unit until you are satisfied that you have done your best to get all the answers.
2. Share your difficulties in understanding the unit with your mates, facilitators and by consulting other relevant materials or internet.
3. Ensure that you only check correct answers to the activities as a way of confirming what you have done.
4. Note that if you follow these instructions strictly, you will feel fulfilled at the end that you have achieved your aim and could stimulate you to do more.

3.0 MAIN CONTENTS

3.1 Major Structural Constituents of an Animal Cell

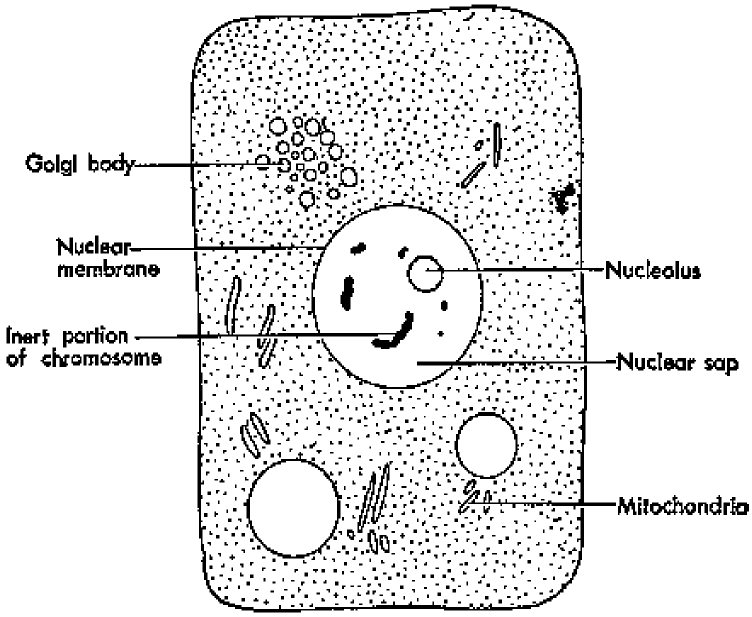


Fig. 39 Structure of an animal cell as it may be seen in life
(Source: Chapman G and Barker W 1968 Zoology Longmans)

In Fig. 39, the cell membrane, cytoplasm, Golgi body, nucleolus, nucleus, nuclear membrane, mitochondria, nuclear sap (nucleoplasm) may be visible as seen in life situation. However, in the conventional diagram (Fig. 40), the structures labeled may be slightly different from those of Fig. 39. These differences are due to the state and stage of the cells when viewed under the light microscope. Other representations are presented in Fig. 41 and Fig. 42. The major constituents of the animal cell are detailed in sections 3.1.1 – 3.1.14.

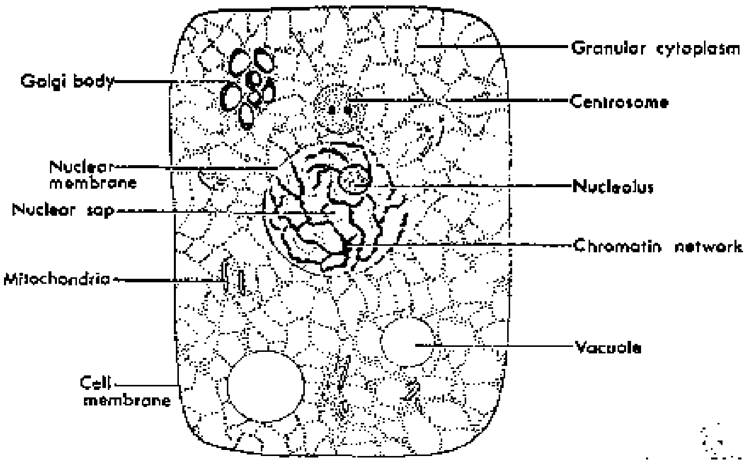


Fig. 40 A Conventional Diagram of the structure of An Animal Cell
(Source: Chapman G and Barker W 1968 Zoology Longmans)

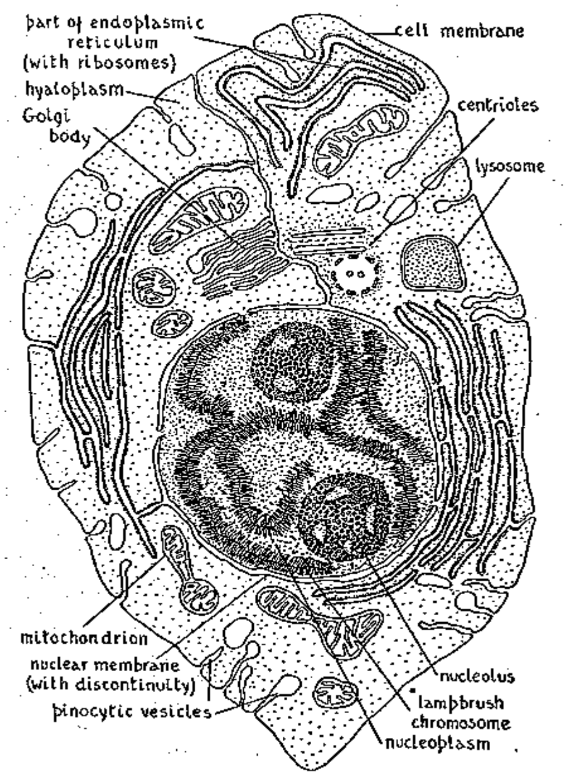


Fig. 41: Diagrammatic representation of an animal cell as seen with the electron microscope
(Source: Vines and Rees, Plant and Animal Biology, Vol. 2)

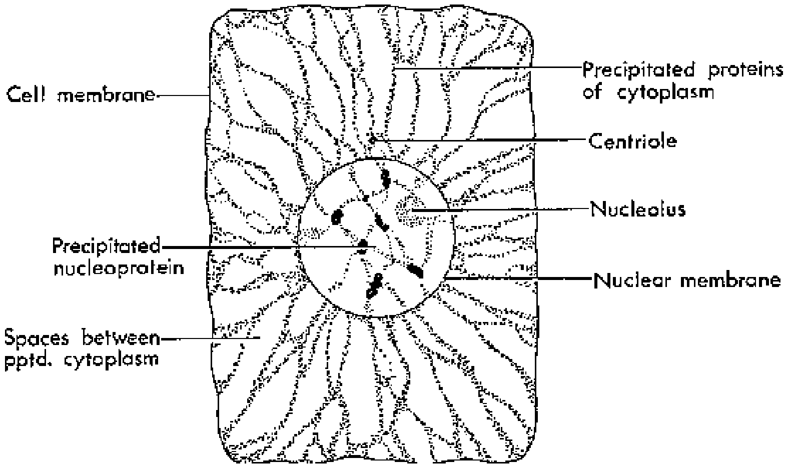


Fig. 42 Diagram to illustrate the structure of the cell as normally seen in fixed and stained preparations
(Source: Chapman G and Barker W 1968 Zoology Longmans)

3.1.1 Endoplasmic Reticulum

The endoplasmic reticulum (ER) is a network of sacs that manufactures, processes, and transports chemical compounds for use inside and outside of the cell. It is connected to the double-layered nuclear envelope, providing a connection between the nucleus and the cytoplasm. ER is a system of membrane-enclosed sacs and tubules in the cell (Remember unit 3, 3.3.1). Their lumens are probably all interconnected, and their membranes are continuous with the outer membrane of the nuclear envelope. All the materials within the system are separated from the cytosol by a membrane.

The endoplasmic reticulum is the site where the cell manufactures the following:

- most of the membranes of the cell (plasma membrane, Golgi apparatus, lysosomes, nuclear envelope);
- lipids (including lipids for membranes, e.g., of the mitochondria, that are not made by the ER);
- transmembrane proteins and secreted proteins

The ER comes in two versions:

- rough endoplasmic reticulum (RER) and
- smooth endoplasmic reticulum (SER).

The Rough Endoplasmic Reticulum (RER)

The RER is typically arranged as interconnecting stacks of disc-like sacs. The cytosolic surface of the RER is studded with ribosomes engaged in protein synthesis. The ribosomes make the RER surface to be rough.

As the messenger RNA is translated by the ribsome, the growing polypeptide chain is inserted into the membrane of the RER. Proteins destined to be secreted by the cell or shipped into the lumen of certain other organelles like the Golgi apparatus and lysosomes pass all the way through into the lumen of the RER. Transmembrane proteins destined for the plasma membrane or the membranes of those organelles are retained within the membrane of the RER.

The RER takes up a large proportion of the cytoplasm of cells specialized for protein synthesis such as those cells secreting digestive enzymes (e.g. the pancreas cell); and antibody-secreting plasma cells.

The Smooth Endoplasmic Reticulum (SER)
The smooth endoplasmic reticulum differs from the RER in lacking attached ribosomes and usually being tubular rather than disc-like. A major function of the SER is the synthesis of lipids from which various cell membranes are made or which, like steroids, are secreted from the cell.

The SER represents only a small portion of the ER in most cells, e.g. serving as transport vesicles for the transport of protein to the Golgi apparatus. However, it is a prominent constituent of some cells. Examples:

- the cells of the adrenal cortex (which secrete steroid hormones);
- the cells of the liver (hepatocytes) where it synthesises lipids for secretion of lipoproteins.
- the sarcoplasmic reticulum of muscle cells is SER.

3.1.2 Golgi Apparatus

The Golgi apparatus is the distribution and shipping department for the cell's chemical products. It modifies proteins and fats built in the endoplasmic reticulum and prepares them for export to the outside of the cell (Fig. 36, unit 3).

3.1.3 Lysosomes

Lysosomes are roughly spherical bodies bounded by a single membrane. They are manufactured by the Golgi apparatus. The main function of these microbodies is digestion. Lysosomes break down cellular waste products and debris from outside the cell into simple compounds, which are transferred to the cytoplasm as new cell-building materials (see unit 3, 3.4.1).

3.1.4 Microfilaments

Microfilaments are solid rods made of globular proteins called actin. These filaments are primarily structural in function and are an important component of the cytoskeleton.

3.1.5 Microtubules

These straight, hollow cylinders, composed of tubulin protein, are found throughout the cytoplasm of all eukaryotic cells and perform a number of functions.

3.1.6 Mitochondria

Mitochondria are oblong shaped organelles that are found in the cytoplasm of every eukaryotic cell. In the animal cell, they are the main power generators, converting oxygen and nutrients into energy. The mitochondrion is made of outer membrane and an inner membrane which contains the electron transport chain. The mitochondrion is the site of electron transport, oxidative phosphorylation and pathways such as the Krebs cycle. It provides most of a non photosynthetic cell's energy under aerobic conditions.

3.1.7 Nucleus

The nucleus is a highly specialized organelle (Fig. 4, module 2, unit 1) that serves as the information and administrative center of the cell. The nucleus is the hallmark of eukaryotic cells; the very term eukaryotic means having a "true nucleus". The nucleus is enveloped by a pair of membranes enclosing a lumen that is continuous with that of the endoplasmic reticulum. The inner membrane is stabilized by a meshwork of intermediate filament proteins called lamins. The nuclear envelope is perforated by thousands of nuclear pore complexes that control the passage of molecules in and out of the nucleus. In module 2, units 2-5 have detailed the functions of the nucleus during the cell division processes.

3.1.8 Peroxisomes

These are microbodies of diverse group of organelles that are found in the cytoplasm, roughly spherical and bound by a single membrane. There are several types of microbodies but peroxisomes are the most common (unit 3, 3.4.2).

3.1.9 Cell membrane

One universal feature of all animal cells is the presence of an outer limiting membrane called the plasma or cell membrane. In addition, all eukaryotic cells contain elaborate systems of internal membranes which set up various membrane-enclosed compartments within the cell. Cell membranes are built from lipids and proteins. All living cells have a plasma membrane that encloses their contents. In prokaryotes, the membrane is the inner layer of protection surrounded by a rigid cell wall. Eukaryotic animal cells have only the membrane to contain and protect their contents (Fig. 34, unit 3). These membranes also regulate the passage of molecules in and out of the cells. In plant cells, the rigid cell wall protects their cell membrane.

3.1.10 Ribosomes

All living cells contain ribosomes. These are tiny organelles composed of approximately 60 percent of ribonucleic RNA and 40 percent protein. In eukaryotes, ribosomes are made of four strands of RNA. In prokaryotes, they consist of three strands of (RNA) acid. Please note the following:

- Ribosomes that synthesize proteins for use within the cytosol (e.g., enzymes of glycolysis) are suspended in the cytosol;
- Ribosomes that synthesize proteins destined for:
    - secretion (by exocytosis)
    - the plasma membrane (e.g., cell surface receptors)
    - lysosomes

3.1.11 Pinocytic vesicles

In pinocytosis ("cell drinking"), the drop engulfed is relatively small. Pinocytosis occurs in almost all cells and it occurs continuously. Pinocytosis is the endocytotic process in which a cell membrane encloses a small amount of the surrounding liquid and its solutes in tiny pinocytotic vesicles (pinosomes).

3.1.12 Chromatin

The nucleus contains the chromosomes of the cell. Each chromosome consists of a single molecule of DNA complexed with an equal mass of proteins. Collectively, the DNA of the nucleus with its associated proteins is called chromatin. Most of the protein consists of multiple copies of 5 kinds of histones. These are basic proteins, bristling with positively charged arginine and lysine residues. (Both Arg and Lys have a free amino group on their R group, which attracts protons (H^+) giving them a positive charge). Just the choice of amino acids you would make to bind tightly to the negatively-charged phosphate groups of DNA. Chromatin also contains small amounts of a wide variety of nonhistone proteins. Most of these are transcription factors (e.g., the steroid receptors) and their association with the DNA is more transient.

3.1.13 Centrioles

Centrioles are self-replicating organelles made up of fine bundles of microtubules and are found only in animal cells. They appear to help in organizing cell division. Do you still remberpreprophase stage of mitosis module 2, unit 3, 3.2.2?

3.1.14 Centrosome

The centrosome is of the following:

- located in the cytoplasm attached to the outside of the nucleus.
- It is duplicated during S phase of the cell cycle.
- Just before mitosis, the two centrosomes move apart until they are on opposite sides of the nucleus.
- As mitosis proceeds, microtubules grow out from each centrosome with their plus ends growing toward the metaphase plate. These clusters of microtubules are called spindle fibers (Fig. 43).

N.B. You may wish to revise centrosome by reading unit 4 of module 2 (Fig. 12) and Fig. 20, (unit 5 of module 2).

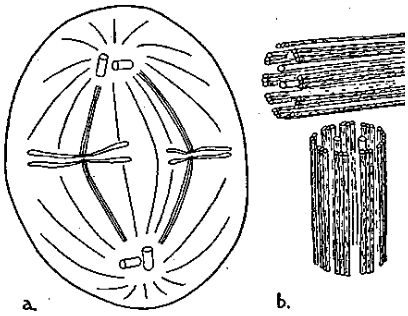


Fig. 43 Centrosome. (a) Positions of centrioles and spindle during nuclear division. (b) Diagram representing the structure of the centrioles.
(Source: Vines and Rees, Plant and Animal Biology, Vol. 2).

4.0 CONCLUSION

Under different conditions the features of the animal cell structure vary but each cellular component has specific functions in the cell.

5.0 SUMMARY

In this unit we have learnt that:

- Lysosomes are manufactured by the Golgi apparatus.
- Mitochondria as the powerhouse are found in the cytoplasm of every eukaryotic cell.
- Cell membranes are built from lipids and proteins.
- All living cells have a plasma membrane that encloses their contents.
- All living cells contain ribosomes.
- Pinocytosis occurs in almost all cells.
- The nucleus contains the chromosomes of the cell.
- Endoplasmic reticulum is rough and smooth

6.0 TUTOR MARKED ASSIGNMENT

1 a. Draw and label an animal cell as seen under the light microscope.

b. Discuss the functions of the Golgi apparatus, endoplasmic reticulum and the mitochondrion.

c. Discuss the current understanding of animal cell structure (Diagrams essential).

7.0 FURTHER READING AND OTHER RESOURCES

Vines, A.E. & Rees, N. (1984).*Plant and Animal Biology*, Vol. 2. Pitman Publishing limited, London.

UNIT 5: REVIEW OF CELL STRUCTURES OF PROKARYOTES AND EUKARYOTES

1.0 Introduction
2.0 A Objectives
2.0 B How to Study this Unit
3.0 Main Contents
- 3.1 Cellular organelles and Their Functions
- 3.2 Cells as the Starting Point
- 3.3 Common Features of Cells
- 3.4 Features of Prokaryotic Cells
- 3.5 Structure and Function in Eukaryotic Cells
- 3.6 Sorting of Materials by the Endomembrane System

4.0 Conclusion
5.0 Summary
6.0 Tutor Marked Assignment
7.0 Further Reading and Other Resources

1.0 INTRODUCTION

In units 1-4, you must have gathered enough knowledge and understanding of cells of prokaryotes, plant and animals. In this unit, as a student you are expected to be familiar with cells of prokaryotes and eukaryotes.

This unit is therefore designed to help you review cell structure. You will find information about the structures of prokaryotic cells and eukaryotic cells, with an emphasis on the endomembrane system more useful. Practicing the diagrams will enrich your review experience. You can test your understanding of what you have learnt by answering questions set in the activity exercise at the end of this unit.

2.0 A OBJECTIVES

By the end of this unit, you should be able to:

- Identify cells as basic units of all living organisms;
- Compare and contrast cells of prokaryotes and eukaryotes
- Relate cell structures to their functions.
- You will explain structure and function of cells and organisms;
- Highlight the functions of cell organelles;
- Explain the importance of the endomembrane system.

2.0 B: HOW TO STUDY THIS UNIT

1. You are expected to read carefully through this unit twice before attempting to answer the activity questions. Do not look at the solution or guides provided at the end of the unit until you are satisfied that you have done your best to get all the answers.
2. Share your difficulties in understanding the unit with your mates, facilitators and by consulting other relevant materials or internet.
3. Ensure that you only check correct answers to the activities as a way of confirming what you have done.
4. Note that if you follow these instructions strictly, you will feel fulfilled at the end that you have achieved your aim and could stimulate you to do more.

3.0 MAIN CONTENTS

3.1 Cellular organelles and Their Functions

Organelles are intracellular structures that perform specific functions in cells just like the organs in our body. The name organelles ("little organ") was coined because biologists saw a parallel between the relationship of organelles of a cell and that of organs to the whole body. It is not proper to define organelle as membrane-bound structure because this would exclude ribosomes and bacterial flagella.

The following are the major functions of organelles:

a) **Plasma membrane -** selectively permeable, mechanical cell boundary, mediates cell-cell interactions and adhesion to surface, secretion
b) **Microfilaments** – cell structure and movements, from the cytoskeleton
c) **Endoplasmic reticulum** – transport of materials, proteins and lipid synthesis
d) **Golgi apparatus** – packaging and secretion of materials for various purposes, lysosome formation
e) **Lysosome** – intracellular digestion
f) **Ribosomes** – protein synthesis
g) **Mitochondrion** – energy production through the use of the tricarboxylic acid cycle, electron transport, oxidative phosphorylation, and other pathways.
h) **Chloroplasts** – photosynthesis-trapping light energy and formation of carbohydrate from carbondioxide and water
i) **Nucleus** – repository for genetic information, control cell for cell
j) **Nucleolus** – ribosomal RNA synthesis, ribosome construction
k) **Cell wall and pellicle** – strengthen and give shape to the cell
l) **Cilia and flagella** – cell movement
m) **Vacuole** – temporary storage and transport, digestion (as food vacuoles), water balance (contractile vacuole).

3.2 Cells as the Starting Point

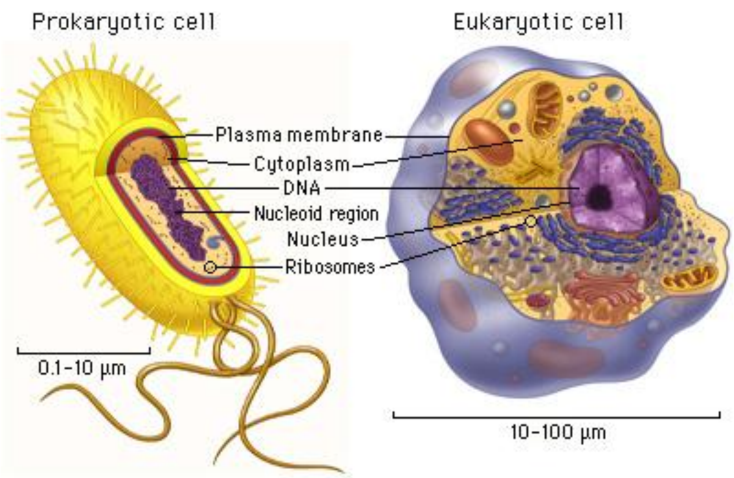
All living organisms are made of individual units that are called cells. Cells make up tissues and tissues make up organs. The cell is well organized and its various structures are so coordinated for the cell to be able to perform different functions. An organism can be a single cell e.g. amoeba.

There are many types of cells. Plant cells are easier to identify because they have a protective structure called a cell wall made of cellulose. Plants have the cell wall; animals do not. Plant cells also have organelles like the chloroplasts (the structures that make them green) or large water-filled vacuoles.

We say that there are many types of cells. Cells are unique to each type of organism. Humans may have several hundred types of cells. Some cells are used to carry oxygen (O_2) through the blood (red blood cells) and others might be specific. A cell may have one nucleus (uninucleate) while other cells may have many nuclei (multinucleate). Cells however have many common features whether in prokaryotes or eukaryotes.

3.3 Common Features of Cells

All cells, whether they are prokaryotic or eukaryotic, have some common features.



(a) (b)

Fig. 44: Prokaryotic cell; (b) eukaryotic cell
(Source: Pearson Education, Inc. 2009)

The common features of prokaryotic and eukaryotic cells are:

1. DNA, the genetic material contained in one or more chromosomes and located in a nonmembrane bound nucleoid region in prokaryotes and a membrane-bound nucleus in eukaryotes
2. Plasma membrane, a phospholipid bilayer with proteins that separates the cell from the surrounding environment and functions as a selective barrier for the import and export of materials

3. Cytoplasm, the rest of the material of the cell within the plasma membrane, excluding the nucleoid region or nucleus, that consists of a fluid portion called the cytosol and the organelles and other particulates suspended in it
4. Ribosomes, the organelles on which protein synthesis takes place

3.4 Features of Prokaryotic Cells

Prokaryotic cells have the following features:

1. The genetic material (DNA) is localized to a region called the nucleoid which has no surrounding membrane.
2. The cell contains large numbers of ribosomes suspended in the cytoplasm that are used for protein synthesis.
3. At the periphery of the cell is the plasma membrane. In some prokaryotes the plasma membrane folds in to form structures called mesosomes, the function of which is not clearly understood.
4. Outside the plasma membrane of most prokaryotes is a fairly rigid wall which gives the organism its shape. The walls of bacteria consist of peptidoglycans. Sometimes there is also an outer capsule. Note that the cell wall of prokaryotes differs chemically from the eukaryotic cell wall of plant cells and of protists.
5. Some bacteria have flagella which are used for locomotion and/or pili, which may be used to pull two cells in close contact, and perhaps to facilitate the transfer of genetic material. Prokaryotes, which include all bacteria and archaea (archaebacteria), are the simplest cellular organisms. Prokaryotic cells are fundamentally different in their internal organization from eukaryotic cells. Notably, prokaryotic cells lack a nucleus and membranous organelles.

3.5 Structure and Function in Eukaryotic Cells

In the last unit, unit 4, we have discussed in great details the major structural constituents of animal cell. In unit 2 plant cell was also discussed. Eukaryotic cells contain a membrane-bound nucleus and numerous membrane-enclosed organelles (e.g., mitochondria, lysosomes, Golgi apparatus) which are not found in prokaryotes. Prokaryotic cells are fundamentally different in their internal organization from eukaryotic cells. Notably, prokaryotic cells lack a nucleus and membranous organelles.

In eukaryotes, the nucleus is bounded by the nuclear envelope, a double membrane with many nuclear pores through which materials enter and leave. Animals, plants, fungi, algae and protists are all eukaryotes. Eukaryotic cells are more complex than prokaryotic cells and are found in a great many different forms.

3.6 Sorting of Materials by the Endomembrane System

Certain materials in the cell, including some proteins, are sorted by the functionally interrelated cellular membranes of the endomembrane system. These membranes consist of phospholipid bilayers with organelle-specific proteins embedded in them. This eukaryotic cell system consists of the nuclear envelope; endoplasmic reticulum (ER) and Golgi apparatus; vesicles and other structures derived from them (e.g., lysosomes, peroxisomes); and the plasma membrane (Fig. 45). These various membranes that are involved, though interrelated, differ in structure and function.

The endomembrane system plays a very important role in moving materials around the cell, notably proteins and membranes (the latter is called membrane trafficking). For example, while many proteins are made on ribosomes that are free in the cytoplasm and remain in the cytoplasm, other proteins are made on ribosomes bound to the rough endoplasmic reticulum (RER). The latter proteins are inserted into the lumen of the RER, carbohydrates are added to them to produce glycoproteins, and they are then moved to cisface of the Golgi apparatus in transport vesicles that bud from the ER membrane. Within the Golgi, the protein may be modified further and then be dispatched from the trans face in a new transport vesicle. These vesicles move through the cytoplasm to their final destinations using the cytoskeleton. We can think of the system as analogous to a series of switching yards and train tracks, where materials are sorted with respect to their destinations at the switching yards and sent to those destinations along specific tracks in the cytoskeleton.

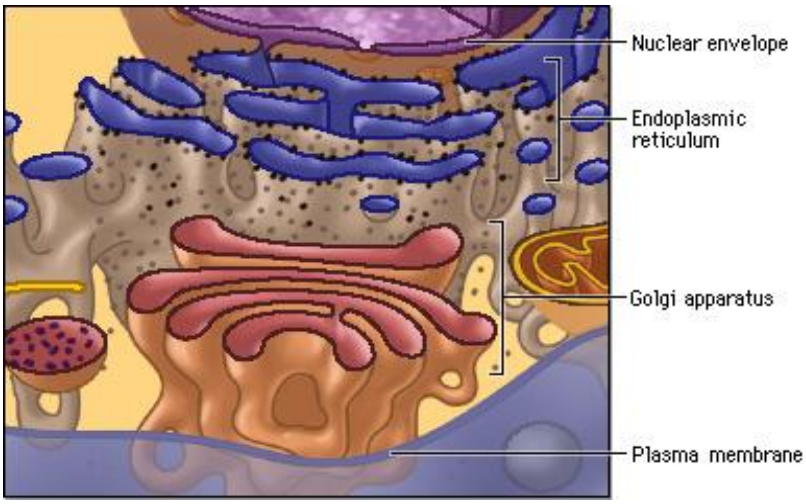


Fig. 45: Endomembrane system
(Source: Pearson Education, Inc. 2009)

Activity

1. Which of the following is not an accurate description of a chromosome?
a. It is a colored body localized in the nucleus.
b. It is a protein and nucleic acid complex.

c. It is the cellular structure that contains the genetic material.
d. In eukaryotes, it is composed of many DNA molecules attached end to end.

2. A centriole is an organelle that is:
a. present in the center of a cell's cytoplasm
b. composed of microtubules and important for organizing the spindle fibers
c. surrounded by a membrane
d. part of a chromosome

3. The rough endoplasmic reticulum is:
a. an intracellular double-membrane system to which ribosomes are attached
b. an intracellular membrane that is studded with microtubular structures
c. a membranous structure found within mitochondria
d. only found in prokaryotic cells

4. In the nucleus of eukaryotic cells, the genetic material is complexed with protein and organized into linear structures called:
a. centrioles
b. histones
c. chromosomes
d. plasmids

5. Which of the following statements does not apply to the nuclear envelope?
a. It is a double membrane.
b. It has pores through which material enters and leaves.
c. It is continuous with the endoplasmic reticulum.
d. It has infoldings to form cristae.

6. Lysosomes are formed by budding from which cellular organelle?
a. smooth endoplasmic reticulum
b. Golgi apparatus
c. rough endoplasmic reticulum
d. nucleus

7. All peroxisomes carry out this function:
a. break down fats and amino acids into smaller molecules that can be used for energy production by mitochondria
b. digest macromolecules using the hydrolytic enzymes they contain
c. synthesize membrane components such as fatty acids and phospholipids
d. control the flow of ions into and out of the cell

Answers to Module 3 unit 5

1d. The chromosome is not composed of many DNA molecules attached end to end

2b. The centriole is composed of microtubules and is important for organizing the spindle fibers.

3a. The rough endoplasmic reticulum (RER) is an intracellular double-membrane system to which ribosomes are attached.

4c. The genetic material is organized into chromosomes

5d. It is the inner membrane of the mitochondrion that is infolded to form cristae

6b. Lysosomes form by budding from the Golgi apparatus and, during this process, the hydrolytic enzymes made on the rough ER by bound ribosomes are packaged into particles.

7a. All perixisomes break down fats and amino acid into smaller molecules that can be used for energy production by mitochondria.

4.0 CONCLUSION

Eukaryotic cells may be more complex than the prokaryotic cells however there are cellular structures that are common to both groups of cells.

5.0 SUMMARY

In this unit we have learnt the:

- Cell structures of prokaryotes and eukaryotes.
- Prokaryotes has single cells without nucleus or other organelles
- Eukaryotes are multicellular
- Common features of prokaryotic and eukaryotic cells
- Cells as the basic units of living organisms
- Movement of many materials within the cell by the endomembrane system, including some proteins.
- Functions of cellular organelles

6.0 TUTOR MARKED ASSIGNMENT

1. Draw and label (i) a prokaryotic cell (ii) a eukaryotic cell
2. List the common features found in prokaryotic and eukaryotic cells
3. Discuss the importance of endomembrane system
4. Compare and contrast cells of eukaryotic with that of prokaryotic

7.0 FURTHER READING AND OTHER RESOURCES

Albert, B., Johnson, A., Lewis, J., Raff, M., Roberts, K. & Walter, P. (2002).*Molecular Biology of the Cell*.4th Edition.Garland Science, Taylor & Francis Group, New York.ISBN 0-8153-3218-1 (hardbound) - ISBN 0-8153-4072-9 (pbk.)