TOPIC: THE CELL-ULTRA STRUCTURE OF CELL

LECTURE NO:01
B.SC PART-II(SUB.)-GROUP A
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1.1 Objectives

Study of this unit will let the students to:

Define Prokaryotic cell;
Explain the structure of prokaryotic cell;
Write about Eukaryotic cell;
Elucidate the structure of Eukaryotic cell;
Differentiate between prokaryotic and eukaryotic cell.

1.2 Introduction

A structure containing a mass of cytoplasm surrounded by semi-permeable membrane called plasma membrane is called a cell. It encloses cytoplasm, many cell organelles along with nucleus or nuclear material. On the basis of organization of membranes, variety and structure of cytoplasmic organelles and complexity of nuclear region, the cells are classified into two types: Prokaryotic cell and Eukaryotic cell. These terms were suggested by **Hans Ris** in **1960s**.

1.3 History and Origin

A cell was defined as **"**unit of biological activity delimited by a semi permeable membrane and capable of self-reproduction in a medium free of other living systems" by **Loewy and Siekevitz (1963)**.

The study of cell has been made possible with the help of light microscope. **Robert Hooke (1665)** with the help of light microscope discovered that a section of cork is made up of small cavities surrounded by firm walls. He used the term **"cell"** for the first time to describe his investigations on the "texture of a piece of cork". Later on **A. Van Leeuwenhoek (1632-1723)** observed various unicellular organisms and cells like bacteria, protozoan's, red blood cells and sperm etc. He observed nucleus in some erythrocytes and all this was made possible with the improved microscopes. In **1809, Mirble M.** stated that all plant tissues are composed of cells. In the same year, importance of cells in living organisms was described by **J.B. Lamarck**. **Robert Brown** in **1831** observed nucleus in certain plant cells. *Mimosa* cells were boiled in nitric acid by **Dutrochet (1837)** to separate the cells to conclude that all organic tissues are composed of globular cells, united by simple adhesive forces. "All living organism are composed of cells" was stated by **Schwann, T. (1839)** after examining a variety of animals and plant tissues.

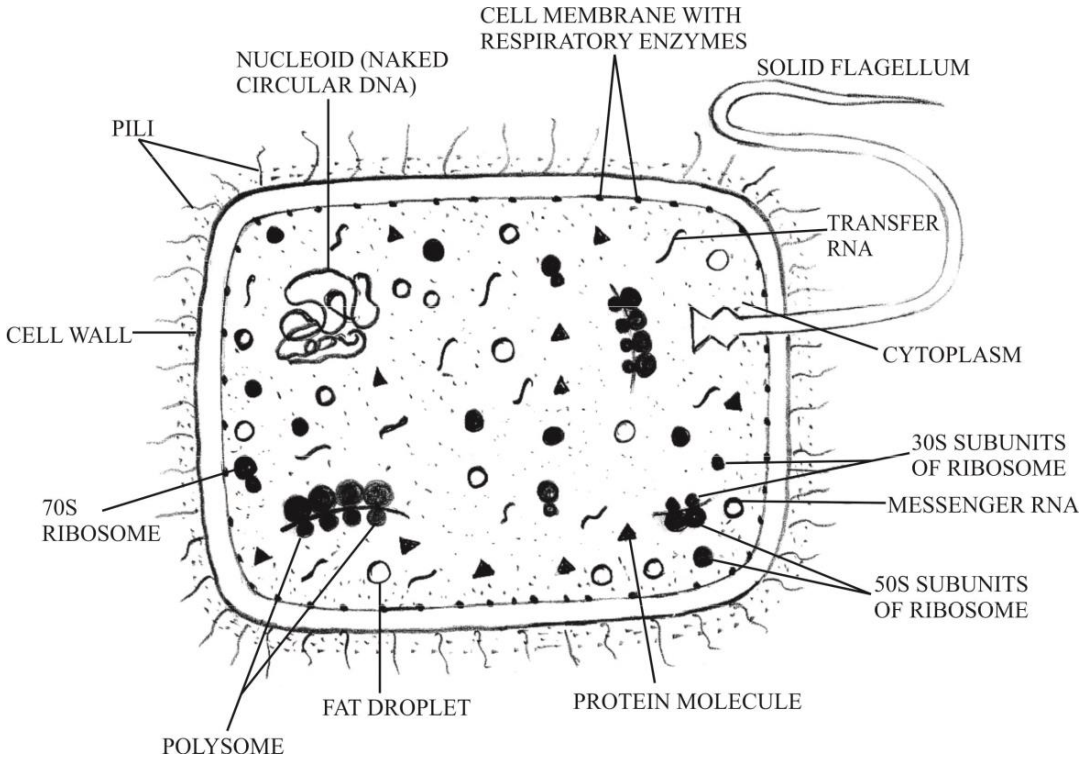

Fig. 1.1: A Bacterial Cell

1.4: BASIC COMPONENTS OF PROKARYOTIC AND EUKARYOTIC CELL

1.4.1 Prokaryotic Cells

Prokaryotic cells are the most primitive cells and have simple structural organization. It has a single membrane system. They include bacteria, viruses, blue-green algae, mycoplasmas, rickettsias, spirochetes etc. Cyanobacteria or blue green algae are the largest and most complex prokaryote, in which photosynthesis of higher plants type have evolved. **Prokaryotes** are included in the kingdom **Monera** and the super kingdom **Prokaryota**. The Prokaryotes have the following characters:

The size of prokaryotic cells ranges between 1 to 10 µm. They occur in a variety of forms.

Prokaryotic cell consists of three main components:

Outer covering: It is composed of inner cell or plasma membrane, middle cell wall and outer slimy capsule.

a. **Cell membrane:** Cell membrane made up of lipids and proteins, is thin and flexible and controls the movement of molecules across the cell. Respiratory enzymes are carried by it for energy releasing reactions. **Mesosomes**, the in-folds of plasma

membrane bears respiratory enzymes and these are considered analogous to mitochondria of eukaryotic cells. Similarly, the pigments and enzymes molecules that absorb and convert the light into chemical energy in photosynthetic cells are also associated with the plasma membrane's in-folds called **photosynthetic lamella**. These lamellae are analogous to the chloroplast of eukaryotic cells. Plasma membrane plays role in replication and division of nuclear material. Since the in-folds remain continuous with the cell membrane, they are not considered as separate compartments. Thus, prokaryotic cell is non-compartmentalized.

b. **Cell wall :** It is a rigid or semi-rigid non-living structure that surrounds the cell membrane and its thickness ranges between 1.5 to 100 µm. Chemically it is composed of **peptidoglycans**. . Some bacteria such as mycoplasmas lack cell wall.

c. **Slimy capsule:** A gelatinous coat outside the cell wall is the slimy capsule. It is composed of largely of polysaccharides and sometimes it may have polypeptides and other compounds also. It protects the cell against desiccation, virus attacks, phagocytosis and antibiotics

Cytoplasm: Prokaryotic cytoplasm contains proteins, lipids, glycogen and inorganic ions along with enzymes for biosynthetic reactions and ribosomes, tRNA and mRNA for protein synthesis. Prokaryotic cytoplasm has some special features as follows:

a. It lacks cell organelles like endoplasmic reticulum, mitochondria, Golgi apparatus, Centrosomes, vacuoles, Lysosomes, microfilaments, intermediate filaments and microtubules.

b. The only cytoplasmic organelle found in prokaryotic cells is the **ribosomes**. They are smaller than eukaryotic ribosomes i.e., 70S and lie free in the cytoplasm. They form poly-ribosomes at the time of protein synthesis. They are the sites of protein synthesis.

c. Like eukaryotic cells, the cytoplasm of prokaryotic cell does not show streaming movement or cyclosis.

d. Gas vacuoles are also formed in some prokaryotic cells.

e. The cell does not show phagocytosis, pinocytosis and exocytose, substances enter and leave the cell through the cell membrane.

f. They may contain deposits of polysaccharides or inorganic phosphates.

Nucleoid: Nuclear envelope is absent in prokaryotic cell and the genetic material lies directly into the cytoplasm. Such nuclear material is known as **nucleoid**. **Nucleoid** consists of greatly coiled single pro-chromosome. It shows the following special features:

a. A short and simple pro-chromosome is present which is attached at least at one point on cell membrane.

b. Mostly there is single copy of chromosome, the prokaryotic cell is haploid.

c. **The DNA is naked** as it is not associated with basic histone proteins. It is double stranded, helical and circular.

d. The amount of DNA is lesser than eukaryotic cell and it codes fewer proteins. Replication of DNA is continuous throughout the cell cycle. Transcription and translation occurs in cytoplasm and processing of mRNA is not required.

e. The processes like meiosis, gamete formation or fertilization are absent.
Conjugation is seen in some bacteria.

f. Mitotic apparatus absent.

g. There is no nucleolus.

h. Cell membrane folds or mesosomes help to segregate the replicated products of chromosomes into daughter cells.

Plasmids: In some prokaryotic cells, in addition to nucleoid, a small circular double stranded DNA molecule is present. It is called **plasmid**. Plasmids have 1000 to 30,000 base pairs and they generally encode proteins required by the organism to resist antibiotic and other toxic material.

Flagellum: It is a whip like locomotory structure found in many bacteria. It is 150Å thick and 10 to 15µm long. As the flagellum does not have any surrounding membrane, it grows at the tip.

It has two main parts: Filament and basal body.

Filament- Filament extends out of cell into the medium and it is composed of many intertwined spiral chains of the subunits of a protein called **flagellin**. Flagellin differs from actins or tubulin.

Basal Body- The basal body attaches the flagellum to the cell and generates the force to rotate it. It is composed of many components and numerous proteins. It has two parts: shaft and hook.

Pili: These are short, rod like non-motile processes or fimbriae present on many bacteria. These are formed of pilin protein. They are usually less than 10 nm thick. They help in attachment of bacteria to surfaces or food or to one another. Tubular sex Pili are present in some bacteria.

Prokaryotic cells have all the biochemical mechanisms required to synthesize complex organic materials from simple organic precursors necessary for life. Thus,

inspite of being simple in structure prokaryotes are more versatile in their synthetic activities than eukaryotes.

1.4.2 Eukaryotic Cells

The internal organization of eukaryotic cell is more developed than prokaryotic cells from which they are believed to have been evolved. They are evolved to have double membrane system. Primary membranes are the one that surrounds the cell, celled cell or plasma membrane and the secondary membrane surround the nucleus and other cellular organelles. Eukaryotic cells occur in protists, fungi, plants and animals. Eukaryotic cells have the following characteristics:

Number- In multicellular organisms the numbers of cells are correlated with the body size. The human blood contains about 30 quadrillion (3×10^{15}) corpuscles and a 60 kg human being has about 60×10^{15} cells. All multicellular organisms begin their life with a single cell "Zygote" and then become multicellular by its mitotic division during development.

Shape- A cell may be spherical, cuboidal, oval, disc-like, polygonal, columnar, spindle like or irregular. Thus, cells acquire a variety of shapes not only in various organisms but also in different tissues of the same organism. The shape of cell is correlated with its functions like the shape of muscles and nerve cells are well adapted to their functions. Many factors such as cell functions, age of cell, presence or absence of cell wall, viscosity of cytoplasm etc. are responsible for various shapes of cells.

Size- Most of the eukaryotic cells is microscopic and their size ranges between to 100µm. Sporozoits of malaria parasite (*Plasmodium vivax)* is among the smallest cells having the size equal to 2µm long. While the Ostrich egg measures 175 × 120mm. Nerve cells are the longest having the size of its fiber to be of few meters long. Human cells generally range from 20 to 30µm.

Components of a cell- Three main components of the eukaryotic cells are cell membrane, cytoplasm and nucleus. The cytoplasm and the nucleus further have several components. Various cell components are discussed below:

Cell membrane- Cell membrane, plasma membrane or plasmalemma is a thin elastic living covering that surrounds the cell keeping the cell contents in place, provides shape to the cell and controls the transfer of materials across it. It is composed of lipid-protein complex. It lacks respiratory enzymes. In many protists and animal cells it allows endocytosis and exocytosis.

In certain protists, many fungi and all plant cells, the cell membrane is covered by a thick, rigid non-living cell wall that protects and supports the cell. In prokaryotes the cell wall surrounding the plasma membrane has a different structure in comparison to eukaryotes.

Cytoplasm- The cytoplasm or the cytosome is a semi-fluid, homogeneous, translucent ground substance known as cytoplasmic matrix or cytosol which is present between the cell membrane and the nucleus. In the protozoan cell the outer firm layer of cytoplasm is called ectoplasm and the inner layer around the central fluid mass is called the endoplasm. The cytosol shows "cyclosis" or the streaming movement. The eukaryotic cytoplasm has the following features:-

a. Organelles*:* The organized structures having the specific functions and capacity of growth and multiplication in some cases are known as organelles. Mitochondria, centrosomes, Golgi bodies, plastids and vacuoles are the organelles that can be observed under light microscope, while endoplasmic reticulum, ribosome, microfilaments, microtubules, intermediate filaments and micro bodies can only be seen under electron microscope. These organelles are often described as protoplasmic structures. The cells having cilia or flagella have their basal bodies at the bases are in the cytoplasm while rest of its part extends out of cytoplasm. These organelles are described as follows:

I. Mitochondria: The rod like or globule shaped structures scattered in the cytoplasm are found singly or in groups. They are bounded by **double membrane** of lipoproteins. The inner membrane gives out finger like structure known as **cristae** which partially subdivide the inner chamber of mitochondrion. On the inner surface of cristae are present mushroom like structures, **oxysomes that** are related to phosphorylation. The space between the membranes and its lumen is filled with mitochondrial **matrix**. Both the membranes and the matrix contain many oxidative enzymes and coenzymes. Since mitochondria contain DNA molecules and ribosomes, they synthesize certain proteins. They produce the energy and reserve it in the form of **adenosine triphosphate (ATP).** Due to the presence of its own DNA and ability of protein synthesis along with its duplication, the mitochondria are called **semi autonomous organelle**. The DNA of mitochondria resembles that of bacterial cell; hence it is also called as **endo-symbiotic organelle**.

Centrosomes: (9+0) there is a clear zone around centrioles, near the nucleus, that includes a specialized portion of cytoplasm, called **centrospheres**. Its matrix is called kinoplasm that bears two rounded bodies the "centrioles". Each centriole consists of **nine fibrillar** units and each of them is found to contain **three microtubules** arranged in a circle. Both the centrioles are arranged at right angle to each other. Centrioles form the spindles of microtubules at the time of cell division. Centrioles are absent in plant cell and the spindle is formed without their help.

Golgi bodies: These are the stack of flattened parallel-arranged **sacs** and **vesicles** found in association of endoplasmic reticulum. They are composed of many **lamellae, tubules, vesicles and vacuoles**. Their membranes are supposed to be originated from ER and are composed of lipoproteins. In plant cells the Golgi complex is called **dictyosome** that secretes required materials for the formation of cell

wall at the time of cell division. It helps in the formation of acrosome of sperms, release of hormones, enzymes and other synthetic materials.

IV. Plastids: These organelles are found in plant cells and are absent in animal cells. They may be colored like chloroplast or chromoplasts or colorless like leucoplast. Since the leucoplast store and metabolise the starch and lipids, they are called amyloplast and lipoplast respectively. Chloroplast contains the green pigment the chlorophyll that helps in photosynthesis and protein storage. Chloroplast has a **double outer membrane**, the **stroma**, that bears many soluble enzymes, and a complex system of membrane bound compartments called **thalakoids** constituting **granna**. Like mitochondria, chloroplast also has their own DNA, ribosomes and complete protein synthetic machinery. Hence these are also called endo-symbiotic and semi-autonomous organelle.

V. Metaplasm: The particles like vacuoles, granules and other cytoplasmic bodies such as ribonucleoprotein molecules are represented by it.

VI. Cilia, basal bodies and flagella: Cilia are the minute structures covering the surface in some cells. Both cilia and flagella originate from the **basal bodies or blepharoplast** lying in cytoplasm. They consist of nine outer fibrils with the two larger fibrils in the centre. Each fibril consists of two microtubules, or has **9+2** arrangement. Cilia and Flagella are the structure born by certain cells. They are composed of microtubules made of the protein **tubulin**. They have 9 + 2 plan of microtubule. Both grow at the base. They act as locomotory organelles, moves by their beats or undulations for they get the energy by breakdown of ATP molecule.

VII. Microtubules: The ultra fine tubules of protein (**tubulin**) traversing the cytoplasm of plant and animal cells providing the structural framework to the cell, determine the cell shape and general organization of the cytoplasm are known as microtubules. Tubules are made up of **13 individual filaments**. Microtubules help in transport of water and ions, cytoplasmic streaming (cyclosis) and the formation of spindles during cell division.

VIII. Basal granules: The spherical bodies found at the base of cilia and flagella are called the basal bodies. Each of them is composed of **nine fibrils** and each fibril consists of the three microtubules, out of which two enter the cilia or flagella.

IX. Ribosome's: Ribosome is the minute spherical structures that originate in nucleolus and are found attached with the membrane of endoplasmic reticulum and in the cytoplasm. They are mainly composed of **ribonucleic acids (RNA) and protein**. They are mainly responsible for **protein synthesis**.

Inclusions: These are the **non-living or deutoplasmic structures** which are incapable of growth and multiplication. Common cell inclusions are stored organic materials such as starch grains, glycogen granules, aleuron grains, fat droplets, pigment granules and inorganic crystals.Cytoplasm is stores raw materials needed for

the metabolism in both the cytoplasm and the nucleus. Many metabolic processes like biosynthesis of fatty acids, nucleotides, proteins and oxidation take place in cytoplasm. It distributes the nutrients, metabolites and enzymes in a cell and brings about exchange of materials between the organelles as well as with the environment or extracellular fluid also.

Nucleus: In a eukaryotic cell the genetic material is enclosed by a distinct **nuclear envelope** that forms a prominent spherical organelle the "Nucleus". The nuclear envelope bears **pores** for the exchange of materials between the cytoplasm and the nucleoplasm.

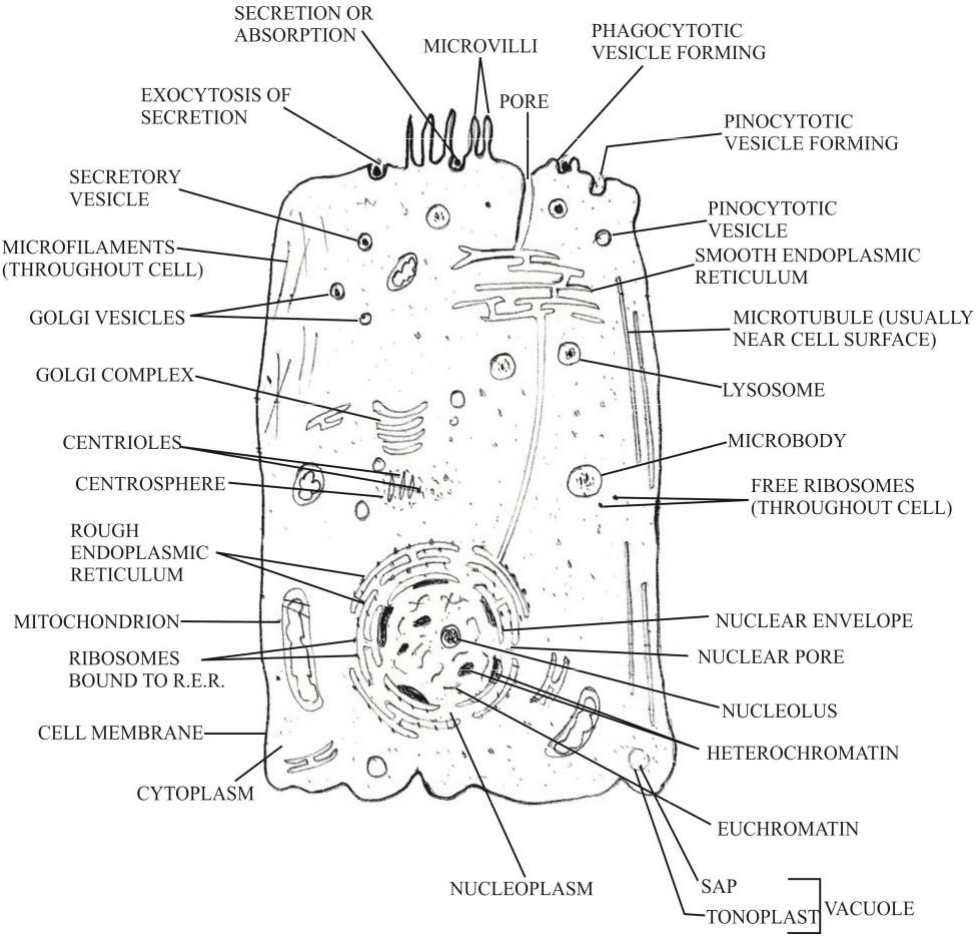

Fig. 1.2: An animal cell as shown by electron microscope

1.4.3 Differences between Prokaryotic Cells and Eukaryotic Cells

The internal organization of eukaryotic cell is more developed than prokaryotic cells from which they are believed to have been evolved.

S. No.	Prokaryotic Cells	S. No.	Eukaryotic Cells
1.	A prokaryotic cell is surrounded by a single membrane layer.	1.	A eukaryotic cell is surrounded by a double membrane layer.
2.	In most cases the cell wall surrounds the plasma membrane and it is composed of carbohydrates, lipids proteins and certain amino acids.	2.	Cell wall is present in protists, most fungi and plants and is composed of chitin in most fungi and or cellulose in others.
3.	Respiratory enzymes are present on cell membranes.	3.	Absent on the cell membrane
4.	Thalakoids occurs free in cytoplasm.	4.	They occur within the chloroplast.
5.	Cytoplasm lacks organelles like centrosomes, endoplasmic reticulum, mitochondria, Golgi apparatus, microfilaments, intermediate filaments, microtubules and micro bodies. While ribosomes are present	5.	All the cell organelles are present in the cell along with ribosomes.
6.	Gas vacuoles may occur while sap vacuoles are absent.	6.	Sap vacuoles are commonly present.
7.	70S ribosomes are present that lie free in cytoplasm or attached to mRNA.	7.	80S ribosome's are present, either free or bound to ER and nuclear envelope or mRNA.

S. No.	Prokaryotic Cells	S. No.	Eukaryotic Cells
8.	Endocytosis and exocytose do not occur.	8.	These processes take place in many protists and in animals.
9.	Process of meiosis or gamete formation or true fertilization does not occur.	9.	In these cells the process of meiosis, gamete formation and true fertilizationoccur in most cases of sexual reproduction.
10.	Cells are haploid.	10.	Cells are diploid, while haploid cells also occur.
11.	Nuclear envelope is absent and nuclear material lie in cytoplasm and is called nucleoid. Nucleoid contains a single chromosome.	11.	Nuclear envelope surrounds the nuclear material. The structure is called nucleus. It contains two tomany chromosomes.
12.	Nucleolus absent.	12.	One or more nucleoli are present within the nucleus.
13.	Circular DNA is present without associated proteins.	13.	Nuclear DNA is linear and is associated with proteins, while extra nuclear DNA is present without proteins.
14.	Flagella if present are simple, consist of a single fibril and are formed of a protein flagellin.	14.	Flagella, if present are complex, have 9+2 pattern of microtubules formed of a protein tubulin.
15.	Plasmids and pili occur in many prokaryotic cells.	15.	These structures are absent.
16.	Most prokaryotes are	16.	Most of them are

S. No.	Prokaryotic Cells	S. No.	Eukaryotic Cells
	asexual organisms.		sexual organisms.

1.5 SUMMARY

Robert Hook (1665) for the first time described the texture of a piece of cork as "cell". Similar structures were observed by many scientists while studying many living organisms. It was Schwann T. (1839) who stated that all living organisms are composed of cells after examining a variety of plant and animal tissues. Basically two types of cells are there, "Prokaryotic" and "Eukaryotic". Prokaryotic cells are the primitive cells that include bacteria, blue-green algae, viruses and photosynthetic cells cyanobacteria etc. Their size varies from 1 to 10 um and they consist of mainly three components: the outer covering that includes all cell membrane, cell wall and a slimy capsule. Another component is cytoplasm which lacks cell organelles except ribosomes. The processes like phagocytosis and endocytosis are absent. The third component is nucleoid that lacks nuclear membrane. Additional small circular DNA the plasmid may also be present. Flagella and pili like structure are also seen in some prokaryotic cells. Eukaryotic cells are more developed and are surrounded by double membranes. Shape and size of these cells and their number in multicellular organisms varies. It is also composed of three main components. Cell membrane or plasma membrane is a thin elastic living covering. The cytoplasm is a semi fluid, homogenous, translucent consisting of many cell organelles, inclusions, cilia, flagella, basal bodies and microtubules.

1.6 GLOSSARY

Cytoplasm: Gel like substance enclosed within the cell membrane excluding nucleus.

Plasma membrane: It is the biological membrane that separates the interior of the cell from the outside environment.

Prokaryote: The cell that lacks a distinct nucleus and other specialized membrane bound organelles.

Eukaryote: an organism whose cell contains a membrane bound distinct nucleus along with other specialized organelles enclosed in membranes.

Mesosome: The in-folding of plasma membrane in some bacterial cells that carry respiratory enzymes.

Poly-ribosome: It is a group of ribosomes associated with a single messenger RNA during the translation process.

Phagocytosis: The process by which a cell engulfs a solid particle to form an internal vesicle known as phagosome is called phagocytosis, also called eating of cell.

Pinocytosis: The process of intake of liquid into a cell by the budding of small vesicles from the cell membrane is called pinocytosis, also called drinking of cell.

Exocytosis: In the process of exocytosis materials are exported outside the cell by using energy from ATP molecules.

Conjugation: When the genetic material is transferred from one bacterial cell to other either by direct contact or by a bridge like connection between two cells is called conjugation.