CELL – STRUCTURE AND FUNCTION

INTRODUCTION

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

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

THE CELL AND CELL THEORY

Landmarks in the study of a cell

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

The cell theory

In 1838 M.J. Schleiden and Theodore Schwann formulated the "cell theory." Which maintains that: all organisms are composed of cells. A cell is the structural and functional unit of life, and cells arise from pre-existing cells.

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

The Cell

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

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

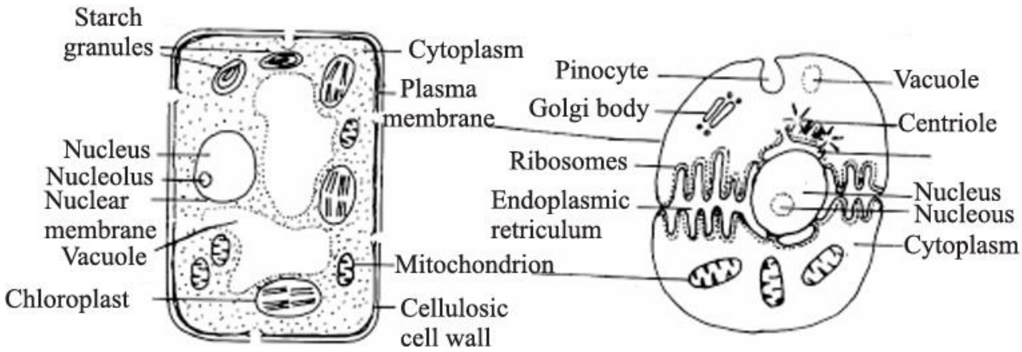
Two basic types of cells

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

READING ASSIGNMENT 1

Differences between Eukaryotic and Prokaryotic cells

The plant cell and the animal cell also differ in several respects



READING ASSIGNMENT 2

Differences between plant and animal cells

COMPONENTS OF THE CELL

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

Cell membrane (Plasma membrane)

Each cell has a limiting boundary, the cell membrane, plasma membrane or plasmalemma. It is a living membrane, outermost in animal cells but internal to cell wall in plant cells. It is flexible and can fold in (as in food vacuoles of Amoeba) or fold out (as in the formation of pseudopodia of Amoeba).

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

According to the fluid mosaic model,

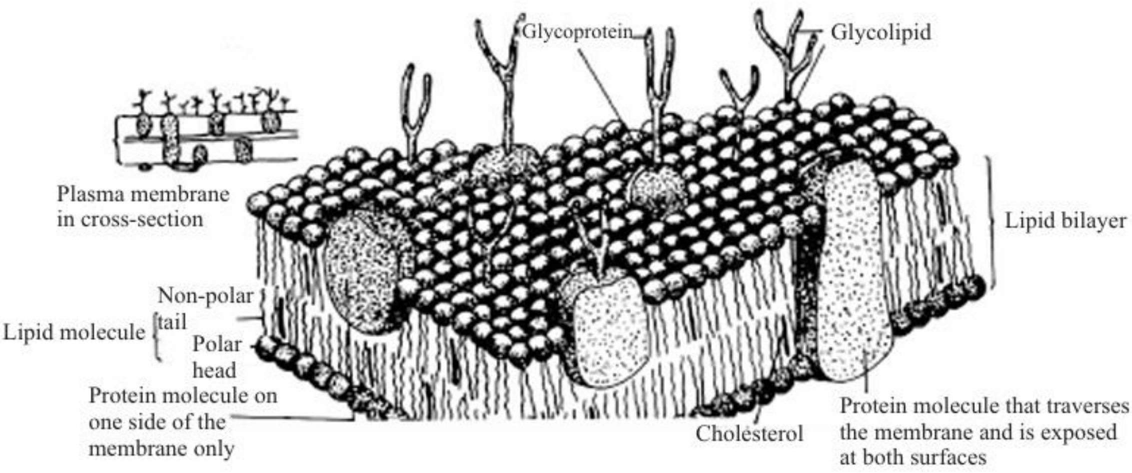
(i) The plasma membrane is composed of a lipid bilayer of phospholipid molecules into which a variety of globular proteins are embedded.

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

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

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

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



Functions

The plasma membrane encloses the cell contents.

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

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

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

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

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

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

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

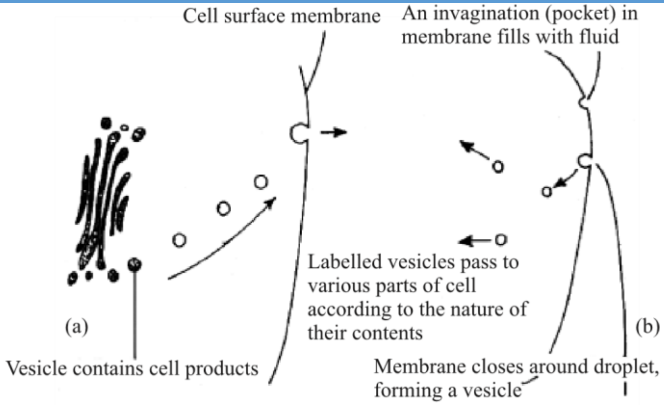
Transport of large molecules (bulk transport)

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

(i) endocytosis (taking the substance in)

(ii) exocytosis (passing the substance out) Endocytosis is of two types:

Endocytosis



Diagrammatic representation of (a) phagocytosis; (b) pinocytosis

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

Cell wall

In bacteria and plant cells the outermost cell cover, present outside the plasma membrane is the **cell wall** about which we shall study now.
Bacterial cell wall is made up of peptidoglycan. Given below is the structure and function of the plant cell wall.

(a) Structure

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

(b) Functions

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

THE CYTOPLASM AND THE CELL ORGANELLES

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

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

Mitochondria and chloroplast - the energy transformers

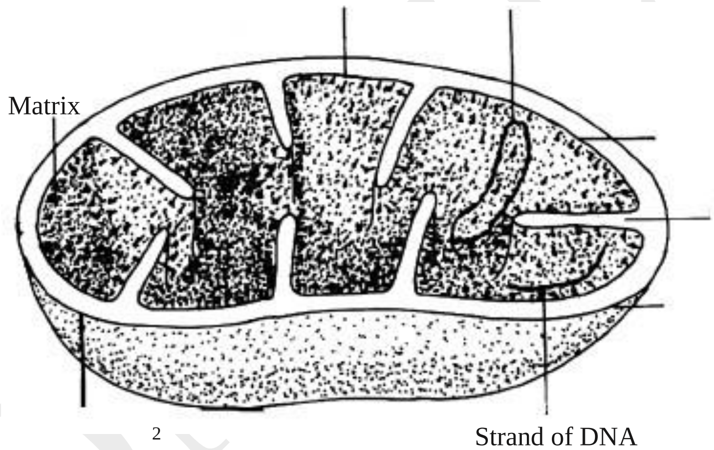
Mitochondria (found in plant and animal cells) are the energy releasers and the chloroplasts (found only in green plant cells) are the energy trappers.

Mitochondria (Singular = mitochondrion)

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

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

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



Structure of a mitochondrion

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

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

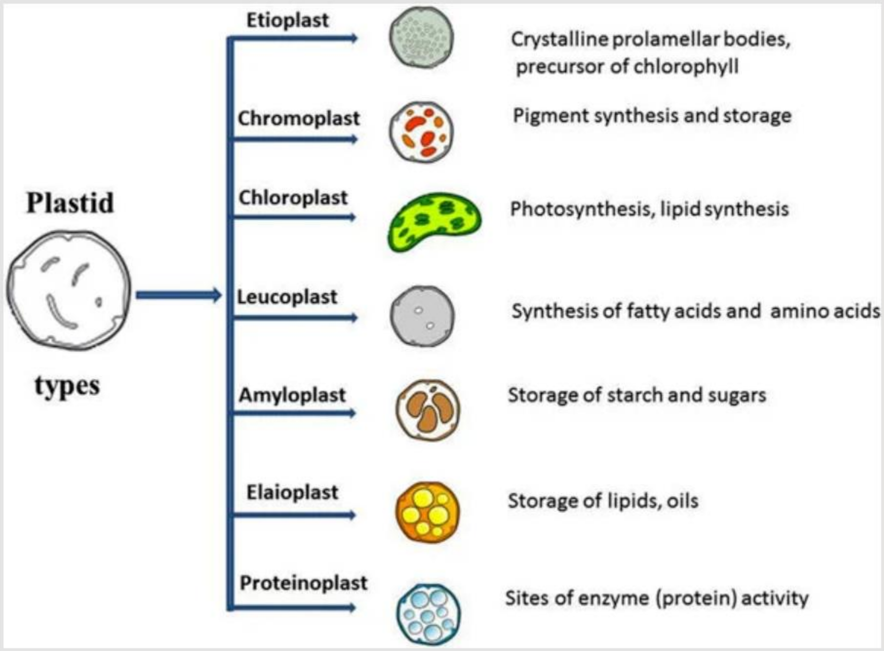
Plastids

- Plastid is a double membrane-bound organelle involved in the synthesis and storage of food, commonly found within the cells of photosynthetic plants.

- Plastids were discovered and named by Ernst Haeckel, but A. F. W. Schimper was the first to provide a clear definition.

These may be colorless or coloured.

- They are necessary for essential life processes, like photosynthesis and food storage.
- A plastid containing green pigment (chlorophyll) is called chloroplast whereas a plastid containing pigments apart from green is called a chromoplast. A plastid that lacks pigments is called a leucoplast and is involved mainly in food storage.



Functions

All plant cells contain plastids in some shape or form. This roll-call indicates their functional diversity and demonstrates that plastids lie at the very core of plant cellular function.

- Plastids are the site of manufacture and storage of important chemical compounds used by the cells of autotrophic eukaryotes.
- The thylakoid membrane contains all the enzymatic components required for photosynthesis. Interaction between chlorophyll, electron carriers, coupling factors, and other components takes place within the thylakoid membrane. Thus the thylakoid membrane is a specialized structure that plays a key role in the capture of light and electron transport.
- Thus, chloroplasts are the centers of synthesis and metabolism of carbohydrates.
- They are not only of crucial importance in photosynthesis but also in the storage of primary foodstuffs, particularly starch.
- Its function largely depends on the presence of pigments. A plastid involved in food synthesis typically contains pigments, which are also the ones responsible for the color of a plant structure (e.g. green leaf, red flower, yellow fruit, etc.).
- Like mitochondria, plastids have their own DNA and ribosomes. Hence, they may be used in phylogenetic studies.

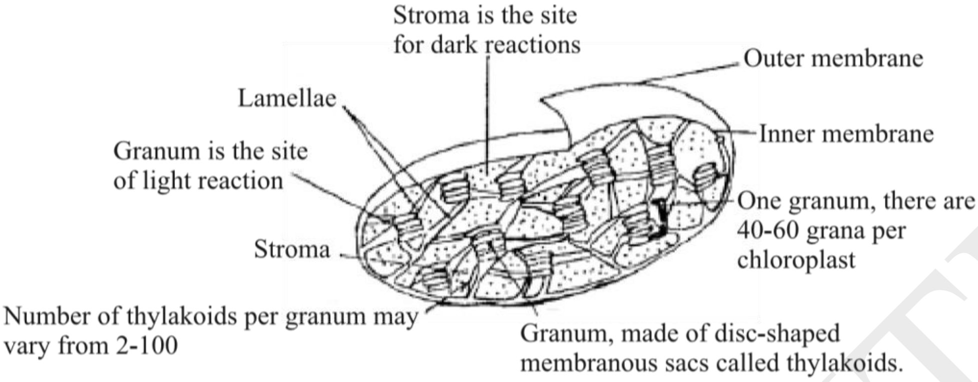
Chloroplast

Found in all green plant cells in the cytoplasm. Number ranges from 1 to 1008.

Shape: Usually disc-shaped or laminate as in most plants around you.

In some ribbon - shaped as in an alga Spirogyra or cup-shaped as in another alga Chlamydomonas.

Structure: the general plan of the structure of a single chloroplast has been shown below



Note the following parts:

Wall made up of double membrane i.e. outer membrane and inner membrane numerous stack-like (piles) groups or grana (singular = granum) are interconnected by lamellae.

Sac-like structures called thylakoids placed one above the other constitute a granum/ numerous stack-like (piles) groups or *grana* (singular = granum) are interconnected by *lamellae*.

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

Chloroplast versus mitochondria

READING ASSIGNMENT 3

Deduce the differences between mitochondria and chloroplasts.

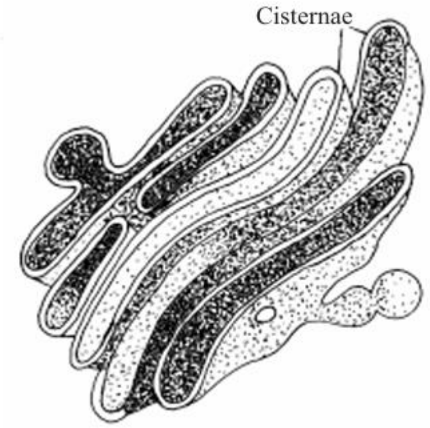
Similarities between mitochondria and chloroplasts:

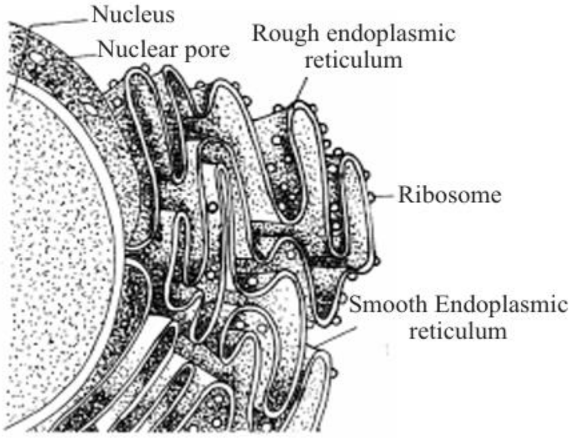
both contain their own DNA (the genetic material) as well as their own RNA (for protein synthesis). Thus, they can self-duplicate to produce more of their own kind without the help of nucleus.

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

Endoplasmic reticulum (ER), Golgi body and ribosomes

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





Golgi body

Endoplasmic reticulum

Endoplasmic reticulum (ER)

The endoplasmic reticulum (ER) is an organelle found in eukaryotic cells only. The ER has a double membrane consisting of a network of hollow tubes, flattened sheets, and round sacs. These flattened, hollow folds and sacs are called cisternae. The ER is located in the cytoplasm and is connected to the nuclear envelope. There are two types of endoplasmic reticulum: smooth and rough ER.

- **Smooth ER**: does not have any ribosomes attached. It is involved in the synthesis of lipids, including oils, phospholipids and steroids. It is also responsible for metabolism of carbohydrates, regulation of calcium concentration and detoxification of drugs.
- **Rough ER:** is covered with ribosomes giving the endoplasmic reticulum its rough appearance. It is responsible for protein synthesis and plays a role in membrane production. The folds present in the membrane increase the surface area allowing more ribosomes to be present on the ER, thereby allowing greater protein production

Golgi body

The Golgi body is found near the nucleus and endoplasmic reticulum. The Golgi body consists of a stack of flat membrane-bound sacs called cisternae. The cisternae within the Golgi body consist of enzymes which modify the packaged products of the Golgi body (proteins).

Functions of the Golgi body

- It is important for proteins to be transported from where they are synthesised to where they are required in the cell. The organelle responsible for this is the Golgi Body. The Golgi body is the sorting organelle of the cell.
- Proteins are transported from the rough endoplasmic reticulum (RER) to the Golgi.

In the Golgi, proteins are modified and packaged into vesicle. The Golgi body therefore receives proteins made in one location in the cell and transfers these to another location within the cell where they are required. For this reason the Golgi body can be considered to be the 'post office' of the cell.

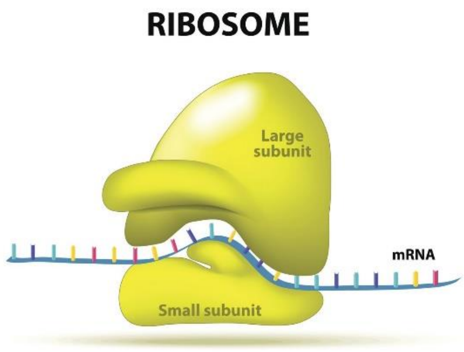
Ribosomes

Ribosomes are composed of RNA and protein.

• They occur in the cytoplasm and are the sites where protein synthesis occurs.

• Ribosomes may occur singly in the cytoplasm or in groups or may be attached to the endoplasmic reticulum thus forming the rough endoplasmic reticulum.

• Ribosomes are important for protein production. Together with a structure known as messenger RNA (a type of nucleic acid) ribosomes form a structure known as a polyribosome which is important in protein synthesis.

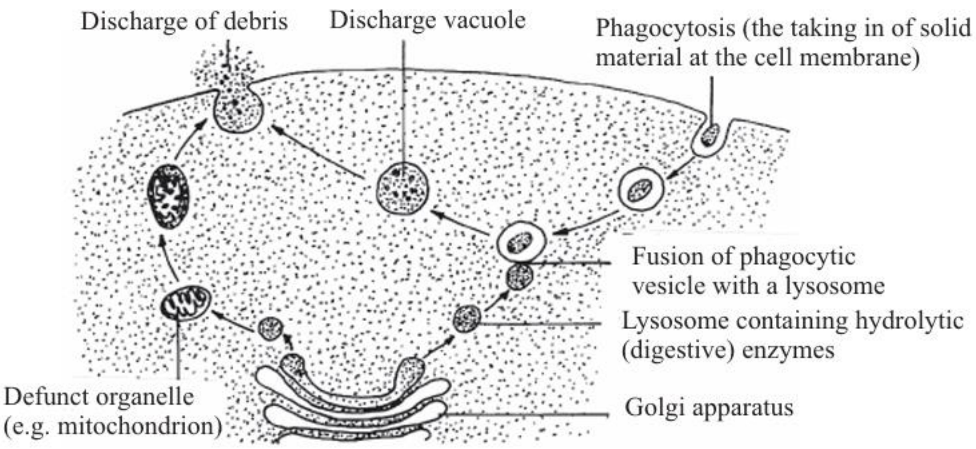


The micro bodies

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

Lysosomes (lysis = breaking down; soma = body)

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



The main features of lysosomes are as follows:

(i) Membranous sacs budded off from Golgi body.

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

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

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

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

Importance of intracellular digestion by the lysosomes

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

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

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

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

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

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

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

Peroxisomes

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

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

3. Glyoxysomes

The micro bodies present in plant cells and morphologically similar to peroxisomes.

Found in the cell of yeast and certain fungi and oil rich seeds in plants.

Functionally

they contain enzymes of fatty acid metabolism involved in the conversion of lipids to carbohydrates during germination.

Cilia and flagella (the organelles for motility)

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

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

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

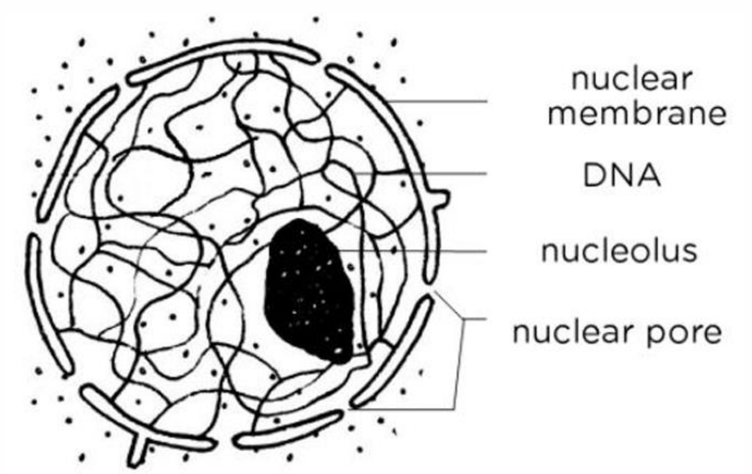
Both are made up of contractile protein tubulin in the form of microtubules.

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

Structure of the centrioles
Basal bodies

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

NUCLEUS (THE HEREDITARY ORGANELLE)



General structure of the nucleus:

(i) It is the largest organelle seen clearly when the cell is not dividing.
(ii) It stains deeply, is mostly spherical, WBC have lobed nuclei.
(iii) It is mostly one in each cell (uninucleate, some cells have many nuclei;(multinucleate).
(v) Double layered nuclear membrane having fine nuclear pores encloses nucleoplasm which contains chromatin network and a nucleolus.

Functions

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

The parts of a nucleus are given here:

Nuclear membrane

Double layered membrane is interrupted by large number of nuclear pores.

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

Chromatin

- Within the nuclear membrane there is jelly like substance (karyolymph or nucleoplasm) rich in proteins.
- In the karyolymph, fibrillar structures form a network called *chromatin fibrils*, which gets condensed to form distinct bodies called **chromosomes** during cell division. On staining the chromosomes, two regions can be identified in the chromatin material heterochromatin, dark and euchromaticn (light). Heterochromatin has highly coiled DNA and genetically less active than euchromatin which has highly uncoiled DNA and genetically more active.
- The number of chromosomes is fixed in an organism. During mitotic cell division chromosomes divide in a manner that the daughter cells receive identical amounts of hereditary matter.

Nucleolus

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

Cytoskeleton

The cytoskeleton is a network of filaments and tubules that extends throughout a cell, through the cytoplasm, which is all of the material within a cell except for the nucleus. It is found in all cells, though the proteins that it is made of vary between organisms. The cytoskeleton supports the cell, gives it shape, organizes and tethers the organelles, and has roles in molecule transport, cell division and cell signaling.

Structure of the Cytoskeleton

All cells have a cytoskeleton, but usually the cytoskeleton of eukaryotic cells is what is meant when discussing the cytoskeleton. Eukaryotic cells are complex cells that have a nucleus and organelles. Plants, animals, fungi, and protists have eukaryotic cells. Prokaryotic cells are less complex, with no true nucleus or organelles except ribosomes, and they are found in the single-celled organisms bacteria and archaea. The cytoskeleton of prokaryotic cells was originally thought not to exist; it was not discovered until the early 1990s.The eukaryotic cytoskeleton consists of three types of filaments, which are elongated chains of proteins: microfilaments, intermediate filaments, and microtubules.

Microfilaments

Microfilaments are also called actin filaments because they are mostly composed of the protein **actin**; their structure is two strands of actin wound in a spiral. They are about 7 nanometers thick, making them the thinnest filaments in the cytoskeleton. Microfilaments have many functions.

- They aid in cytokinesis, which is the division of a cytoplasm of a cell when it is dividing into two daughter cells.
- They aid in cell motility and allow single-celled organisms like amoebas to move.
- They are also involved in cytoplasmic streaming, which is the flowing of cytosol (the liquid part of the cytoplasm) throughout the cell. Cytoplasmic streaming transports nutrients and cell organelles. Microfilaments are also part of muscle cells and allow these cells to contract,

along with myosin. Actin and myosin are the two main components of muscle contractile elements.

Intermediate Filaments

Intermediate filaments are about 8-12 nm wide; they are called intermediate because they are in-between the size of microfilaments and microtubules. Intermediate filaments are made of different proteins such as keratin (found in hair and nails, and also in animals with scales, horns, or hooves), vimentin, desmin, and lamin. All intermediate filaments are found in the cytoplasm except for lamins, which are found in the nucleus and help support the nuclear envelope that surrounds the nucleus.

- The intermediate filaments in the cytoplasm maintain the cell's shape, bear tension, and provide structural support to the cell.

Microtubules

Microtubules are the largest of the cytoskeleton's fibers at about 23 nm. They are hollow tubes made of alpha and beta tubulin.

- Microtubules form structures like flagella, which are "tails" that propel a cell forward. They are also found in structures like cilia, which are appendages that increase a cell's surface area and in some cases allow the cell to move.
- Most of the microtubules in an animal cell come from a cell organelle called the centrosome, which is a microtubule organizing center (MTOC). The centrosome is found near the middle of the cell, and microtubules radiate outward from it.
- Microtubules are important in forming the spindle apparatus (or mitotic spindle), which separates sister chromatids so that one copy can go to each daughter cell during cell division.
- They are also involved in transporting molecules within the cell and in the formation of the cell wall in plant cells.

Function of the Cytoskeleton

As described above, the cytoskeleton has several functions.

- it gives the cell shape. This is especially important in cells without cell walls, such as animal cells, that do not get their shape from a thick outer layer.
- It can also give the cell movement. The microfilaments and microtubules can disassemble, reassemble, and contract, allowing cells to crawl and migrate, and microtubules help form structures like cilia and flagella that allow for cell movement.
- The cytoskeleton organizes the cell and keeps the cell's organelles in place, but it also aids in the movement of organelles throughout the cell. For example, during endocytosis when a cell engulfs a molecule, microfilaments pull the vesicle containing the engulfed particles into the cell.
- Similarly, the cytoskeleton helps move chromosomes during cell division.

ARCHAE BACTERIA AND EU-BACTERIA

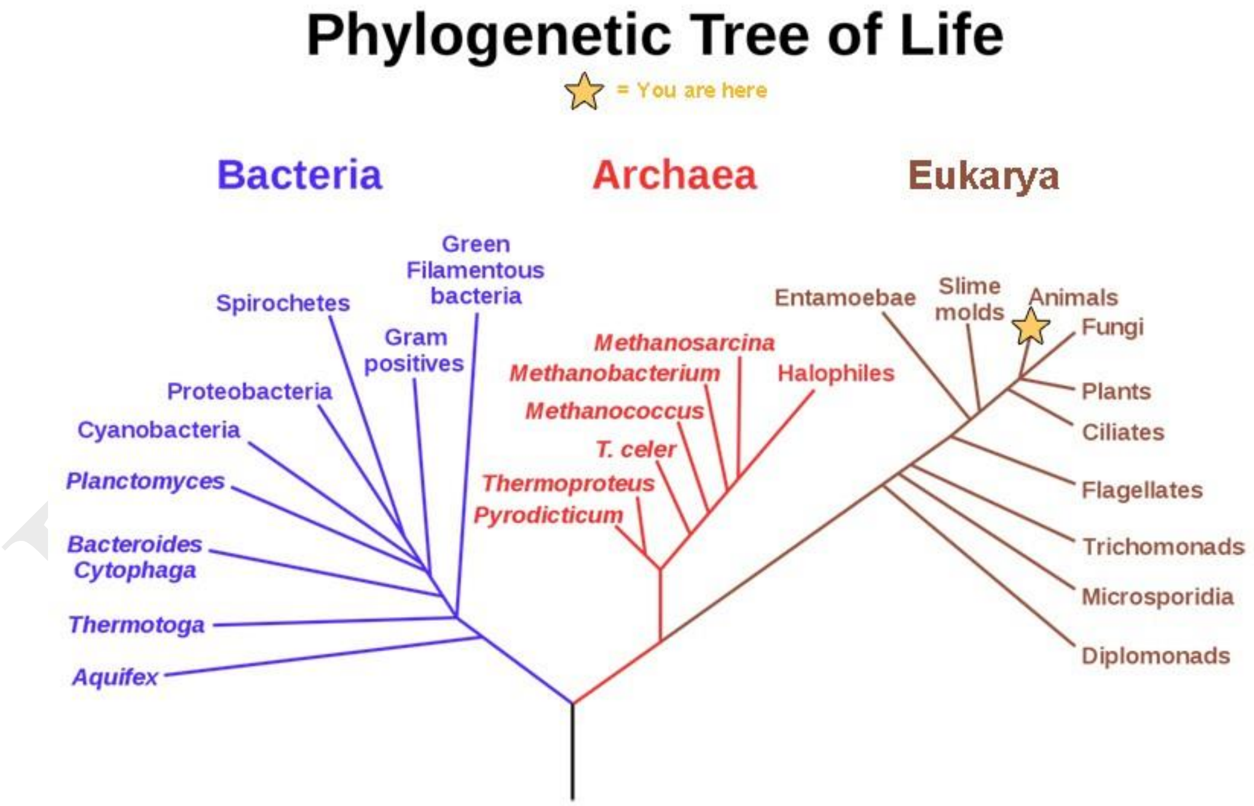
The primitive living world was classified into two primary domains of **Eukaryotes** (*Eukarya*) and **Prokaryotes** (*Bacteria*) based on microscopic characteristics such as the presence or absence of membrane-bound nuclei and other cellular organelles.

In 1977, American microbiologist and physicist Carl Richard Woese and his co-workers discovered the third domain of life, **Archaea** based on distinctive 16S ribosomal RNA (rRNA) signature sequences which had long been categorized as prokaryotic organisms. This became widely accepted as the third domain in 1990.

Similar nature of cells led to hypotheses on the origin of all cells from a common ancestor termed the **Last Universal Common Ancestor (LUCA)**, also known as the theoretical ancestor of Bacteria, Archaea and Eukarya. Thus, he reorganized the Tree of Life (ToL) into three separate Domains: Archaea, Eukarya, and Eubacteria (true bacteria), and pioneered a novel view of the biological world.

The conclusions drawn out of research conducted by Woese that led to the differentiation of archaea from bacteria are listed as:

- Both of them differed in 16S rRNA genes. Archaea possesses three RNA polymerases while bacteria have only **one**.
- Archaeal cell walls consist of **pseudo peptidoglycan** however, bacterial cell walls are made of **peptidoglycan** and **lipopolysaccharide (LPS)**.
- Archaea shared more **close** phylogenetic evolutionary relationship with eukaryotes than with bacteria.
- The application of a genetic approach rather than similarities based on morphology has revolutionized the evolutionary study as these rRNA genes, that are universally distributed and conserved in every organism have helped to trace our ancestors and apprehend the point of diversification of life.



Domain *Bacteria* (Kingdom: Eubacteria (True bacteria)

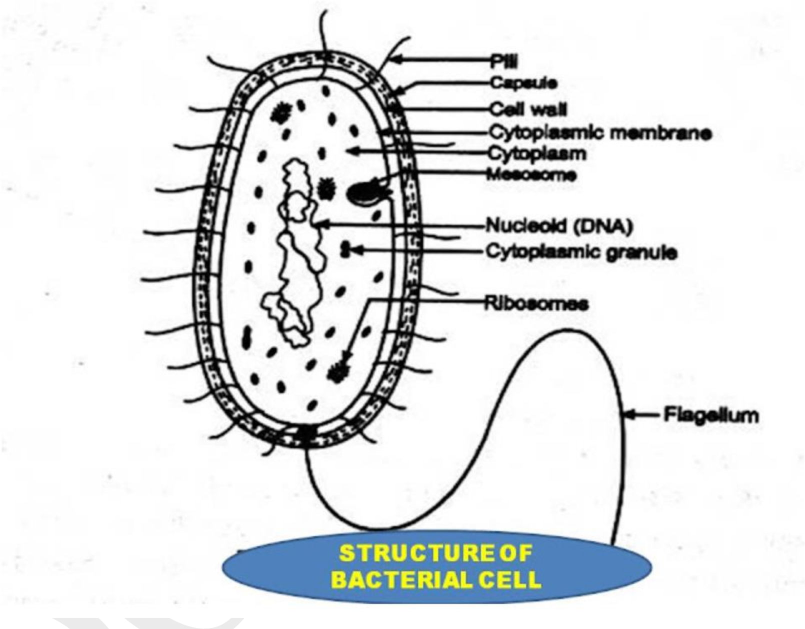
Bacteria are unicellular prokaryotic microscopic organisms.
Their unique feature covers the presence of peptidoglycan in the cell wall unlike the *Archaea* and *Eukarya*, membrane composed of unbranched fatty acid chains attached to glycerol by ester linkages and their unique rRNA type.
Examples: Cyanobacteria, Mycoplasmas, Gram-Positive bacteria, and Gram-negative bacteria.

- These are sensitive to most antibacterial antibiotics however show resistance against antibiotics that affect *Eukarya.*
- They show the asexual mode of reproduction.
- Generally, these are pathogenic but some are part of essential microbiota such as commensals. Such commensals play a vital role in digestion and absorption of foods, preventing pathogen colonization, activation of the immune system, and many more.
- Bacteria are considered to be the primary decomposers of the natural ecosystem.

READING ASSIGNMENT 4

What are some of the characteristics of bacteria?

ULTRA- STRUCTURE OF A BACTERIAL CELL



Under electron microscope the structure of bacterial cell is look like a capsule. It has various components. Some of these are outside the cell membrane; others are inside of cell membrane. The outer layer or cell envelope consists of two components such as **cell wall** and a **cytoplasmic or plasma membrane.** Inside the plasma membrane, there is protoplasm comprising the **cytoplasm**, **cytoplasmic inclusions** such as *ribosomes, mesosomes, granules, vacuoles, and nuclear body*. The cell may be enclosed in a viscid layer which is termed as **capsule**. Many bacteria have filamentous appendages called **fimbriae** or **pili** (organ of adhesion). Many bacteria also posses **flagella** which are organs of locomotion.

Components outside the cell membrane:-

1. *Capsule*
2. *Pilli*

3. *Flagella*
4. *Cell wall*

Components inside the cell wall

1. Cytoplasmic membrane (Plasma membrane)
2. Cytoplasm
3. Ribosomes
4. Mesosomes
5. Intracytoplasmic inclusion
6. Nucleoid & nucleus
7. Spores

1. **CAPSULE**

It is the outer layer of the bacterial cell. Many prokaryotic micro organisms synthesize amorphous organic exo-polymers which are deposited outside the cell wall called capsules or slime layer or glycol-calyx or sugar coat.

Capsules may be composed of a complex polysaccharide (Klebsiella pneumoniae) polypeptide (Bacillus anthrocis) hyaluronic acid (Streptococcus pyogenes). Water (98%) is the main component of bacterial capsule. Capsule or slime layer has less affinity for battle dyes and is not visible in Gram staining. Special capsule staining techniques are used by using copper salts as mordants. Capsules may be easily observed by negative staining in wet films with Indian ink.

Functions of capsule:

1. They may provide protection against mechanical injury, temperature & temporary drying by binding water molecules.
2. They may promote attachment of bacteria to surfaces. E.g. Streptococcus mutant that cause dental carries attach on teeth surface by its capsule.
3. They may promote the stability of bacterial suspension by preventing the cells from aggregation and settling.

They inhibit phagocytosis (antiphagocytic) and contribute to the virulence of pathogenic bacteria.

2. PILLI/FIMBRIAE

Many Gram negative bacilli contain short, thin, hair-like microfibrils called Pilli. The size of the pilli is 0.5 to 2 um in length and 5 to 7 nm in diameter.

They are more numerous than flagella. Fimbriae are composed of protein known as pillin and its molecular weight is 18000 daltons. Fimbriae can be seen only under the electron microscope. They are best developed in freshly isolated strains and in liquid cultures. They may disappear after sub culturing on solid media.

FUNCTIONS OF PILI:-

- Pilli are non motile but adhesive structure. They enable the bacteria to stick firmly to other bacteria & to a surface hence pili is also called an **organ of adhesion.**
- Pili is used for the transfer of genetic material from the donor to the recipient cell (bacterial conjugation).

FLAGELLA

Flagella are long, slender, thin hair like structure. The size of the flagella is about 0.01 µm to 0.02 µm in diameter & 3 to 20 µm in length. Flagella are made up of a protein **(flagellin)** similar to keratin or myosin & they are responsible for the motility of bacteria hence it is called as organs of locomotion.

Flagella are found in both Gram positive and Gram negative bacteria. A large no of bacteria such as spirilla, vibrios, most of bacilli & few coccal forms, are motile by means of flagella.

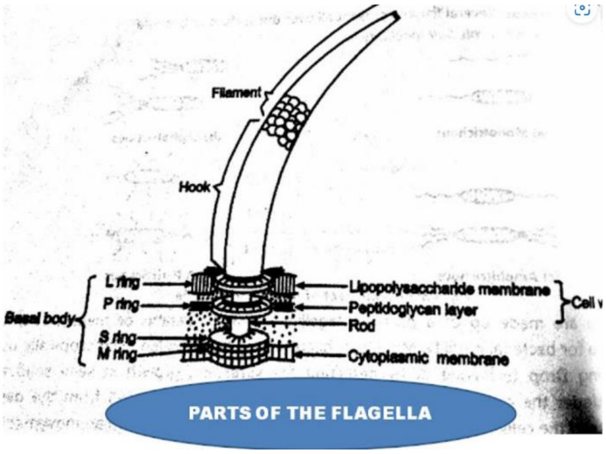
Flagella can be seen by an ordinary light microscope by special staining techniques in which their thickness is increased by mordanting.

Flagellum has three basic parts

- **Filament**

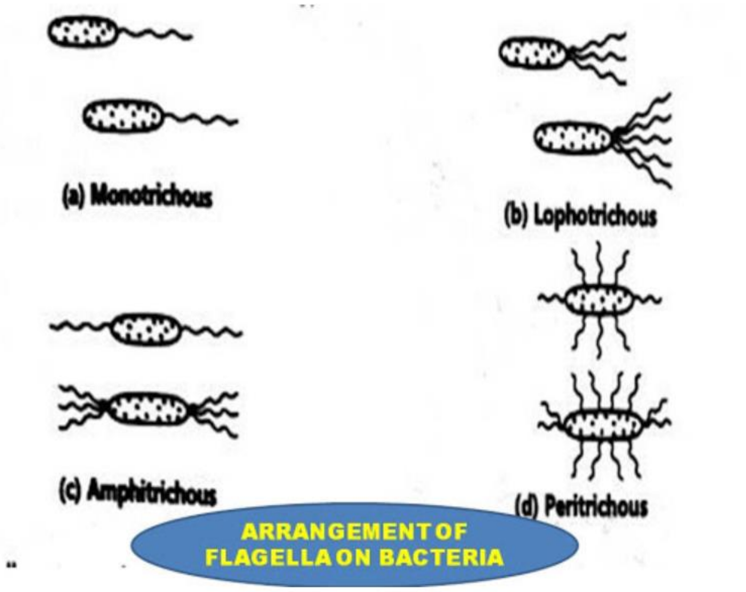
This is the thin, cylindrical, long outermost region with a Constant diameter. The protein in the filament is made up of monomers called 'flagellin' with molecular weight ranging between 20,000 to 40,000. The filament is attached to a slightly wider **hook**, consisting of a different protein .

- **The basal body** is composed of a small central rod inserted into a series or rings.



The number and arrangement of flagella are characteristics of each bacteria. Flagella may be seen on bacterial body in the following manner.

1. **MONOTRICHOUS:-** These bacteria have single polar flagellum. E.g. vibrio cholera, pseudomonas aeruginosa, spirillum.
2. **LOPHOTRICHOUS:-** Bacteria have two or more flagella only at one end of the cell. E.g. pseudomonas fluorescens.
3. **AMPHITRICHOUS:-** Bacteria have single polar flagella at both poles. E.g. Alcaligenes fecales, Aquaspirillum serpenes.
4. **PERITRICHOUS:-** Several flagella present all over the surface of bacteria. E.g. E.coli, Salmonella typhi.



CELL WALL

Cell wall is a rigid structure which gives definite shape to the cell and protect from osmotic lysis.

They are situated between the capsule and plasma membrane.

It is about 10 20 nm in thickness and constitutes 20-30% of the dry Weight of the cell.

The wall can protect a cell from toxic substances and is the site of action of several antibiotics.

Peptidoglycan-the most important molecule in the cell walls of bacteria.

Peptidoglycan or murein is an enormous polymer composed of many identical subunits. The polymer contains two sugar derivatives, N-acetylglucosamine and Nacetylmuramic acid (the lactyl ether of Nacetylglucosamine), and several different amino acids, three of which—D-glutamic acid, D-alanine, and meso-diaminopimelic acid

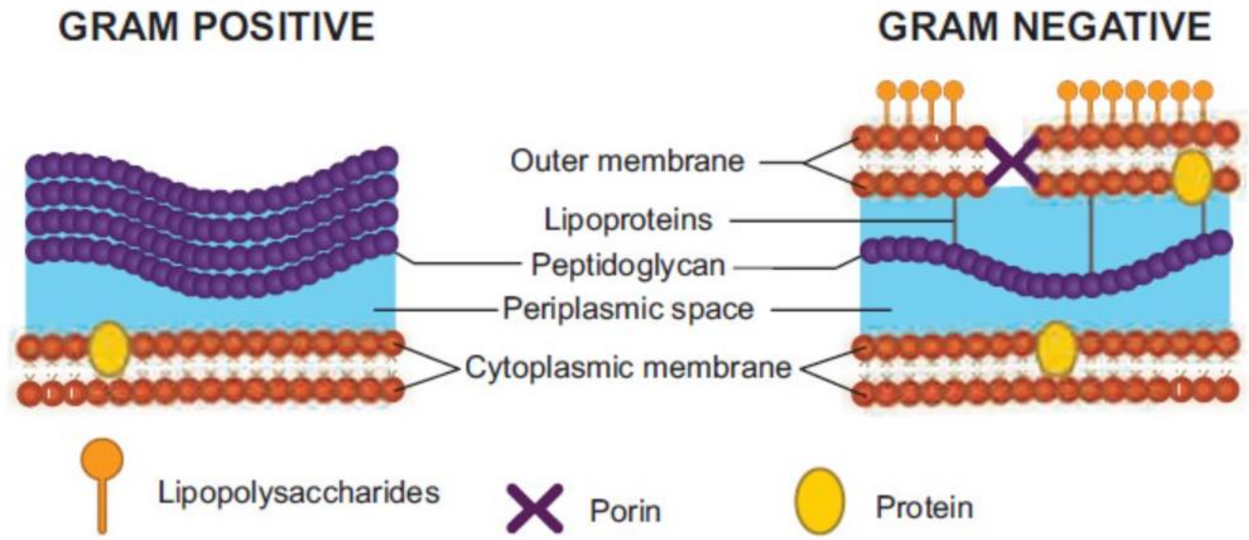
Gram + cell wall:- The gram-positive cell wall consists of a single 20 to 80 nm thick. They are homogeneous peptidoglycan or murein layer lying outside the plasma membrane. Homogeneous cell wall of gram-positive bacteria is composed primarily of peptidoglycan, which often contains a peptide interbridge . The teichoic acids are connected to either the peptidoglycan by a covalent bond with Nacetylmuramic acid or to plasma membrane lipids are called lipoteichoic acids.

Gram – cell wall:- The gram-negative cell wall is quite complex. It has a 2 to 7 nm peptidoglycan layer surrounded by a 7 to 8 nm thick outer membrane. The outer membrane lies outside the thin peptidoglycan layer

• The most abundant membrane protein is Braun's lipoprotein, covalently joined to the underlying peptidoglycan and embedded in the outer membrane by its hydrophobic end.

• Constituents of the outer membrane are its lipopolysaccharides

• outer membrane is more permeable than the plasma membrane due to the presence of special porin proteins



Functions of cell wall

1. Cell wall is involved in growth and cell division of bacteria.
2. It gives shape to the cell.
3. It gives protection to the internal structure and acts as a supporting layer.
4. It provides attachment to complement.
5. It shows resistance to the harmful effects of environment.

CYTOPLASMIC MEMBRANE

Also called as plasma membrane, is the most dynamic structure of a bacterial cell. The cytoplasmic membrane is a thin (5 to 10 nm) layer lining the inner surface of the cell wall and separating it from the cytoplasm. It is composed Of phospholipids (20 to 30%) and proteins (60 to 70%).

The phospholipids form a bilayer surrounding the cytoplasm and regulate the flow of substance in and out of the cell in which most of the proteins are tenaciously held and are called integral proteins. Other proteins are loosely attached are called peripheral proteins. The phospholipids molecules are arranged in two parallel rows. called a phospholipids bilayer. Each phospholipid molecule contains a polar head composed of a phosphate group and glycerol. The non-polar tails are in the interior of the bilayer and the polar heads are on the two surfaces of the phospholipids bilayer.

Functions of cytoplasmic (plasma) membrane:-

1. Its main function is a **selective permeability barrier** that regulates the passage of substances into and out of the cell.
2. It provides mechanical strength to the bacterial cell.
3. It helps in DNA replication, segregation with septum formation & cell division.
4. It contains the enzyme, permease, which plays an important role in the passage of selective nutrients & ions through membranes.
5. It contains the enzymes involved in the biosynthesis of membrane lipids and synthesis of murein (cell wall peptidoglycan) & other macromolecules of the bacterial cell

CYTOPLASM

The bacterial cytoplasm is a Gel-like matrix composed of mostly water (4/5 th), enzymes, nutrients, wastes, and gases The cytoplasm of bacteria differs from that of higher eukaryotic microorganisms as it not contain endoplasmic reticulum, Golgi apparatus, mitochondria and lysosomes. It contains ribosome, chromosomes, plasmids, proteins as well as the components necessary for bacterial metabolism. It carries out very important functions for the cell - growth, metabolism, and replication.

The main constituents of cytoplasm is Proteins including enzymes Vitamins, Ions, Nucleic acids and their precursors – Amino acids and their precursors – Sugars, carbohydrates and their derivatives – Fatty acids and their derivatives.

RIBOSOMES

The most notable structures in the bacterial cytoplasm are the ribosomes. They are involved in protein synthesis & translate the genetic code from the molecular language of nucleic acid to that of amino acids.

Bacterial ribosome's are similar to those of eukaryotes, but are smaller and have a slightly different composition and molecular structure. Bacterial ribosome's are never bound to other organelles as they sometimes are bound to the endoplasmic reticulum in eukaryotes, but are free-standing structures distributed throughout the cytoplasm.

Their number varies with the rate of protein synthesis {15000/cell).

The greater the rate of protein synthesis the greater the number of ribosome's.

The bacterial ribosomes are referred to as 70S ribosomes. (S-Svedberg unit, the unit of sedimentation).

These ribosome's when placed in a low concentration of magnesium, dissociate into two components as 5OS and 30S particles.. These ribosome's, during active protein synthesis are associated with the m-RNA and such associations are called polysomes.

MESOSOMES

Mesosomes are also called chondroids and are visualized only under an electron microscope. Mesosomes are the invaginated structures formed by the localized infoldings of the plasma membrane. The invaginated structures comprise of vesicles, tubules of lamellar whorls. In some bacteria particularly in gram-positive bacteria depending upon the growth conditions the membrane appears to be infolded at more than one point such infoldings are called as mesosomes. Generally mesosomes are found in association with nuclear area or near the site of cell division. They are absent in eukaryotes.

- ✓ Mesosomes are supposed to take part in respiration but they are not analogous to mitochondria because they lack outer membrane. In the vesicle of mesosomes the respiratory enzymes and the components of electron transport such as ATPase, dehydrogenase, cytochrome are either absent or present in low amount.
- ✓ Mesosomes might play a role in reproduction also. During binary fission a cross wall is formed resulting in formation of two cells. Mesosomes begin the formation of septum and attach bacterial DNA to the cell membrane.
- ✓ In addition, the infoldings of mesosomes increase the surface area of plasma membrane that in turn increases the absorption of nutrients.

INTRACYTOPLASMIC INCLUSIONS

It is also called as inclusion bodies. Bacteria can produce within their cytoplasm a variety of small bodies which is called as **inclusion bodies.** Some are called granules and other are called vesicles. They are mainly used for storage of energy & reduce osmotic pressure by tying up molecules in particulate forms like polysaccharides granules, glycogen granules, metachromatic granules, lipid granules etc.

Inclusions are considered to be nonliving components of the cell that do not possess metabolic activity and are not bounded by membranes. The most common inclusions are glycogen, lipid droplets, crystals, and pigments.

Vesicles

Some aquatic photosynthetic bacteria and cyano bacteria have rigid gas-filled vacuoles and it helps in floating at a certain level - allowing them to move up or down into water layers with different light intensities and nutrient levels.

NUCLEOID AND NUCLEUS

The nucleoid is a region of cytoplasm where the chromosomal DNA (genetic material) is located. Bacterial nucleus does not possess nuclear membrane, nucleolus and deoxyribonucleoprotein.

Most bacteria have a single, circular chromosome that is responsible for replication, although a few species do have two or more smaller circular auxiliary DNA strands, called **plasmids**, are also found in the cytoplasm.

SPORES

Many bacterial species produce spores inside the cell (endospores) as well as outside the cell (exospores). eg. Bacillus anthracis, Bacillus subtilis, Clostridium tetani etc.

Endospores are thick-walled, highly refractile bodies that are produced one per cell.

Each bacterial spore on germination forms a single vegetative cell.

Therefore sporulation in bacteria is a method of preservation and not reproduction. Spores are extremely resistant to dessication, staining, disinfecting chemicals, radiation and heat.They help bacteria to survive for long periods under unfavourable environments.

All endospores contain large amount of dipicolinic acid (DPA) with 10 to 15 percent of the spores being dry weight

READING ASSIGNMENT 5

- ***What are the importances of bacteria in our day to day life (15 marks)?***
- ***State any 10 commercial applications of bacteria in our society.***
- ***How do we address the problem of bacterial diseases in our society?***

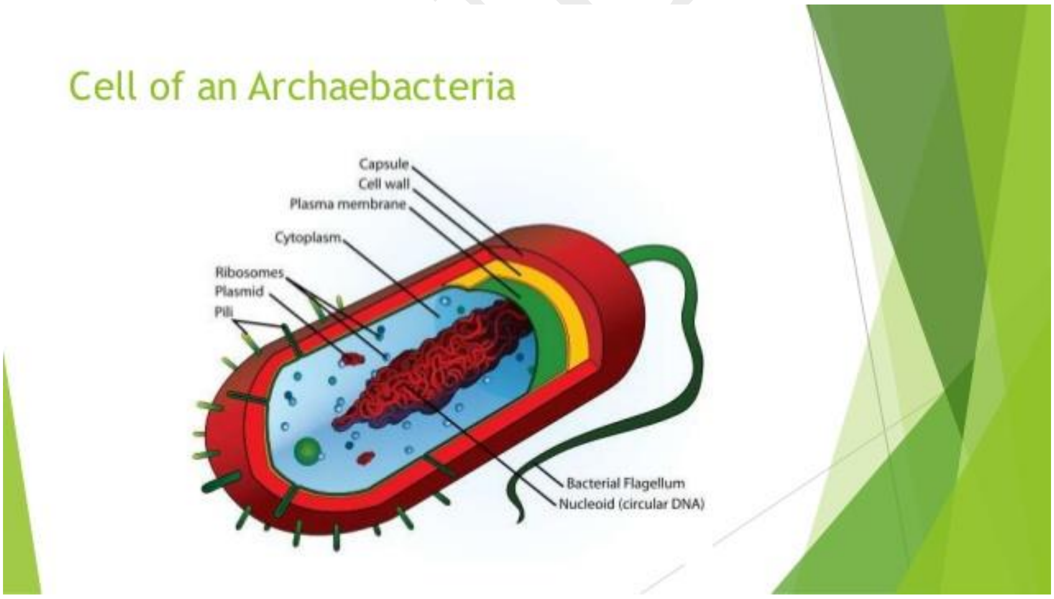
Domain *Archaea* (Kingdom: Archaebacteria)

These are unicellular prokaryotic organisms that resemble bacteria in their appearance, and hence were fallaciously placed under bacteria before the rise of three domain systems.

Characteristics of Archaebacteria

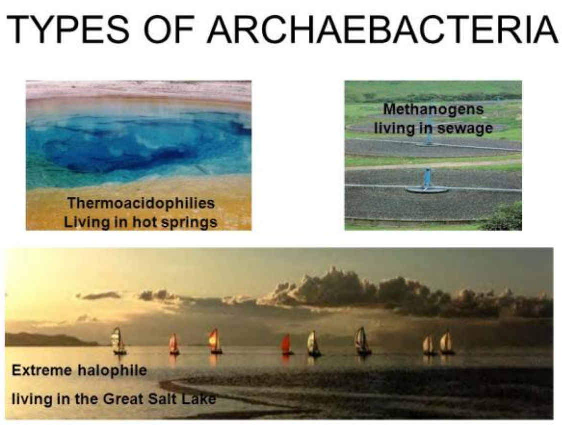
- Archaebacteria are obligate or facultative anaerobes, i.e., they flourish in the absence of oxygen and that is why only they can undergo methanogenesis.
- The cell membranes of the Archaebacteria are composed of lipids.
- The rigid cell wall provides shape and support to the Archaebacteria. It also protects the cell from bursting under hypotonic conditions.

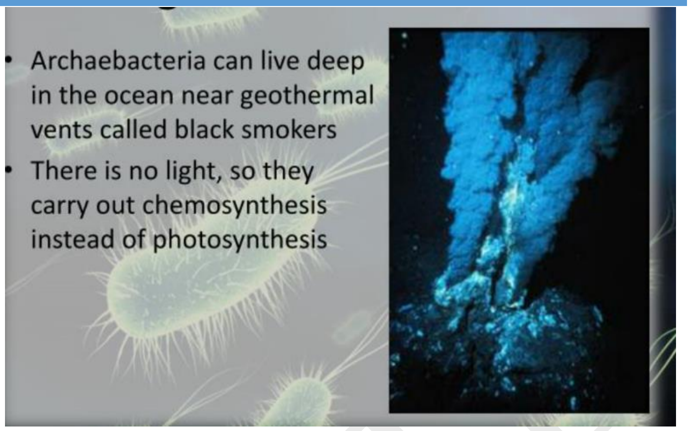
- The cell wall is composed of Pseudomurein, which prevents archaebacteria from the effects of Lysozyme. Lysozyme is an enzyme released by the immune system of the host, which dissolves the cell wall of pathogenic bacteria.
- These do not possess membrane-bound organelles such as nuclei, endoplasmic reticulum, mitochondria, lysosomes or chloroplast. Its thick cytoplasm contains all the compounds required for nutrition and metabolism.
- They can live in a variety of environments and are hence called extremophiles. They can survive in acidic and alkaline aquatic regions, and also in temperature above boiling point.
- They can withstand a very high pressure of more than 200 atmospheres.
- Archaebacteria are indifferent towards major antibiotics because they contain plasmids which have antibiotic resistance enzymes.
- The mode of reproduction is asexual, known as binary fission.
- They perform unique gene transcription.
- The differences in their ribosomal RNA suggest that they diverged from both prokaryotes and eukaryotes.



These are the foremost primitive and ancient forms among the three domains of life and are known to be present within the most extreme conditions of the environment. For example

- ✓ acidophiles- live at pH below 1
- ✓ alkalophiles- live in very salty environments, thermophiles- live at high temperatures (113°C),
- ✓ psychrophiles- live in cold temperatures (4°C), methanogens- produce the gas methane,
- ✓ thermoacidophiles-withstand acidic high-temperature water, etc.





Contrary to this, all archaea are not extremophiles as it has been recorded from normal environments such as soil, and ocean, and also found to cohabit with bacteria like within the human gut, the occurrence of methane-producing archaea.

Their unique characteristics include

- their membranes chemistry which consists of branched hydrocarbon chains attached to glycerol by ether linkages that helps to stabilize them even under extreme environments.
- They share a number of the properties that are common to either bacteria or eukaryotes.

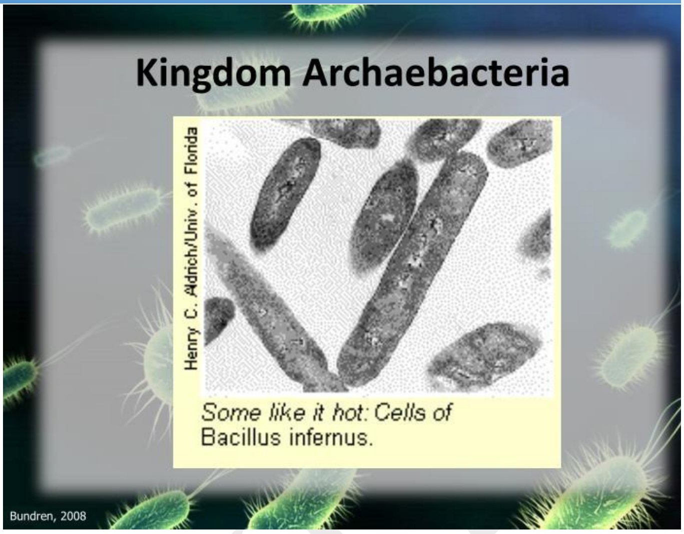
Similarities with bacteria

- Unicellular prokaryotic nature
- Absence of membrane-bound nucleus and other internal structures
- Occurrence of single circular chromosome- a chunk of circular, double-stranded DNA (dsDNA)
- Asexual reproduction by the fission process
- Presence of flagella for locomotion in their environment

Archaea show resemblance to eukaryotes specifically for the enzymatic machinery associated with the processing of genetic information like DNA packaging and replication, RNA transcription, and protein translation.

These don't have a peptidoglycan layer in their cell envelope and are immune to antibiotics that affect the bacteria but are sensitive to some antibiotics that influence the Eukaryotes.

Recent conclusions made by biologists after Woese proposed three equal domains, suggested eukaryotes to be the direct descendants of archaea rather than sister groups.



Importance of Archaebacteria

The importance of archaebacteria can be understood from the following points:

- Archaebacteria have compelled the scientists to reconsider the common definition of species. Species are a group with gene flow within its members. The archaebacteria exhibit gene flow across its species.
- The Archaebacteria are methanogens, i.e., they are capable of producing methane. They act on the organic matter and decompose it to release methane which is then used for cooking and lighting.

ALUTA CONTINUA