Prokaryotes and Eukaryotes

Microorganisms and all other living organisms are classified as prokaryotes or eukaryotes. Prokaryotes and eukaryotes are distinguished on the basis of their cellular characteristics.

*Prokaryotes*

Prokaryotes are organisms made up of cells that lack a cell nucleus or any membrane-encased organelles. This means the genetic material DNA in prokaryotes is not bound within a nucleus. Additionally, the DNA is less structured in prokaryotes than in eukaryotes. In prokaryotes, DNA is a single loop. In Eukaryotes, DNA is organized into chromosomes. Most prokaryotes are made up of just a single cell ( unicellular) but there are a few that are made of collections of cells (multicellular). Scientists have divided the prokaryotes into two groups, the Bacteria and the Archaea.

*Eukaryotes*

Eukaryotes are organisms made up of cells that possess a membrane-bound nucleus (that holds genetic material) as well as membrane-bound organelles. Genetic material in eukaryotes is contained within a nucleus within the cell and DNA is organized into chromosomes. Eukaryotic organisms may be multicellular or single-celled organisms. Eukaryotic cell membrane contain sterols, whereas no prokaryotes except the wall of *Mycoplasma*, has sterol in its membrane. All animals are eukaryotes. Other eukaryotes include plants, fungi, and protists.

<table>
<thead>
<tr>
<th>The differences between eukaryotic and prokaryotic cell</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Eukaryotic Cell</strong></td>
</tr>
<tr>
<td>Nucleus:</td>
</tr>
<tr>
<td>Number of chromosomes:</td>
</tr>
<tr>
<td>Cell Type:</td>
</tr>
<tr>
<td>True Membrane bound Nucleus:</td>
</tr>
<tr>
<td>Example:</td>
</tr>
<tr>
<td>Lysosomes and peroxisomes:</td>
</tr>
<tr>
<td>Feature</td>
</tr>
<tr>
<td>-------------------------------</td>
</tr>
<tr>
<td>Microtubules</td>
</tr>
<tr>
<td>Endoplasmic reticulum</td>
</tr>
<tr>
<td>Mitochondria</td>
</tr>
<tr>
<td>Ribosomes</td>
</tr>
<tr>
<td>Vesicles</td>
</tr>
<tr>
<td>Golgi apparatus</td>
</tr>
<tr>
<td>Chloroplasts</td>
</tr>
<tr>
<td>Flagella</td>
</tr>
<tr>
<td>Permeability of Nuclear Membrane</td>
</tr>
<tr>
<td>Plasma membrane with steroids</td>
</tr>
<tr>
<td>Vacuoles</td>
</tr>
<tr>
<td>Cell size</td>
</tr>
</tbody>
</table>

**Structure of bacterial cell:**

The most elemental structural property of bacteria is cell morphology (shape). Typical examples include:

- coccus (spherical)
- bacillus (rod-like)
- spirillum (spiral)
- filamentous

Cell shape is generally characteristic of a given bacterial species, but can vary depending on growth conditions. Bacteria generally form distinctive cell morphologies when examined by light microscopy and distinct colony morphologies when grown on Petri plates. These are often the first characteristics observed by a microbiologist to determine the identity of an unknown bacterial culture.
In addition to their characteristic shapes, the arrangement of bacteria is important. For ex., certain cocci occur in pairs (diplococci), some in chains (streptococci), and others in grapelike cluster (staphylococci).

Structurally, a bacterial cell has three architectural regions: appendages (attachments to the cell surface) in the form of flagella and pili (or fimbriae); a cell envelope consisting of a capsule, cell wall and plasma membrane; and a cytoplasmic region that contains the cell chromosome (DNA) and ribosomes and various sorts of inclusions.

*Cell envelope:-

The cell envelope is a descriptive term for the several layers of material that envelope or enclose the protoplasm of the cell. The cell protoplasm (cytoplasm) is surrounded by the plasma membrane, a cell wall and a capsule. The cell wall itself is a layered structure in Gram-negative bacteria. All cells have a plasma membrane, which is the essential and definitive characteristic of a "cell". Almost all procaryotes have a cell wall to prevent damage to the underlying protoplast. Outside the cell wall, foremost as a surface structure, may be a polysaccharide capsule or glycocalyx.

1-Capsules:

Most bacteria contain some sort of a polysaccharide layer outside of the cell wall polymer. In a general sense, this layer is called a capsule. A true capsule is a discrete detectable layer of polysaccharides deposited outside the cell wall. A less discrete structure or matrix which embeds the cells is a called a slime layer or a glycocalyx is a very thin layer of tangled polysaccharide fibers on the cell surface, often mediate adherence of cells to surfaces. Capsules are generally composed of polysaccharides; rarely they contain amino sugars or peptides.

Capsules have several functions and often have multiple functions. Capsules mediate adherence of cells to surfaces, protect bacterial cells from engulfment by phagocytes and invasiveness of pathogen.

2-Cell wall:-

Most prokaryotes have a rigid cell wall. The cell wall is an essential structure that protects the cell protoplast (the region bound by and including the membrane) from mechanical damage and from osmotic rupture or lysis. Bacterial murein is a unique type of peptidoglycan. Peptidoglycan is a polymer of sugars (a glycan) cross-linked by short chains of amino acids (peptide). A layer of peptidoglycan consist of two types of alternating joined molecules called N-acetylmuramic acid, and N-acetylglucose amine and asset of identical tetrapeptide side chain. The glycan backbone of the peptidoglycan molecule can be cleaved by an enzyme called lysozyme that is present in animal serum, tissues and secretions, and in phagocyte granules. The function of lysozyme is to lyse (rupture) bacterial cells as a defense
against bacterial pathogens. Bacteria are classified as gram positive and gram negative according to the response to the gram staining procedure.

The cell are first stained with crystal violet dye and iodine then washed with acetone or alcohol then stained with safranin. The acetone or alcohol decolorize G-ve bacteria (because its cell wall contains little peptidoglycan and a lot of lipopolysaccharide) but not G+ve bacteria which contain a lot of peptidoglycan that take the stain and not dissolved or affected by acetone or alcohol so it appear blue purple in color, while G-ve bacteria often loss this color by decolorize, it will stain with counter stain safranin that give it the red or pink color.

In Gram-positive Bacteria the cell wall is thick (15-80 nanometers), consisting of several layers of peptidoglycan. It have a layer of teichoic acids on the outside of the peptidoglycan which are unique to the Gram-positive cell wall.

In the Gram-negative Bacteria the cell wall is relatively thin (10 nanometers) and is composed of a single layer of peptidoglycan surrounded by a membranous structure called the outer membrane. The outer membrane of Gram-negative bacteria invariably contains a unique component, lipopolysaccharide (LPS or endotoxin), which is toxic to animals, lipoprotein, and phospholipid. Lying between the outer membrane layer and the cytoplasmic membrane is the periplasmic space which is the site in some species of enzymes (e.g, beta lactamases) that degrade penicillin and other beta lactam drugs.

Bacterial lipopolysaccharides are toxic. When injected in small amounts LPS or endotoxin activates several host responses that lead to fever, inflammation and shock. **The toxic component of endotoxin (LPS) are:-**

1- Lipid A which is responsible for the toxic effect
2- a core polysaccharide of 5 sugar linked through ketodeoxyoctulonate to lipid A
3- The O-specific polysaccharide may provide for adherence or resistance to phagocytosis, in the same manner as fimbriae and capsules. The O polysaccharide (also referred to as the O antigen) also accounts for multiple antigenic types (serotypes) among Gram-negative bacterial pathogens.

**The function of LPS are:-**

1- it's essential for bacterial growth and survival
2- help in adherence (colonization ) of bacteria
3- prevent distribution by phagocytosis
4- its permeable to only low molecular weight, hydrophobic molecules of less than 700 daltons. These prevent the penetration of bile salts and other toxic molecules from gastrointestinal tract from penetration in to these types of bacteria especially enterobacteriaceae.
* Cell wall of acid fast bacteria:

Mycobacteria, e.g. *Mycobacterium tuberculosis* have an unusual cell wall, resulting in their inability to be gram-stained. These bacteria are said to be acid fast this property is related to the high concentration in the cell wall of lipids called (mycolic acid).

3- Plasma membrane:

The plasma membrane, also called the cytoplasmic membrane, is the most dynamic structure of a prokaryotic cell. Its main function is a s a selective permeability barrier that regulates the passage of substances into and out of the cell. Bacterial membranes are composed of 40 percent phospholipid and 60 percent protein.

Functions of plasma membrane:

1. Osmotic or permeability barrier
2. Location of transport systems for specific solutes (nutrients and ions)
3. Energy generating functions, involving respiratory and photosynthetic electron transport systems, establishment of proton motive force, and transmembranous, ATP-synthesizing ATPase
4. Synthesis of membrane lipids (including lipopolysaccharide in Gram-negative cells)
5. Synthesis of murein (cell wall peptidoglycan)
6. Assembly and secretion of extracytoplasmic proteins
7. Chemotaxis (both motility per se and sensing functions)
8. Location of specialized enzyme system

* Cytoplasmic region:

The cytoplasmic constituents of bacterial cells invariably include the procaryotic chromosome (nucleoid), ribosomes, and several hundred proteins and enzymes.

1- Chromosome:

The chromosome is typically one large circular molecule of DNA, more or less free in the cytoplasm. The cell chromosome is the genetic control center of the cell which determines all the properties and functions of the bacterium.
2- Plasmids:-

Are extrachromosomal pieces of DNA double strand, circular DNA. Plasmid are not essential for the life of cell. They may confer certain properties like toxigenicity, virulence and drug resistance.

3- Ribosome:-

The ribosomes of prokaryotes are smaller than cytoplasmic ribosomes of eukaryotes. Prokaryotic ribosomes are 70S in size, being composed of 30S and 50S subunits. The 80S ribosomes of eukaryotes are made up of 40S and 60S subunits. Ribosomes are involved in the process of translation (protein synthesis), ribosomes the site of action of many antibiotics that inhibit bacterial but not human protein synthesis. Consist of two subunits, the protein and RNA.

4- Inclusions:-

Inclusions are distinct granules that may occupy a substantial part of the cytoplasm. Inclusion granules are usually reserve materials of some sort. For example, carbon and energy reserves may be stored as glycogen.

* Appendages:-

1- Flagella:-

Flagella are filamentous protein structures attached to the cell surface that provide the swimming movement for most motile procaryotes. The flagellar filament is rotated by a motor apparatus in the plasma membrane allowing the cell to swim in fluid environments. The flagellar apparatus consists of several distinct proteins: a system of rings imbedded in the cell envelope (the basal body), a hook-like structure near the cell surface, and the flagellar filament composed of polymerized protein called flagellin.

Some bacteria has single flagella called monotrichus or has flagellum at each end of the cell called amphitrichus, or multiple flagella at one end called lophotrichus or flagella distributed over the entire body called peritrichus.

2- Fimbriae and Pili:-

Fimbriae and pili are interchangeable terms used to designate short, hair-like structures on the surfaces of procaryotic cells. Like flagella, they are composed of protein called pillin. Fimbriae are shorter and stiffer than flagella, and slightly smaller in diameter. Generally, fimbriae have nothing to do with bacterial movement (there are exceptions, e.g. twitching movement on Pseudomonas). Fimbriae are very common in Gram-negative bacteria, but occur in some Gram-positive bacteria as well.
Role of pili:-
1- pili are most often involved in adherence of bacteria to surfaces, substrates and other cells or tissues in nature. They are major determinants of bacterial virulence because they allow pathogens to attach to (colonize) tissues and/or to resist attack by phagocytic white blood cells
2- Type of pilus, the F or sex pilus, apparently stabilizes mating bacteria during the process of conjugation between the male (donor) and the female (recipient).

* Endospore:-
• These spores are designed for survival and not reproduction.
• These are formed within cells
• They are resistant to heat, drying, acids, bases, disinfectants, and radiation. Spores form when nutrients are depleted from a culture.
• Few spores are formed when nutrients are plentiful and environmental conditions are favorable.

An endospore consists of a core, surrounded by a cortex, a spore coat and in some species a thin layer called the exosporium. Endospore is present in some sp. of bacteria like Bacillus or Clostridium.

They contain dipicolinic acid and a large number of calcium ions.
• These materials contribute to heat resistance
• The low water content enables them to survive