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((Microbial Physiology))

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LEC- (2)

The Cell Wall

By

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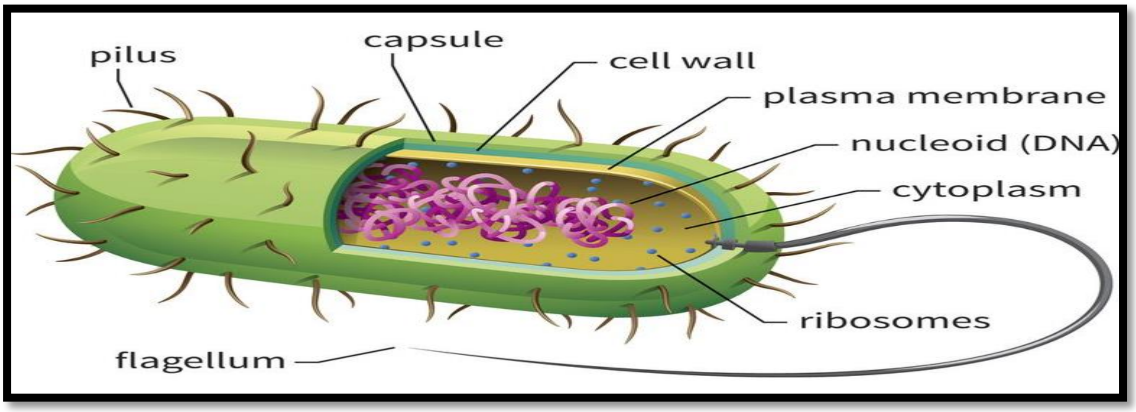
Bacterial Cell wall



Bacteria cell structure

Prokaryotic cells have a cell wall that provides the physical strength to maintain their shapes. **Murein is the main component of the cell wall of bacteria. The cell wall in Gram-negative bacteria is much thinner than in Gram-positive bacteria, which have a complex cell wall with other polymers and do not possess an outer membrane . Murein (peptidoglycan) is a polymer with a backbone of 1,4-linked N-acetylglucosamine and N-acetylmuramate** .

Gram-positive bacteria do not have an outer membrane but have a much thicker cell wall containing teichoic acid, lipoteichoic acid and lipoglycan in addition to murein

The structure of teichoic acid differs depending on the bacterial species. Teichoic acids are polymers of ribitol phosphate, glycerol phosphate and their derivatives. In some cases, the hydroxyl groups of the poly alcohols are bonded with amino acids or sugars. Teichoic acid is linked to murein through a linkage unit . **The Gram-positive bacterial cell wall contains various proteins, including the autolytic enzymes mentioned above. They are attached to the cell wall through the action of an enzyme called sortase after they are excreted through the cytoplasmic membrane. Their functions include (1) metabolism of cell surface structures, (2) invasion into the host, (3) hydrolysis of polymers such as proteins and polysaccharides and (4) adhesion to solid surfaces.**

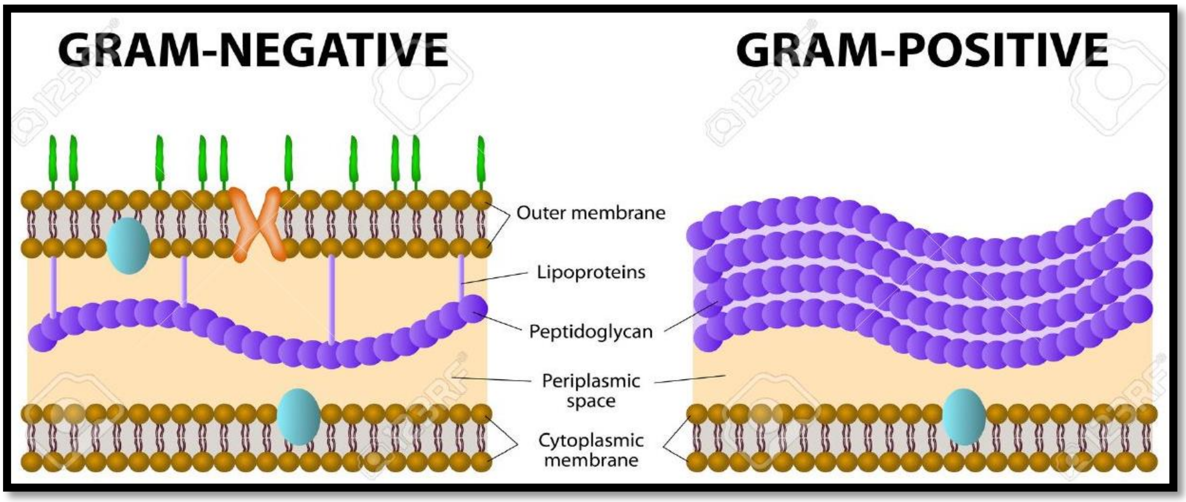


Figure (1) : Structure of cell wall in gram-positive and gram negative bacteria

The term periplasm is used to describe a separate compartment between the outer membrane and the cytoplasmic membrane in Gram-negative bacteria. Murein (cell wall) is contained within this compartment. The periplasm is in a gel state and contains proteins and oligosaccharides. Under high osmotic pressure conditions, Gram-negative bacteria accumulate an oligosaccharide known as osmoregulated periplasmic glucan, which buffers the osmolarity. A variety of proteins are found in the periplasm including sensor proteins, enzymes for the synthesis of cell surface components, transporters , solute-binding proteins, regulatory proteins , part of the electron transport system , and hydrolytic enzymes such as lactamase, amylase and alkaline phosphatase.

Plasma membrane

The plasma membrane or bacterial cytoplasmic membrane is composed of a phospholipid bilayer and thus has all of the general functions of a cell membrane such as acting as a permeability barrier for most molecules and serving as the location for the transport of molecules into the cell. In addition to these functions, prokaryotic membranes also function in energy conservation as the location about which a proton motive force is generated. Unlike eukaryotes, bacterial membranes (with some exceptions e.g. *Mycoplasma* and methanotrophs) generally do not contain sterols. Unlike eukaryotes, bacteria can have a wide variety of fatty acids within their membranes.

As a phospholipid bilayer, the lipid portion of the outer membrane is impermeable to charged molecules. However,

channels called porins are present in the outer membrane that allow for passive transport of many ions, sugars and amino acids across the outer membrane. These molecules are therefore present in the periplasm, the region between the cytoplasmic and outer membranes. The periplasm contains the peptidoglycan layer and many proteins responsible for substrate binding or hydrolysis and reception of extracellular signals. Because of its location between the cytoplasmic and outer membranes, signals received and substrates bound are available to be transported across the cytoplasmic membrane using transport and signalling proteins imbedded there.

Functions of the procaryotic 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.

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. Coordination of DNA replication and segregation with septum formation and cell division 8. Chemotaxis (both motility per se and sensing functions)

9. Location of specialized enzyme system .

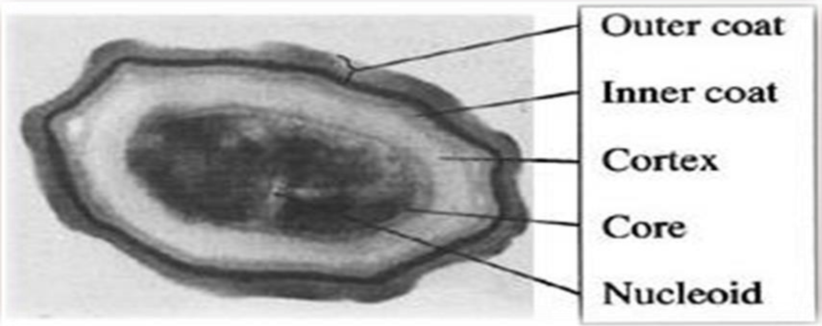
Cytoplasm

The cytoplasm refers to everything inside the cytoplasmic membrane . Cells are classified as prokaryotes or eukaryotes depending on the possession of a nucleus. Eukaryotic cells have well-developed intracellular organelles such as mitochondria , chloroplasts and endoplasmic reticulum in addition to the nucleus. With only a few exceptions, prokaryotic cells do not have subcellular organelles within the cytoplasm. Prokaryotic cytoplasm contains DNA, ribosomes, proteins, RNA, salts and metabolites and is viscous due to the high concentration of macromolecules. **Some of these macromolecules form aggregates, while others are soluble. The soluble part is called the cytosol**. The cytoplasm is not a random mixture of its components. The intra cytoplasmic membrane structures in these bacteria contain proteins that determine the specific physiological properties of these bacteria.

6. Resting cells

Many bacteria differentiate into resting cells when the growth environment becomes unfavorable, such as by depletion of nutrients . The best known resting cells are spores as found in the Gram-positive aerobic *Bacillus* and anaerobic *Clostridium* genera . Cysts are another form of

resting cells, these are resistant against physical and chemical stresses such as desiccation and ionizing radiation. Spores are resistant to high temperatures, but cysts are not. Spores can remain viable for several decades under dry conditions. Spore-specific structures include the outer coat, inner coat and cortex. The coats mainly comprise protein and the cortex murein. The cortex, occupying the region between the spore wall and the coats, renders the resistance property of the spores. The structure of cysts is similar to vegetative cells except for the exine and intine. The exine is the outer cyst wall consisting of mainly alginate, protein and lipid, and the intine is the inner cyst wall comprising polymannuronic acid. The cyst central body transforms to a vegetative cell under favorable growth conditions but is not resistant to external stresses.



7. Elemental composition

From over 100 natural elements, microbial cells generally only contain 12 in significant quantities. These are known as major elements, and are listed in (Table **2**) together with some of their major functions and predominant chemical forms used by microorganisms.

Table (2): Major elements found in microbial cells with their functions

Element	Chemical forms used by microbes	Function
C	organic compounds, CO, CO2	**major constituents of cell material in proteins, nucleic acids, lipids, carbohydrates and others**
O	organic compounds, CO2, H2O, O2	
H	organic compounds, H2O, H2	
N	organic compounds, NH4, NO3 , N2	
S	organic sulfur compounds, SO4 , HS^-, S0, S2O3	**proteins, coenzymes**
P	$HPO4^{-2}$	**nucleic acids, phospholipids, teichoic acid, coenzymes**
K	K^+	major inorganic cation, compatible solute, enzyme cofactor
Mg	Mg^{+2}	**enzyme cofactor, bound to cell wall, membrane and phosphate esters including nucleic acids and ATP**
Fe	Fe^{+2}, Fe^{+3}	cytochromes, ferredoxin, Fe-S proteins, enzyme cofactor
Na	Na +	involved in transport and energy transduction
Ca	Ca^{+2}	**enzyme cofactor, bound to cell wall**

Outer membrane :

Gram-negative bacteria are more resistant to lysozyme, hydrolytic enzymes, surfactants, bile salts and hydrophobic antibiotics than Gram-positive bacteria. These properties are due to the presence of the outer membrane in Gram-negative bacteria . The outer membrane (OM) is different in structure from the cytoplasmic membrane (CM).

The CM consists of phospholipids while lipopolysaccharide (LPS) forms the outer leaflet of the OM with the inner leaflet composed of phospholipids. LPS provides a permeability barrier against the hydrophobic compounds listed above. In addition to these lipids, the OM contains protein and lipoprotein (Table 1). **Lipopolysaccharide (LPS) consists of three components: lipid A, core polysaccharide and repeating polysaccharide. The repeating polysaccharide is referred to as O-antigen.** Lipid A is embedded in the membrane to form the lipid layer, and the sugar moieties extend into the surface. The sugar moieties of LPS consist of hexoses, hexosamines, deoxyhexoses and keto-sugars with different structures depending on the species and on the culture conditions

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Table 1. Outer membrane (OM) components and their functions in *Escherichia coli*

Component	Function
Phospholipid	inner leaflet
Lipopolysaccharide	outer leaflet, hydrophilic in nature providing a barrier against hydrophobic compounds. Stabilization of the surface structure by bonding with metal ions such as Mg^{+2}
Lipoprotein	lipid part is embedded in the OM hydrophobic region, and the sugar part is covalently bound to murein which stabilizes the OM
OM protein A	maintenance of OM stability, receptor for amino acids and peptides, F- pilus in recipient cell for conjugation
Porin	**three different porins, OmpC, OmpF and PhoE, each consisting of three peptides, act as specific and non-specific channels for hydrophilic solutes**