MIC 362 Lect. (5) :

Cell Wall

The cell walls of bacteria deserve special attention for several reasons:

1. They are an essential structure for viability.
2. They are composed of unique components found nowhere else in nature.
3. They are one of the most important sites for attack by antibiotics.
4. They provide ligands for adherence and receptor sites for drugs or viruses.
5. They cause symptoms of disease in animals.
6. They provide for immunological distinction and immunological variation among strains of bacteria.

*. Most prokaryotes have a rigid **cell wall**.

*. The cell wall is an essential structure that protects the cell protoplast from mechanical damage and from osmotic rupture or **lysis**.

*. Prokaryotes usually live in relatively dilute environments such that the accumulation of solutes inside the prokaryotic cell cytoplasm greatly exceeds the total solute concentration in the outside environment. Thus, the osmotic pressure against the inside of the plasma membrane may be the equivalent of 10-25 atm.

*Since the membrane is a delicate, plastic structure, it must be restrained by an outside wall made of porous, rigid material that has high tensile strength. Such a material is **murein**, the ubiquitous component of bacterial cell walls. *Since the membrane is a delicate, plastic structure, it must be restrained by an outside wall made of porous, rigid material that has high tensile strength. Such a material is **murein**, the ubiquitous component of bacterial cell walls.

Murein:

A unique type of **peptidoglycan**, a polymer of disaccharides (glycan) cross-linked by short chains of amino acids (peptide).

- Many types of peptidoglycan exist.
- All Bacterial peptidoglycans contain N-acetylmuramic acid, which is the definitive component of murein.
- The cell walls of Archaea may be composed of protein, polysaccharides, or peptidoglycan-like molecules, but never do they contain murein. This feature distinguishes the Bacteria from the Archaea.

In the **Gram-positive Bacteria:**

1- the cell wall consists of several layers of peptidoglycan. Running perpendicular to the peptidoglycan sheets is a group of molecules called **teichoic acids** which are unique to the Gram-positive cell wall (Figure 14).

2-In the Gram-positive Bacteria, the cell wall is thick (15-80 nanometers), consisting of several layers of peptidoglycan

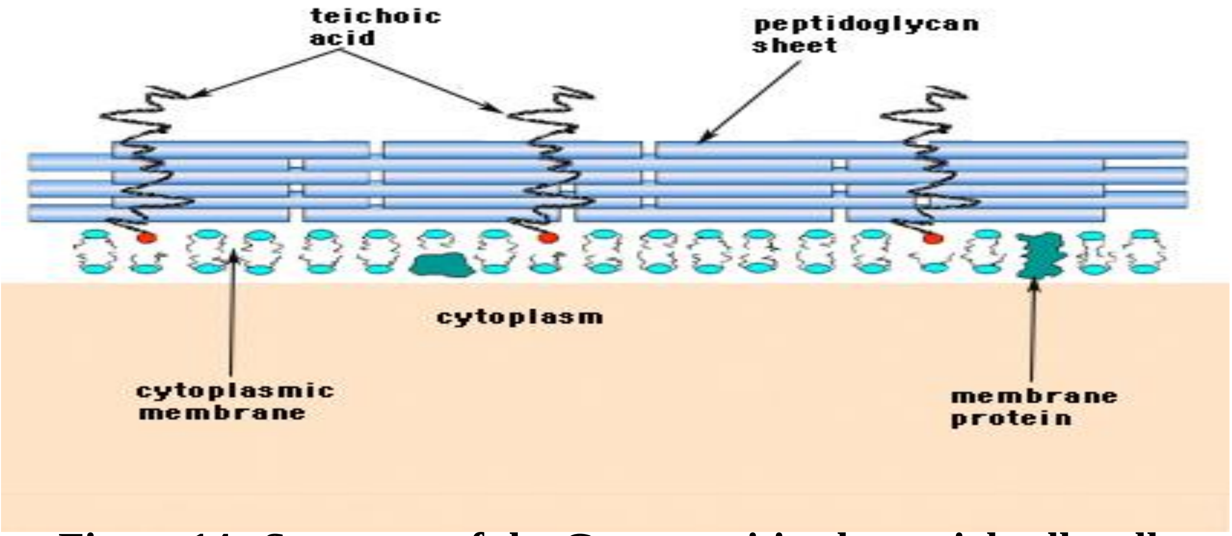


Figure 14. Structure of the Gram-positive bacterial cell wall. The wall is relatively thick and consists of many layers of peptidoglycan interspersed with teichoic acids that run perpendicular to the peptidoglycan sheets.

In the **Gram-negative Bacteria:**

•the cell wall 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 host.

• In Gram-negative bacteria the outer membrane is usually thought of as part of the cell wall (Figure 15).

•In the Gram-negative Bacteria the cell wall is relatively thin (10 nanometers) and is composed of a single layer of peptidoglycan surrounded by an outer membrane

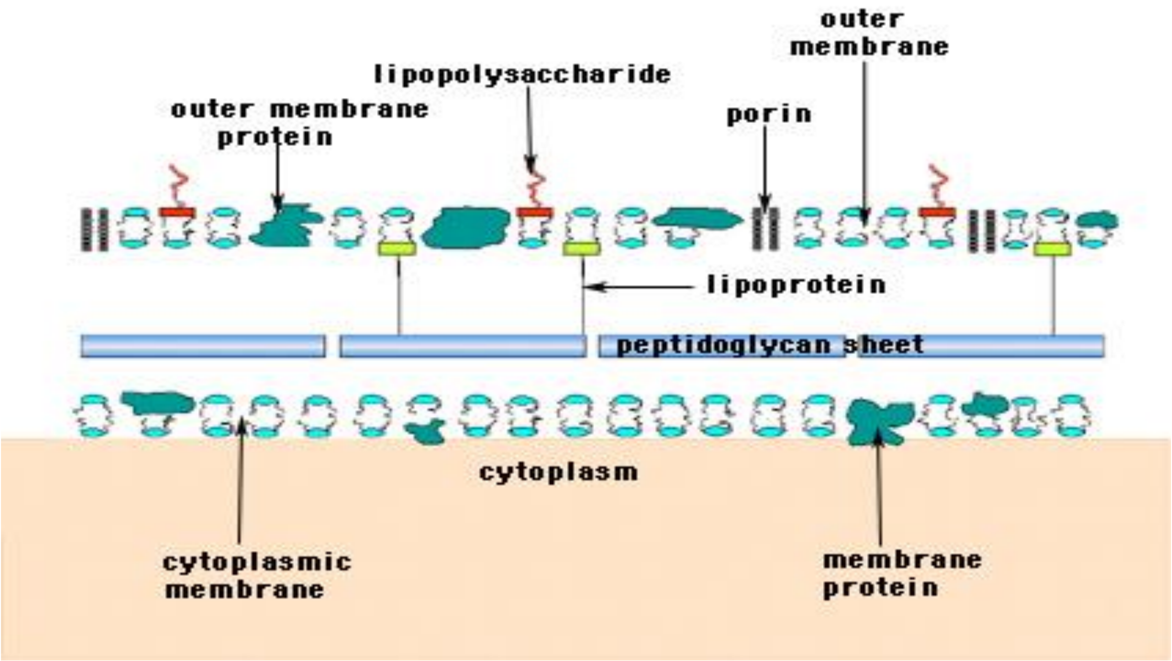
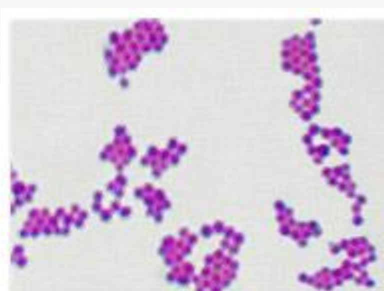
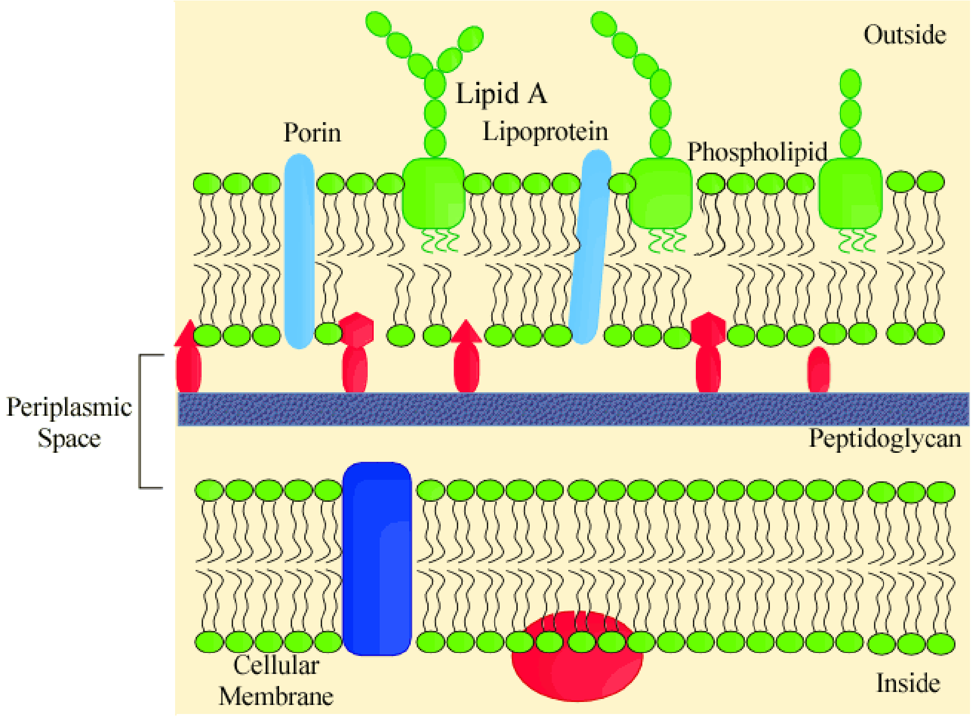


Figure 15. Structure of the Gram-negative cell wall. The wall is relatively thin and contains much less peptidoglycan than the Gram-positive wall. Also, teichoic acids are absent. However, the Gram negative cell wall consists of an outer membrane that is outside of the peptidoglycan layer. The outer membrane is attached to the peptidoglycan sheet by a unique group of lipoprotein molecules.

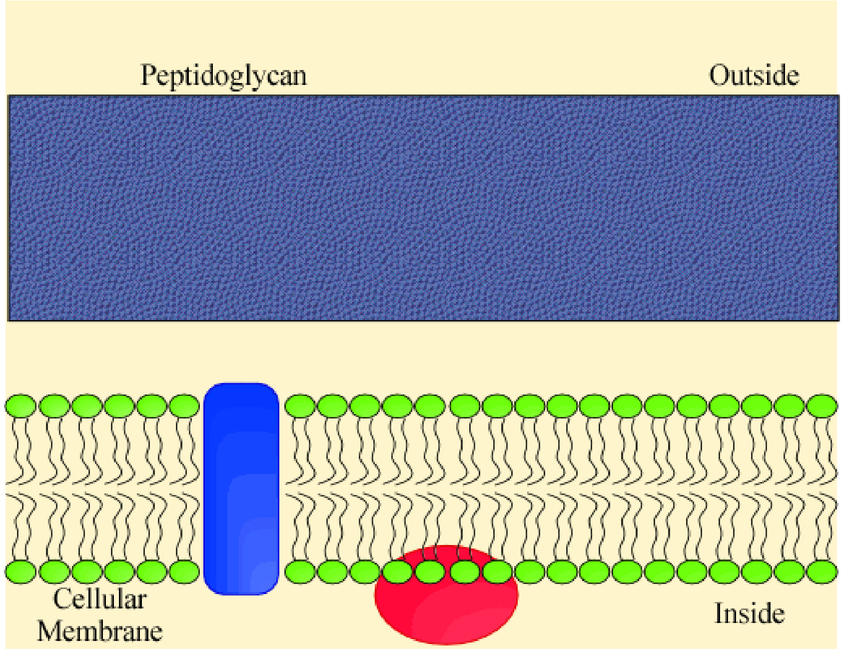
Step	Gram-positive organisms	Gram-negative organisms
1. Unstained	Clear	Clear
2. Crystal violet	Violet	Violet
3. Iodine enters bacterial cell & forms iodine-crystal violet complexes	Violet	Violet
4. Decolorization (alcohol-acetone)	Violet	Clear
5. Safranin	Purple	Red



Gram-negative cell structure



The gram-positive cell wall



The glycan backbone of the peptidoglycan molecule can be cleaved by an enzyme called **lysozyme** that is present in host serum, tissues and secretions, and in the phagocytic lysosome.

The function of lysozyme is:

- To lyse bacterial cells as a constitutive defence against bacterial pathogens.
- Some Gram-positive bacteria are very sensitive to lysozyme and the enzyme is quite active at low concentrations. Lachrymal secretions (tears) can be diluted 1:40,000 and retain the ability to lyse certain bacterial cells.
- Gram-negative bacteria are less vulnerable to attack by lysozyme because their peptidoglycan is shielded by the outer membrane.

Teichoic acids:

- linear polymers with phosphates and a few amino acids and sugars.
- The teichoic acid polymers are occasionally anchored to the plasma membrane (called **lipoteichoic acid**, **LTA**).

The functions of teichoic acid :

- ❖ They are essential to viability of Gram-positive bacteria in the wild. One idea is that they provide a channel of regularly-oriented negative charges for threading positively charged substances through the complicated peptidoglycan network.
- ❖ Teichoic acids are involved in the regulation and assembly of muramic acid subunits on the outside of the plasma membrane.
- ❖ There are instances, particularly in the streptococci, where in teichoic acids have been implicated in the adherence of the bacteria to tissue surfaces.

The Outer Membrane of Gram-negative Bacteria

MIC 362
Lect. (6):

The Outer Membrane of Gram-negative Bacteria

- The Gram-negative cell wall is composed of an outer membrane, a peptidoglygan layer, and a periplasm.
- The outer membrane of Gram-negative bacteria contains lipopolysaccharides, proteins, and phospholipids.
- The lipopolysaccharide component acts as a virulence factor and causes disease in animals.
- More virulence factors are harbored in the periplasmic space between the outer membrane and the plasma

membrane

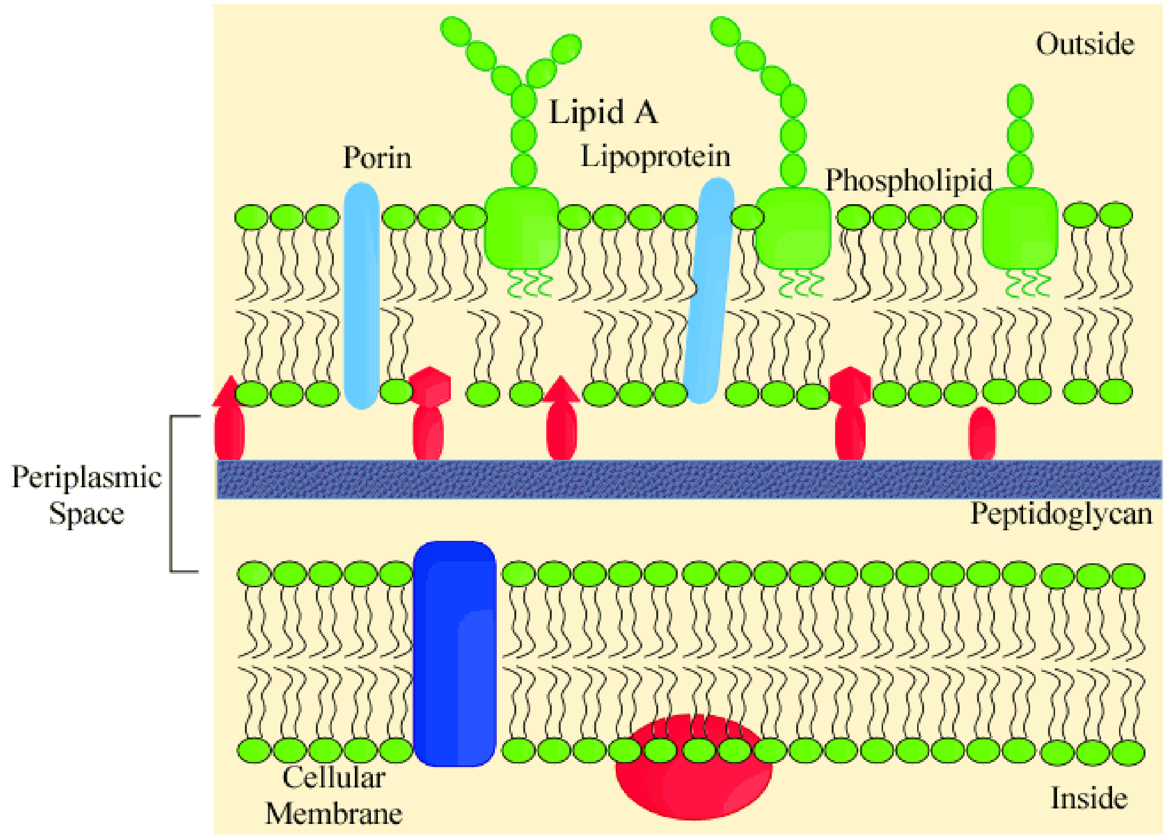


Figure. the outer membrane, cell wall and plasma membrane of a Gram-negative bacterium. Note the structure and arrangement of molecules that constitute the outer membrane.

In the Gram-negative Bacteria the cell wall is composed of a single layer of peptidoglycan surrounded by a membranous structure called the outer membrane.

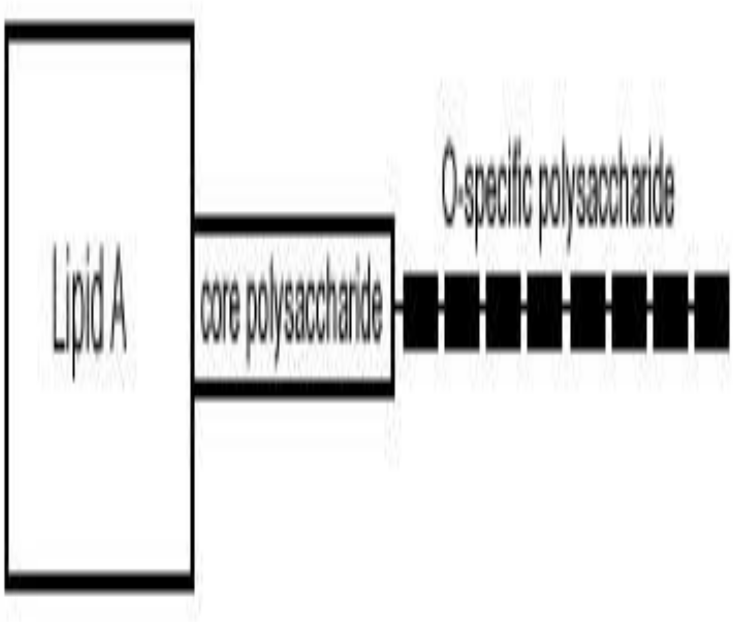
The outer membrane of Gram-negative bacteria invariably contains a lipopolysaccharide (LPS) in addition to proteins and phospholipids. The LPS molecule is toxic and is classified as an endotoxin that elicits a strong immune response when the bacteria infect the host.

The LPS molecule that constitutes the outer face of the outer membrane is composed of :

•A hydrophobic region, called **Lipid A** that is attached to a hydrophilic linear polysaccharide region.

• **core polysaccharide** .

• **the O-specific polysaccharide(**O antigen) may provide ligands for bacterial attachment



usually and relatively permeable. It contains structures that help bacteria adhere to animal cells and cause disease.

- The peptidoglycan layer of the cell wall is non-covalently anchored to lipoprotein molecules called Braun's lipoproteins through their hydrophobic head.
- Sandwiched between the outer membrane and the plasma membrane, a concentrated gel-like matrix called the periplasmic space.
- The periplasm space can act as reservoir for virulence factors and a dynamic flux of macromolecules representing the cell's metabolic status and its response to environmental factors.
- Together, the plasma membrane and the cell wall (outer membrane, peptidoglycan layer, and periplasm) constitute the gram-negative envelope.

Table 5. Functions of the outer membrane components of *Escherichia coli*.

Component	Function
Lipopolysaccharide (LPS)	Permeability barrier
Mg++ bridges	Stabilizes LPS and is essential for its permeability characteristics
lipoprotein	Anchors the outer membrane to peptidoglycan (murein) sheet
Omp C and Omp F porins	proteins that form pores or channels through outer membrane for passage of hydrophilic molecules
Omp A protein	provides receptor for some viruses and bacteriocins; stabilizes mating cells during conjugation

A correlation between Gram stain reaction and cell wall properties of bacteria is summarized in Table below:

Property	Gram-positive	Gram-negative
Thickness of wall	thick (20-80 nm)	thin (10 nm)
Number of layers	1	2
Peptidoglycan (murein) content	>50%	10-20%
Teichoic acids in wall	Present	absent
Lipid and lipoprotein content	0-3%	58%
Protein content	0	9%
Lipopolysaccharide content	0	13%
Sensitivity to Penicillin G	Yes	no (1)
Sensitivity to lysozyme	Yes	no (2)

MIC 362 Lect. (7):

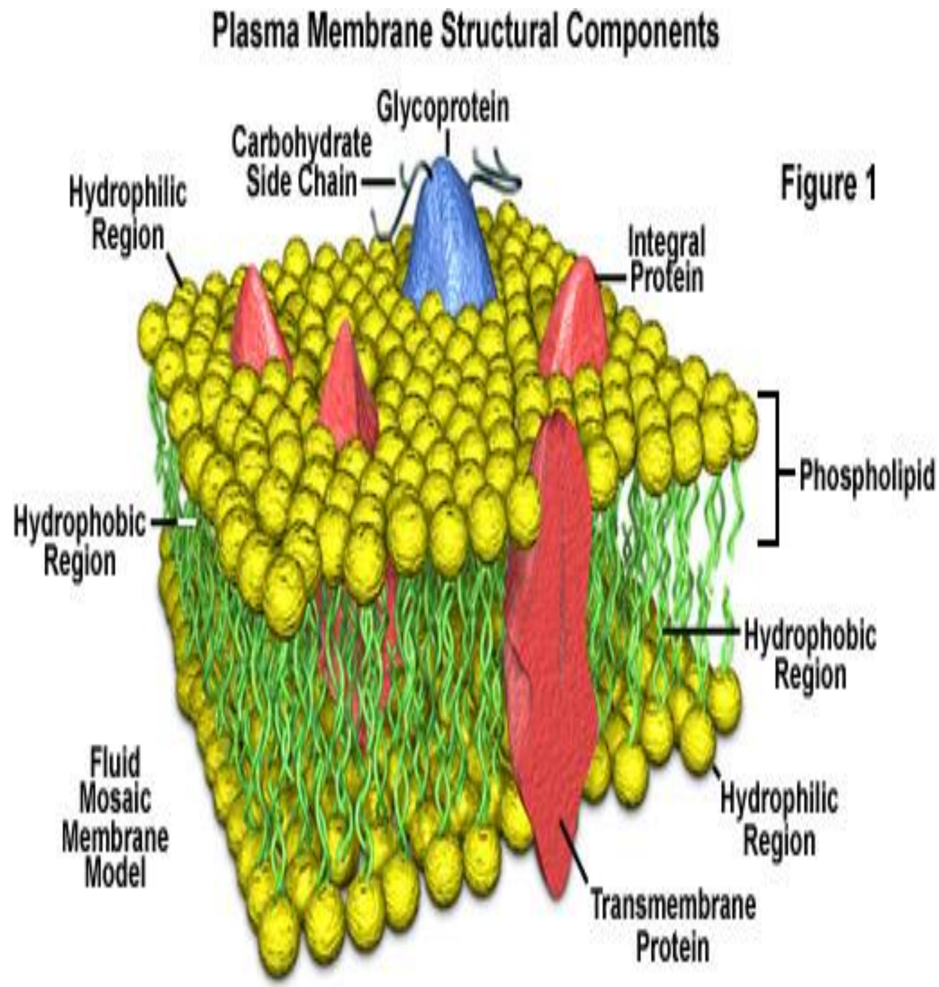
The Plasma Membrane

interior of all cells from the outside environment.

•The cell membrane is selectively permeable to ions and organic molecules and controls the movement of substances in and out of cells.

•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.

•The phospholipids are amphoteric molecules with a polar hydrophilic glycerol "head" attached via an ester bond to two nonpolar hydrophobic fatty acid tails, which naturally form a bilayer in aqueous environments. Dispersed within the bilayer are various structural and enzymatic proteins which carry out most membrane functions.



Fluid mosaic model of a biological membrane. In aqueous environments membrane phospholipids arrange themselves in such a way that they spontaneously form a fluid bilayer. Membrane proteins, which may be structural or functional, may be permanently or transiently associated with one side or the other of the membrane, or even be permanently built into the bilayer, while other proteins span the bilayer and may form transport channels through the membrane.

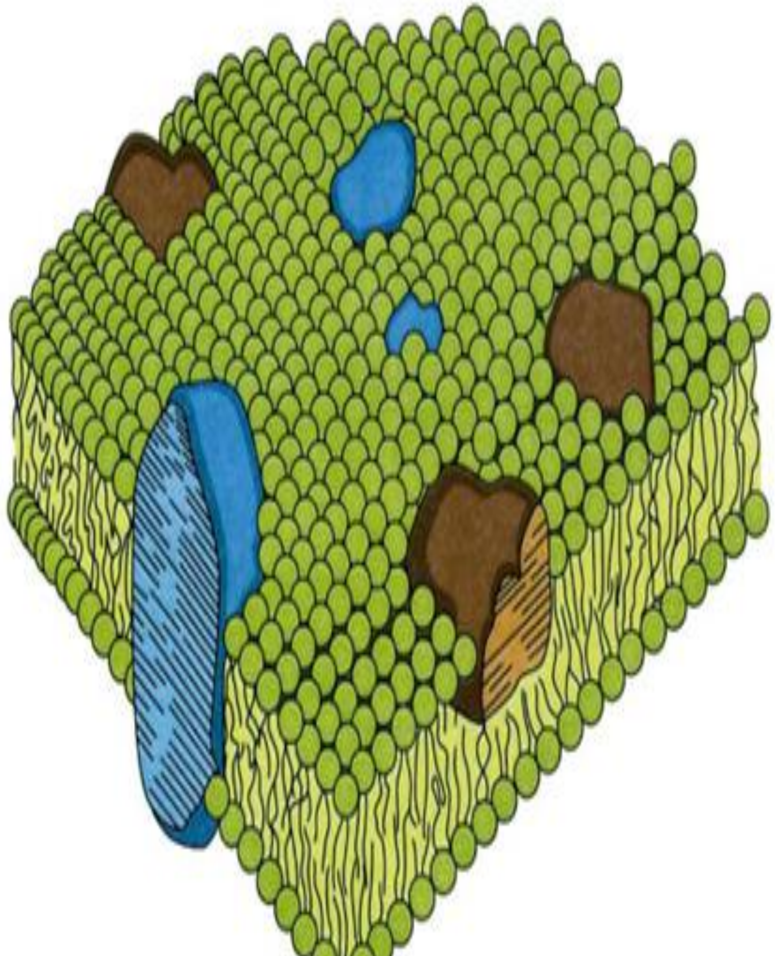
Since prokaryotes lack any intracellular organelles for processes such as respiration or photosynthesis or secretion, the plasma membrane subsumes these processes for the cell and consequently has a variety of functions in:

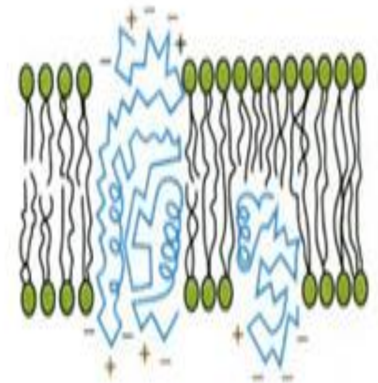
1. Osmotic or permeability barrier
2. Location of transport systems for specific solutes (nutrients and ions)

* transport proteins that selectively mediate the passage of substances into and out of the cell. *prokaryotic membranes contain sensing proteins that measure concentrations of molecules in the environment or binding proteins that translocate signals to genetic and metabolic machinery in the cytoplasm.

*Membranes also contain enzymes involved in many metabolic processes such as cell wall synthesis, septum formation, membrane synthesis, DNA replication, CO_2 fixation and ammonia oxidation.

3. Energy generating functions, involving respiratory and photosynthetic electron transport systems, establishment of proton motive force, ATP-synthesizing ATPase (The photosynthetic chromophores that harvest light energy for conversion into chemical energy are located in the membrane. Hence, the plasma membrane is the site of oxidative phosphorylation and photophosphorylation in prokaryotes, analogous to the functions of mitochondria and chloroplasts in eukaryotic cells).
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





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Functions of the prokaryotic plasma membrane

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