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Bacterial Cell Wall

Function of the cell wall:

1- Cell wall prevents bacterial cells from rupturing when the water pressure inside the cell is greater than that outside the cell.

2- It also helps maintain the shape of a bacterium

3- It serves as a point of anchorage for flagella.

Characteristic and composition of cell wall:

- The cell wall of the bacterial cell is a complex, semirigid structure.
- The bacterial cell wall is composed of a macromolecular network called peptidoglycan (*murein*).

Peptidoglycan composed of two portions: Glycan portion and Peptide portion.

1- **Glycan portion of peptidoglycan** consists of a **repeating disaccharide.** The **disaccharide** portion is made up of **N-acetylglucosamine (NAG)** and **N-acetylmuramic acid (NAM)**, which are related to glucose. Alternating NAM and NAG molecules are linked in **rows** to form a **carbohydrate backbone**.

Adjacent **rows** are linked by **polypeptides** (**the peptide portion of peptidoglycan**).

2- The peptide portion of peptidoglycan:

The **polypeptide** link includes:

tetrapeptide side chains, which consist of four amino acids attached to NAMs in the backbone. The amino acids occur in an alternating pattern of d and l forms.

Parallel tetrapeptide side chains may be directly bonded to each other or linked by a ***peptide cross-bridge***, consisting of a short chain of amino acids.

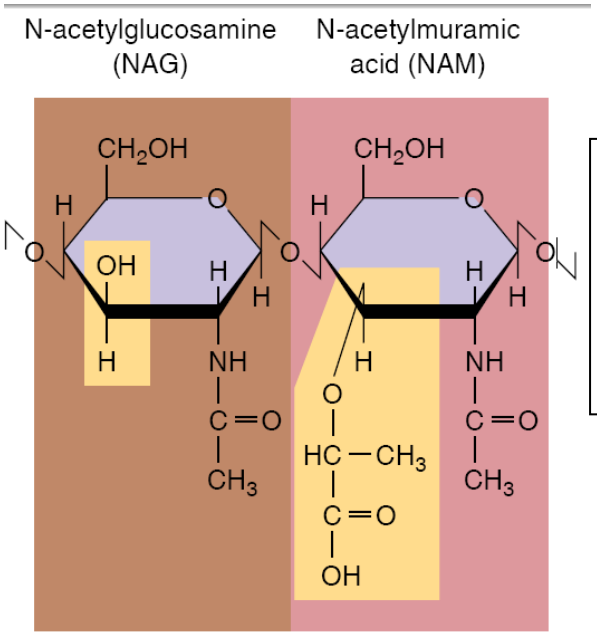
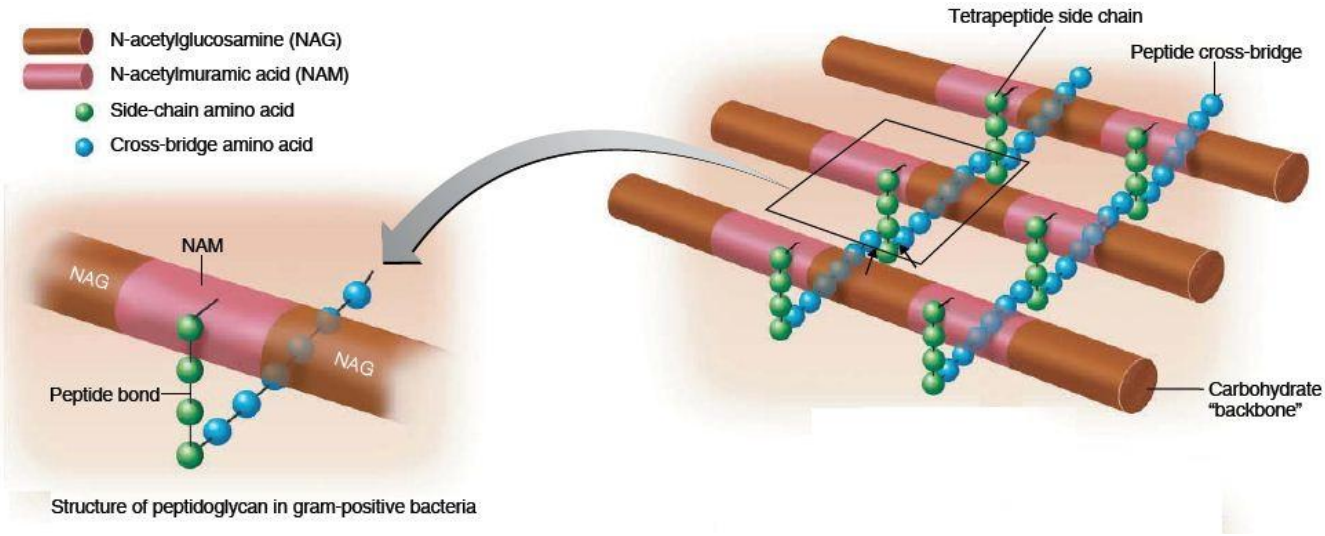


Figure: N-acetylglucosamine (NAG) and N-acetylmuramic acid (NAM) joined as in a peptidoglycan. The gold areas show the differences between the two molecules. The linkage between them is called a β-1,4 linkage.



Structure of peptidoglycan in gram-positive bacteria

Peptidoglycan consists of a **repeating disaccharide** connected by **polypeptides.**

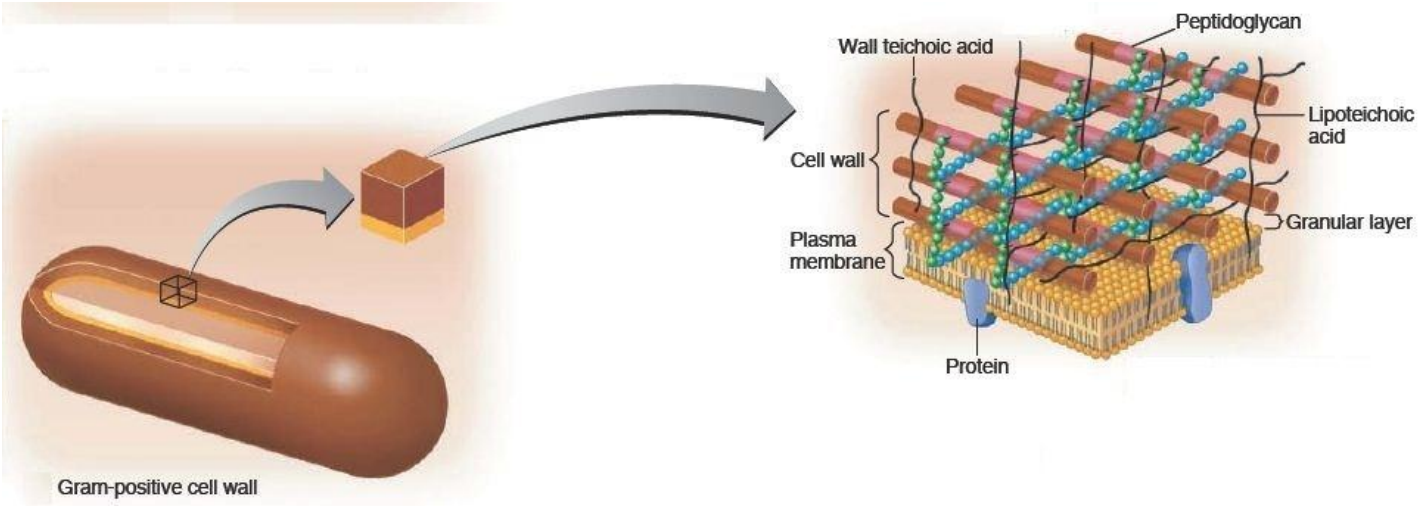
Gram-Positive Cell Walls:

- In most gram-positive bacteria, the cell wall consists of **many layers of peptidoglycan**, forming a thick, rigid structure, and ***teichoic acids***, which consist of alcohol and phosphate.
- There are two classes of teichoic acids:
  1- **Lipoteichoic acid**, which spans the peptidoglycan layer and is linked to the plasma membrane.
  2- **Wall teichoic acid**, which is linked to the peptidoglycan layer.

• The space between the cell wall and plasma membrane of gram-positive bacteria is the periplasmic space. It contains the granular layer, which is composed of lipoteichoic acid.

Importance of teichoic acids:

Because of their negative charge (from the phosphate groups), teichoic acids may bind and regulate the movement of cations (positive ions) into and out of the cell.



Gram-Negative Cell Walls:

The cell walls of gram-negative bacteria consist of one or a very few layers of **peptidoglycan** and an **outer membrane**. The peptidoglycan is bonded to **lipoproteins** in the outer membrane.

Periplasmic space is the region between the outer membrane and the plasma membrane. The periplasm contains a high concentration of degradative enzymes and transport proteins.

The **outer membrane** consists of: **lipopolysaccharides (LPS), lipoproteins, and phospholipids.**

- The **lipopolysaccharide (LPS)** of the outer membrane consists of three components: **lipid A, a core polysaccharide, and O polysaccharide.**

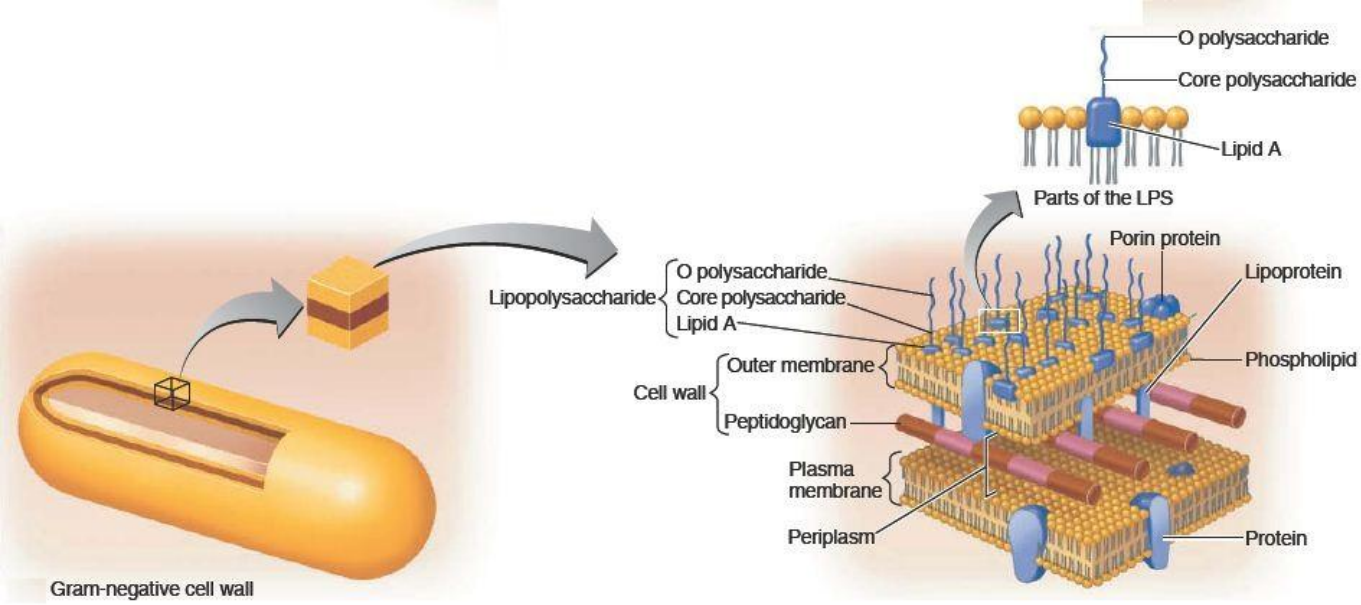
Lipid A is the lipid portion of the LPS and is embedded in the top layer of the outer membrane. When gram-negative bacteria die, they release lipid A which functions as an endotoxin and responsible for the symptoms such as fever, dilation of blood vessels, shock, and blood clotting.

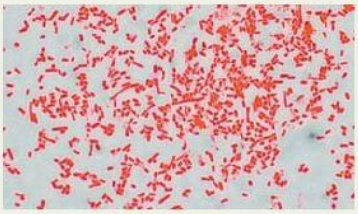
The outer membrane has several specialized functions:

1- Its strong negative charge is an important factor in evading phagocytosis.

2- The outer membrane is barrier to detergents, heavy metals, bile salts, certain dyes, antibiotics (for example, penicillin), and lysozyme.

3- Part of the permeability of the outer membrane is due to proteins called **porins**, that form channels. Porins permit the passage of molecules such as nucleotides, disaccharides, peptides, amino acids, vitamin B12, and iron.



Some Comparative Characteristics of Gram-Positive and Gram-Negative Bacteria		
Characteristic	**Gram-Positive**	**Gram-Negative**
	 LM 12 μm	 LM 15 μm
Gram Reaction	Retain crystal violet dye and stain blue or purple	Can be decolorized to accept counterstain (safranin) and stain pink or red
Peptidoglycan Layer	Thick (multilayered)	Thin (single-layered)
Teichoic Acids	Present in many	Absent
Periplasmic Space	Granular layer	Periplasm
Outer Membrane	Absent	Present
Lipopolysaccharide (LPS) Content	Virtually none	High
Lipid and Lipoprotein Content	Low (acid-fast bacteria have lipids linked to peptidoglycan)	High (because of presence of outer membrane)
Flagellar Structure	2 rings in basal body	4 rings in basal body

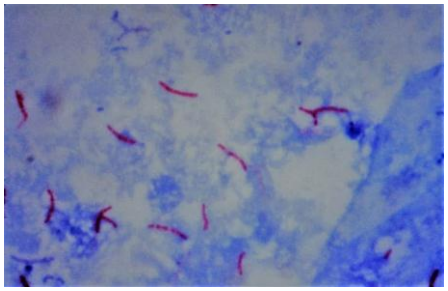
Toxin produced	**Exotoxins**	**Exotoxin and endotoxins**

Atypical Cell Walls:

- Among prokaryotes, the genus ***Mycoplasma*** cells have no walls. Mycoplasmas are the smallest known bacteria that can grow and reproduce outside living host cells. Their plasma membranes are unique among bacteria in having lipids called ***sterols***, which are thought to help protect them from lysis (rupture).
- **Archaea** have unusual walls composed of polysaccharides and proteins called *pseudomurein*.

Acid-Fast Cell Walls:

- These bacteria contain high concentrations (60%) of a hydrophobic waxy lipid (**mycolic acid**) in their cell wall that prevents the uptake of dyes.
- The mycolic acid forms a layer outside of a thin layer of peptidoglycan. The **mycolic acid and peptidoglycan are held together by a polysaccharide**.
- The **acid-fast** bacteria such as *Mycobacterium* and *Nocardia*.



Acid Fact Bacteria

Damage to the Cell Wall:

- Chemicals that damage bacterial cell walls, often do not harm the cells of an animal host **because the bacterial cell wall is made of chemicals unlike those in eukaryotic cells**. Thus, **cell wall is the target** for some antimicrobial drugs.
- The cell wall can be damaged by **enzyme *lysozyme***. This enzyme occurs naturally in perspiration, tears, mucus, and saliva. **Lysozyme hydrolyze the bonds between the sugars in the disaccharide of peptidoglycan** (**a β-1,4 linkage**).
- **Penicillin, destroy bacteria** by interfering with the formation of the peptide cross-bridges of peptidoglycan, thus preventing the formation of a functional cell wall.
- Most gram-negative bacteria are not as susceptible to penicillin because the outer membrane of gram-negative bacteria forms a barrier that inhibits the entry of this substance, and gram-negative bacteria have fewer peptide cross-bridges.

L forms:

Some bacteria can lose their cell walls and swell into irregularly shaped cells called **L forms**. They may form spontaneously or develop in response to penicillin (which inhibits cell wall formation) or lysozyme. L forms can live and divide repeatedly or return to the walled state.

- The **gram-positive cell** wall is almost completely destroyed by lysozyme. The cellular contents surrounded by the plasma membrane may remain intact if lysis does not occur; this **wall-less cell** is termed a **protoplast**.
- When lysozyme is applied to **gram-negative cells**, some of the outer membrane also remains. In this case, the cellular contents, plasma membrane, and remaining outer wall layer are called a **spheroplast**.