Structure of Bacterial Cells

Dr. Zaman Salman

SHAPE & SIZE OF BACTERIA

► **Bacteria are classified by shape into three basic groups:-**

- **The cocci are round**
- **The bacilli are rods**
- **The spirochetes are spiral-shaped**

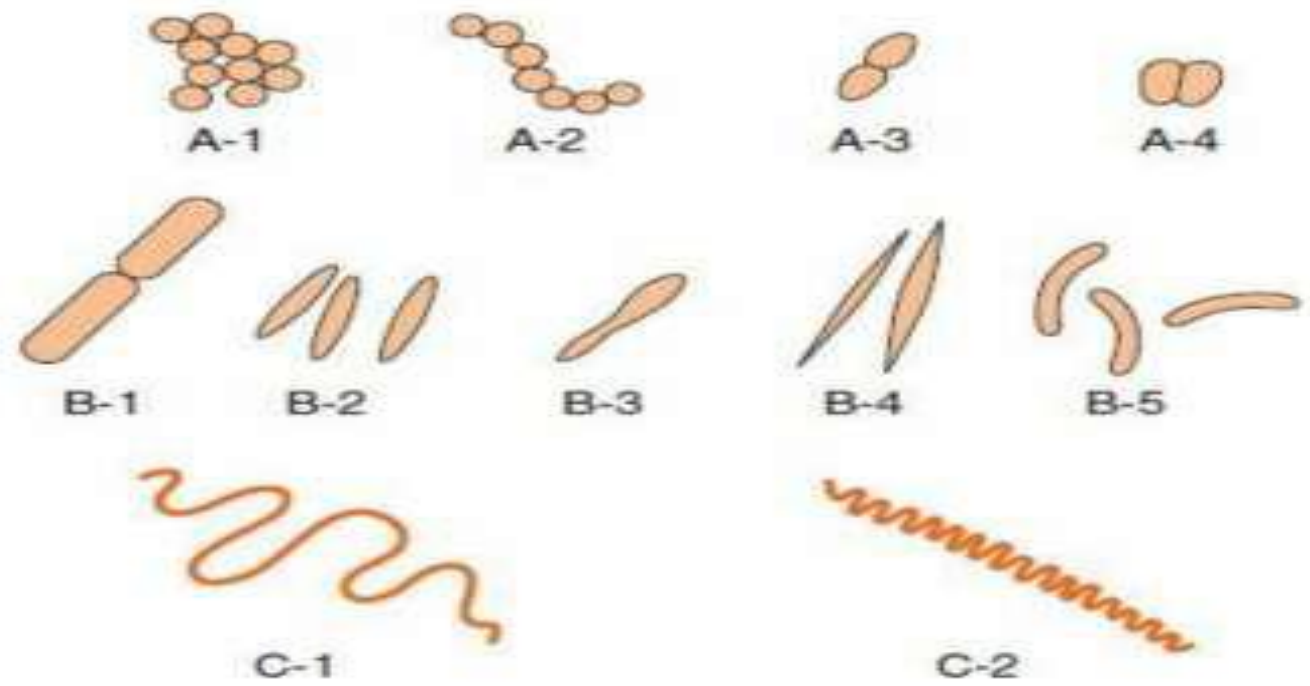

FIGURE 2–1 Bacterial morphology. A: Cocci in clusters (e.g., *Staphylococcus*; A-1); chains (e.g., *Streptococcus;* A-2); in pairs with pointed ends (e.g., *Streptococcus pneumonia* ; A-3); in pairs with kidney bean shape (e.g., Neisseria; A-4). B: Rods (bacilli): with square ends (e.g., *Bacillus*; B-1); with rounded ends (e.g., *Salmonella*; B-2); club-shaped (e.g., *Corynebacterium* ; B-3); fusiform (e.g., *Fusobacterium* ; B-4); comma-shaped (e.g., *Vibrio*; B-5). C: Spirochetes: relaxed coil (e.g., *Borrelia* ; C-1); tightly coiled (e.g., *Treponema*; C- 2).

- Bacteria range in size from about 0.2 to 5 μm. The smallest bacteria (Mycoplasma) are about the same size as the largest viruses (poxviruses)and are the smallest organisms capable of existing outside a host. The longest bacteria rods are the size of some yeasts and human red blood cells (7 μm).

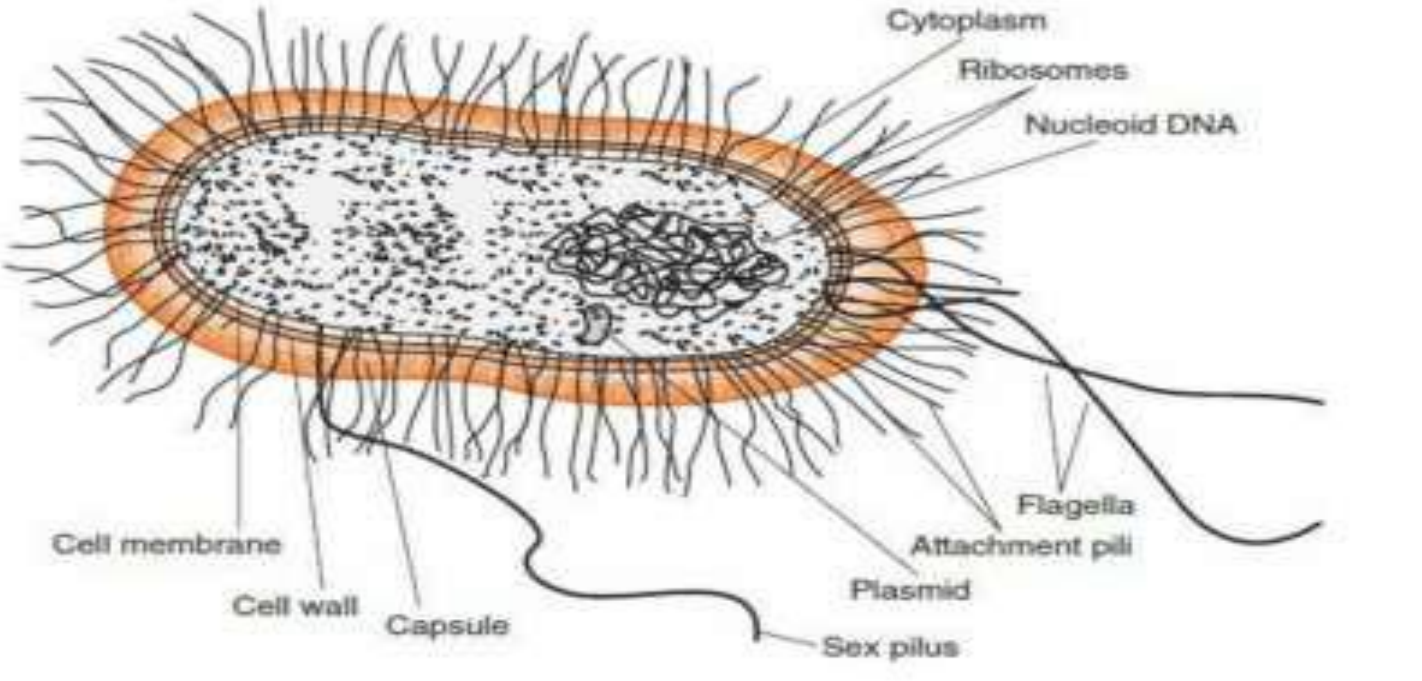

FIGURE 2–2: Bacterial structure.

Cell Walls of Gram-Positive and Gram-Negative Bacteria

The structure, chemical composition, and thickness of the cell wall differ in gram positive and gram-negative bacteria (Table 2–2 and Figure 2–4).

TABLE 2–2 Comparison of Cell Walls of Gram-Positive and Gram-Negative Bacteria

Component	Gram-Positive Cells	Gram-Negative Cells
Peptidoglycan	Thicker; multilayer	Thinner; single layer
Teichoic acids	Yes	No
Lipopolysaccharide (endotoxin)	No	Yes

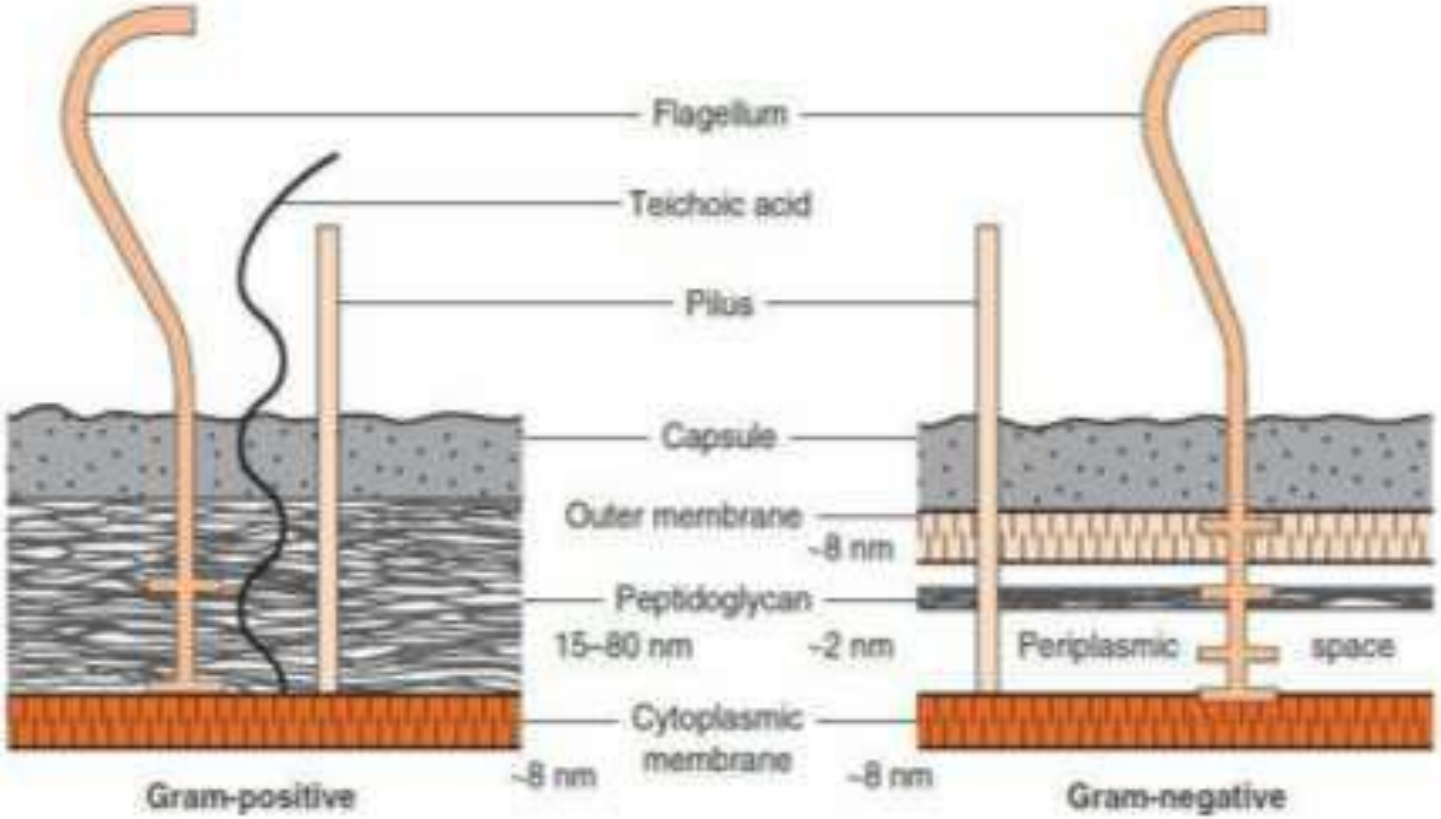

FIGURE 2–4 Cell walls of gram-positive and gram-negative bacteria. Note that the peptidoglycan in gram-positive bacteria is much thicker than in gram-negative bacteria. Note also that only gram-negative bacteria have an outer membrane containing endotoxin (lipopolysaccharide [LPS]) and have a periplasmic space where β-lactamases are found. Several important gram-positive bacteria, such as staphylococci and streptococci, have teichoic acids.

(1)-The peptidoglycan layer is much thicker in gram-positive than in gram negative bacteria. Many gram-positive bacteria also have fibers of teichoic acid, outside the peptidoglycan, whereas gram negative bacteria do which protrude not have teichoic acids.

(2)-In contrast, the gram-negative bacteria have a complex outer layer consisting of lipopolysaccharide, lipoprotein, and phospholipid. Lying between the outer membrane layer and the cytoplasmic membrane in gram-negative bacteria is the periplasmic space, which is the site, in some species, of enzymes called β-lactamases that degrade penicillins and other β-lactam drugs.

The cell wall has several other important properties:

(1) In gram-negative bacteria, it contains endotoxin, a lipopolysaccharide

(2) Its polysaccharides and proteins are antigens that are useful in laboratory identification.

(3) Its porin proteins play a role in facilitating the passage of small, hydrophilic molecules into the cell. Porin proteins in the outer membrane of gram-negative bacteria act as a channel to allow the entry of essential substances such as sugars, amino acids, vitamins, and metals as well as many antimicrobial drugs such as penicillins.

Cell Walls 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 because they resist decolorization with acid–alcohol after being stained with carbolfuchsin. This property is related to the high concentration of lipids, called mycolic acids, in the cell wall of mycobacteria. In view of their importance, three components of the cell wall (i.e., peptidoglycan, lipopolysaccharide, and teichoic acid) .

Peptidoglycan

- Peptidoglycan is a complex, interwoven network that surrounds the entire cell and is composed of a single covalently linked macromolecule.
- It is found only in bacterial cell walls
- It provides rigid support for the cell
- It is important in maintaining the characteristic shape of the cell, and allows the cell to withstand media of low osmotic pressure, such as water.

- The term peptidoglycan is derived from the peptides and the sugars (glycan) that make up the molecule.

- Synonyms for peptidoglycan are murein and mucopeptide.

Lysozyme

- an enzyme present in human tears, mucus, and saliva.

- can cleave the peptidoglycan backbone by breaking its glycosyl bonds, thereby contributing to the natural resistance of the host to microbial infection.

- Lysozyme-treated bacteria may swell and rupture as a result of the entry of water into the cells, which have a high internal osmotic pressure

Lipopolysaccharide

- The lipopolysaccharide (LPS) of the outer membrane of the cell wall of gram negative bacteria is endotoxin.

- It is responsible for many of the features of disease, such as fever and shock (especially hypotension), caused by these organisms .

- It is called endotoxin because it is an integral part of the cell wall
- which are actively secreted from the bacteria
- The constellation of symptoms caused by the endotoxin of one gram-negative bacteria is similar to another, but the severity of the symptoms can differ greatly.

Teichoic Acid

- Teichoic acids are fibers located in the outer layer of the gram-positive cell wall and extend from it .
- They are composed of polymers of either glycerol phosphate or ribitol phosphate.
- Some polymers of glycerol teichoic acid penetrate the peptidoglycan layer and are covalently linked to the lipid in the cytoplasmic membrane.
- The medical importance of teichoic acids lies in their ability to induce septic shock when caused by certain gram-positive bacteria
- Teichoic acids also mediate the attachment of staphylococci to mucosal cells. Gram-negative bacteria dont have teichoic acids.

Cytoplasmic Membrane

Just inside the peptidoglycan layer of the cell wall lies the cytoplasmic membrane, which is composed of a phospholipid bilayer similar in microscopic appearance to that in eukaryotic cells. They are chemically similar, but eukaryotic membranes contain sterols, whereas prokaryotes generally do not. The only prokaryotes that have sterols in their membranes are members of the genus Mycoplasma.

The membrane has four important functions:

(1) active transport of molecules into the cell

(2) energy generation by oxidative phosphorylation

(3) synthesis of precursors of the cell wall

(4) secretion of enzymes and toxins.

Cytoplasm

The cytoplasm has two distinct areas when seen in the electron microscope:

(1) An amorphous matrix that contains ribosomes, nutrient granules, metabolites, and plasmids.

(2) An inner, nucleoid region composed of DNA.

Ribosomes

♦Bacterial ribosomes are the site of protein synthesis as in eukaryotic cells, but they differ from eukaryotic ribosomes in size and chemical composition.

♦ Bacterial ribosomes are 70S in size, with 50S and 30S subunits, whereas eukaryotic ribosomes are 80S in size, with 60S and 40S subunits.

♦The differences in both the ribosomal RNAs and proteins constitute the basis of the selective action of several antibiotics that inhibit bacterial, but not human, protein synthesis.

Granules

- The cytoplasm contains several different types of granules that serve as storage areas for nutrients and stain characteristically with certain dyes. For example, volutin is a reserve of high energy stored in the form of polymerized metaphosphate.

- It appears as a "metachromatic" granule since it stains red with methylene blue dye instead of blue as one would expect.

- Metachromatic granules are a characteristic feature of Corynebacterium diphtheriae, the cause of diphtheria.

Nucleoid

- The nucleoid is the area of the cytoplasm in which DNA is located.

The DNA of prokaryotes is a single, circular molecule that has a molecular weight (MW) of approximately 2 × 10 9 and contains about 2000 genes. (**By contrast, human DNA has approximately 100,000 genes**.) Because the nucleoid contains no nuclear membrane, no nucleolus, no mitotic spindle, and no histones, there is little resemblance to the eukaryotic nucleus.

- One major difference between bacterial DNA and eukaryotic DNA is that bacterial DNA has no introns, whereas eukaryotic DNA does.

Plasmids

- Plasmids are extrachromosomal, double-stranded, circular DNA molecules that are capable of replicating independently of the bacterial chromosome.

- Plasmids occur in both gram-positive and gram-negative bacteria.

Transposons

- Transposons are pieces of DNA that move readily from one site to another either within or between the DNAs of bacteria, plasmids, and bacteriophages. Because of their unusual ability to move, they are nicknamed "jumping genes.

- Some transposons move by replicating their DNA and inserting the new copy into another site (replicative transposition), whereas others are excised from the site without replicating and then inserted into the new site (direct transposition).

- Transposons can code for drug-resistant enzymes, toxins, or a variety of metabolic enzymes and can either cause mutations in the gene into which they insert or alter the expression of nearby genes.

Capsule

- The capsule is a gelatinous layer covering the entire bacterium
- It is composed of polysaccharide, except in the anthrax bacillus, which has a capsule of polymerized D-glutamic acid.
- The sugar components of the polysaccharide vary from one species of bacteria to another and frequently determine the serologic type serotype) within a species. For example, there are 84 different serotypes of Streptococcus pneumoniae, which are distinguished by the antigenic differences of the sugars in the polysaccharide capsule.

Flagella

- Flagella are long, whip like appendages that move the bacteria toward nutrients and other attractants, a process called chemotaxis.
- The long filament, which acts as a propeller, is composed of many subunits of a single protein, flagellin, arranged in several intertwined chains.
- The energy for movement, the proton motive force, is provided by adenosine triphosphate (ATP), derived from the passage of ions across the membrane.
- Flagellated bacteria have a characteristic number and location of flagella: some bacteria have one, and others have many; in some, the flagella are located at one end, and in others, they are all over the outer surface

Pili (Fimbriae)

Pili are hair like filaments that extend from the cell surface. They are shorter and straighter than flagella and are composed of subunits of pilin, a protein arranged in helical strands. They are found mainly on gram negative organisms.