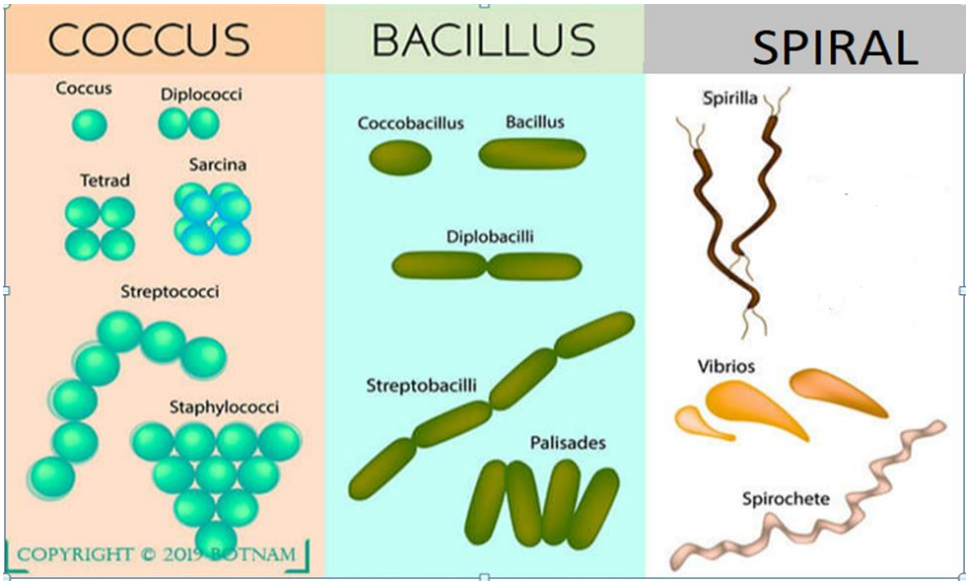
Shapes of bacteria

Typically bacteria come in three basic shapes: **spherical (Cocci), rod-shaped (Bacilli), and spiral**, however pleomorphic bacteria can assume several shapes.

- **Cocci** (or coccus for a single cell) are round cells, sometimes slightly flattened when they are adjacent to one another.
- **Bacilli** (or bacillus for a single cell) are rod-shaped bacteria.
- **Spirilla** (or spirillum for a single cell) are curved bacteria that can range from a gently curved shape to a corkscrew-like spiral.



Pleomorphism

Bacteria appear in several different forms. Environmental conditions are affecting the size and shape of bacteria which is seen obviously in bacilli forms other than cocci forms.

Arrangement

(ملاحظة: الامثلة غير مطلوبة)

In addition to characteristic shapes, many bacteria also are found in distinctive arrangements of groups of cells.

*Arrangement of Cocci

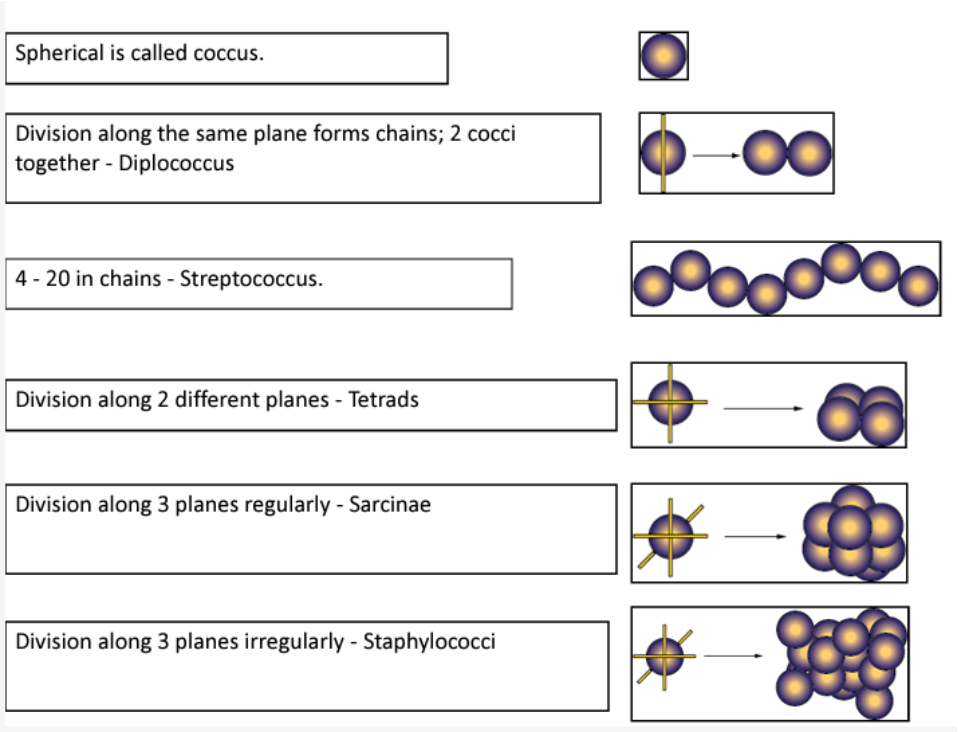
1. Diplococci: The cocci are arranged in pairs (Example: *Neisseria gonorrhoeae*)

2. Streptococci: The cocci are arranged in chains, as the cells divide in one plane (Example: *Streptococcus pyogenes*).

3. Tetrads: The cocci are arranged in packets of four cells, as the cells divide in two plains (Example: *Aerococcus*).

4. Sarcinae: The cocci are arranged in a cuboidal manner, as the cells are formed by regular cell divisions in three planes (Example: *Sporosarcina ureae*).

5. Staphylococci: The cocci are arranged in grape-like clusters formed by irregular cell divisions in three plains (Example: *Staphylococcus aureus*).



*Arrangement of Bacilli

Bacilli divide in only one level, but they can produce cells connected end-to-end (like train cars) or side-by-side.

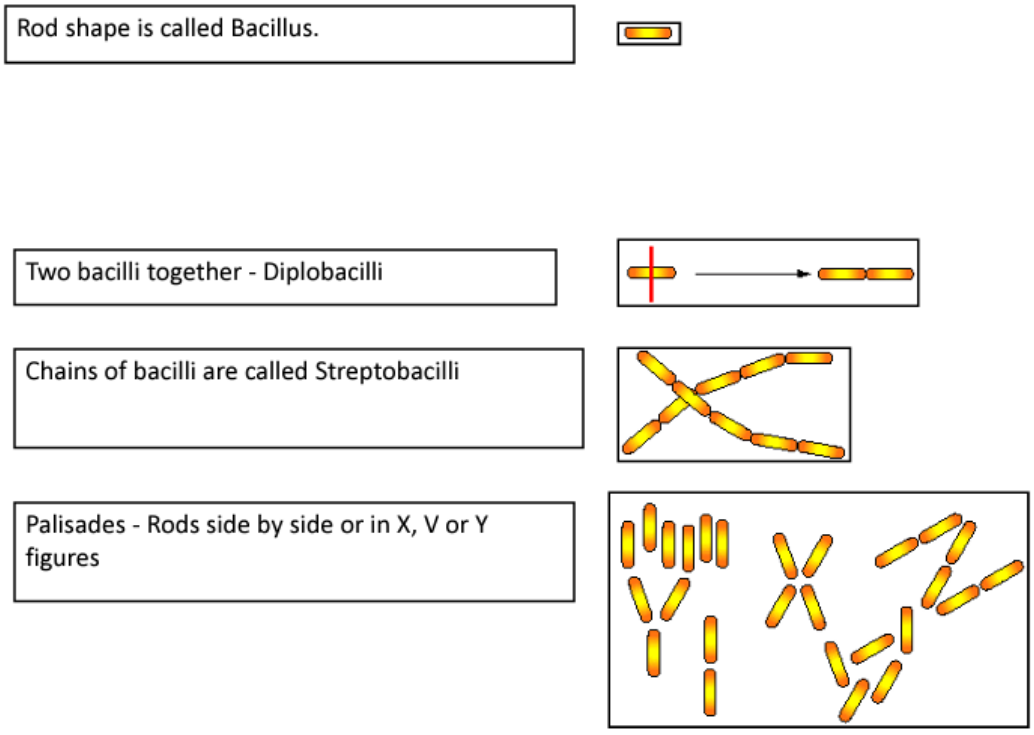
1-Monobacillus: appear as single rods after division (Example: *Bacillus cereus*).

2. Diplobacilli: appear in pairs after division (Example: *Coxiella burnetii*).

3. Streptobacilli: The bacilli are arranged in chains, as the cells divide in one plane (Example: *Streptobacillus moniliformis*).

4. Coccobacilli: These are so short and stumpy that they appear ovoid. They look like coccus and bacillus (Example: *Haemophilus influenza*).

5. Palisades : The bacilli bend at the points of division following the cell divisions, resulting in a palisade arrangement resembling a picket fence and angular patterns that look like Chinese letters (Example: *Corynebacterium diphtheria*).



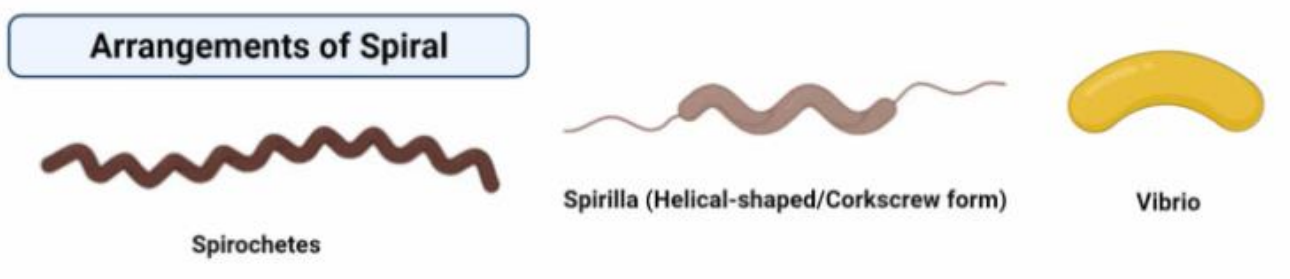
*Arrangement of Spiral Bacteria

Spiral bacteria are not generally grouped together. But they have shapes often used to help identify certain Spiral Bacteria:-

1. Vibrio: They are comma-shaped bacteria with less than one complete turn or twist in the cell (Example: *Vibrio cholerae*).

2. Spirilla: They have rigid spiral structure (Example: *Helicobacter pylori*).

3. Spirochetes: have a helical shape and flexible bodies. Spirochetes move by means of axial filaments (Example: Leptospira species).



Structure of bacteria

Structurally, bacterial cells consist of the following regions:

1- Appendages (attachments to the cell surface) in the form of flagella and pili (or fimbriae).

2- Cell envelope consisting of cell wall and plasma membrane. Some bacteria may even have a protective layer called the capsule.

3- Cytoplasmic region that contains the cell chromosome (DNA) and ribosomes and various sorts of inclusions.

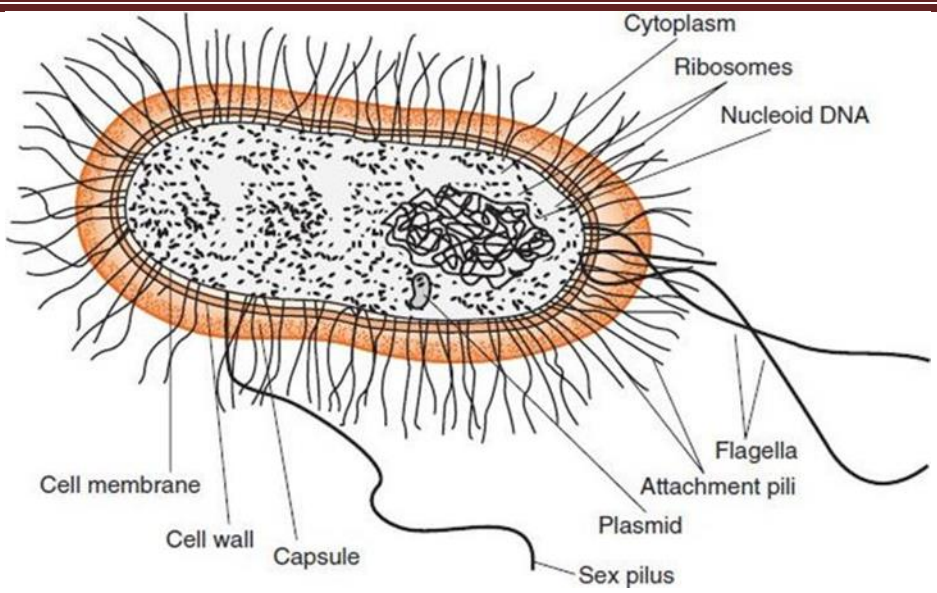


TABLE 1: Bacterial Structures

Structure	Function	Chemical composition
Flagellum	Movement	Protein
Pili	Attachment, protection	Protein
F /or sex pili	Transfer DNA during conjugation	Protein
Capsule	Attachment to surfaces, protection against phagocytosis	Polysaccharides
Cell wall	Protection, gives form, stability	Peptidoglycan
Cytoplasmic membrane	Permeability barrier, transport, energy, enzymes	Lipoprotein bilayer without sterols
Ribosomes	Protein synthesis	RNA, protein
Inclusions	Reserve storage for nutrients	Carbohydrate, lipid, protein, salts
Chromosomes	Genetic material	DNA
Plasmids	Extrachromosomal DNA	DNA

The Cell Wall

The cell wall is the outermost component common to all bacteria (except Mycoplasma species, which are bound by a cell membrane, not a cell wall). Some bacteria have surface features external to the cell wall, such as a capsule, flagella, and pili, which are less common components.

Most bacterial cells are surrounded by a rigid wall that has been thought to determine the shape of the cells. In both Gram-negative and –positive cells, the cell wall is located on the outside of the inner membrane, but is further surrounded by the outer membrane in Gram-negative bacteria. It performs two important functions:

1- It maintains the characteristic shape of the cell. If the cell wall is digested away by enzymes, the cell takes on a spherical shape.

2- It prevents the cell from bursting when fluids flow into the cell by ***osmosis***.

Although the cell wall surrounds the cell membrane, in many cases it is extremely porous and does not play a major role in regulating the entry of materials into the cell.

Components of cell wall

The bacterial cell wall differs from that of all other organisms by the presence of peptidoglycan which is located immediately outside of the cytoplasmic membrane. **Peptidoglycan (also known as murein)** is a polymer consisting of sugars (polysaccharide) and amino acids. The sugar component consists of alternating

residues of N-acetylglucosamine (NAG) and N-acetylmuramic acid (NAM). Attached to the N-acetylmuramic acid is a peptide chain of three to five amino acids. The peptide chain can be cross-linked to the peptide chain of another strand forming the 3D mesh-like layer. Peptidoglycan serves a structural role in the bacterial cell wall, giving structural strength, as well as counteracting the osmotic pressure of the cytoplasm. Peptidoglycan is also involved in binary fission during bacterial cell reproduction.

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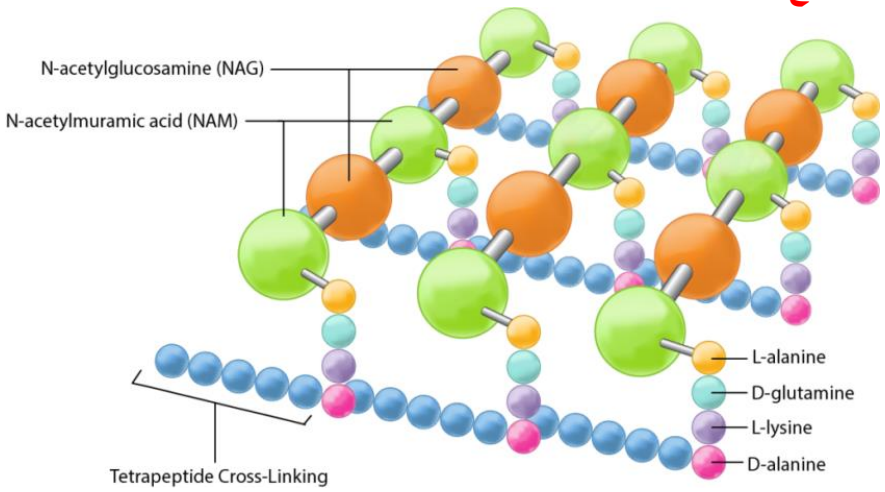

In Gram-positive Bacteria (those that retain the purple crystal violet dye when subjected to the Gram-staining procedure), the cell wall consists of several layers of peptidoglycan (20 - 80 nanometers) with an additional molecule, **teichoic acid**.

Teichoic acid consists of glycerol, phosphates, and the sugar alcohol ribitol, and occurs in polymers up to 30 units long. These polymers extend beyond the rest of the cell wall, even beyond the capsule in encapsulated bacteria. Although its exact

function is unclear, teichoic acid furnishes attachment sites for bacteriophages (viruses that infect bacteria) and probably serves as a passageway for the movement of ions into and out of the cell.

In Gram-negative Bacteria (which do not retain the crystal violet), the cell wall is composed of a single layer of peptidoglycan (7 - 8 nanometers) 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. In Gram-negative bacteria the outer membrane is usually thought of as part of the cell wall.

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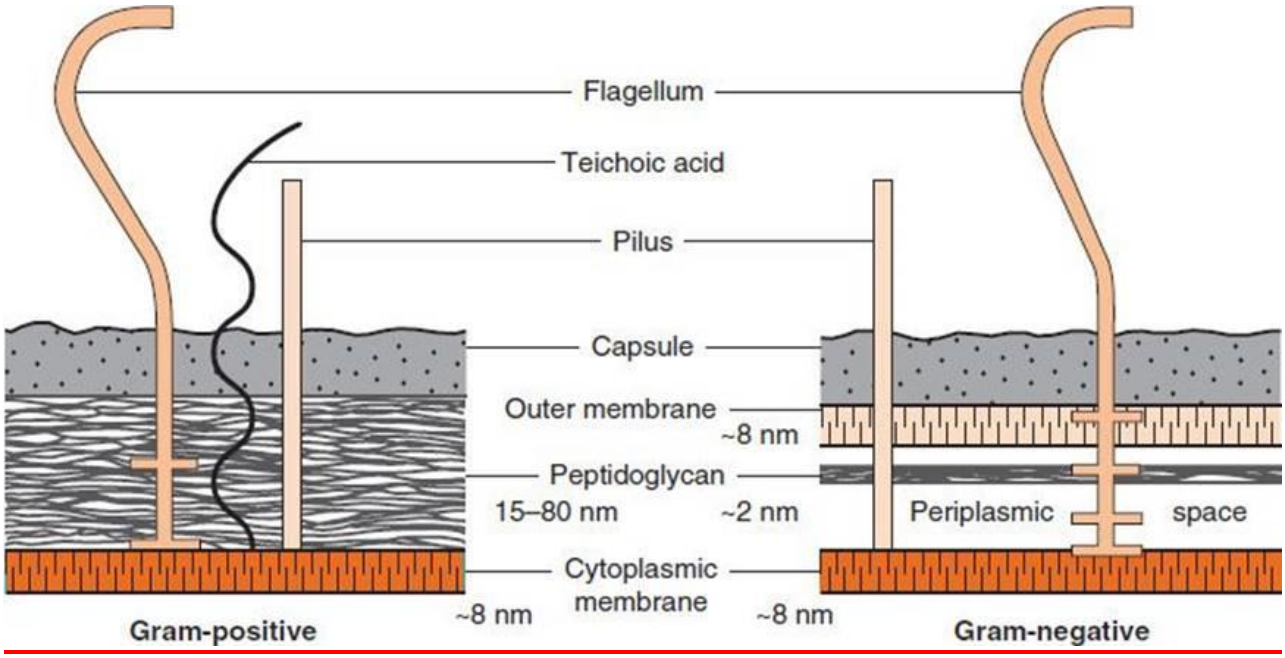

Cell walls of gram-positive and gram-negative bacteria.

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

Characteristic	Gram Positive	Gram Negative
Peptidoglycan	Yes, thick layer	Yes, thin layer
Teichoic acids	Yes	No
Outer membrane	No	Yes
Lipopolysaccharides (LPS)	No	Yes
Porin proteins	No	Yes
Periplasm	No	Yes

Gram stain

This staining procedure, developed in 1884 by the Danish physician Christian Gram, is the most important in microbiology. It separates most bacteria into two groups: the gram-positive bacteria, which stain blue, and the gram-negative bacteria, which stain red. However, not all bacteria can be seen in the Gram stain.

The Gram stain is useful in two ways:

(1) In the identification of many bacteria.

(2) In the choice of antibiotic because, in general, gram-positive bacteria are more susceptible to penicillin G than are gram-negative bacteria.

Mechanism action of Gram stain

Gram staining involves three processes: **staining with a water-soluble dye called crystal violet, decolonization, and counter-staining, usually with safranin**. Due to differences in the thickness of a peptidoglycan layer in the cell membrane between Gram-positive and Gram-negative bacteria, Gram-positive bacteria (with a thicker peptidoglycan layer) retain crystal violet stain during the decolonization process,

while Gram-negative bacteria lose the crystal violet stain and are instead stained by the safranin in the final staining process. The process involves three steps:

1. Cells are stained with **crystal violet dye**. Next, a **Gram's iodine solution** (iodine and potassium iodide) is added to form a complex between the crystal violet and iodine. This complex is a larger molecule than the original crystal violet stain and iodine and is insoluble in water.
2. A decolorizer such as **ethyl alcohol or acetone** is added to the sample, which dehydrates the peptidoglycan layer, shrinking and tightening it. The large crystal violet-iodine complex is not able to penetrate this tightened peptidoglycan layer and is thus trapped in the cell in Gram-positive bacteria. Conversely, the outer membrane of Gram-negative bacteria is degraded and the thinner peptidoglycan layer of Gram-negative cells is unable to retain the crystal violet-iodine complex, and the color is lost.
3. A counter-stain, such as the weakly water-soluble **safranin**, is added to the sample, staining it red. Since the safranin is lighter than crystal violet, it does not disrupt the purple coloration in Gram-positive cells. However, the decolorized Gram-negative cells are stained red.

Some examples of Gram positive & Gram negative bacteria

Gram positive bacteria	Gram Negative Bacteria
❑ *Streptococcus pneumoniae*	❑ *Escherichia coli*
❑ *Streptococcus mutans*	❑ *Pseudomonas aeruginosa*
❑ *Staphylococcus aureus*	❑ *Neisseria gonorrhoeae*
❑ *Streptococcus sanguinis*	❑ *Chlamydia trachomatis*
❑ *Bacillus subtilis*	❑ *Yersinia pestis*