The Fine Structure of Bacteria

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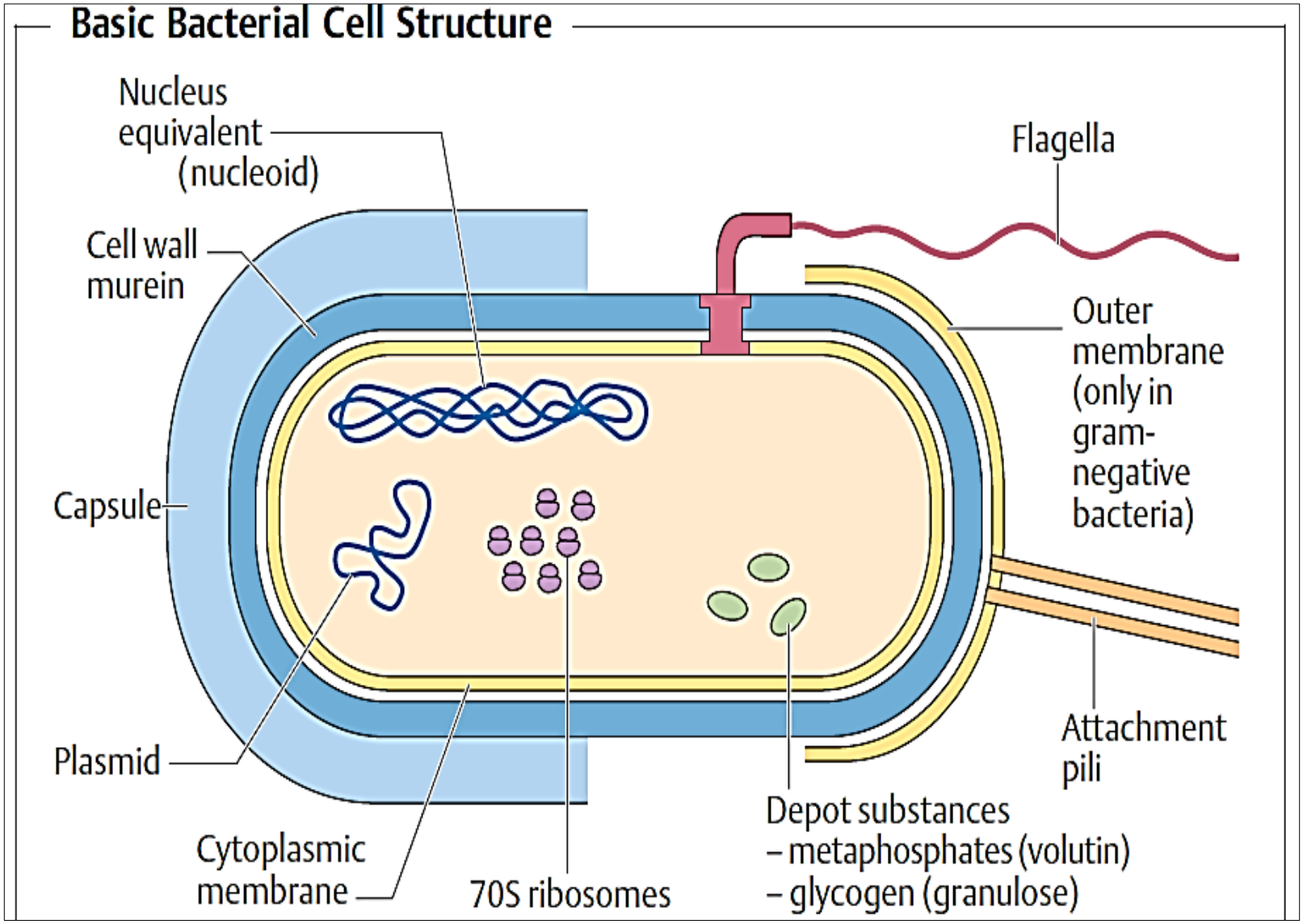

Basic Bacterial Cell Structure
Nucleus equivalent (nucleoid)
Flagella
Cell wall murein
Outer membrane (only in gram-negative bacteria)
Capsule
Plasmid
Attachment pili
Cytoplasmic membrane
70S ribosomes
Depot substances
– metaphosphates (volutin)
– glycogen (granulose)

Nucleoid

- ✓ The nucleoid consists of a tangle of double-stranded DNA, not surrounded by a membrane and localized in the cytoplasm.
- ✓ Bacterial DNA is Haploid.
- ✓ DNA is stabilized by small polyamines and Mg ions and associated with histone-like proteins.

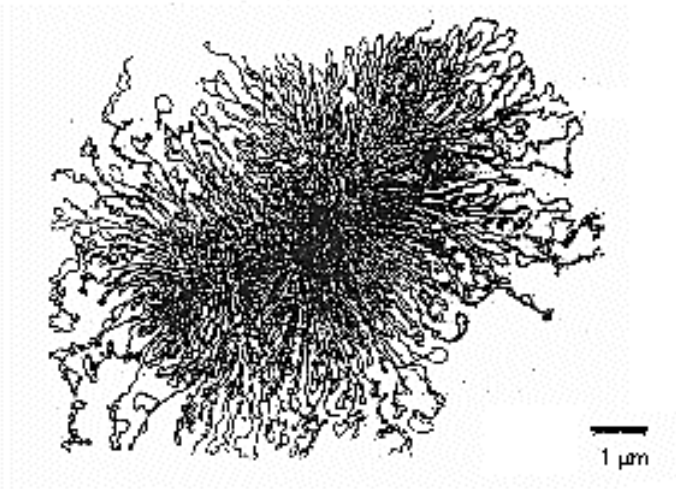
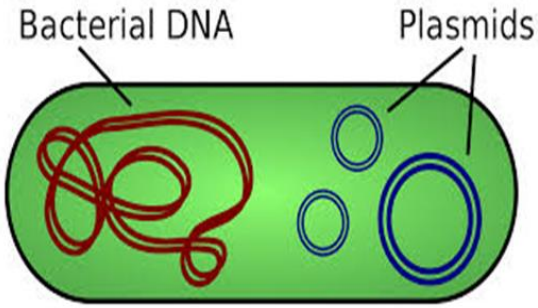


Figure : Electron Micrograph of a Bacterial Chromosome

Plasmids are small, circular, non-chromosomal, double-strand DNA molecules that are capable of self-replication.



Specific Types of Plasmids

There are five main types of plasmids:

a) Fertility plasmid- Also known as F plasmid. It contains a transferred gene that allows genes to be transferred from one cell to another through conjugation.

b) Col plasmid- Col plasmid contains genes that make bacteriocins (also known as colicins), which are protein that kills other bacteria .

c) Resistance plasmid – (R plasmid) contains genes that help the bacteria cell defend against the environment, factors such as poisons or antibiotics.

d)Virulence Plasmids

When a virulence plasmid is inside a bacterium, it turns that bacterium into a pathogen, which is an agent of disease.

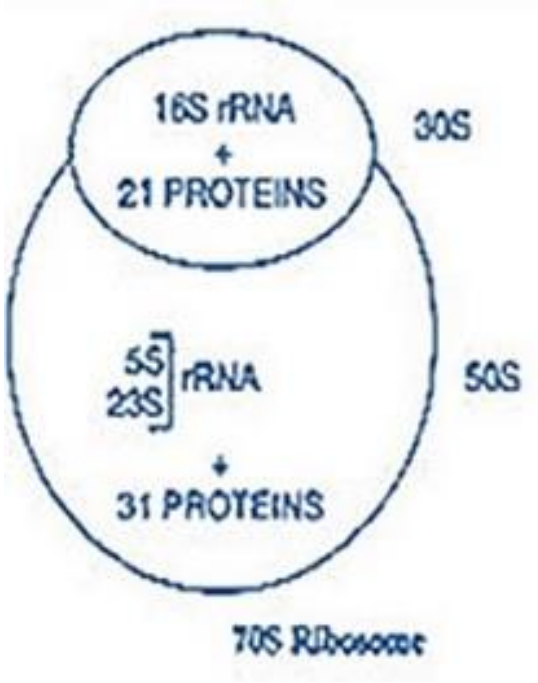
e) Degradative Plasmids

Degradative plasmids help the host bacterium to digest compounds that are not commonly found in nature, such as camphor, xylene, toluene, and salicylic acid.

Ribosomes

Ribosomes are minute particles composed of ribosomal RNA (rRNA) and protein. Bacterial ribosomes are composed of two subunits ; 50S and 30S. The 30S subunit contains 16S rRNA and 21 proteins; the 50S subunit contains 5S and 23S rRNA and 31 proteins.

The two subunits combine during protein synthesis to form a complete 70S ribosome .



Ribosomes function to synthesize proteins

Cytoplasm

- ✓ The cytoplasm contains a large number of solute low- and high-molecular weight substances, RNA and ribosomes.

- ✓ The cytoplasm is also frequently used to store reserve substances (glycogen depots, polymerized metaphosphates, lipids).

The Cell Envelope

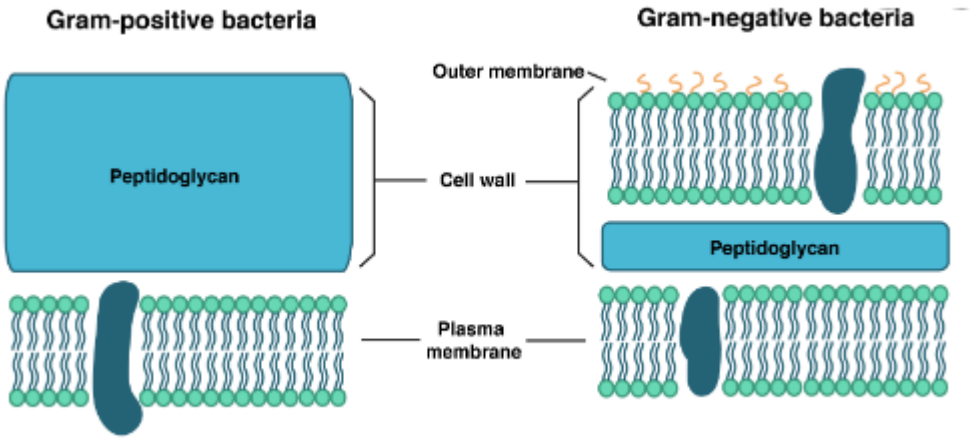
Prokaryotic cells are surrounded by complex envelope layers that differ in composition among the major groups.

- It comprises the **inner cell membrane** and the **cell wall**.

In Gram- negative bacteria an **outer membrane** is also included.

Functions

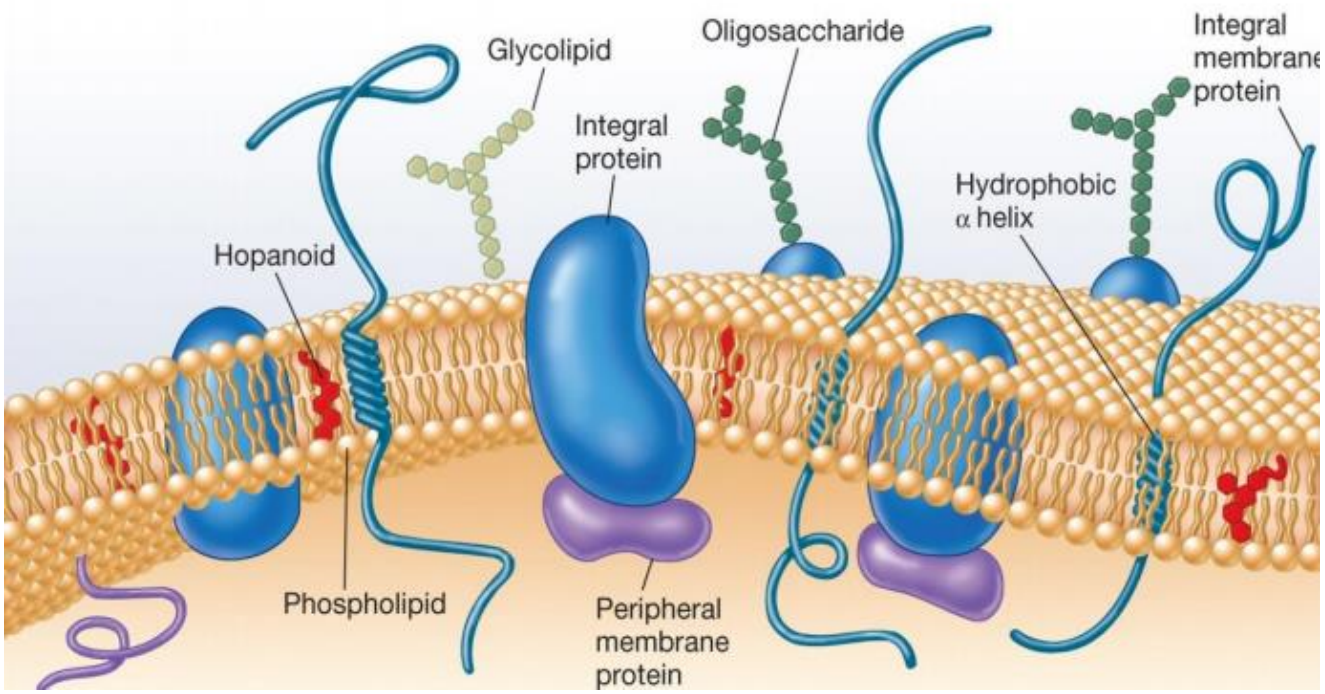
- Protect the organisms from hostile environments, such as extreme osmolarity, harsh chemicals, and even antibiotics.



The Cytoplasmic Membrane

Also known as the **plasma membrane**. It is basically a double layer of phospholipids with numerous proteins integrated into its structure.

The most important of these membrane proteins are permeases, enzymes for the biosynthesis of the cell wall, transfer proteins for secretion of extracellular proteins, sensor or signal proteins, and respiratory chain enzymes.



The Most Important Bacterial Cytoplasmic Membrane Proteins

Permeases	Active transport of nutrients from outside to inside against a concentration gradient.
Biosynthesis enzymes	Required for biosynthesis of the cell wall, e.g., its murein.
Secretion system proteins	The secretion systems differing in structure and mode of action. Proteins are moved out of the cell with the help of these systems. A common feature of all systems is the formation of protein cylinders that traverse the cytoplasmic membrane and, in Gram-negative bacteria, the outer cell wall membrane as well.
Sensor proteins (also known as signal proteins)	Transmit information from the cell's environment into its interior.
Respiratory chain enzymes	Occur in bacteria with aerobic metabolism.

Cytoplasmic membrane Function

The major functions of the cytoplasmic membrane are

1) Selective permeability and transport of solutes.
2) Excretion of hydrolytic exoenzymes (degrade the polymers to subunits small enough to penetrate the cell membrane).
3) Bearing the enzymes and carrier molecules that function in the biosynthesis of DNA, cell wall polymers, and membrane lipids.
4) Bearing the receptors and other proteins of the chemotactic.
5)Electron transport and oxidative phosphorylation in aerobic species.

Cell Wall

The cell wall refers to that portion of the cell envelope that is external to the cytoplasmic membrane and internal to the capsule or glycocalex.

Function

- ✓ Protect the protoplasts from external environment.
- ✓ To withstand and maintain the osmotic pressure gradient between the cell interior and the extracellular environment,
- ✓ To give the cell its outer form.
- ✓ To facilitate communication with its surroundings.

The bacterial cell wall owes its strength to a layer composed of a substance known as **murein**, **mucopeptide**, or **peptidoglycan** (all are synonyms).

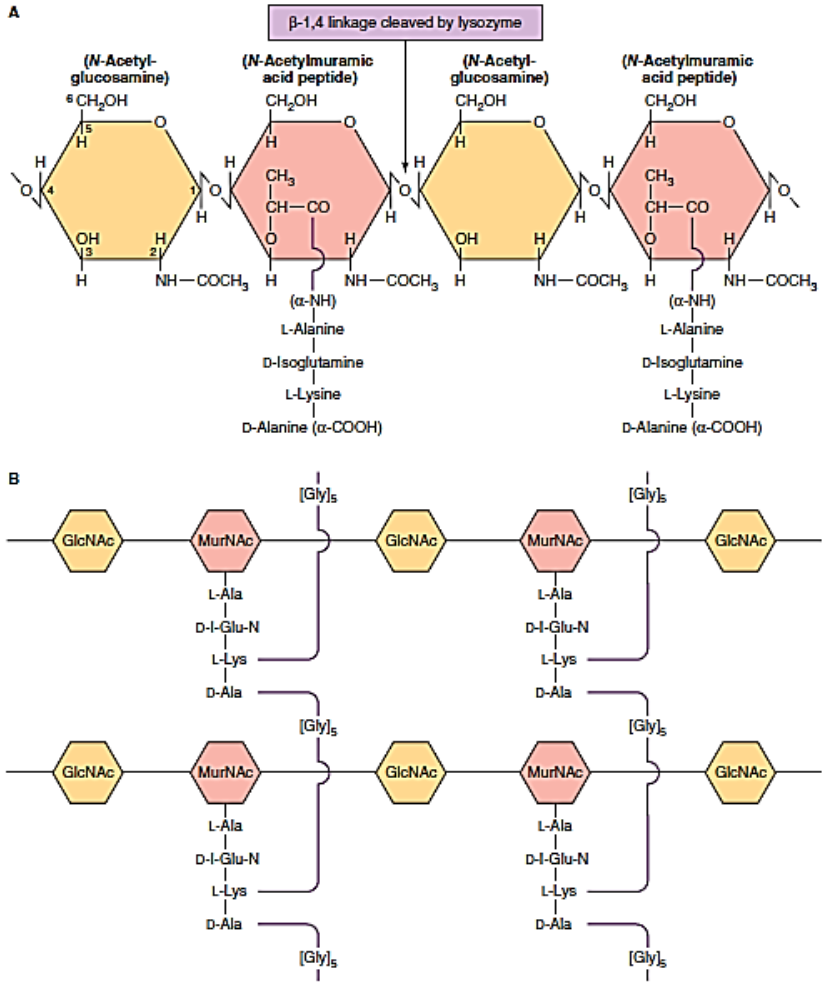
The Peptidoglycan Layer

Peptidoglycan is a complex polymer consisting of three parts:
A **backbone**, composed of alternating *N*-acetylglucosamine and *N*-acetylmuramic acid connected by β1→4 linkages;

a set of identical tetrapeptide side chains attached to *N*-acetylmuramic acid; and

a set of identical peptide cross-bridges.

It may contain **Diaminopimelic acid**, an amino acid unique of bacterial cell walls.

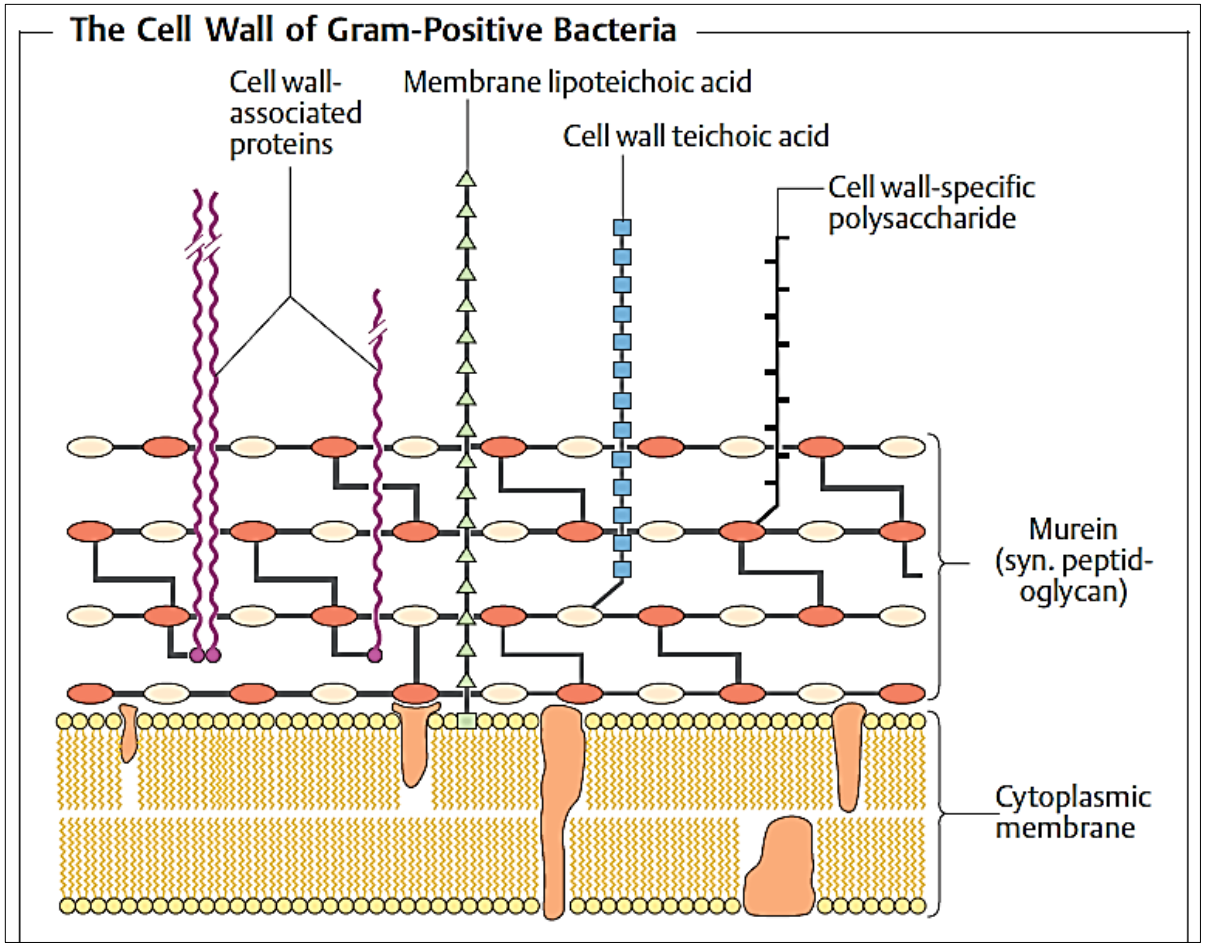


The cell wall of Gram-positive bacteria

It is composed of

- **Peptidoglycan(50% of cell wall)**
- **Teichoic acids and teichuronic acids(water -soluble polymers).**
- **Polysaccharides.**

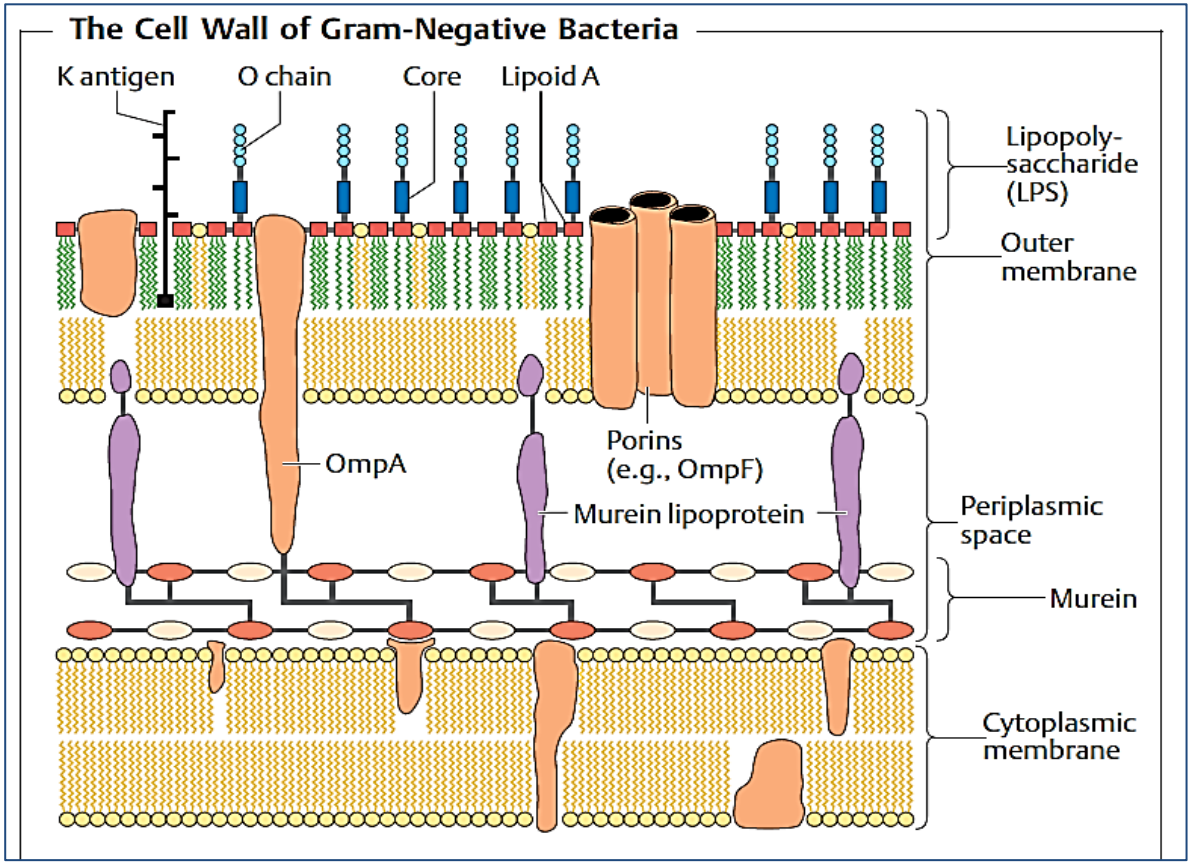
There are two types of teichoic acids:
wall teichoic acid), covalently linked to peptidoglycan, and **membrane teichoic acid**, covalently linked to membrane glycolipid. Because the latter are intimately associated with lipids, they have been called **lipoteichoic acids.**



The cell wall of Gram-negative bacteria

It is composed of:

- **Peptidoglycan(2% - 10% of cell wall)**
- **Lipoprotein**(cross links the peptidoglycan and outer membrane**).**
- **An outer membrane**



Outer membrane:

Is a phospholipid bilayer, its inner leaflet resembles in composition that of the cell membrane and its outer leaflet contains a distinctive component, a **lipopolysaccharide (LPS)**.

Function:

Protect cells from harmful enzymes, some antibiotics and to prevent leakage of periplasmic proteins.

Outer membrane proteins:

- **OmpA** (outer membrane protein A) and the **murein lipoprotein** form a bond between outer membrane and murein.
- **Porins**, proteins that form pores in the outer membrane, allow passage of hydrophilic, low-molecular-weight substances into the periplasmic space.
- **Outer membrane-associated proteins** constitute specific structures that enable bacteria to attach to host cell receptors.
- **A number of Omps are transport proteins.** Example include the **LamB proteins** for maltose transport

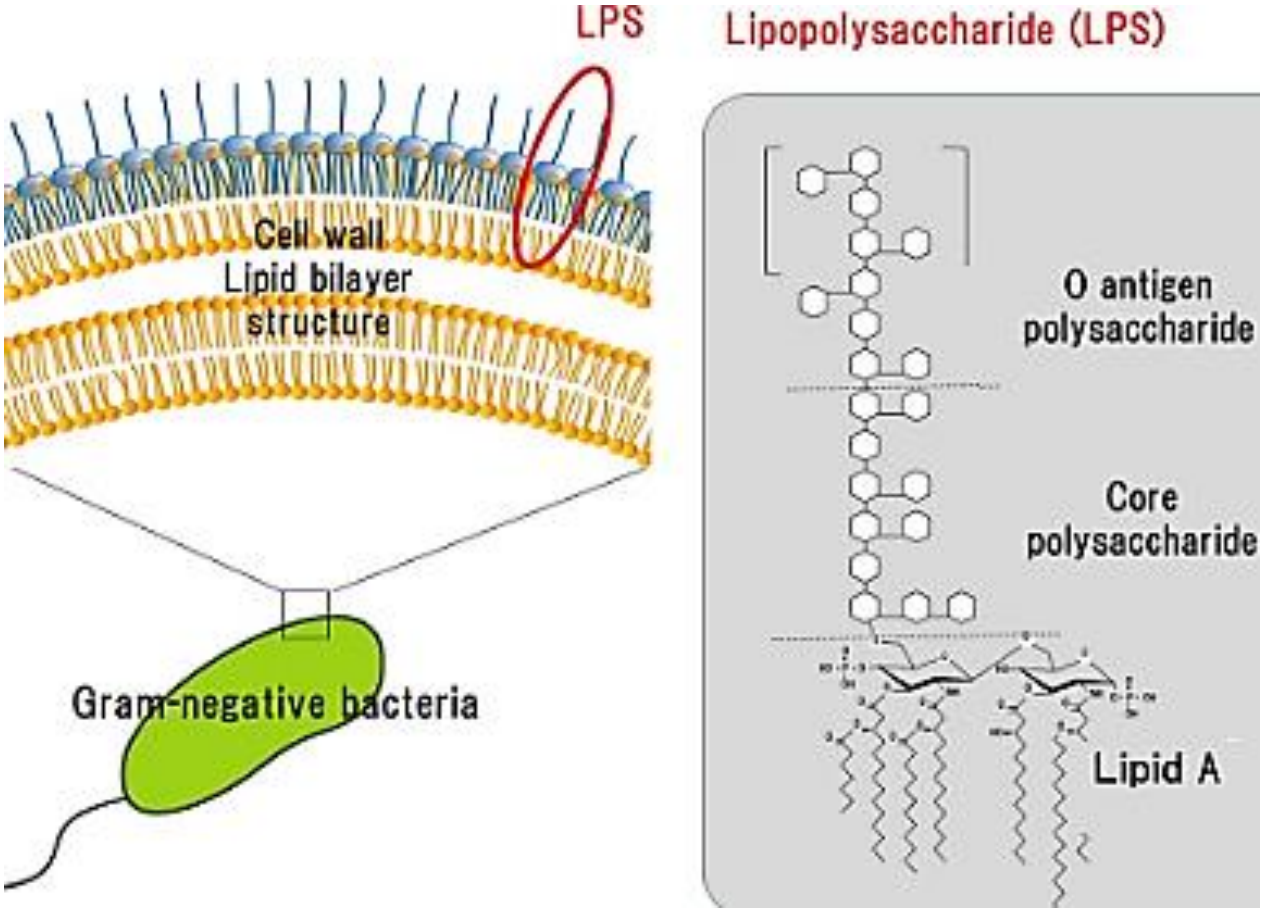
Lipopolysaccharide (LPS)

This molecular complex is comprised of the lipid A, the core polysaccharide, and the O-specific polysaccharide chain.

Function:

1-Also known as endotoxin, the toxicity is associated with the lipid A.

2- Contains major surface antigenic determinants, including O antigen found in the polysaccharide components.



The periplasmic space

- **The periplasm** is the **space** between the inner and **outer membrane in Gram-negative bacteria**.

In **Gram-positive bacteria** a smaller **periplasmic space** is found between the inner membrane and the peptidoglycan layer.

- Hydrated peptidoglycan, hydrolytic enzymes including β- lactamases, specific carrier molecules, and oligosaccharides are found in the periplasmic space.

Glycocalyx

Is a network of polysaccharides that project from cellular surfaces of bacteria, found just outside the bacterial cell wall.

This layer can come in one of two forms:

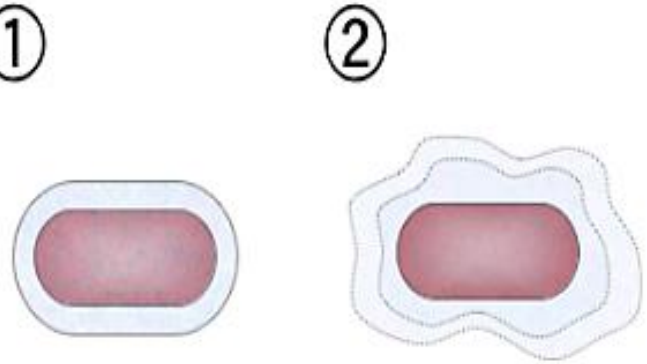
1-Capsule

The capsule is a well-defined structure of **polysaccharide** surrounding a bacterial cell and is external to the cell wall.

The one exception to the polysaccharide structure is the poly-D glutamic acid capsule of *Bacillus anthracis.*

Function:

- Protects the bacteria from phagocytosis.
- Plays a role in bacterial adherence.



2-Slime Layer

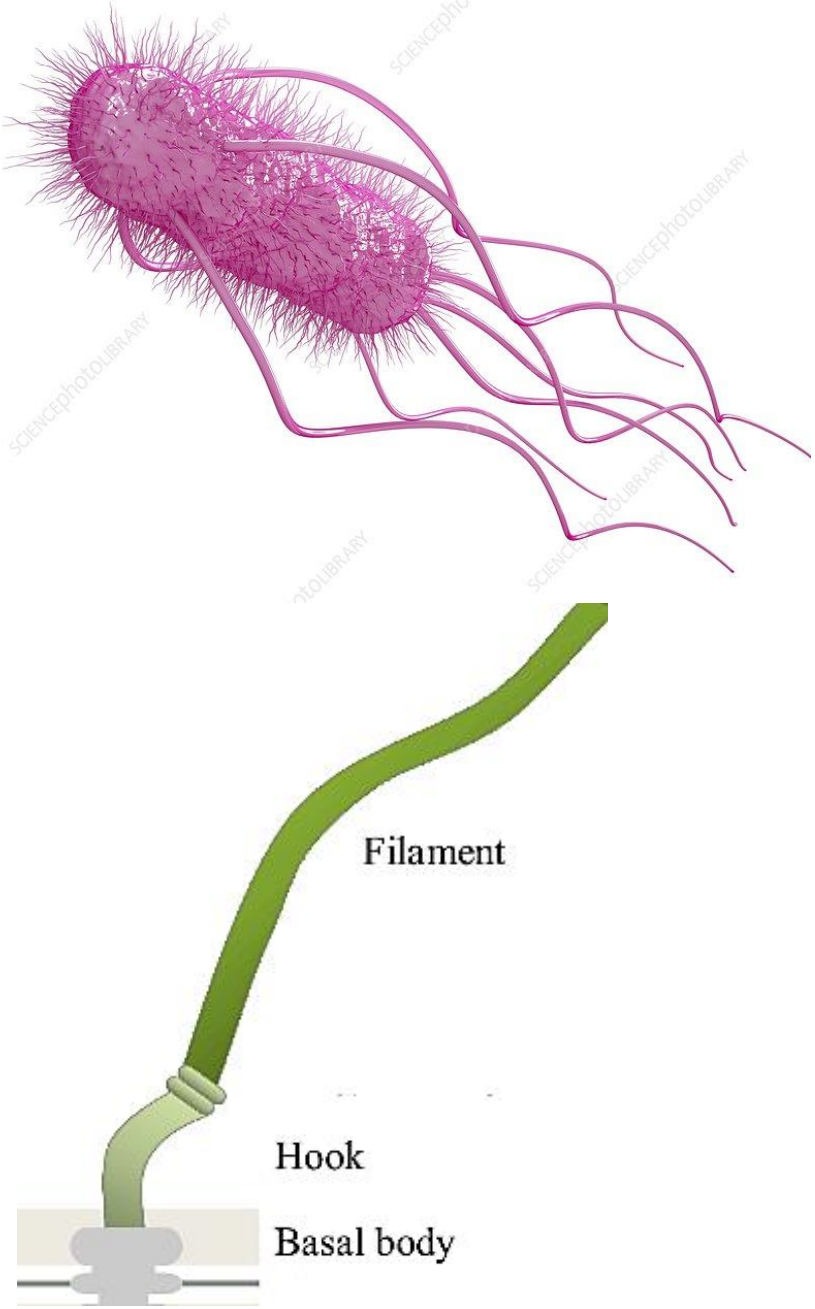
Refers to a loose network of polysaccharide fibrils that surrounds some bacterial cell walls.

Function: associated with adhesive prosperities of the bacterial cell.

Flagella

Structure

Bacterial flagella are thread-like appendages consist of a **basal body, hook**, and a **long filament** composed of a polymerized protein called **flagellin**. They are the organs of locomotion for the forms that possess them.



Three types of arrangement are known:

- **monotrichous** (single polar flagellum).
- **lophotrichous** (multiple polar flagella).
- **peritrichous** (flagella distributed over the entire cell).

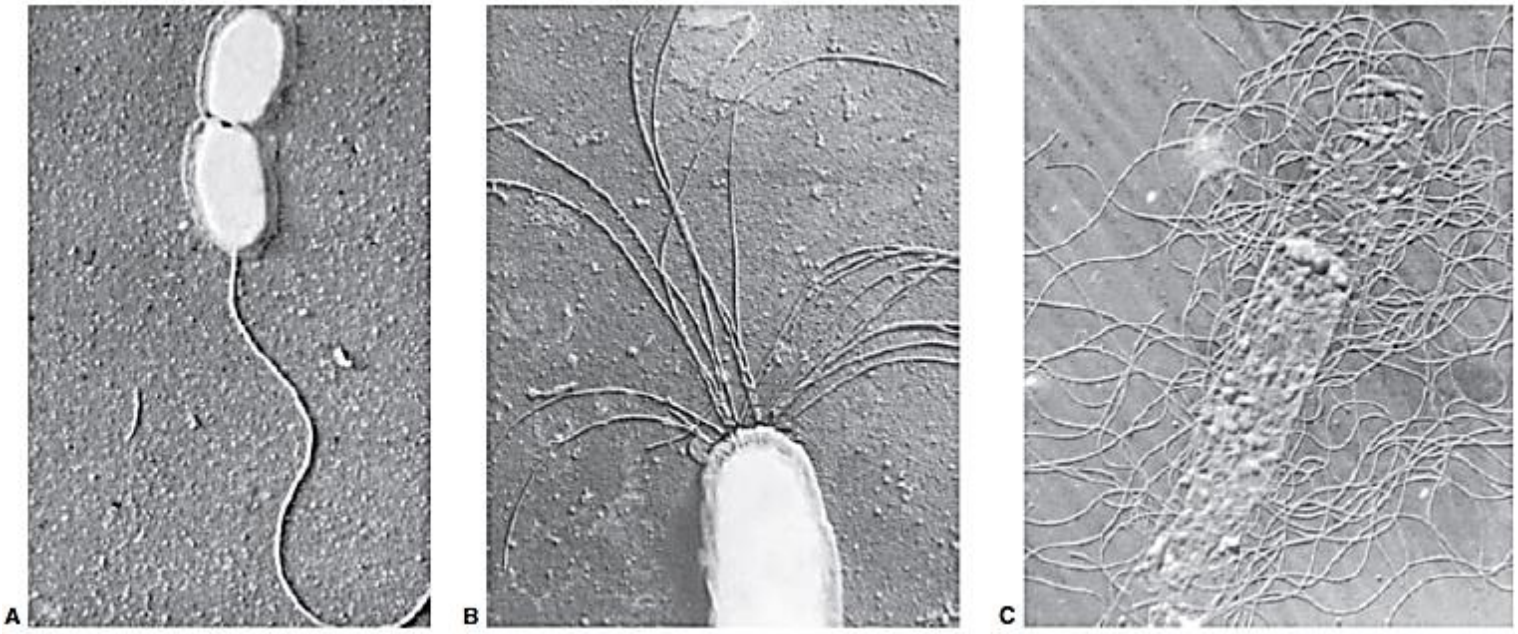
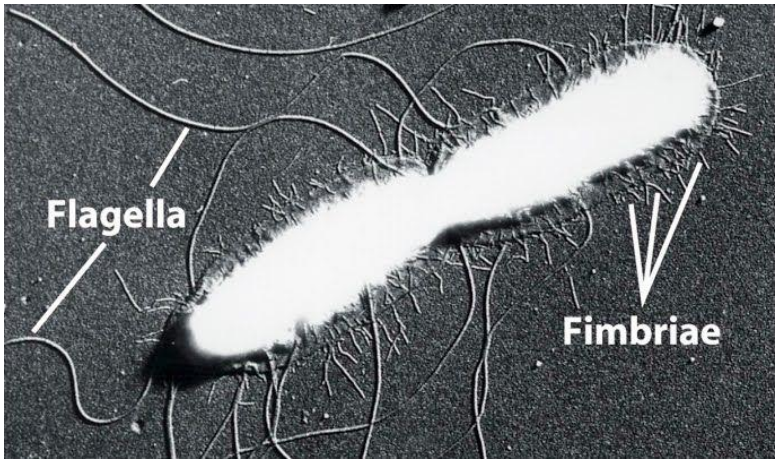


FIGURE : Bacterial flagellation. **A:** a monotrichous bacterium **B:** lophotrichous flagellation **C:** peritrichous flagellation

Pili (Fimbriae)



They are rigid surface appendages composed of structural protein subunits termed **pilins**. Minor proteins termed **adhesins** are located at the tips of pili and are responsible for the attachment properties.

Two classes can be distinguished:

- **Ordinary pili**, which play a role in the adherence of bacteria to host cells.
- **Sex pili,** which are responsible for the attachment of donor and recipient cells in bacterial conjugation.

Functions

-Ordinary pili are the colonization antigens or virulence factors.

- Antiphagocytic properities.

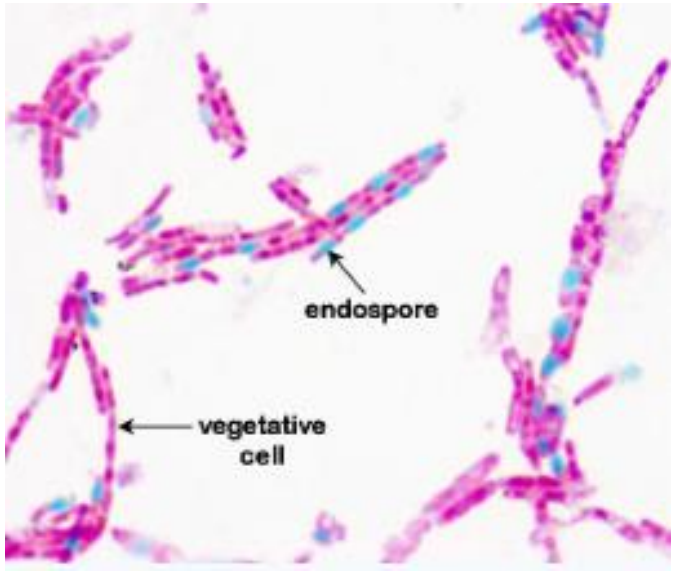
Endospores

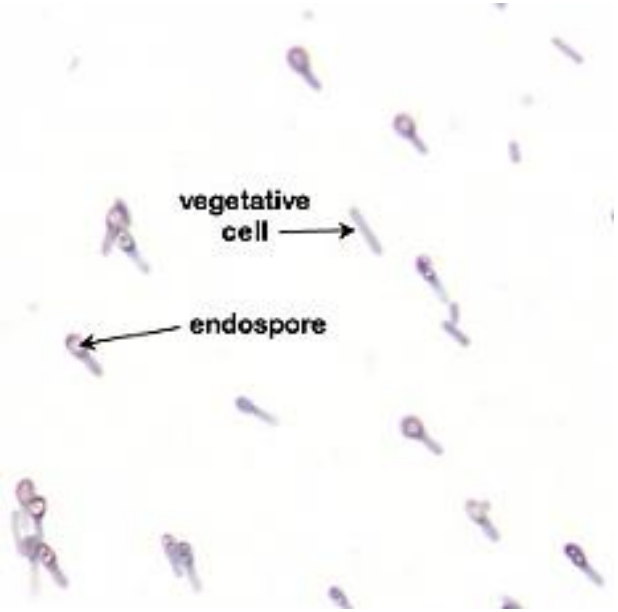
The spore is a resting cell, highly resistant to desiccation, heat, and chemical agents; when returned to favorable nutritional conditions and activated, the spore **germinates** to produce a single vegetative cell.

Structure:

They posses **a core** that contains many cell components(a nucleoid, some ribosomes, RNA molecules, and enzymes) **a spore wall**, a **cortex**, **a coat**, and an **exosporium**.

The genus **Bacillus** (an obligate aerobe often living in the soil) and the genus **Clostridium** (an obligate anaerobe living in the gastrointestinal tract of animals) produce endospores.





Bacterial endospores are resistant to antibiotics, most disinfectants, and physical agents such as radiation, boiling, and drying.

The resistance of endospores is due to a variety of factors:

- **Calcium-dipicolinate,** stabilizes and protects the endospore's DNA.

- **Small acid-soluble proteins (SASPs)** saturate the endospore's DNA and protect it from heat, drying, chemicals, and radiation.

- **The cortex may osmotically remove water** from the interior of the endospore and the dehydration that results is thought to be very important in the endospore's resistance to heat and radiation.

- **DNA repair enzymes** contained within the endospore are able to repair damaged DNA during germination.

Biofilm

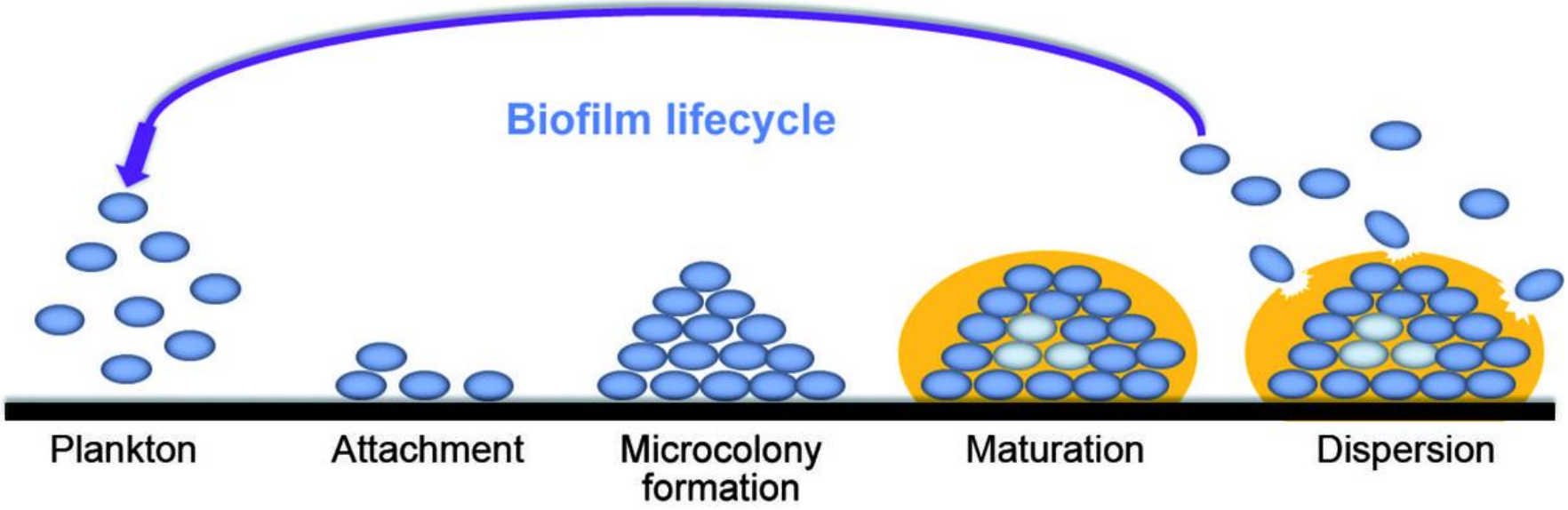
- A biofilm is an aggregate of interactive bacteria attached to a solid surface or to each other and encased in an exopolysaccharide matrix.
- The matrix is typically **composed of** polysaccharides, proteins, lipids, and DNA.

By living as a community of bacteria as a biofilm, these bacteria are better able to:

- resist attack by antibiotics;
- trap nutrients for bacterial growth and remain in a favorable niche;
- adhere to environmental surfaces and resist flushing;
- live in close association and communicate with other bacteria in the biofilm; and
- protected from the host's immune mechanisms.

Stages of biofilm development

- To initiate biofilm formation, planktonic bacteria (free individual bacteria not in a biofilm) contact an environmental surface .These planktonic bacteria then attach to that surface using pili or cell wall adhesins.
- Biofilm formation is commonly considered to occur in four main stages: (1) bacterial attachment to a surface, (2) microcolony formation, (3) biofilm maturation and (4) dispersion of bacteria which may then colonize new areas.



Thanks