Microbiology I

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Lecture 1

Introduction

A microorganisms (or microbes):

Are microscopic organisms, which may exist in their single-celled form or in a colony of cells. They can be found around us and even inside our bodies.

The category 'Microbes' includes a massive range of organisms including **bacteria, fungi, viruses, microscopic algae, archaea, and protozoa**. Some of these, such as **bacteria and fungi**, are well known, but others such as **archaea** are so much less. **Viruses** represent another special case; they are most certainly microscopic but by most accepted definitions they are not living.

What is microbiology?

Microbiology: **The science *(logos)* of small *(micro)* life *(bios)*, is the study of living things so small that they cannot be seen with the naked eye.** It is essential for understanding their biology, ecology, and applications in fields like medicine, biotechnology, and environmental science.

Why is microbiology important?

To get some idea of the importance of microbiology in the world today, just consider the following list of some of the general sciences which the expertise of a microbiologist might be used:

- **Medicine**
- **Environmental science**
- **Food and drink production**
- **Agriculture**

- **Pharmaceutical industry**
- **Genetic engineering.**

For example:

1- Soil microbes help break down wastes and incorporate nitrogen gas from the air into organic compounds thereby recycling chemical elements in the soil, water and air.

2- Other play an important role in photosynthesis (food and oxygen generating process that is critical to life on earth).

3- Other helps in digestion of food in their hosts and help to produce some vitamins.

4- Other, play an important role in commercial application which are used in the synthesis of such chemical products including acetone, organic acid, enzymes, alcohols and many drugs.

5- The food industry also uses microbes in producing vinegar, pickles, buttermilk, cheese, yogurt and breed.

History of Microbiology

Humans knew how to deal with germs before even knowing about their existence even though microorganisms were on Earth about 4,000 million years ago:-

1- Storing food in cooler temperatures.

2- Salting, drying, smoking.

3- Use of spices.

4- Cremation of dead.

5- Burying dead in a distant area.

Prominent Scientists in the Development of Microbiology

Microbiology has seen significant advancements over the centuries, thanks to the contributions of numerous dedicated scientists. Here are some of the most influential figures in the field of microbiology:

1. Antonie van Leeuwenhoek (1632 – 1723):

He was a Dutch businessman and a scientist, he is commonly known as **"the Father of Microbiology"**. He **invented the first simple optical microscope** and was the first microbiologist. Van Leeuwenhoek is best known for his pioneering work in microscopy and for his contributions toward the establishment of microbiology as a scientific discipline.

In the 1670s, he started to explore microbial life with his microscope. Using single-lens microscopes of his own design to check a drop of pond water, van Leeuwenhoek was the first who did an experiment with microbes, which he originally referred to as **animalcules (from Latin animalculum = "tiny animal").** He was also **the first to document microscopic observations of muscle fibers, bacteria, spermatozoa, and red blood cells**.

Van Leeuwenhoek's microscope.

- Composed of one lens.
- Light shines objects at a45˚angle.
- Worked like a dark field microscope.
- Magnification: 50-300 fold.

2. Louis Pasteur (1822–1895):

"He was a renowned **French biologist, microbiologist, and chemist** known for his groundbreaking discoveries **in vaccination, microbial fermentation, and pasteurization (a technique for preventing spoilage in food and drinks).** His contributions have significantly impacted disease prevention. He played a vital role in **reducing mortality from puerperal fever and developed the first vaccines for <u>rabies and anthrax</u>**, earning him the title **<u>"father of microbiology."</u>** His medical breakthroughs provided strong support for **<u>the germ theory of disease</u>** and its application in clinical medicine. Pasteur also played a pivotal role **<u>in disproving the theory of spontaneous generation</u>** (he demonstrated that microorganisms could not develop in sterilized and sealed containers but could grow in sterilized yet open containers).

3. Ferdinand Julius Cohn (1828 –1898):

He was a German biologist. He is one of the founders of modern bacteriology and microbiology. **Cohn** was **the first to classify algae as plants and to define what distinguishes them from green plants. His classification of bacteria into four groups based on shape (spherical, short rods, threads, and spirals)** is still used today. Among other things, Cohn is remembered for being the first to show that *Bacillus* can change from a vegetative state to an endospore state when subjected to an environment harmful to the vegetative state.

4. Robert Koch (1843 – 1910):

"He was, <u>a German physician and microbiologist</u>, is a key figure in modern bacteriology. He **<u>identified the causes of tuberculosis, cholera, and anthrax,</u>** provided experimental proof of **<u>infectious diseases</u>**, and **<u>developed laboratory techniques</u>**. His work led to **<u>Koch's postulates,</u>** four principles that link specific microorganisms to particular diseases, still used as **<u>the gold standard</u>** in medical microbiology."

Koch’s postulates

1- The microorganism must be present in every instance of the disease and absent from healthy individuals.

2- The microorganism must be capable of being isolated and grown in pure culture.

3- When the microorganism is inoculated into a healthy host, the same disease condition must result.

4- The same microorganism must be re-isolated from the experimentally infected host.

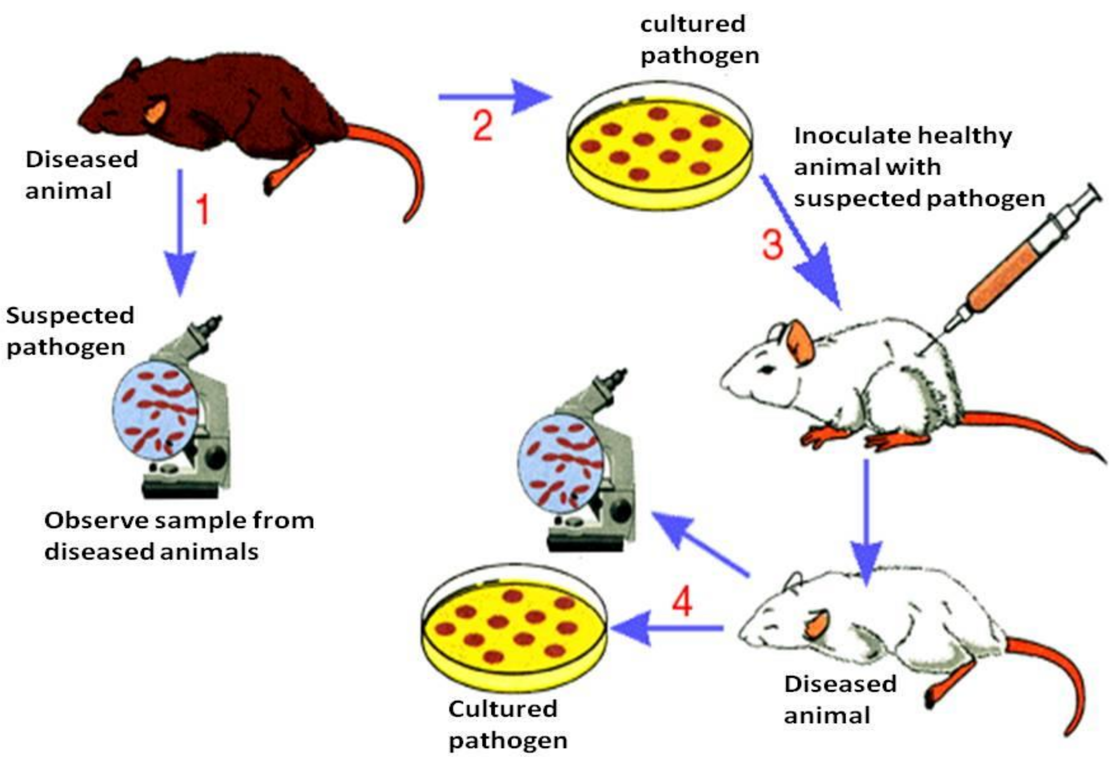

Figure 2: Schematic diagram illustrating Koch's postulates.

5. Alexander Fleming (1881-1955):

He was a Scottish physician and microbiologist, **Fleming's discovery of penicillin**, the first antibiotic, revolutionized medicine. His observation of mold inhibiting bacterial growth paved the way for the development of antibiotics, saving countless lives and shaping **the field of antimicrobial research**.

6. **Selman Waksman (1888-1973):**

   Waksman was instrumental in **the discovery of streptomycin**, the first effective treatment for tuberculosis. He coined the term **"antibiotic"** and conducted extensive research on soil microorganisms, leading to the isolation of numerous antibiotics.

7. **Carl Woese (1928-2012):**

   He was an American microbiologist and biophysicist. Woese's work in molecular biology and genomics reshaped our understanding of **microbial diversity**. He introduced the concept of **the Archaea domain**, which expanded the tree of life, highlighting the importance of **extremophiles in Earth's ecosystems.**

8. **Rita Colwell (1934-present):**

   She is an American environmental microbiologist. Colwell is known for her groundbreaking research on ***Vibrio cholerae*** and her work in **environmental microbiology**. Her discoveries have had implications for understanding **waterborne diseases** and the role of **climate change in microbial ecology**.

9. **Craig Venter (1946-present):**

   He is an American biotechnologist , Venter is a pioneer in **genomics and synthetic biology**. His contributions include sequencing the human genome and **developing novel techniques for studying microbial communities**, which have applications in medicine and environmental science.

These scientists and many others have made significant contributions to the field of microbiology, advancing our understanding of microorganisms and their role in health, disease, and the environment. Their work continues to shape the way we approach microbiological research and its practical applications.

Lecture 2

Cell Structure and Organizing

The basic unit of all living things is **the cell**.

The cell theory is one of the fundamental concepts of biology; it states that: all organisms are made up of cells, and that all cells derive from other, pre-existing cells.

An organism may comprise just a single cell (***unicellular***), a collection of cells that are not morphologically or functionally differentiated (***colonial***), or several distinct cell types with specialized functions (***multicellular***).

Among microorganisms, all bacteria and protozoans are unicellular; fungi may be unicellular or multicellular.

The most fundamental difference between prokaryotic and eukaryotic cells is reflected in their names; ***Eukaryotic cells*** possess a true nucleus, and several other distinct subcellular organelles that are bounded by a membrane. ***Prokaryotes*** have no such organelles.

Types of microorganisms

The present classification of microbes might read as follows:

1. Prokaryotes:

A. Archaea

B. Bacteria (*Cyanobacteria*, *mycoplasma*, Gram-positive bacteria, and Gram-negative bacteria).

2. Eukaryotes

A. Algae
B. Protozoa
C. Fungi
D. Slime molds

Note: viruses are also classed as microorganisms, but they are shapely differentiated from all cellular forms of life by their dependence upon a host for replication.

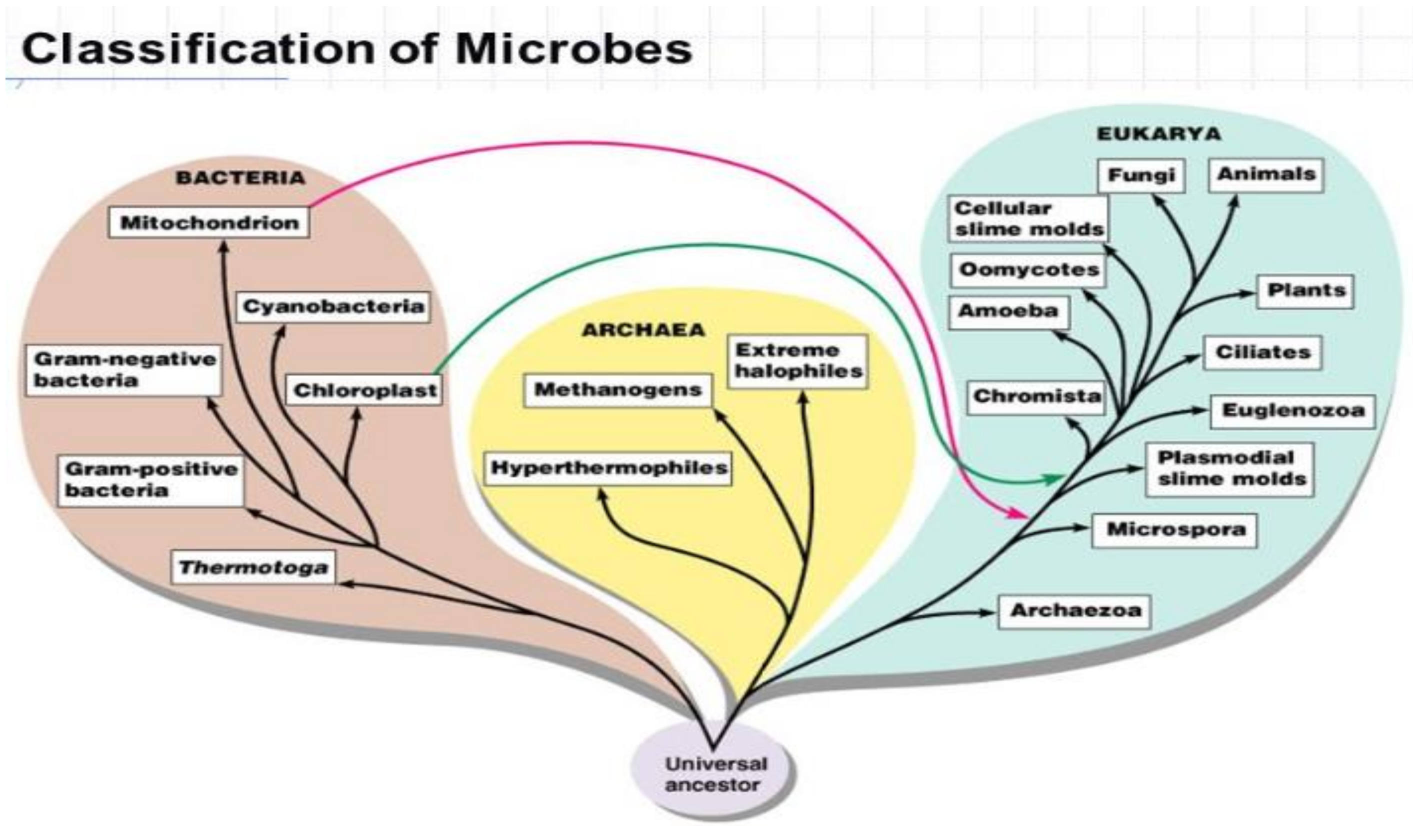

Figure 1*:* Classification of microbes

The differences between prokaryotes and eukaryotes:

	Prokaryotes	Eukaryotes
DNA	DNA is naked (no histones)	DNA associated with histones
	DNA is circular	DNA is linear
	Genes do not contain introns	Genes may contain introns
	DNA found in cytoplasm (nucleoid)	DNA found in nucleus
Internal Structures	No membrane-bound organelles	Have membrane-bound organelles
Ribosomes	Have 70S ribosomes	Have 80S ribosomes
Reproduction	Asexual (binary fission)	Asexual (mitosis) or sexual (meiosis)
	DNA is singular (haploid)	DNA is usually paired (diploid or more)
Average Size	Smaller (≈1 – 5 μm)	Larger (≈10 – 100 μm)

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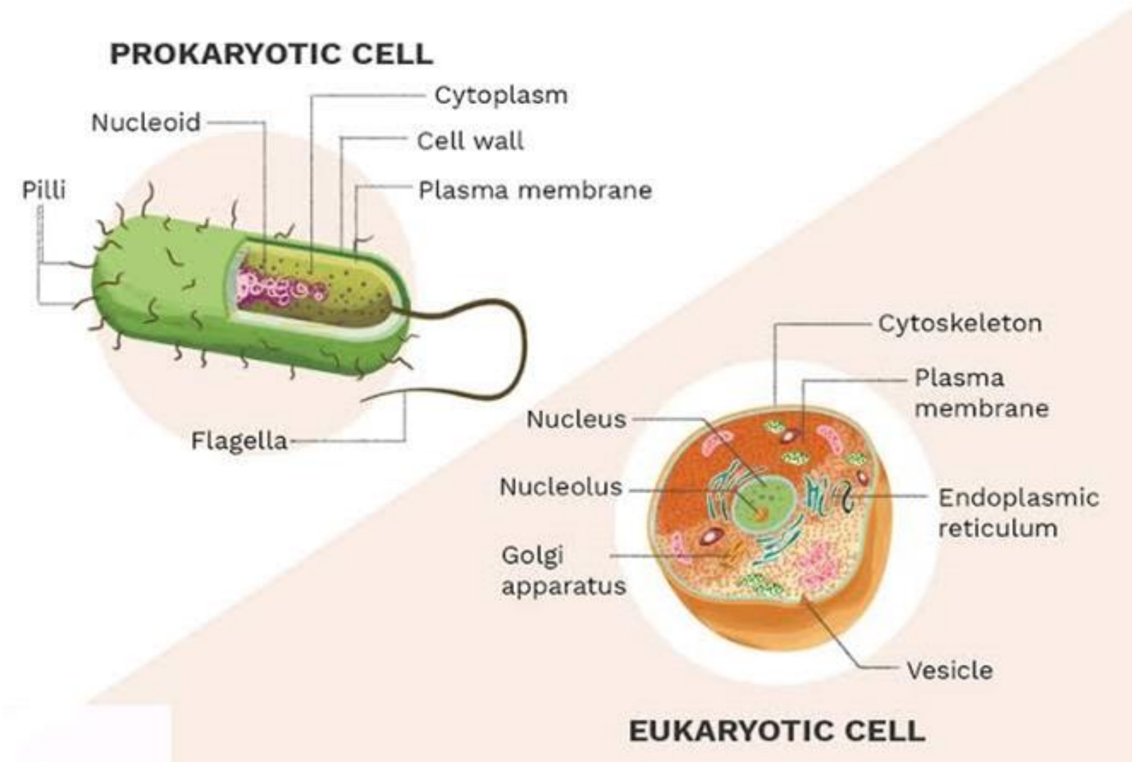

Figure 2:*Prokaryotes vs Eukaryotes*

Archaea (archaebacteria):

Archaea or Archaebacteria (singular archaeon, the word archaea means "ancient things"):

The Archaea possess the following characteristics:

- Archaea are prokaryotic cells, single-celled microorganisms looking very similar in size and shape to bacteria.

- Unlike the bacteria and the Eukarya, the Archaea have membranes composed of branched hydrocarbon chains (many also containing rings within the hydrocarbon chains) attached to glycerol by ether linkages.

- The cell walls of Archaea contain no peptidoglycan.

- Archaea are not sensitive to some antibiotics that affect the bacteria, but are sensitive to some antibiotics that affect the Eukarya.

- Archaea contain ribosomal RNA (rRNA) that is unique to the Archaea as indicated by the presence molecular regions distinctly different from the rRNA of bacteria and Eukarya.

- Archaea often live in extreme environments and include methanogens, extreme halophiles, and hyperthermophiles. One reason for this is that the ether-containing linkages in the Archaea membranes is more stable than the ester-containing linkages in the bacteria and Eukarya and are better able to withstand higher temperatures and stronger acid concentrations.

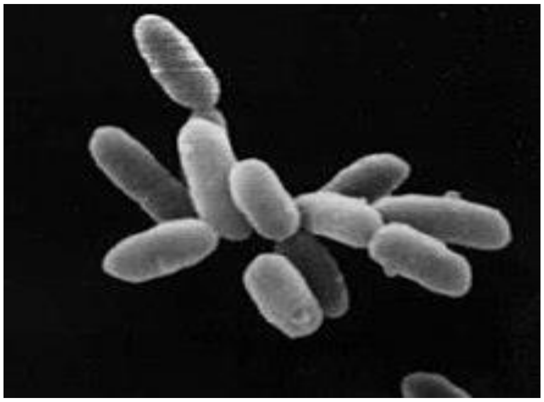

Figure 3*:* Halobacterium sp.

The bacteria (Eubacteria):

Bacteria (also known as eubacteria or "true bacteria"): are prokaryotic cells that are common in human daily life. Eubacteria can be found almost everywhere and kill thousands of people each year, but also serve as antibiotics producers and food digesters in our stomachs. The bacteria possess the following.

Characteristics of bacteria:

1- Bacteria are prokaryotic cells (have no membrane bounded nucleus).

2- Generally small size (the size range between 0.5-5 micrometers).

3- Have single chromosome as genetic material.

4- Except for ribosomes, there are no cytoplasmic organelles (mitochondria, chloroplasts, and the other organelles present in eukaryotic cells, such as the Golgi apparatus and endoplasmic reticulum).

5- Enclosed in a rigid cell wall made up of peptidoglycan. Cell wall may be surrounded by a capsule.

6- Reproduce by amitosis (binary-fission / asexual form of reproduction).

7- Many bacteria form spores.

8- May have flagella for movement.

Cyanobacteria: are aquatic bacteria, and are some of the oldest living organelles on Earth. Because these water-dwelling bacteria photosynthesize, they are also referred to as "blue-green algae." Cyanobacteria can be found in many different environments, including freshwater and marine ecosystems and that can have major effects on the water quality and functioning of aquatic ecosystems.

Figure 4: Cyanobacteria

Lecture 3

The prokaryotic cell

Bacterial cell

Bacteria are prokaryotic, unicellular microorganisms, they lack membrane-bound organelles like those found in eukaryotes, and much smaller than eukaryotic cells; In general, bacteria are between 0.2 and 2.0 um - the average size of most bacteria. Mycoplasma is a type of bacteria which is considered as the smallest organism, measures a size of 0.25 µm.

Research studies have shown their size to play **an important role in survival over time** (Bacteria have a high surface area to volume ratio that allows them to take up as many nutrients as possible for survival. In the process, they are able to continue growing and reproducing at a steady rate). The small size of bacteria is also **beneficial for parasitism and oligotrophy** (Bacteria can continue relying on a range of hosts for their nutrition. In addition, they can also live and survive in environments that contain a low concentration of nutrients; for instance, a group of bacteria known as oligotrophic bacteria).

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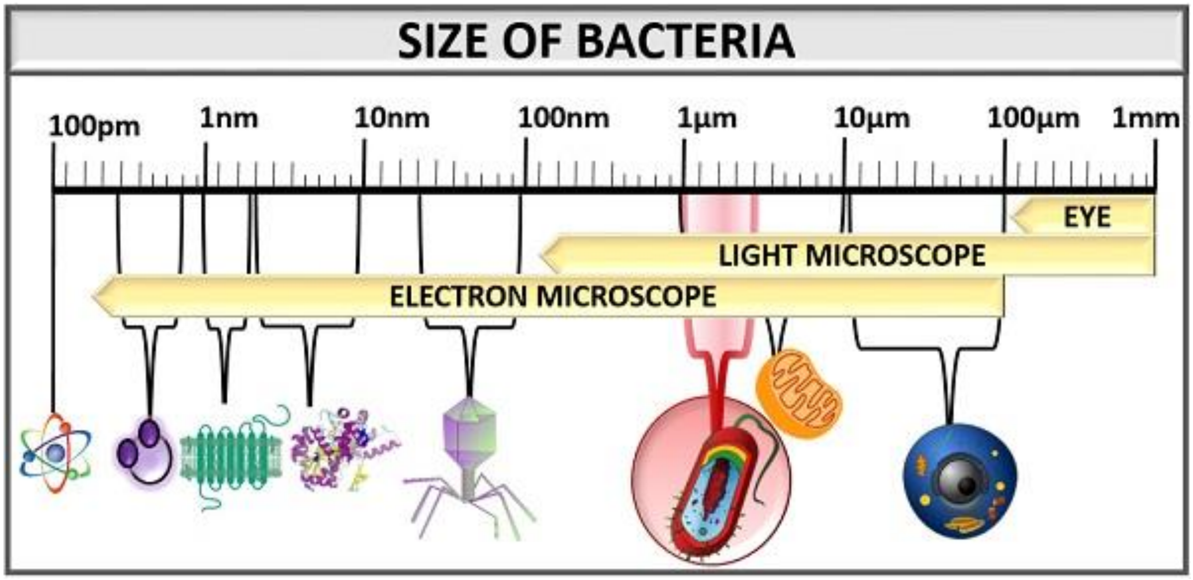


Shapes of bacteria

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 which can range from a gently curved shape to a corkscrew-like spiral.

Pleomorphism

Bacteria appear in number of 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: *Sarcina 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*).

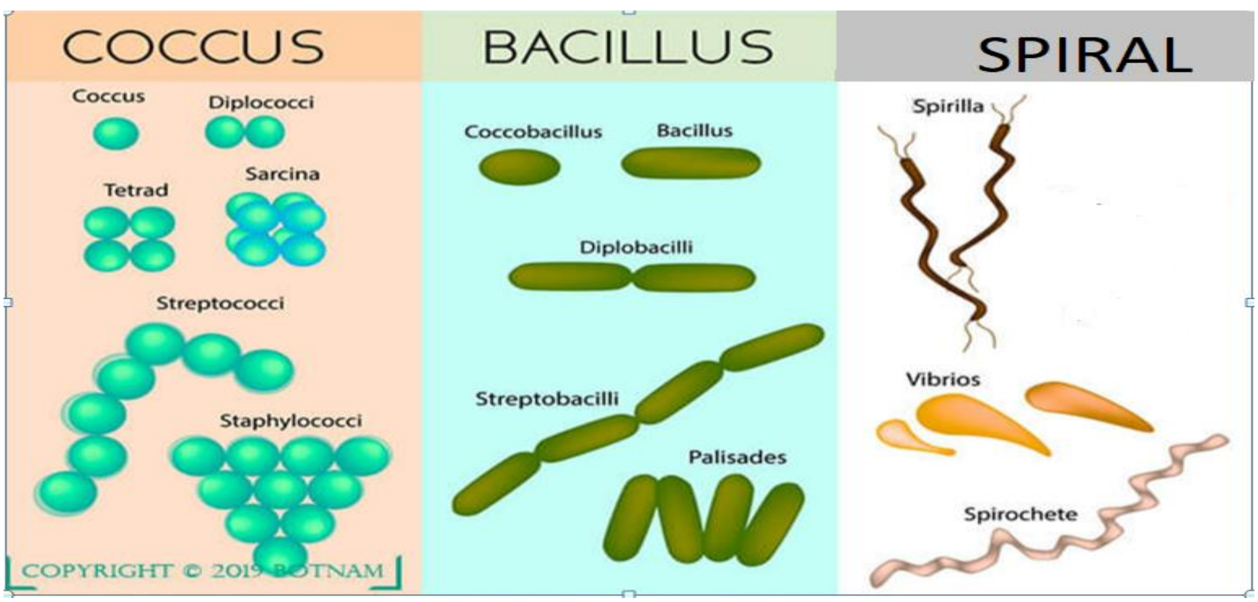
***Arrangement of Spiral Bacteria**

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).



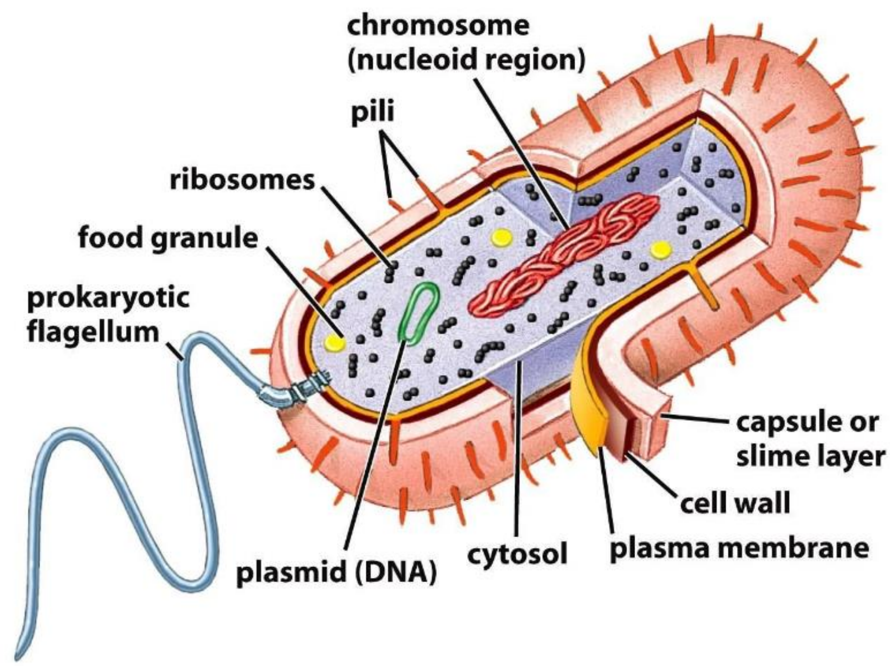
Structure of bacteria

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.



Common structures bacteria cell

	Function	Kemisk opbygning
Flagel	movement	protein
Pili	attachment, protection	protein
F or sex pili	transfer DNA under conjugation	protein
Capsule	attachment to surfaces, protection against phagocytosis	polysaccharides
Cell wall	protect, give form, stability	peptidoglycan
Cytoplasmic membrane	permeabilitets barriere, transport, energy, enzymes	
Ribosomes	make synthesis of proteins	RNA, protein
Inclusions	reservelager for nærings-stoffer	carbohydrate, lipid, protein, salts
Chromosomes	genetic material	DNA
Plasmids	extrachromosomal DNA	DNA

The Cell Wall

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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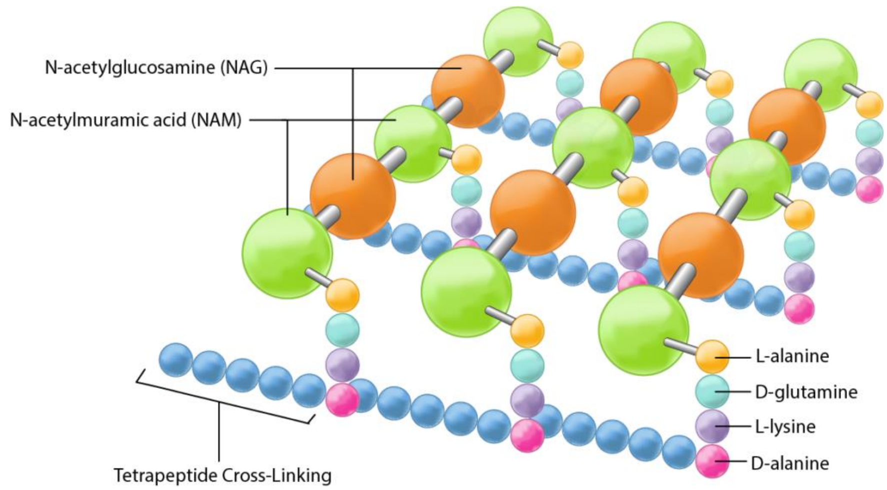

In the Gram-positive Bacteria (those that retain the purple crystal violet dye when subjected to the Gram-staining procedure), the cell wall consists of several layers of peptidoglycan (20 - 80 nanometers) with an additional molecule, **teichoic acid**.

Teichoic acid consists of glycerol, phosphates, and the sugar alcohol ribitol, 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 movement of ions into and out of the cell.

In the 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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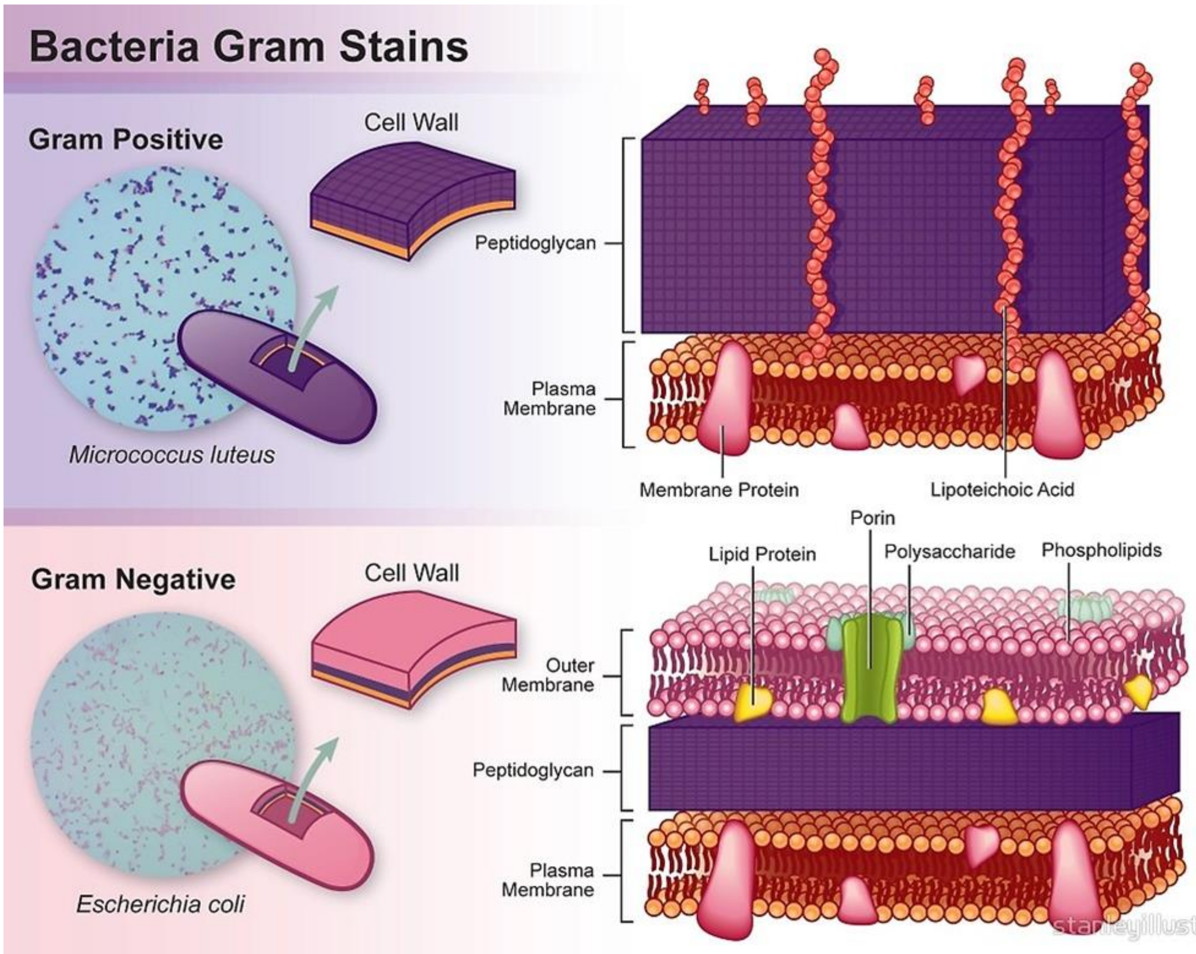

	Gram-positive cell wall	Gram-negative cell wall
Peptidoglycan	90% of cell wall, 20nm thick 2 tetrapeptides of adjacent chains of NAM, NAG are linked by peptide bridges (which contain 5 Glycine)	Thinner 2 tetrapeptides of NAM, NAG are directly linked between D-Alanine and DAG within 2 tetrapeptides
Teichoic acid	10% of cell wall Polyribitol/polyglycerol phosphate linked to peptidoglycan	None
Lipoteichoic acid	Lipid linked teichoic acid	None
Periplasmic space	Small or none	Contains enzymes for transport, degradation and synthesis
Outer membrane	None	Phospholipids with saturated fatty acids. Embedded porins, lipoproteins, transport proteins
Lipopolysaccharide	None	Lipid A (endotoxin), core polysaccharide, O antigen

Lecture 4

The outer membrane

The Gram-negative cell wall is composed of an outer membrane, a peptidoglygan layer, and a periplasm.

The outer membrane of Gram-negative bacteria is a bilayer membrane acts as **a protective barrier and excludes many toxic compounds.**

The outer membrane is composed of phospholipids, lipoproteins, lipopolysaccharides (LPS), and proteins.

Lipopolysaccharides (LPS), also known as **endotoxins** and **lipoglycans** act as **virulence factor** and causes disease in animals.

The LPS are large molecules consisting of three parts; two of them are medically significant:-

1. Lipid A: embedded in membrane, this portion is also referred as an endotoxin since it is a toxic to a host.

2. Core Oligosaccharide (glycoside part): located on the surface of membrane. Is highly- charged (negative charge).

3. O antigen (or O polysaccharide): which are short polysaccharides extended out from core. This O-antigen portion is the primary site of gram negative bacteria, recognized by antibodies. The variability of the O-antigen chain can cause problems with the immune response.

Porins: are barrel proteins form channels (pores) through both sides of the outer membrane of gram-negative bacteria, through which molecules can diffuse.

Periplasm: The region between the cytoplasmic membrane and the outer membrane is filled with a gel-like fluid called periplasm**.** The periplasm consists of **the peptidoglycan, proteins** (that are involved in various cellular activities, including nutrient degradation and transport), and metabolites found in the periplasmic space.

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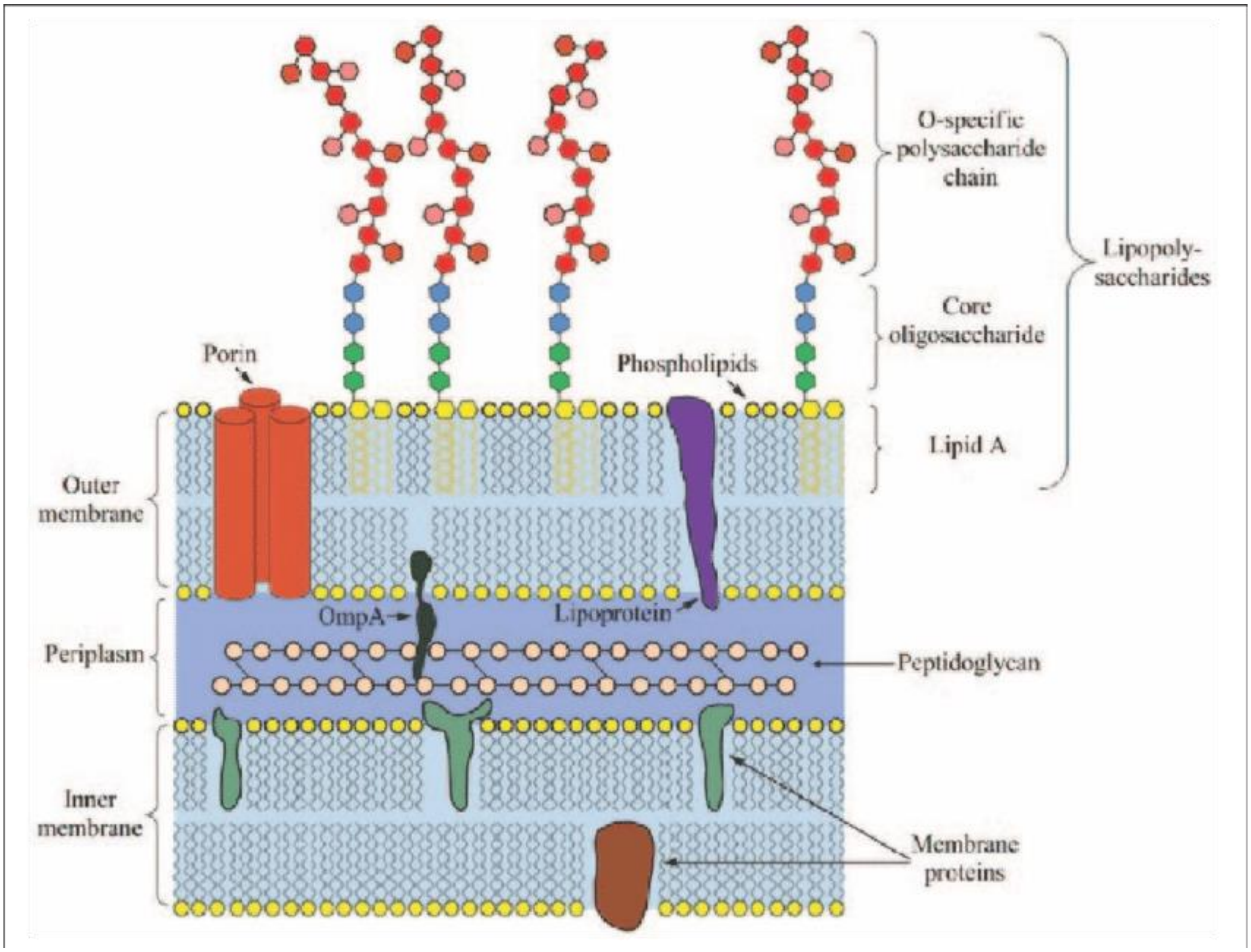
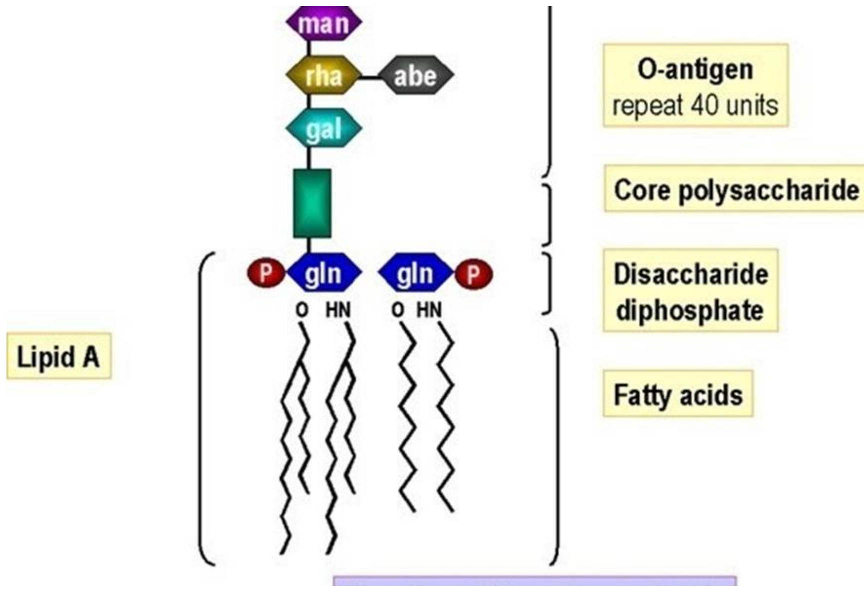


The outer and inner membranes of Gram-negative bacteria

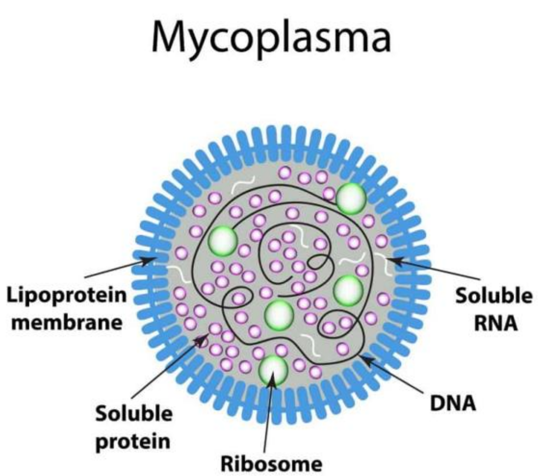


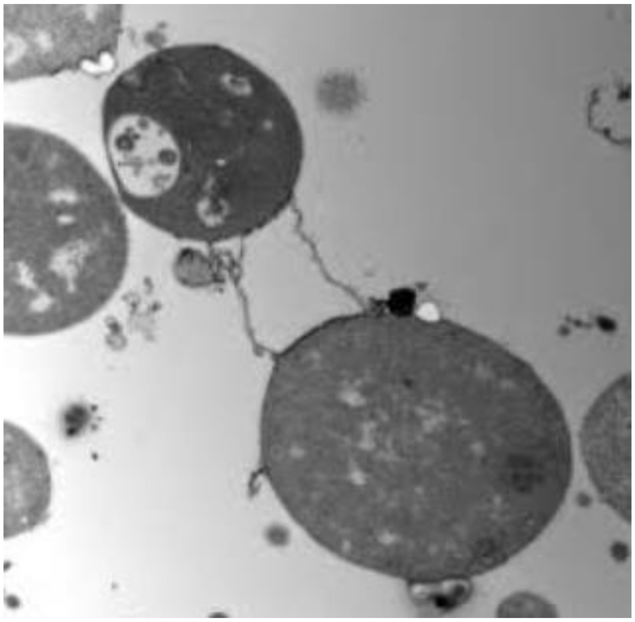
Chemical structure of lipopolysaccharides

<u>Cell-Wall-Deficient Bacteria (Bacteria without cell wall)</u>

Some bacteria lack a cell wall but retain their ability to survive by living inside another host cell like **<u>Mycoplasma species.</u>**

<u>Mycoplasma</u> is a genus of bacteria that lack a cell wall around their cell membranes. This characteristic makes them naturally resistant to antibiotics that target cell wall synthesis (like the beta-lactam antibiotics). They can be **<u>parasitic or saprotrophic</u>**. Several species are pathogenic in humans. Mycoplasma species are the smallest bacterial cells yet discovered, can survive without oxygen, and come in various shapes. ملاحظة :الشكل للاطلاع فقط





L-form bacterial lack a cell wall structure

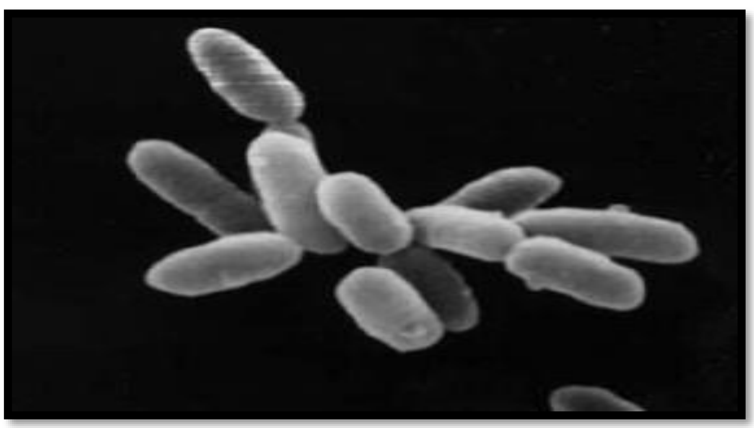
Other bacterial species occasionally mutate or respond to extreme nutritional conditions by forming cells lacking walls, termed **<u>L-forms (also known as Sam Cannon, L-phase variants, and cell wall-deficient (CWD) bacteria)</u>**. This phenomenon is observed in both gram-positive and gram-negative species.

<u>*Mycoplasma are not considered L-forms</u> since they are not derived from bacteria that normally have cell walls.

Cell Walls of Archaea (singular archaeon)

Archaeal cell walls differ from bacterial cell walls in their chemical composition and lack of peptidoglycans. Archaeal cell walls are composed of different polysaccharides and proteins, with no peptidoglycan. Many archaea have cell walls made of the polysaccharide pseudomurein.

The most striking chemical differences between Archaea and other living things lie in their cell membrane. There are four fundamental differences between the archaeal membrane and those of all other cells: **(1) chirality of glycerol, (2) ether linkage, (3) isoprenoid chains, and (4) branching of side chains.**



Cluster of *Halobacterium* (archaea)

The cell membrane

The cell membrane (also known as the plasma membrane (PM) or cytoplasmic membrane) is a biological membrane that separates the interior of all cells from the outside environment.

Plasma Membrane Composed of:-

- Phospholipid bilayer asymmetric (the phosphate group called the "head" is negatively charged, making the head polar and hydrophilic, or "water loving" and the lipid called the "tails. " nonpolar, and hydrophobic, or "water fearing").

- Protein molecules (integral proteins & peripheral proteins).
- Hopanoids - embedded in bilayer (Sterol-like (similar to cholesterol) which stabilize membrane.

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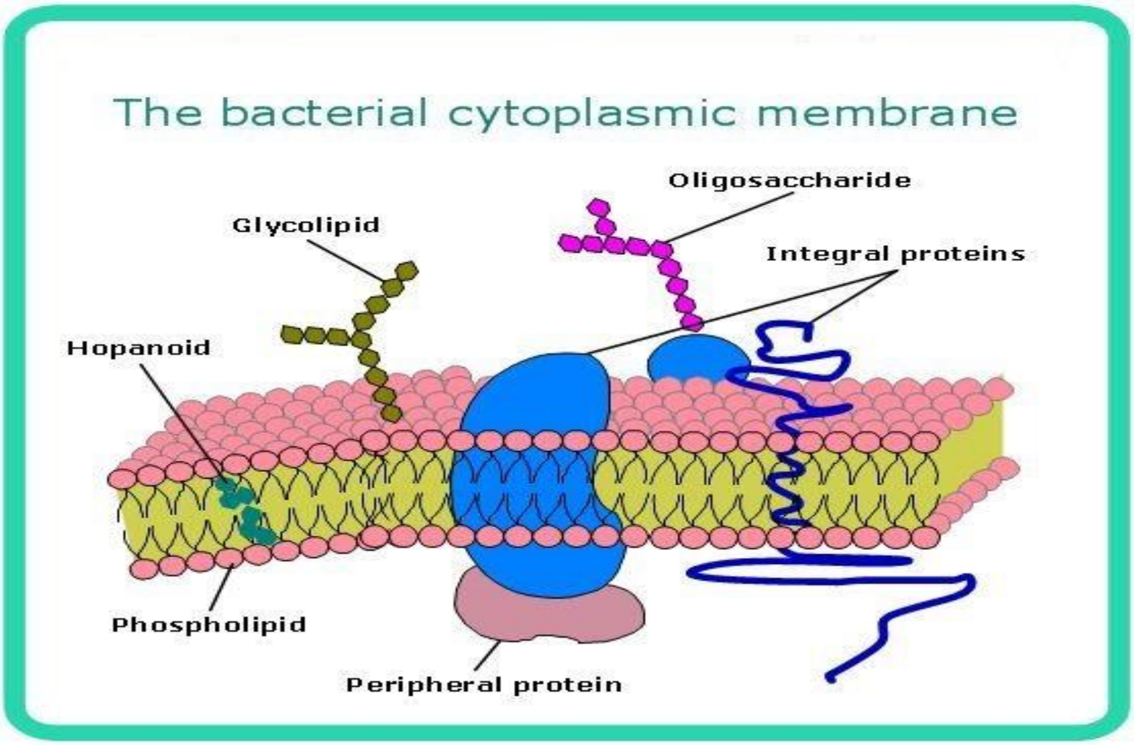
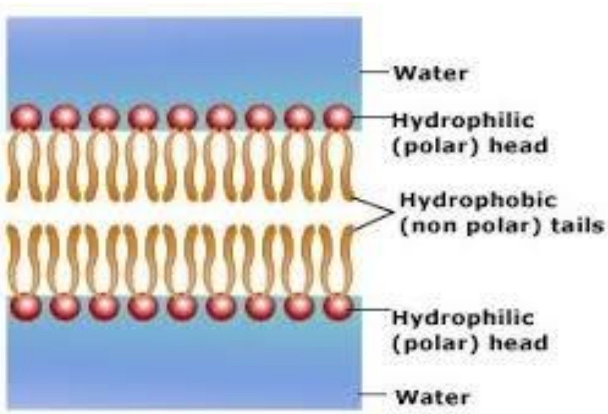




Plasma membrane functions:-

1- Separates cell from the outside environment.

2- Selectively permeable barrier.
3- Captures energy as ATP.
4- Location of metabolic reactions.
5- Synthesizes cell wall components and DNA.
6- Responds to chemical substances in the environment (Chemotaxis).

Internal Structure

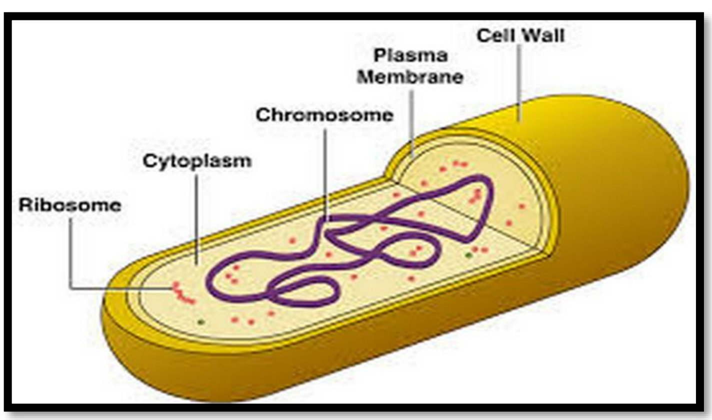
1- Cytoplasm

The cytoplasm, or protoplasm, of bacterial cells is where the functions for cell growth, metabolism, and replication are carried out. It is a gel-like matrix composed of water, enzymes, nutrients, wastes, and gases and contains cell structures such as ribosomes, a chromosome, and plasmids. The cell envelope encases the cytoplasm and all its components.

2- Ribosomes

Ribosomes are microscopic "factories" found in all cells, including bacteria. They are composed of a complex of protein and RNA, and are the site of protein synthesis in the cell.. Bacterial ribosomes are similar eukaryotes ribosomes (80S), but are smaller (70S) and have a slightly different composition and molecular structure. They are never bound to other organelles as in eukaryotes, but are free structures in the cytoplasm. There are sufficient differences between bacterial ribosomes and eukaryotic ribosomes that some antibiotics will inhibit the functioning of bacterial ribosomes, but not a eukaryote's, thus killing bacteria but not the eukaryotic organisms they are infecting.

S = the Svedberg unit (Symbol S or Sv): is a measure of the sedimentation rate of a particle when centrifuged.



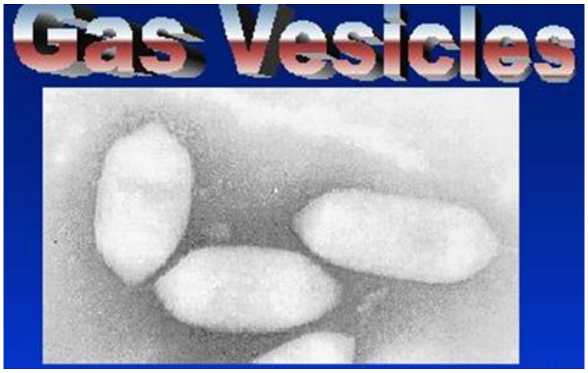
3- Inclusions and granules

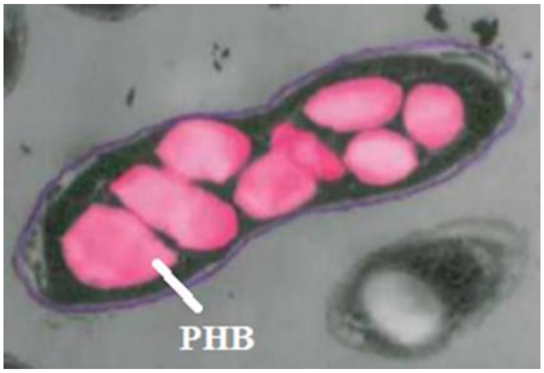
– Intracellular storage bodies within the cytoplasm of certain bacteria act as food reserves.
– Vary in size, number, and content
– Bacterial cell can use them when environmental sources are depleted.

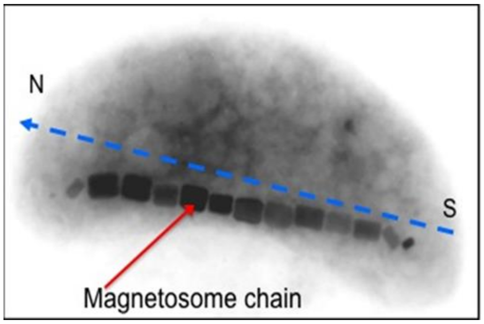
Examples:

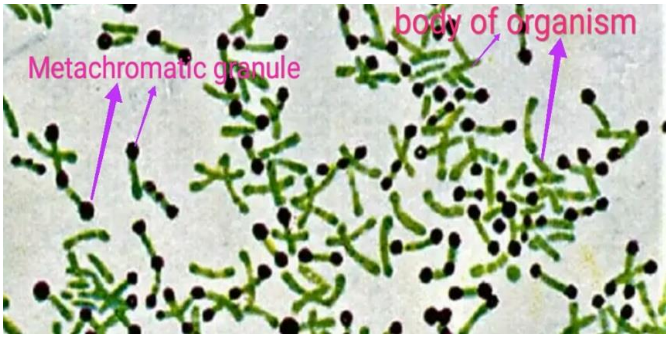
- **Glycogen granules:** storage of glucose polymers (starch).
- **Gas vesicles:** provide buoyancy (floatation) in aquatic environment.
- **Magnetosomes:** Particles of iron oxide (magnetite), Provide orientation in magnetic field.
- **Volutin granules (or metachromatic granules):** a storage form for inorganic phosphate and energy.
- **Poly β-hydroxybutyrate (PHB):** For lipid storage.

الاشكال للاطلاع فقط









Lecture 5

هذه النقطة مكملة للمحاضرة الرابعة

4- The Nucleoid

The nucleoid (meaning nucleus-like): is an irregularly shaped region within the cell of a prokaryote that contains all or most of the genetic material which is represented by DNA, and called **the bacterial chromosome**.

The nucleoid is mostly composed of multiple compacted copies of DNA in a continuous thread, with the addition of some RNA and proteins. The DNA in prokaryotes is double-stranded and generally takes a circular shape. But the DNA can sometimes also be found in other regions outside the nucleoid.

Function of Nucleoid: The nucleoid is essential for controlling the activity of the cell and reproduction. It is where transcription and replication of DNA take place.

*Most bacteria have one or two circular chromosomes (nucleoids), the numbers of nucleoids, depend on the growth conditions. Rapidly growing bacteria have more nucleoids per cell than slowly growing ones.

Plasmids

In addition to the bacterial chromosome, bacteria often contain small usually circular, double-stranded DNA molecules called **plasmids**, that contain (usually) non-essential genes.

Plasmids not connected to main bacterial chromosome but have very important functions:

 Antibiotic resistance Tolerance to toxic metals Production of toxins the synthesis of enzymes.

 *Plasmids can be transferred from one bacterium to another.

*In fact, plasmid DNA is used for gene manipulation in biotechnology.

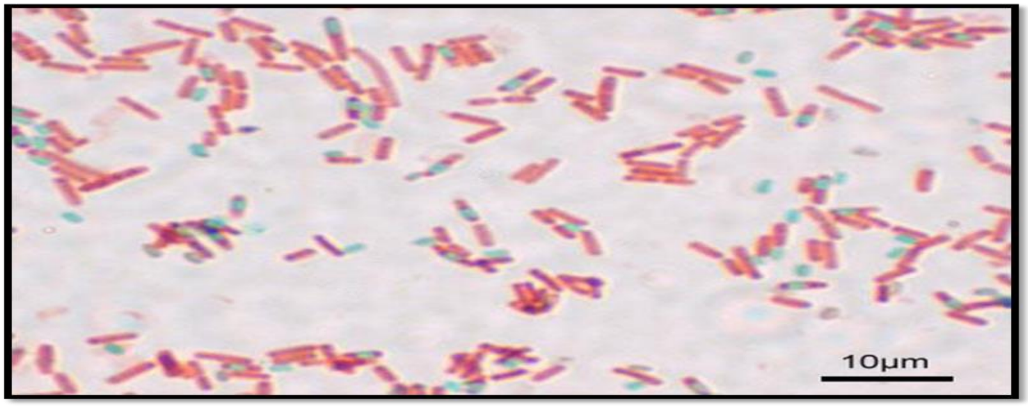
5- Endospores

When essential nutrients are depleted, certain gram-positive bacteria, such as those of the genera **Clostridium** and **Bacillus**, form specialized "resting" cells called **endospores.**

Endospores are dormant, non-reproductive and enzymatically inert forms of bacterial vegetative cells.

The primary function of most endospores is to ensure the survival of a bacterium through periods of environmental stress. They are therefore resistant to radiation, desiccation, lysozyme, temperature, starvation, and chemical disinfectants.

*For example, 7500-year-old endospores of Thermo-actinomyces vulgaris from the freezing muds of Elk Lake in Minnesota have germinated when rewarmed and placed in a nutrient medium. **(المثال للاطلاع)**



A stained preparation of the cell *Bacillus subtilis* showing endospores as green and the vegetative cell as red **(الشكل غير مطلوب)**

Bacterial endospore structure:- From the inner to the outer:

a) The core (contains the bacterial DNA).

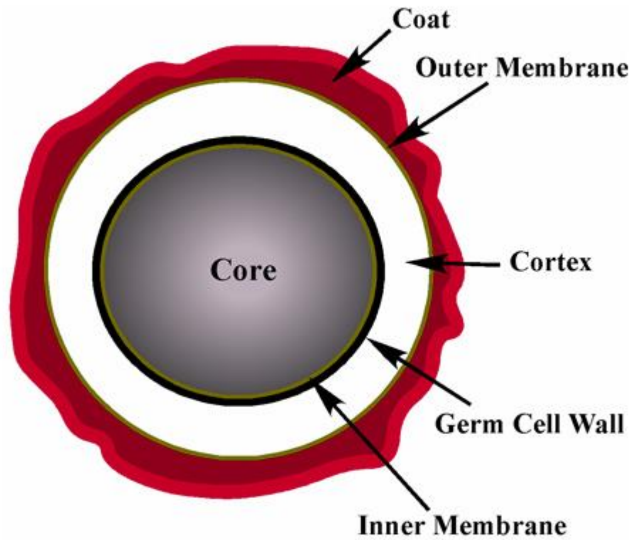
b) Inner membrane

c) Cortex

d) Outer membrane

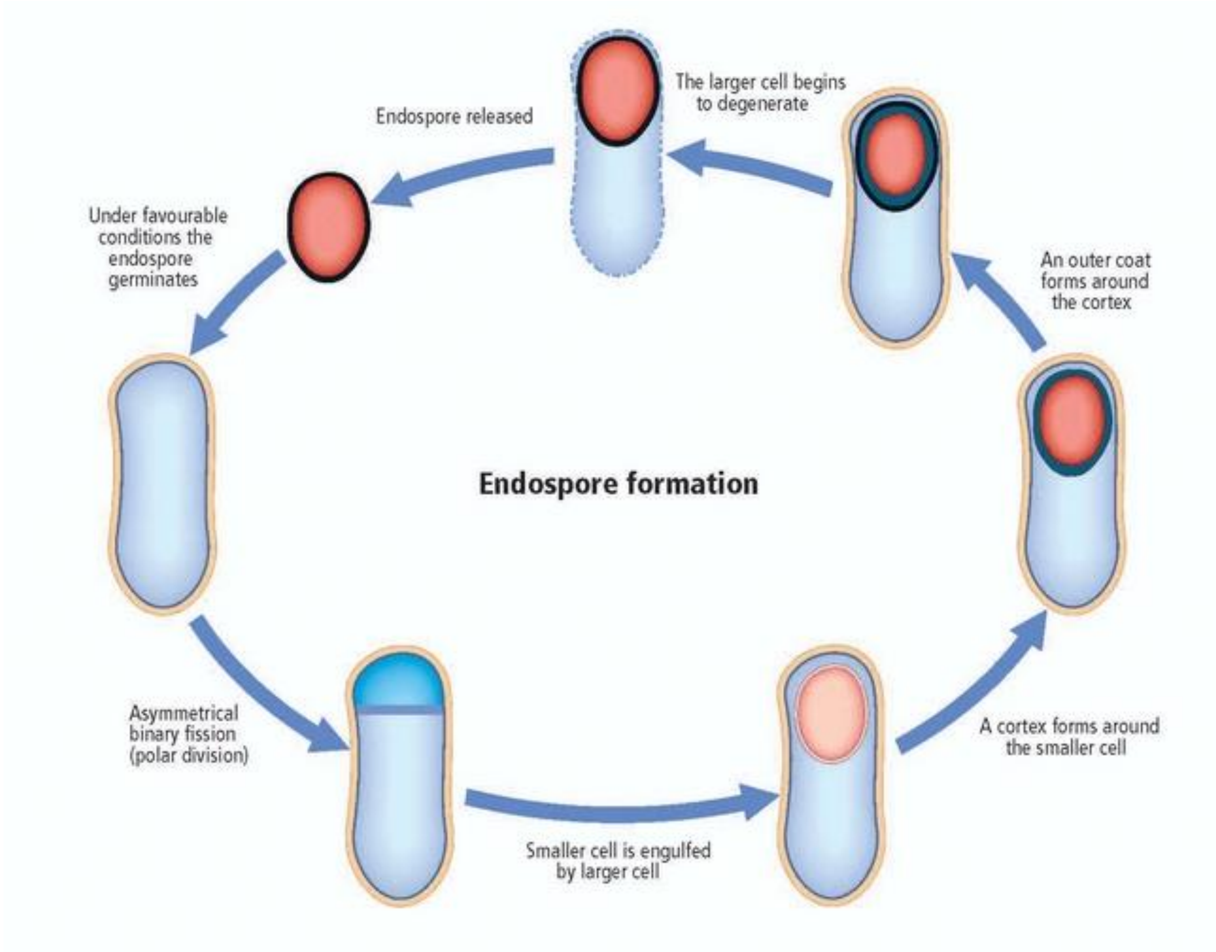
e) Coat

f) *Exosporium, a facultative external structure present only in some bacterial spores



Unlike vegetative cells, endospores contain **dipicolinic acid** and a large quantity of **calcium ions** (Ca^{2+}). Dipicolinic acid forms a complex with calcium ions within the endospore core. This complex binds free water molecules, causing dehydration of the spore. As a result, the heat resistance of macromolecules within the core increases. The calcium-dipicolinic acid complex also functions to protect DNA from heat denaturation, thereby increasing the stability of DNA.

(الشكل الاتي غير مطلوب)



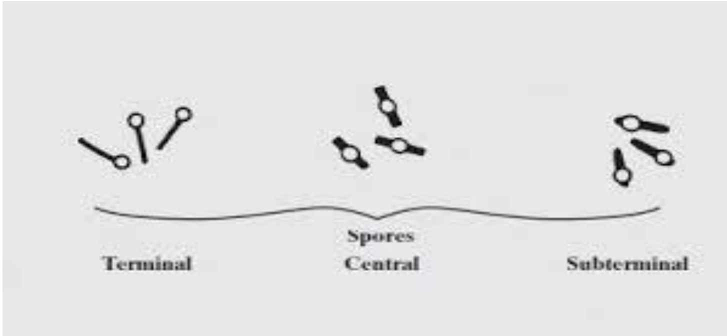
Formation of an endospore through the process of sporulation

<u>The location of the endospores in bacterial cell:-</u> **(الامثلة غير مطلوبة)**

1- Central/ e.g: *Bacillus cereus*

2- Terminal /e.g: *Clostridium tetani*

3- Subterminal/ e.g: *Clostridium botulinum*



External Structures (cell wall appendages)

1- **Glycocalyx**
2- **Pili (Fimbriae)**
3- **Flagella**

1- Glycocalyx (Slime Layer and Capsule)

Beyond the cell wall, some bacteria have an additional layer called the glycocalyx. The structural features and chemical composition of glycocalyces differ depending on the species of bacteria, but in general this additional layer may be composed of polysaccharides, polypeptides, or both and can come in one of two forms:

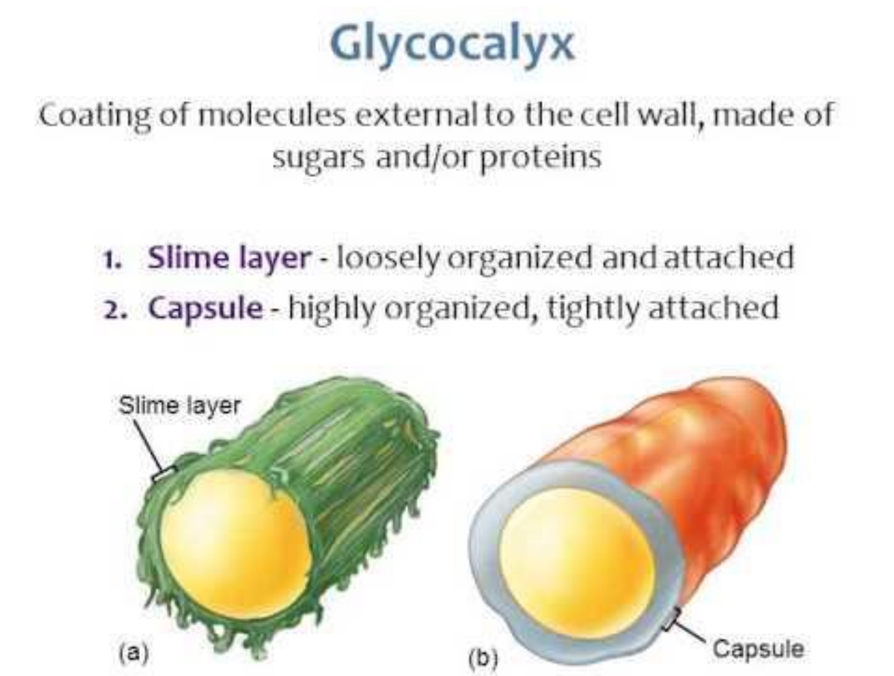
a- Slime Layer

A glycocalyx is considered a slime layer when the glycoprotein molecules are loosely associated with the cell wall. Bacteria that are covered with this loose shield are protected from dehydration and loss of nutrients.

b- Capsule

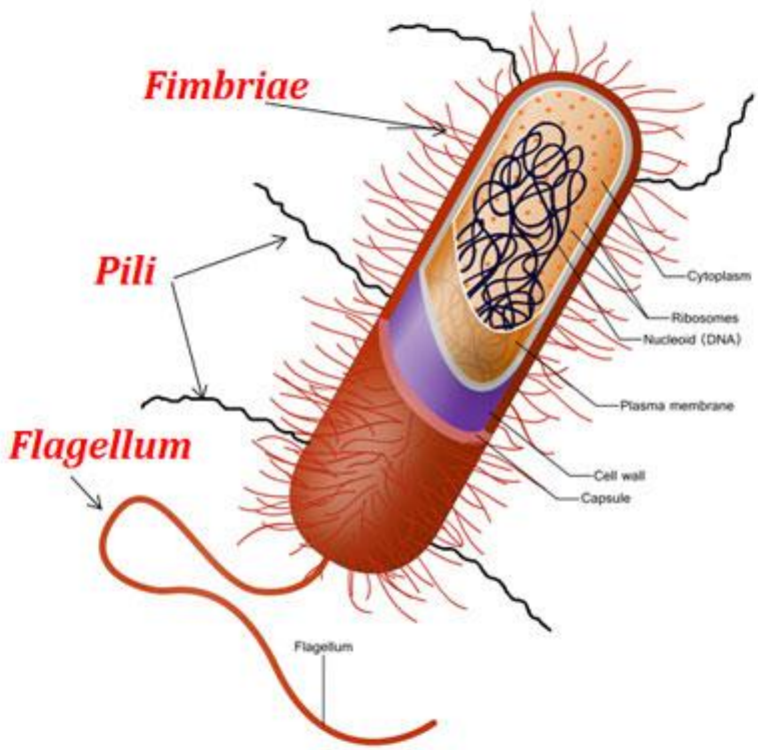
The glycocalyx is considered a capsule when the polysaccharides are more firmly attached to the cell wall. Capsules have a gummy, sticky consistency and provide protection as well as adhesion to solid surfaces and to nutrients in the environment.

*Bacteria that possess capsules are considered to be encapsulated, and generally have greater pathogenicity (ability to cause disease) because capsules **protect bacteria from phagocytosis** (white blood cells of the immune system). The adhesive power of capsules is also **a major factor in the initiation of some bacterial diseases.** **(الشكل غير مطلوب)**



2- Pili and Fimbriae

Pili and Fimbriae are filamentous structures composed of protein , that extend from the surface of a cell and can have many functions.



Cell-Surface Appendages of a Bacterial Cell

Difference between Fimbriae and Pili

Fimbriae (S., Fimbria)	Pili (S., Pilus)
Tiny, bristle-like fibers arising from bacterial cells	Hair-like microfibers on the surface of bacteria
Occur in both Gram-positive and Gram-negative bacteria	Occur in Gram-negative bacteria.
Around 200-400 fimbriae occur per bacterial cell	Only 1-10 pili occur per bacterial cell.
Made up of fimbrillin protein	Made up of pilin protein.
Governed by bacterial genes in the nucleoid region (chromosome)	Governed by plasmid genes.
Shorter	Longer
Thin	Thicker
Less rigid	More rigid
Attach the bacterium to the substrate	Aid in bacterial conjugation

3- Flagella

Flagella (singular: flagellum): thin hair-like appendages that protrude from the cell body of certain bacteria, often much longer than the cell itself, and used for locomotion in many bacteria (move the bacteria towards nutrients and other attractants). .

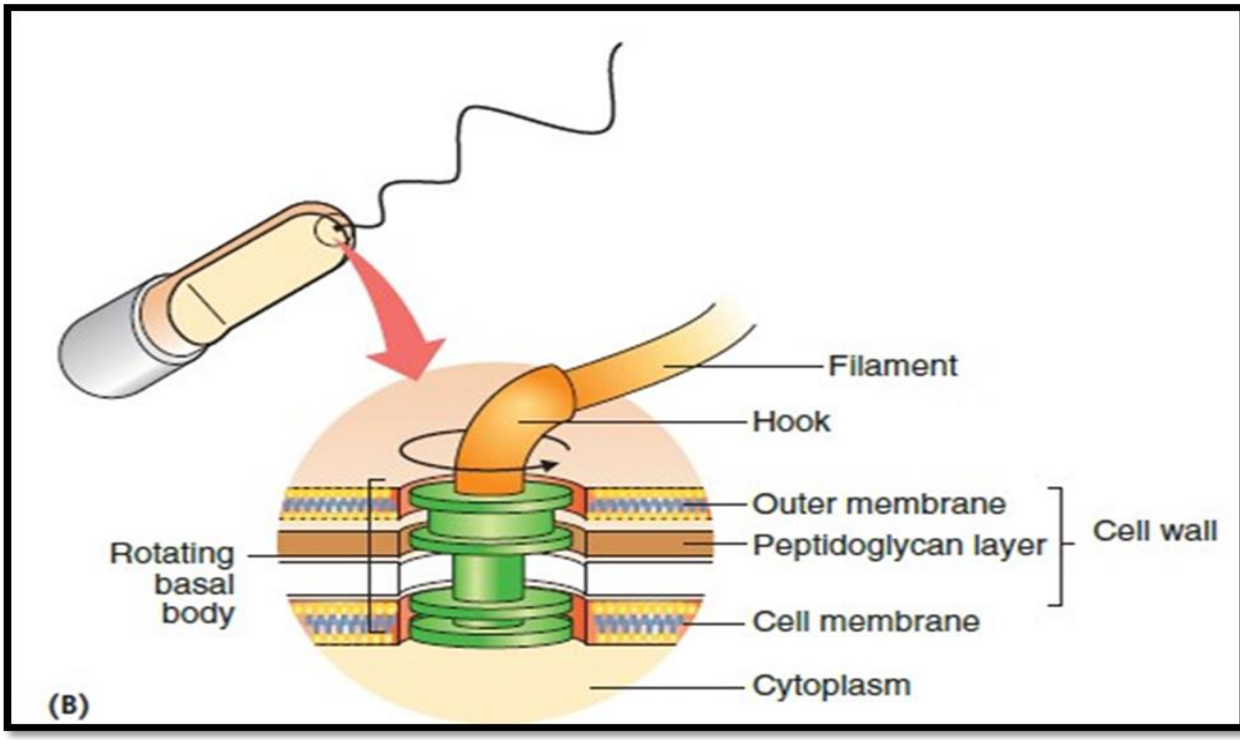
They consist of the three main components:

1- **Filament (helical propeller)**

2- **Hook (universal joint)**

3- **Basal body (rotary motor)**

(الشكل الاتى غير مطلوب)



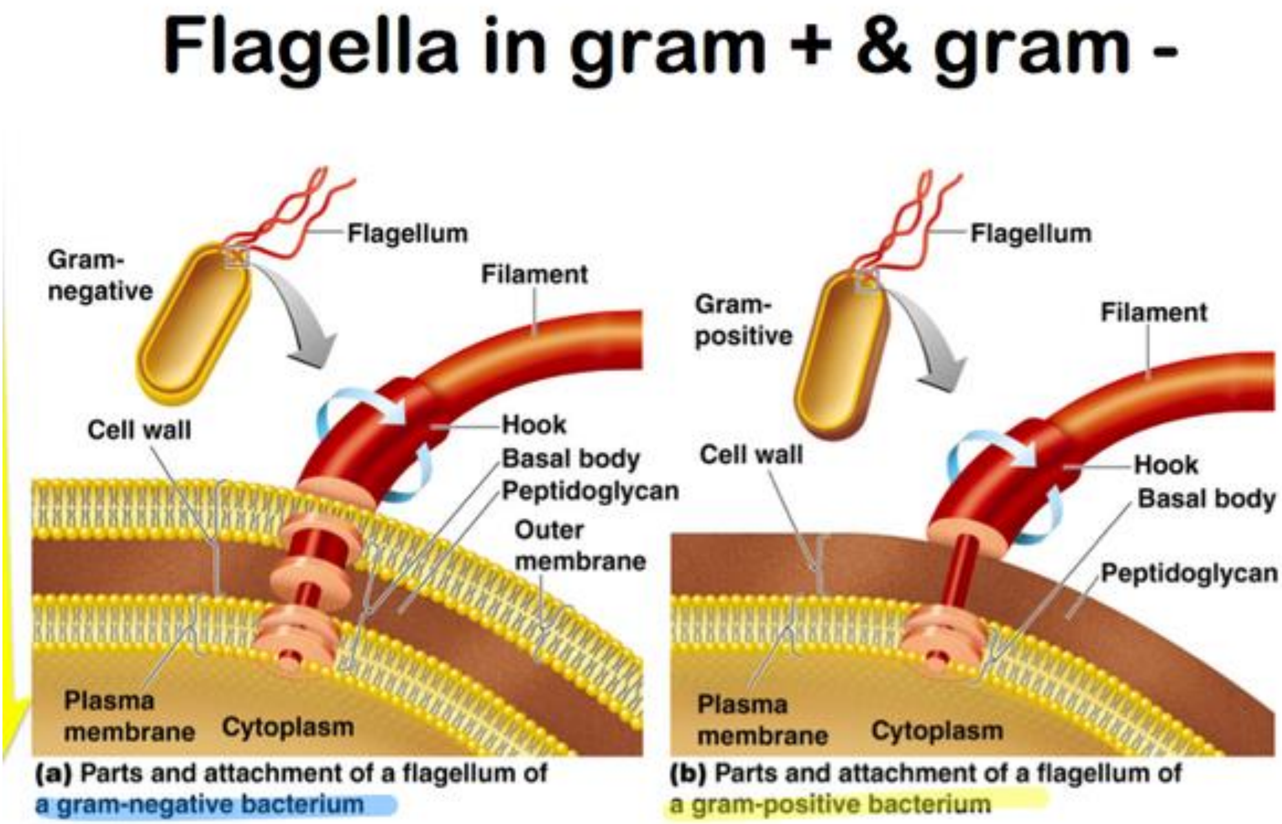
Structure of bacterial flagellum

***The filament** is the largest part, is about 20 nm in diameter, extends out to the cell's environment, and usually composed of many subunits of a single protein called **flagellin**.

***The hook:** is a short tubular structure, It is different in structure than that of the filament, It is connects the filament to the basal body.

The basal body consists of a central rod or shaft surrounded by a set of rings.

The flagellar structure of **Gram-positive bacteria** has two rings in the basal body. The flagellar structure of **Gram-negative bacteria** has four rings in the basal body. **(الشكل الاتي غير مطلوب)**



Gram Positive 2 rings in basal body -Gram Negative 4 rings in basal body.

Flagella arrangement schemes

Different species of bacteria have different numbers and arrangements of flagella:

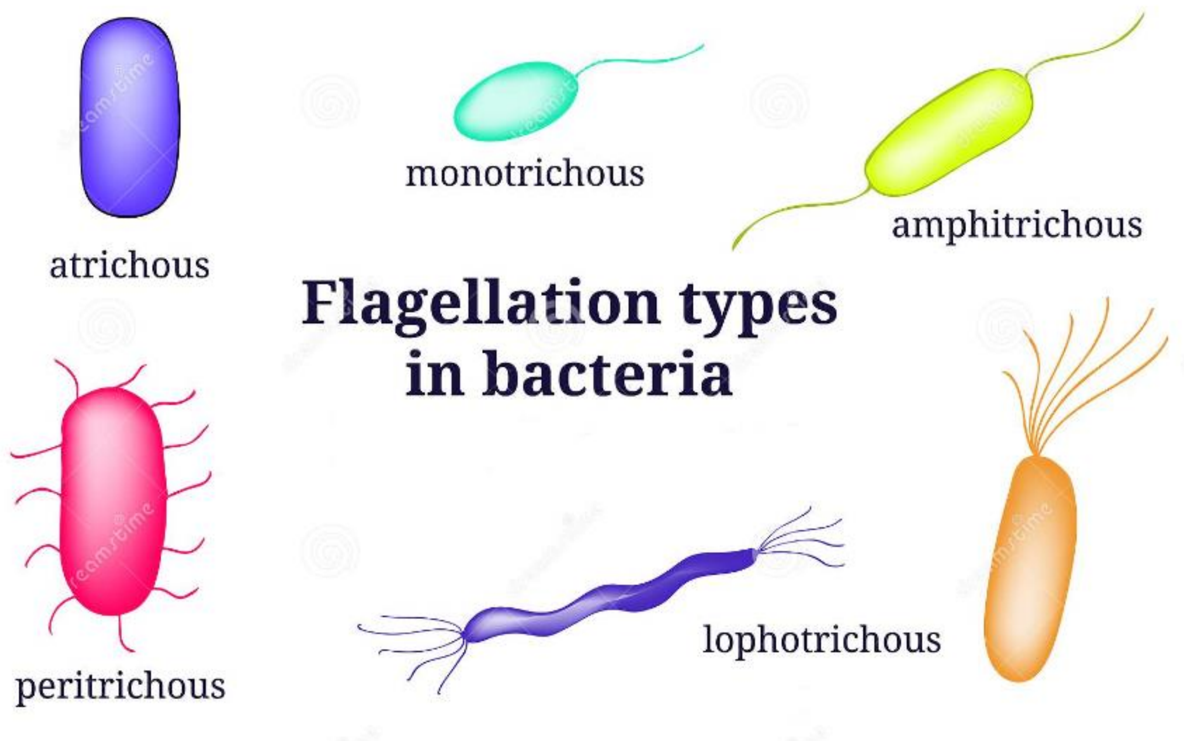
1- **Atrichous bacteria:** Flagella absent

2- **Monotrichous bacteria:** Single polar flagellum (e.g., *Vibrio cholera*).

3- **Amphitrichous bacteria:** Single flagellum at both ends.

4- **Lophotrichous bacteria:** tuft of flagella at one or both ends.

5- **Peritrichous bacteria:** Many flagella all over the body (e.g., *E. coli*).



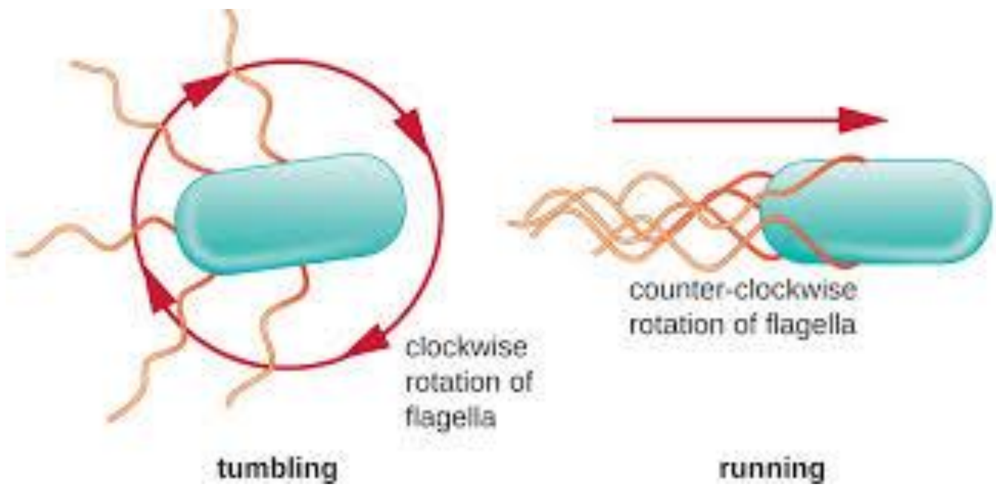
Types of flagellar arrangement

Rotation of the flagellum is an energy-dependent process driven by the basal body, and <u>the direction of rotation</u> determines <u>the nature of the resulting cellular movement</u>.

When flagella bundle together they rotate counterclockwise, and the bacteria run, or move in a straight line.

When the flagella rotate clockwise, the flagellar bundle comes apart, causing the bacterium to tumble randomly.

(الشكل الاتي غير مطلوب)



Bacterial movement occurs in response to stimuli (taxis).In the presence of favorable stimuli, the receptors that found on the surface of the cells, send signals to the flagella, which then adjust their speed and direction of rotation.

The stimulus may be:

- Light: **Phototaxis**
- Chemical like glucose: **Chemotaxis**
- Presence of Oxygen: **Aerotaxis**
- Response to magnetic field: **Magnetotaxi**