

Microbiology

The bacteria

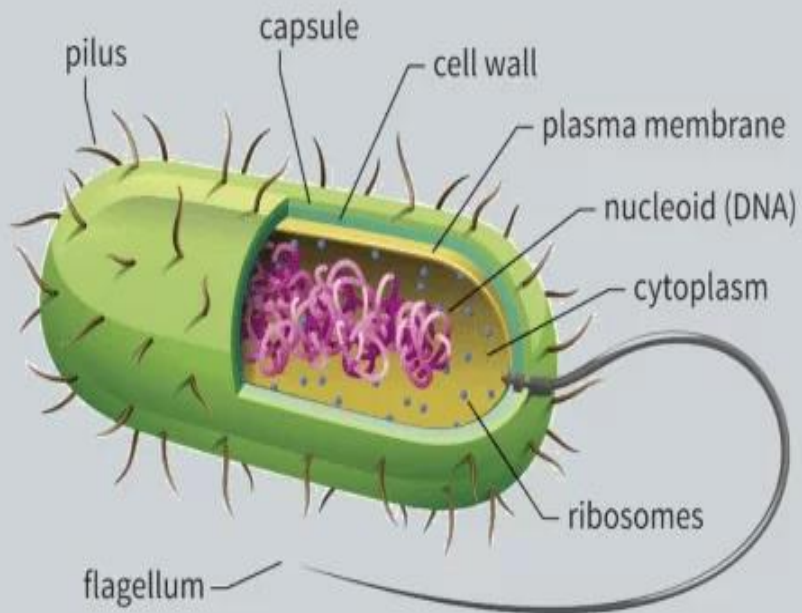
Asst. prof. Dr. Dhay Ali Azeez

2024-2025

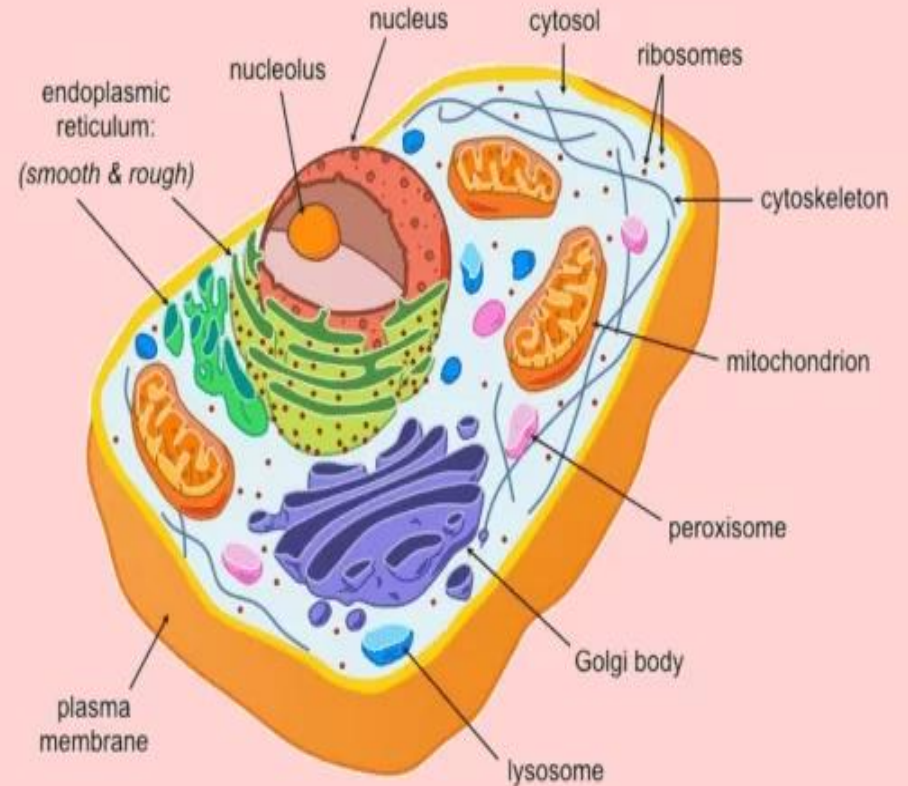
(1st) semester

2nd lecture

Prokaryotic cell



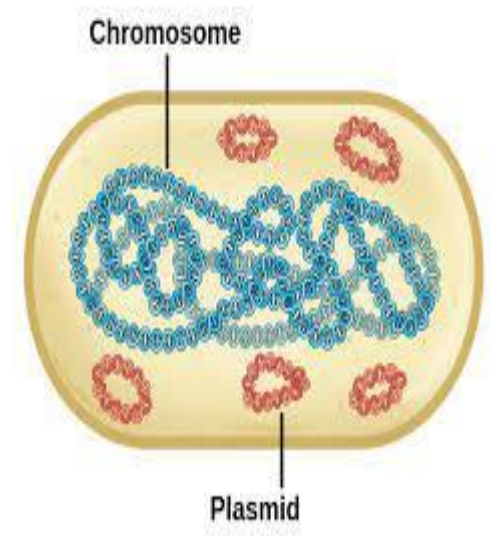
Eukaryotic cell



Eukaryote	Prokaryote
1-Have true nucleus	1 - Don't have nucleus
2- DNA is complex with histone proteins, have nuclear membrane.	2- Chromosome; is a single, circular molecule of double-stranded DNA, lacking a nuclear membrane.
3- Peptidoglycan is not present in the cell wall.	3- Peptidoglycan is present in the cell wall.
4- Divided by mitosis and meiosis	4- Divided by binary fission
5- 80S ribosomes	5- 70S ribosomes
6- Have mitochondria and chloroplasts.	6- Not have mitochondria and chloroplasts

✿ In **prokaryotes** the **bacterial genome**, or **chromosome**, is a single, circular molecule of double-stranded DNA, lacking a nuclear membrane (Smaller circular DNA molecules called **Plasmids** may also be present in bacteria)

✿ Whereas **the eukaryotic cell** has a true nucleus with multiple chromosomes surrounded by a nuclear membrane. Bacteria comprise the vast majority of human pathogens.



Bacteria

Bacteria (singular - bacterium) (The science that study of bacteria – **Bacteriology**)

1. Prokaryotic: The genetic material not enclosed in a special nuclear membrane.
2. Unicellular
3. Size: 1/1000 the volume of a typical eukaryotic cell
4. **Two groups (discovered in 1970's) - we'll discuss more later**
 - ☐ a. **Archaeobacteria** - ancient bacteria
 - ☐ b. **Eubacteria** - true bacteria
5. Motile or non motile
6. Temperature extremes: $-20\text{ }^{\circ}\text{C}$ to $110\text{ }^{\circ}\text{C}$ (that's really cold & really hot! freezing is $0\text{ }^{\circ}\text{C}$ and boiling is $100\text{ }^{\circ}\text{C}$)

7. The shape of a bacterium is determined by its rigid cell wall, The bacterial cell wall is made up of **peptidoglycan** consisting of **N-acetylmuramic acid and D-amino acids**.

8. Some shapes: **bacilli** (rod), **cocci** (spherical), **Spirillum** (spiral), **vibrio** (curved rod). Some bacteria with variable shapes, appearing both as coccal and bacillary forms, are called **Pleomorphic** (pleo:many; morphic: shaped) in appearance.

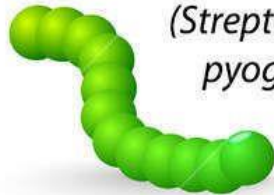
-May form in **singles, pairs, chains, clusters**, or other formations characteristic to a genus or species enclosed in cell walls composed of carbohydrate and protein complexes called peptidoglycans

SHAPES OF BACTERIA

COCCI



Diplococci
(*Streptococcus pneumoniae*)



Streptococci
(*Streptococcus pyogenes*)

Tetrad

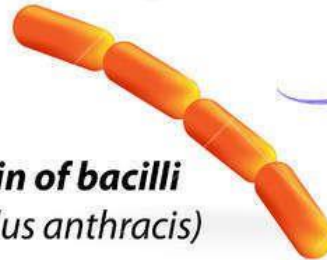


Staphylococci
(*Staphylococcus aureus*)

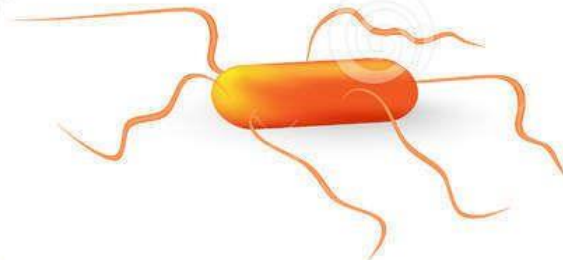


Sarcina
(*Sarcina ventriculi*)

BACILLI



Chain of bacilli
(*Bacillus anthracis*)



Flagellate rods
(*Salmonella typhi*)



Spore-former
(*Clostridium botulinum*)

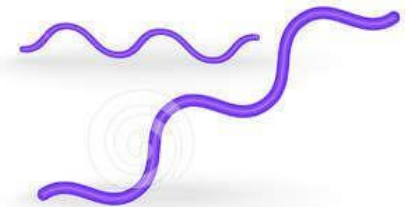
OTHERS



Vibrios
(*Vibrio cholerae*)



Spirilla
(*Helicobacter pylori*)



Spirochaetes
(*Treponema pallidum*)

9. How do they obtain their energy?

- a. **Photosynthetic autotrophs** - use energy from the sun to produce their own carbohydrates for energy.
- b. **Chemosynthetic autotrophs** - process inorganic molecules for energy (ex. sulfur or iron).
- c. **Heterotrophs** - depend on outside sources of organic molecules (ex. carbohydrates or sugars) for energy

10. Reproduce by cell division (**binary fission**) much like mitosis (Some bacteria are capable of forming spores that help them survive extreme conditions for a particular period of time).

11. The t-RNA in bacteria is **consist of Thymine**.

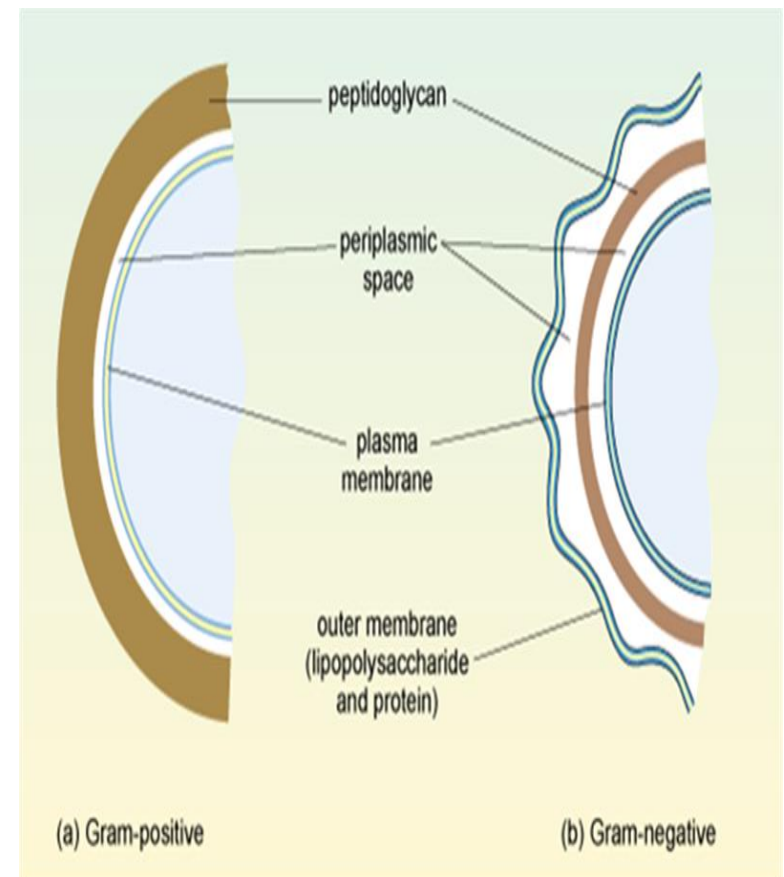
BACTERIAL CLASSIFICATION



(A): Classification on the basis of gram stain and Bacterial cell wall

- Of all the different classification systems, the gram stain has withstood the test of time. Discovered by H.C. Gram in 1884 it remains an important and useful technique to this day.
- It allows a large proportion of clinically important bacteria to be classified as either **Gram positive or negative** based on their morphology and differential staining properties.
- Slides are sequentially stained with crystal violet, iodine, then destained with alcohol and counterstained with safranin. Gram positive bacteria stain blue-purple and Gram negative bacteria stain red.

- **The difference between the two groups is believed to be due to a much larger peptidoglycan (cell wall) in Gram positives.** As a result the iodine and crystal violet precipitate in the thickened cell wall and **are not eluted by alcohol** in contrast with the Gram negatives where the crystal violet is **readily eluted** from the bacteria. As a result bacteria can be **distinguished** based on their morphology and staining properties.
- Some bacteria such as **mycobacteria** are **not reliably stained** due to the large lipid content of the peptidoglycan. Alternative staining techniques (**Kinyoun or acid fast stain**) are therefore used that take advantage of the resistance to destaining after lengthier initial staining.



(B): Classification of bacteria on the basis of shape

In the year 1872 scientist Cohn classified bacteria to 4 major types depending on their shapes are as follows:

A) Cocci: These types of bacteria are unicellular, spherical or elliptical shape. Either they may remain as a single cell or may aggregate together for various configurations. They are as follows:

1) **Monococcus**— they are also called **micrococcus** and represented by single, discrete round Example: ***Micrococcus flavus***.

2) **Diplococcus**— the cell of the Diplococcus divides ones in a particular plane and after division, the cells remain attached to each other. Example: ***Diplococcus pneumonia***.

3) **Streptococcus**: — here the cells divide repeatedly in one plane to form chain of cells. Example: ***Streptococcus pyogenes***.

4) **Tetracoccus**: — this consists of four round cells, which divided in two planes at a right angles to one another. Example: ***Gaffkya tetragena***.

Staphylococcus: — here the cells divided into three planes forming a structured like bunches of grapes giving an irregular configuration. Example: ***Staphylococcus aureus***.

5) **Sarcina**: -in this case the cells divide in three planes but they form a cube like configuration consisting of eight or sixteen cells but they have a regular shape. Example: ***Sarcina lutea***.

B) Bacilli: – These are rod shaped or cylindrical bacteria which either remain singly or in pairs. Example: ***Bacillus cereus***.

C) Vibrio: – The vibrio are the curved, comma shaped bacteria and represented by a single genus. Example: ***Vibrio cholerae***.

D) Spirilla: – These type of bacteria are spiral or spring like with multiple curvature and terminal flagella. Example: ***Spirillum volutans***.

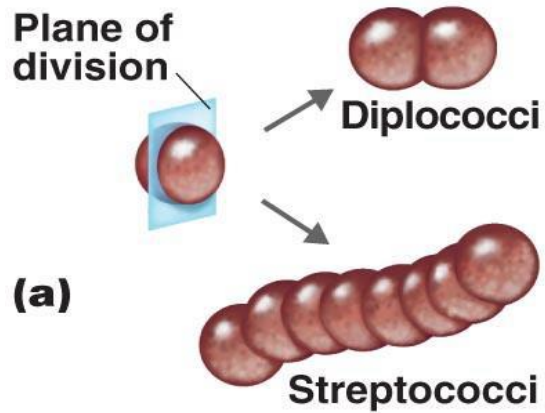
E) Others:-

Actinomycetes are branching filamentous bacteria, so called because of a fancied resemblance to the radiating rays of the sun when seen in tissue lesions (from actis meaning ray and mykes meaning fungus).

Mycoplasmas are bacteria that are cell wall deficient and hence do not possess a stable morphology. They occur as round or oval bodies and as interlacing filaments.

Bacterial shapes and arrangements

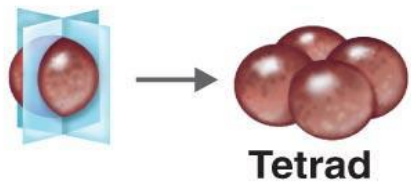
 Coccus		 Rod, or Bacillus		 Curved forms: Spirillum/Spirochete
 Diplococci (cocci in pairs)	 Neisseriae (coffee-bean shape in pairs)	 Coccobacilli		 Vibrios (curved rods)
 Tetrads (cocci in packets of 4)	 Sarcinae (cocci in packets of 8, 16, 32 cells)	 Mycobacteria	 Corynebacteria (palisades arrangement)	 Spirilla
 Streptococci (cocci in chains)	 Micrococci and staphylococci (large cocci in irregular clusters)	 Spore-forming rods	 Streptomyces (moldlike, filamentous bacteria)	 Spirochetes



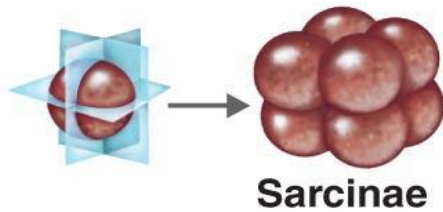
(a)



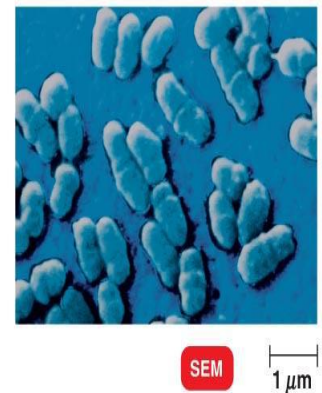
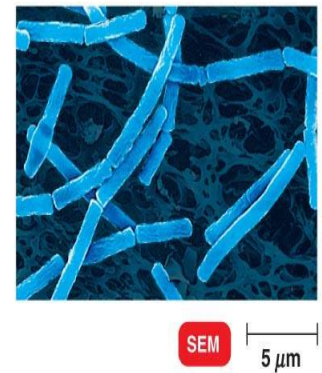
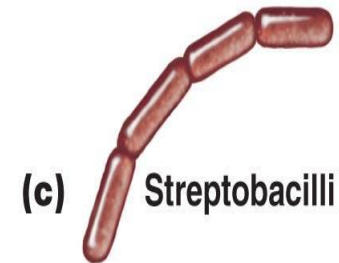
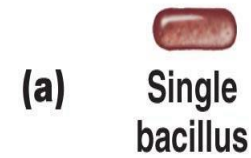
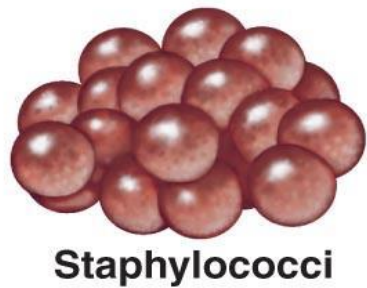
(b)



(c)



(d)



(C): Classification on the basis of Mode of Nutrition

1. Phototrophs:

Those bacteria which gain **energy from light**. Phototrophs are further divided into two groups on the basis of source of electron.

- **Photolithotrophs:** these bacteria gain energy from light and use reduced inorganic compounds such as H_2S as electron source.
- **Photoorganotrophs:** these bacteria gain energy from light and use organic compounds such as succinate as electron source.

2. Chemotrophs:

Those bacteria gain energy from chemical compounds. They cannot carry out photosynthesis. Chemotrophs are further divided into two groups on the basis of source of electron.

- **Chemolithotrophs:** they gain energy from oxidation of chemical compound and reduce inorganic compounds such as NH_3 as electron source.
- **Chemoorganotrophs:** they gain energy from chemical compounds and use organic compound such as glucose and amino acids as source of electron.

3. Autotrophs:

Those bacteria which uses carbon dioxide as sole source of carbon to prepare its own food.

Autotrophs are divided into two types on the basis of energy utilized to assimilate carbondioxide.

- **Photoautotrophs:** they utilized light to assimilate CO₂. They are further divided into two group on the basis of electron sources. Ie. **Photolithotropic autotrophs** and **Photoorganotropic autotrophs**
- **Chemoautotrophs:** They utilize chemical energy for assimilation of CO₂.

4. Heterotrophs:

- Those bacteria which uses organic compound as carbon source.
- They lack the ability to fix CO₂. Most of the human pathogenic bacteria are heterotrophic in nature.
- Some heterotrophs are simple, because they have simple nutritional requirement.
- However there are some bacteria that require special nutrients for their growth; known as **fastidious heterotrophs**.

(D): Classification of bacteria on the basis of temperature Requirement

Bacteria can be classified into the following major types on the basis of their temperatures response as indicated below:

1. Psychrophiles:

- Bacteria that can grow at 0°C or below but the optimum temperature of growth is 15°C or below and maximum temperature is 20°C are called psychrophiles.
- Psychrophiles have polyunsaturated fatty acids in their cell membrane which gives fluid nature to the cell membrane even at lower temperature.

2. Psychrotrops (facultative psychrophiles):

Those bacteria that can grow even at 0°C but optimum temperature for growth is $(20-30)^{\circ}\text{C}$

3. Mesophiles:

- Those bacteria that can grow best between $(25-40)^{\circ}\text{C}$ but optimum temperature for growth is 37°C .
- Most of the human pathogens are mesophilic in nature.

4. Thermophiles:

- Those bacteria that can best grow above 45C.
- Thermophiles capable of growing in mesophilic range are called facultative thermophiles.
- True thermophiles are called as **Stenothermophiles**, they are obligate thermophiles,
- Thermophiles contain saturated fatty acids in their cell membrane so their cell membrane does not become too fluid even at higher temperature.

5. Hyper thermophiles:

- Those bacteria that have optimum temperature of growth above 80C.
- Mostly Archeobacteria are hyperthermophiles.
- Monolayer cell membrane of Archeobacteria is more resistant to heat and they adapt to grow in higher temperature.

(E): Classification of bacteria on the basis of Oxygen Requirement

- 1) **Aerobes:** Require oxygen to live.
- 2) **Facultative Anaerobes:** Can use oxygen, but can grow in its absence. They have complex set of enzymes.
- 3) **Obligate Anaerobes:** Cannot use oxygen and are harmed by the presence of toxic forms of oxygen.
- 4) **Aerotolerant Anaerobes:** Cannot use oxygen, but tolerate its presence. Can break down toxic forms of oxygen.
- 5) **Microaerophiles:** Require oxygen, but at low concentrations. Sensitive to toxic forms of oxygen.

(F): Classification of bacteria on the basis of pH of Growth

1. Acidophiles:

- These bacteria grow best at an acidic pH.
- The cytoplasm of these bacteria are acidic in nature.
- Some acidophiles are thermophilic in nature, such bacteria are called **Thermoacidophiles**.

2. Alkaliphiles: These bacteria grow best at an alkaline pH. Ex: *Vibrio cholerae* (PH is 8.2).

3. Neutrophiles: These bacteria grow best at neutral pH (6.5-7.5). Ex: *E. coli*

(G): Classification of bacteria on the basis of Spore formation

- 1. Spore forming bacteria:** Those bacteria that produce spore during unfavorable condition. These are further divided into two groups:
 - i) Endospore forming bacteria:** Spore is produced within the bacterial cell. Ex: *Clostridium*
 - ii) Exospore forming bacteria:** Spore is produced outside the cell. Ex: *Methylosinus*
- 2. Non sporing bacteria:** Those bacteria which do not produce spores. Ex: *E. coli*.

(H): Classification of bacteria on the basis of Number of Flagella

1. **Atrichos:-** These bacteria have no flagella. Example:

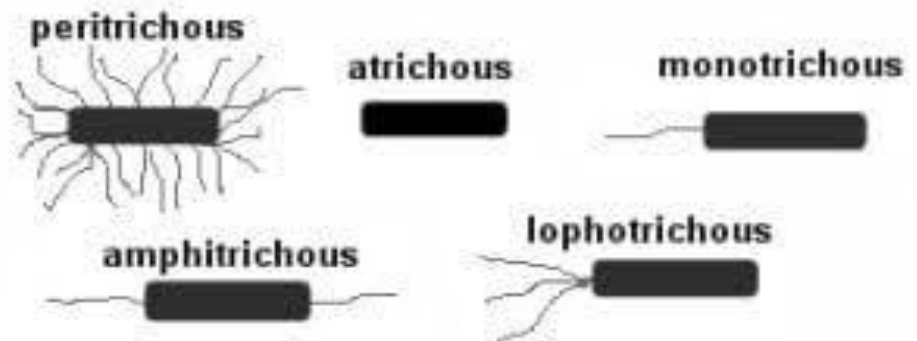
Corynebacterium diphtheriae.

2. **Monotrichous:-** One flagellum is attached to one end of the bacteria cell. Ex: *Vibrio cholerae*.

3. **Lophotrichous:-** Bunch of flagella is attached to one end of the bacteria cell. Ex: *Pseudomonas*.

4. **Amphitrichous:-** bunch of flagella arising from both ends of the bacteria cell. Ex: *Rhodospirillum rubrum*

5. **Peritrichous:-** the flagella are evenly distributed surrounding the entire bacterial cell. Ex: *Bacillus*



BACTERIAL MORPHOLOGY AND STRUCTURE



Structure of Bacteria

Essential structures

Cell wall

Cell membrane

Cytoplasm

Nuclear material

Particular structures

Capsule

Flagella

Pilli

Spore

Uptake of Nutrients

- Microbes can only take in dissolved particles across a selectively permeable membrane
- Some nutrients enter by passive diffusion
- Microorganisms use transport mechanisms
 - Facilitated diffusion – all microorganisms
 - Active transport – all microorganisms
 - Group translocation – Bacteria and Archaea
 - Endocytosis – Eukarya only

Bacterial Cell Organization Common Features

1. Cell envelope (2 layers)

- Cell wall
- Cell membrane

3. External structures

- Layers outside the cell – glycocalyx (capsule, S layer, slime layer)
- Flagella
- Fimbriae

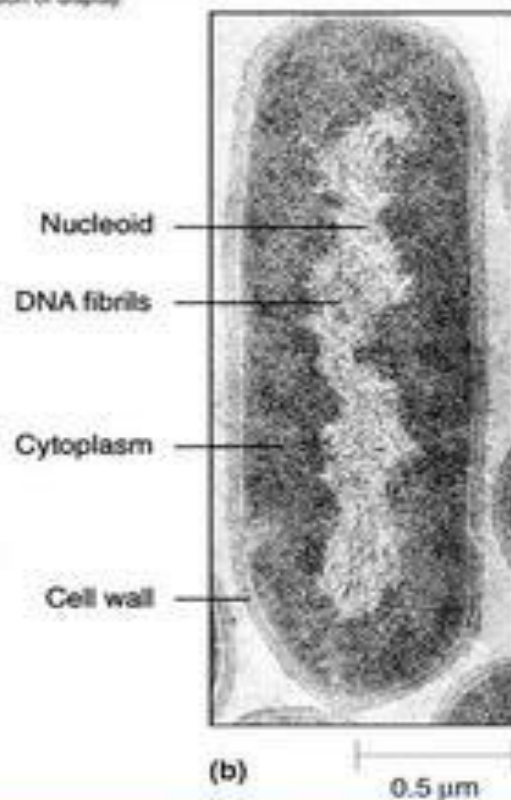
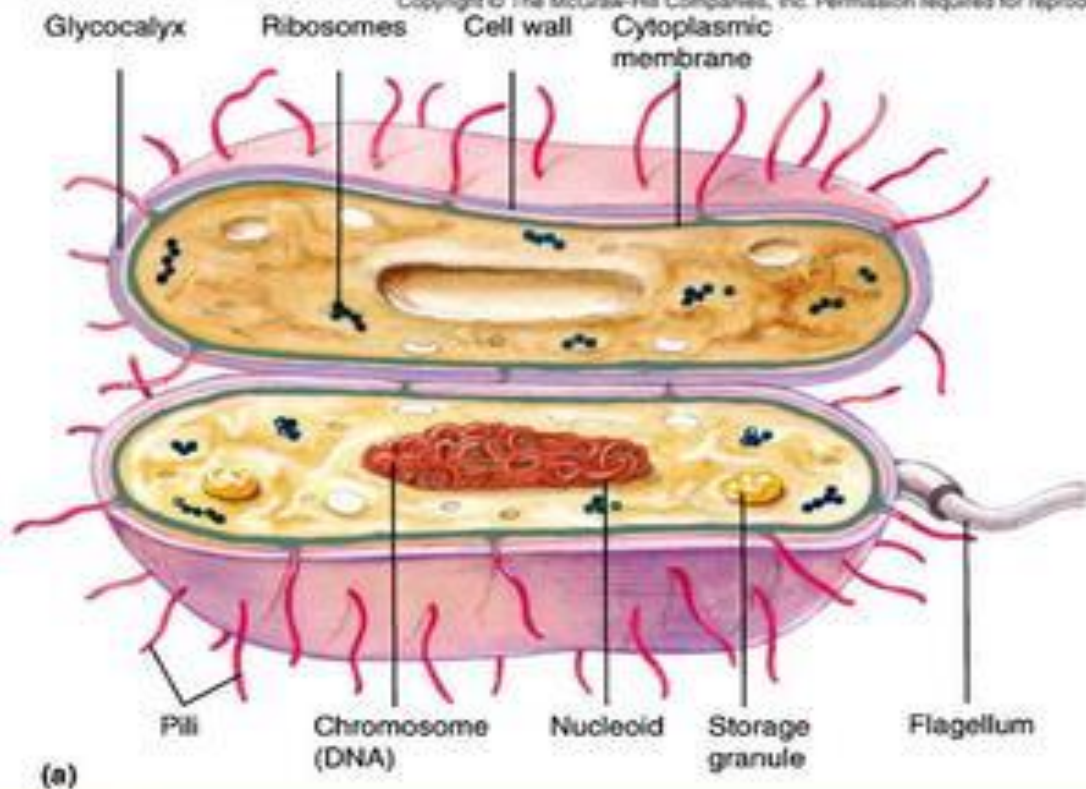
2. Internal structure

□ Cytoplasm

- Nucleoid chromosome and plasmids
- Ribosomes
- Inclusion bodies
- Actin Cytoskeleton
- Cytoplasmic matrix
- Endospore

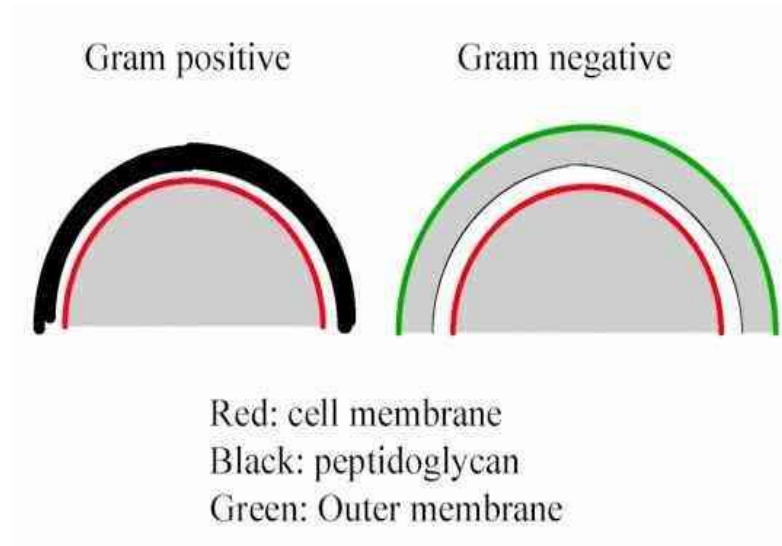
Typical Prokaryotic Cell

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Cell Envelope

- The cell envelope is all the layers from the cell membrane outward, including the cell wall, the periplasmic space, the outer membrane, and the capsule.
- All free-living bacteria have a cell wall
- Periplasmic space and outer membrane are found in Gram-negatives
- The capsule is only found in some strains



A. Structures External to the Cell Wall

(1): Glycocalyx

Coating of molecules **external to the cell wall**, made of sugars and/or proteins. two types:

Slime layer - loosely organized and attached

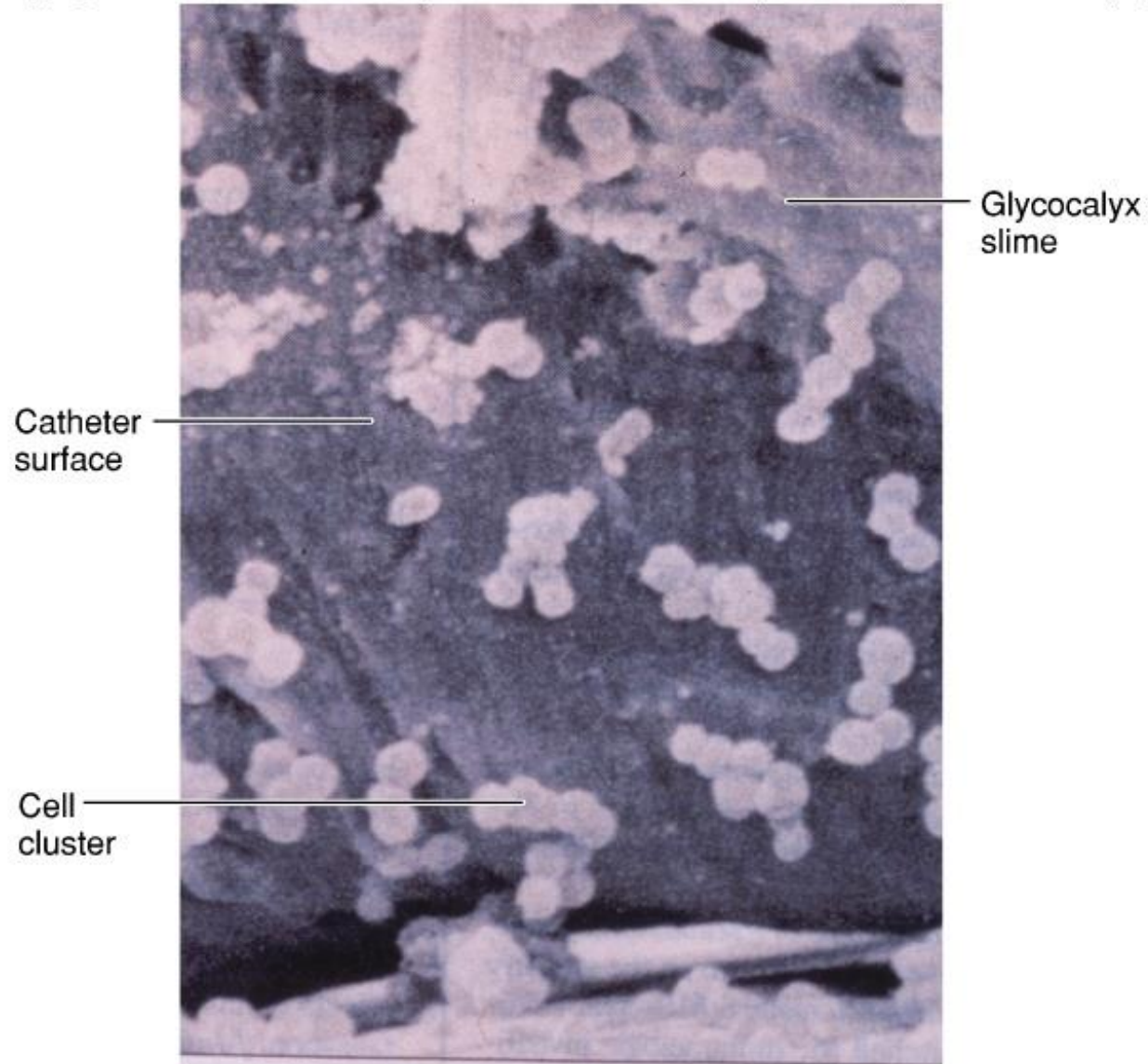
Capsule - highly organized, tightly attached

Functions:

- Protect cells from dehydration and nutrient loss
- Inhibit killing by white blood cells by phagocytosis, contributing to pathogenicity
- May allow bacteria to attach to a surface on teeth - formation of **biofilms** ex: *Streptococcus mutans*

Biofilm on a catheter

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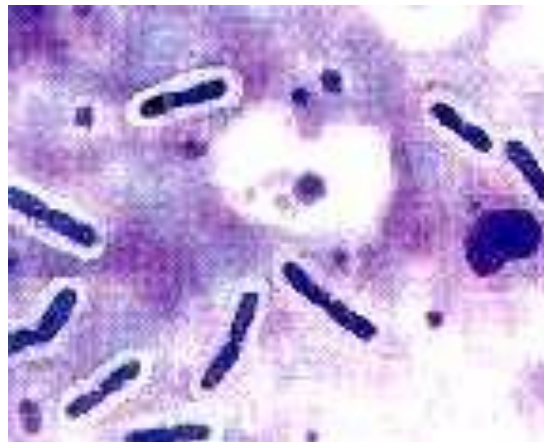


(2): Capsules and slime layers

- These are structures surrounding **the outside of the cell envelope** (usually more substantial than the glycocalyx).
- They usually consist of polysaccharide; however, and sometimes protein (e.g: *Bacillus anthrax*).
- They are not essential to cell viability and some strains within a species will produce a capsule, whilst others do not.
- Capsules are often lost during *in vitro* culture.

Functions:

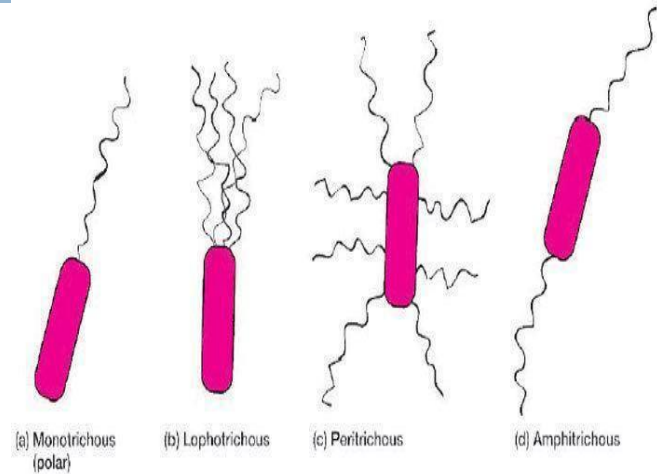
- **Attachment**
- **Protection from phagocytic engulfment.**
- **Resistance to drying.**
- **Depot for waste products.**
- **Reservoir for certain nutrients.**
- **protection**



(3):Flagella: long filamentous (thread-like) appendages used by bacteria for movement

a. Arrangement of flagella

- 1) Monotrichous
- 2) Amphitrichous
- 3) Lophotrichous
- 4) Peritrichous



- A few pathogenic bacteria use their flagella to invade the surface of mucous membranes during infections. ***Helicobacter pylori***, the agent of gastric ulcers, bores through the stomach lining, and ***Vibrio cholerae***, the cause of cholera, penetrates the small intestine with the help of its flagellum.

b. Structure of flagella (3 parts):

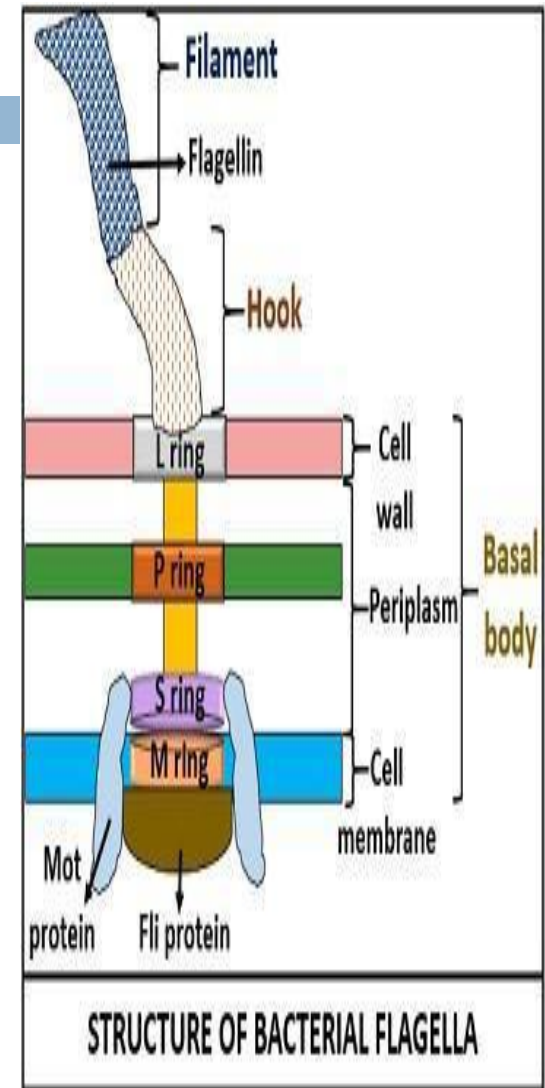
1) **Filament:** long, threadlike, outer most part. Made of a protein called **flagellin** (which may not be exactly the same in all bacteria).

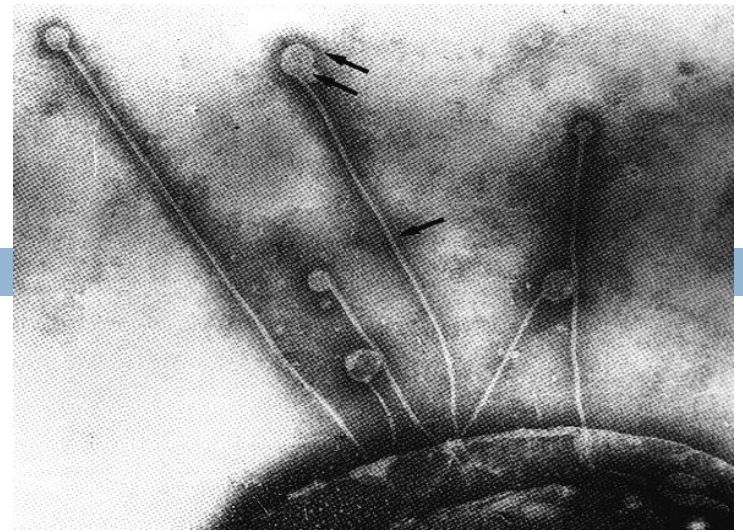
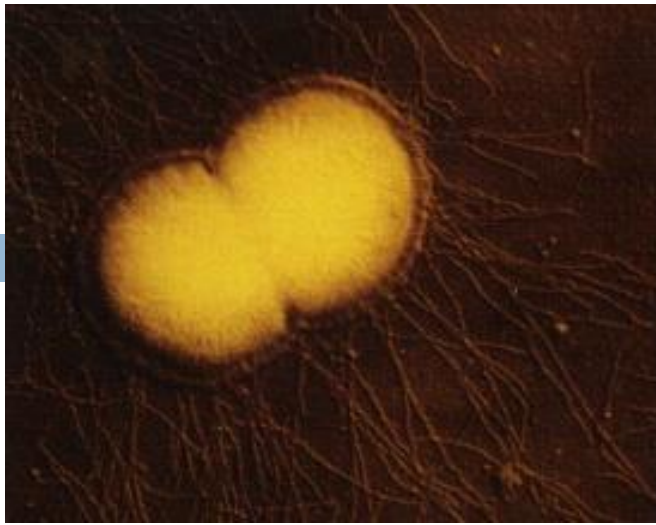
2) **Hook:** connects filament and basal body

3) **Basal body:** anchors flagellum to cell wall and plasma membrane.

c. **Movement** is produced by **rotation of the basal body**. Bacteria possessing flagella can use them to move toward a favorable environment or away from harm. Flagella often function as more than just a locomotor device. They are sensory appendages that can detect and respond to environmental signals. When the signal is of a chemical nature, the behavior is called chemotaxis.* Positive chemotaxis is movement of a cell in the direction of a favorable chemical stimulus (usually a nutrient); negative chemotaxis is movement away from a repellent (potentially harmful) compound.

d. The flagellar protein called **H antigen** can be used for distinguishing variations within a species of gram-negative bacteria.





(4): Pili: are hair-like projections of the cell , They are known to be receptors for certain bacterial viruses. Chemical nature is **pilin**. They are shorter and thinner than flagella, and are used for attachment (not motility). They are found on some gram-negative bacteria.

Classification and Function

(a): Common pili or fimbriae: fine , Fimbriae-vary from a few to several hundred---used for attachment to surfaces, such as mucous membranes

(b): Sex Pili: longer and coarser, only 1-4, related to bacterial conjugation (transfer of DNA).

(5)Fimbriae: are small, bristle like fibers emerging from the surface of many types of bacterial cells. Their exact composition varies, but most of them contain protein. Fimbriae have an inherent tendency to stick to each other and to surfaces. They may be responsible for the mutual clinging of cells that leads to biofilms

- Some pathogens can colonize and infect host tissues because of a tight adhesion between their fimbriae and epithelial cells.
- For example, *Escherichia coli* colonizes the intestine and begins its invasion of tissues by this means. Mutant forms of these pathogens that lack fimbriae are unable to cause infections.

(B): The Bacterial Cell wall:

The structure, chemical composition, and thickness of the cell wall differ in gram-positive and gram-negative bacteria:

(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** that protrude outside the peptidoglycan, whereas gram-negative bacteria do 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 Bacterial Cell wall:

Gram -ve bacteria, it is composed of:

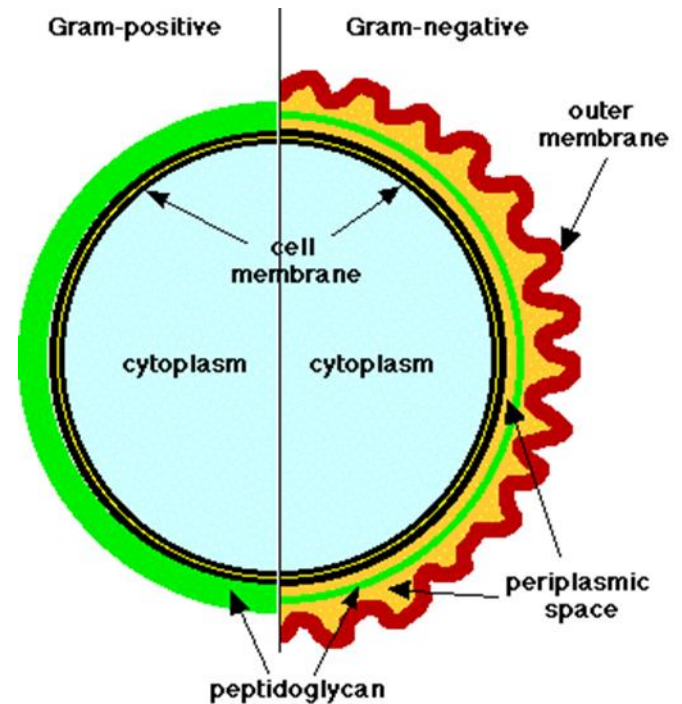
Outer membrane

Periplasmic space

Cytoplasmic membrane.

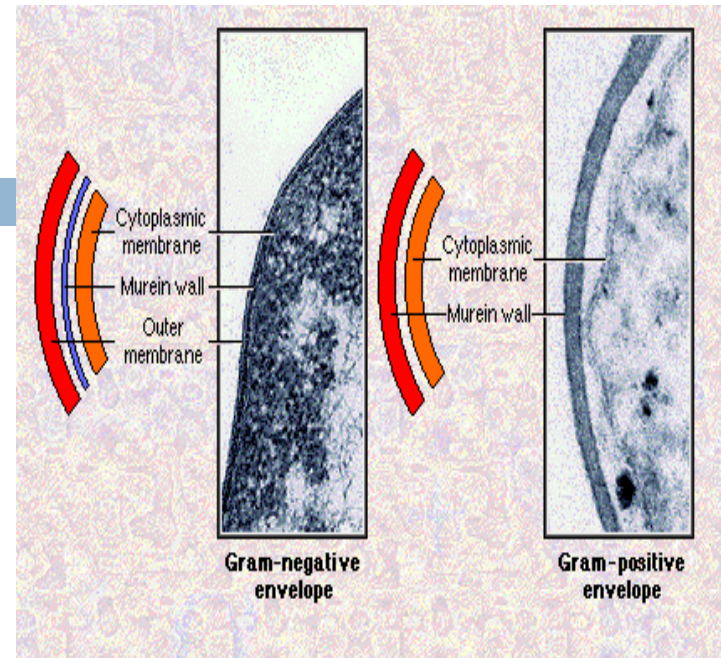
Gram +ve bacteria:

- 1) Thick compact peptidoglycan layer
- 2) No Outer membrane layer
- 3) No periplasmic space,
- 4) Cytoplasmic membrane.

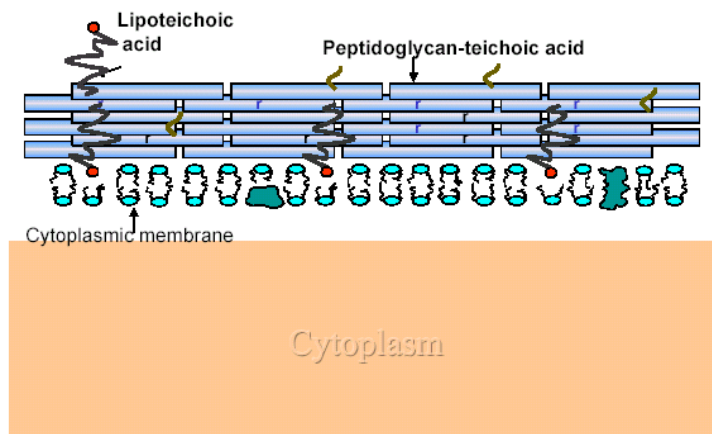


Cell wall

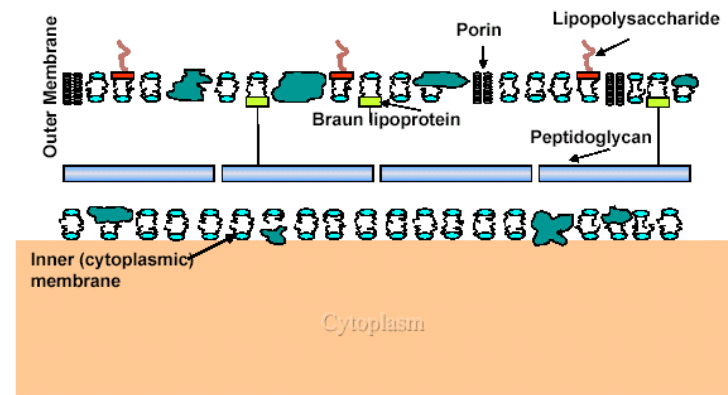
- Situation: The cell wall is the outermost component common to all bacteria (except *Mycoplasma* species, which are bounded by a cell membrane, not a cell wall).
- 15-30nm in thickness, 10%-25% of dry weight.



Gram Positive Cell Envelope



Gram Negative Cell Envelope

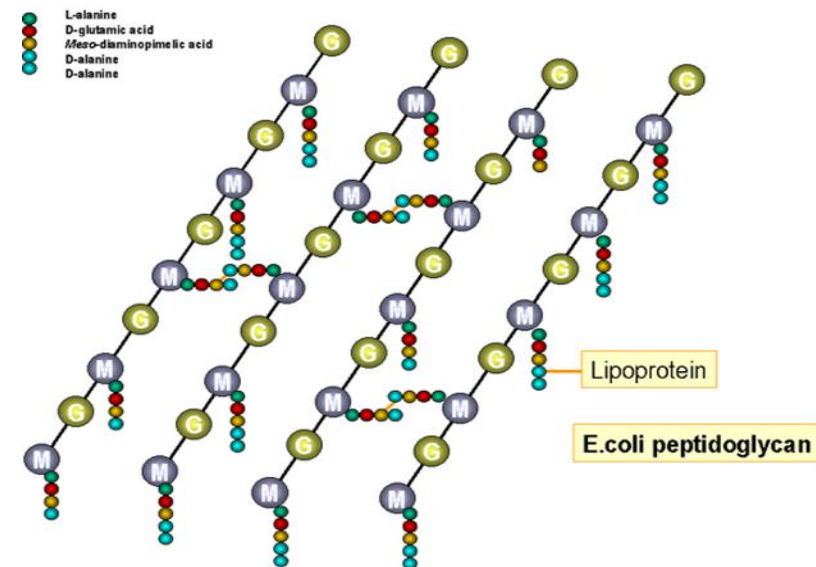
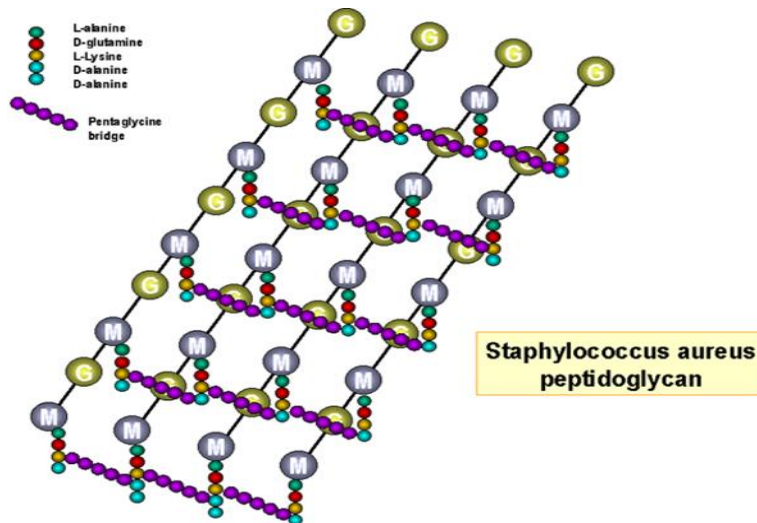


Functions of Cell Wall

1. Maintaining the cell's characteristic shape- the rigid wall compensates for the flexibility of the **phospholipid membrane** and keeps the cell from assuming a spherical shape
2. Countering the effects of **osmotic pressure**
3. Providing **attachment sites** for bacteriophages
4. Providing a rigid platform for surface appendages- **flagella, fimbriae, and pili** all emanate from the wall and extend beyond it
5. Play an essential role in **cell division**
6. 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
6. Its polysaccharides and proteins are antigens that are useful in laboratory identification.
7. In gram-negative bacteria, it contains **endotoxin**
8. **Resistance of Antibiotics**

Cell wall :Common peptidoglycan layer

- The term peptidoglycan is derived from the peptides and the sugars (glycan) that make up the molecule. Synonyms for peptidoglycan are murein and mucopeptide.
- A backbone of **N-acetyl glucosamine** and **N-acetylmuramic acid**: Both discovered in Gram positive and Gram negative bacteria.
- A set of identical **tetrapeptide side chain** attached to N-acetyl-muramic acid: different components and binding modes in Gram positive and Gram negative bacteria.
- A set of identical peptide **cross bridges**: only in Gram positive bacteria



- Because peptidoglycan is present in bacteria but not in human cells, it is a good target for antibacterial drugs. Several of these drugs, such as penicillins, cephalosporins, and vancomycin, inhibit the synthesis of peptidoglycan by inhibiting the transpeptidase that makes the cross-links between the two adjacent tetrapeptides
- 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. However, if the lysozyme-treated cells are in a solution with the same osmotic pressure as that of the bacterial interior, they will survive as spherical forms, called **protoplasts**, surrounded only by a cytoplasmic membrane.

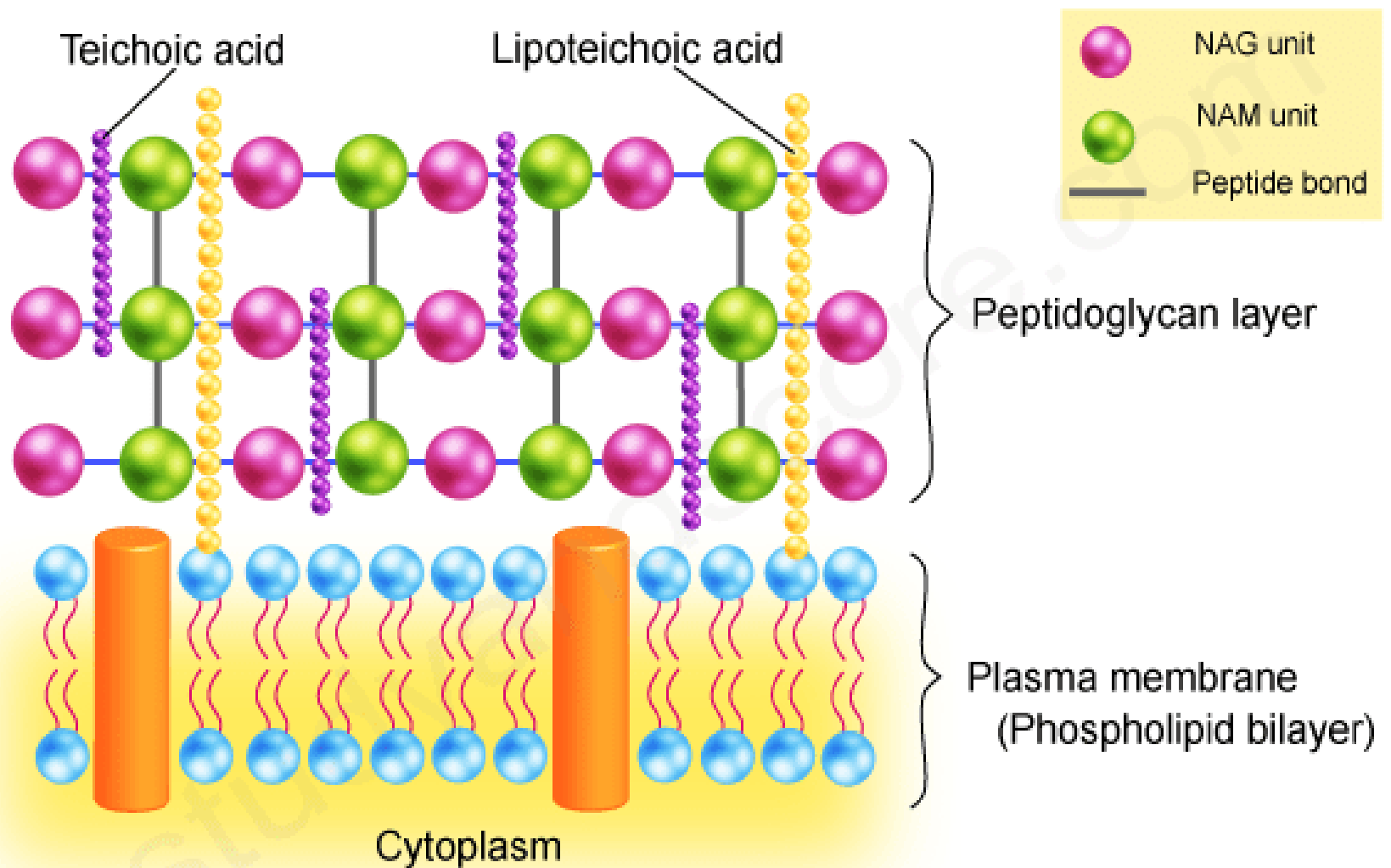
The cell wall of Gram Positive bacteria

Characterized by the following:

- No Outer membrane layer
- Cytoplasmic membrane
- **Thick** compact **Peptidoglycan** layer
- May also contain **teichoic acids (negatively charged)** help maintain cell envelope , protect from environmental substances may bind to host cells
- Some gram-positive bacteria have layer of proteins on surface of peptidoglycan
- Periplasm has relatively **few proteins**
- Enzymes secreted by Gram-positive bacteria are called **exoenzymes** aid in degradation of large nutrients

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, in which case they are called **lipoteichoic acid**; others anchor to the muramic acid of the peptidoglycan.
- The medical importance of teichoic acids lies in their ability to induce **inflammation and septic shock** when caused by certain gram-positive bacteria; that is, they activate the same pathways as does endotoxin (LPS) in gram-negative bacteria.
- Teichoic acids also mediate the attachment of staphylococci to mucosal cells.
- Gram-negative bacteria do not have teichoic acids.

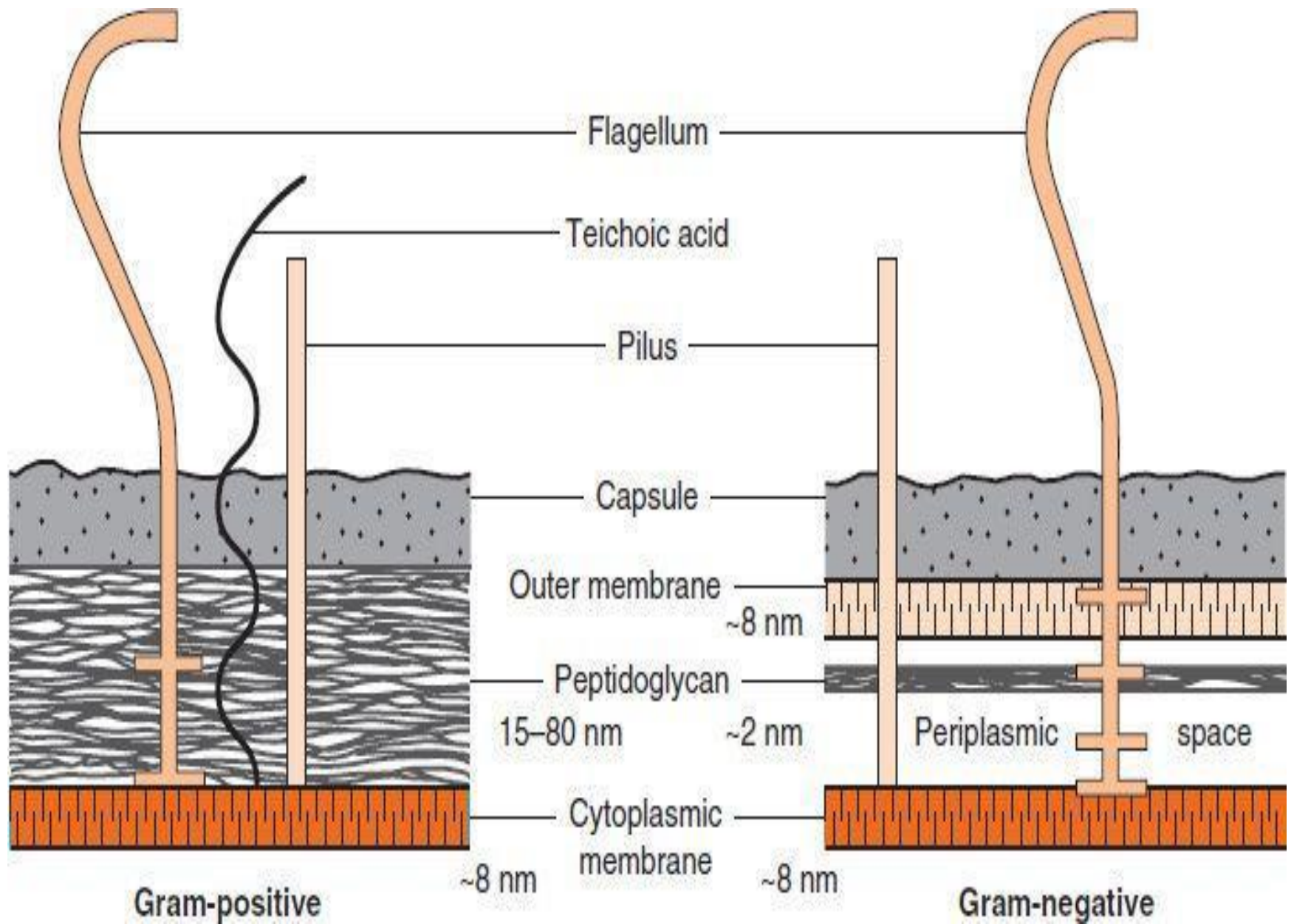


CELL WALL STRUCTURE OF GRAM POSITIVE BACTERIA

The cell wall of Gram Negative bacteria

- **More complex** than Gram- positive
- Consist of a **thin layer of peptidoglycan** surrounded by an outer membrane
- **Outer membrane** composed of lipids, lipoproteins, and lipopolysaccharide (LPS)
- **No** teichoic acids
- Peptidoglycan is **~5-10%** of cell wall weight
- **Periplasmic space** differs from that in Gram-positive cells
- may constitute **20–40%** of cell volume
- many enzymes present in periplasm (hydrolytic enzymes, transport proteins and other protein)





Outer membrane (present in Gram negative only):

- Important to protect against environment (digestive enzymes).
- Maintain bacterial structure,
- Help the bacterium avoid phagocytosis and effects of complement
- Provides a barrier to certain antibiotics and harmful chemicals
- Allows nutrients to enter through channels called porins
- LPS in the outer membrane is:
 - The Gram negative main bacterial endotoxin. (Lipid A is an endotoxin causes fever and shock) It is called endotoxin because it is an integral part of the cell wall, in contrast to exotoxins, which are actively secreted from the bacteria.
 - Stimulate both innate and adaptive immune response.
 - Activates B cells and macrophages
 - Causes fever and shock

The lipopolysaccharide (LPS)

- The LPS is composed of three distinct units:
 - (1) A phospholipid called **lipid A**, which is responsible for the toxic effects.
 - (2) A **core polysaccharide** of five sugars linked to lipid A.
 - (3) An outer polysaccharide consisting of up to 25 repeating units of three to five sugars. This outer polymer is the important **somatic, or O, antigen** that is used to identify certain organisms in the clinical laboratory.
- ❖ Some bacteria, notably members of the genus *Neisseria*, have an **outer lipooligosaccharide (LOS)** containing very few repeating units of sugars.

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 so dye cannot penetrate .

C. Structures Internal to the Cell Wall

1. Plasma (Cytoplasmic) Membrane: lies inside the cell wall and encloses the cytoplasm. The cell membrane (often called the **plasma membrane**) is composed of :

a. Phospholipids and proteins.

b. Membrane Proteins

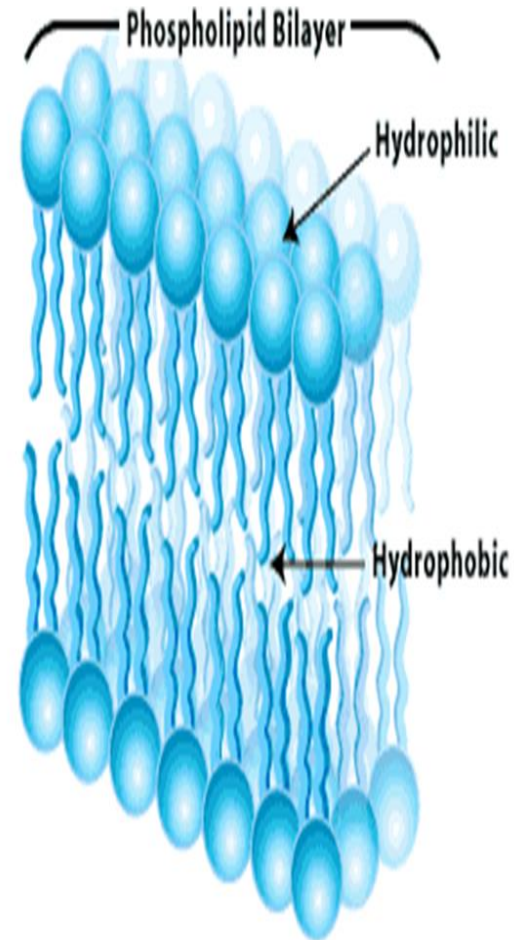
1. Plasma (Cytoplasmic) Membrane:

A. Phospholipids have polar heads and non-polar tails.

1. “Polar” implies that the heads are hydrophilic: they like to stay in an aqueous environment: facing the outside world and the inside of the cell.

2. “non-polar” means that the tails are hydrophobic: they want to be away from water, in an oily environment. The tails are in the center of the membrane

- A pure phospholipid membrane only allows water, gasses, and a few small molecules to move freely through it.



Cytoplasmic membrane

Phospholipid bilayer, **no steroids except mycoplasma** (The only prokaryotes that have sterols in their membranes).

Functions:

1. The plasma membrane serves as a selective barrier to substances entering or leaving the cell. Some things are allowed to cross while others are not. This is selective permeability.
2. It performs electron transport and energy ATP production (replaces mitochondria) by oxidative phosphorylation.
 - In bacteria, the plasma membrane is associated with the breakdown of nutrients and the synthesis of ATP.
3. secretion of enzymes and toxins.

- 
4. Contains transport proteins
 5. Contains ion pumps to maintain membrane potential.
 6. Contains actin-like protein filaments: helps determine shape of cell, determine site of septum formation for cell division

--- Damage to the membrane by alcohols, detergents and polymyxin antibiotics causes leakage of cell contents.

Membrane Proteins

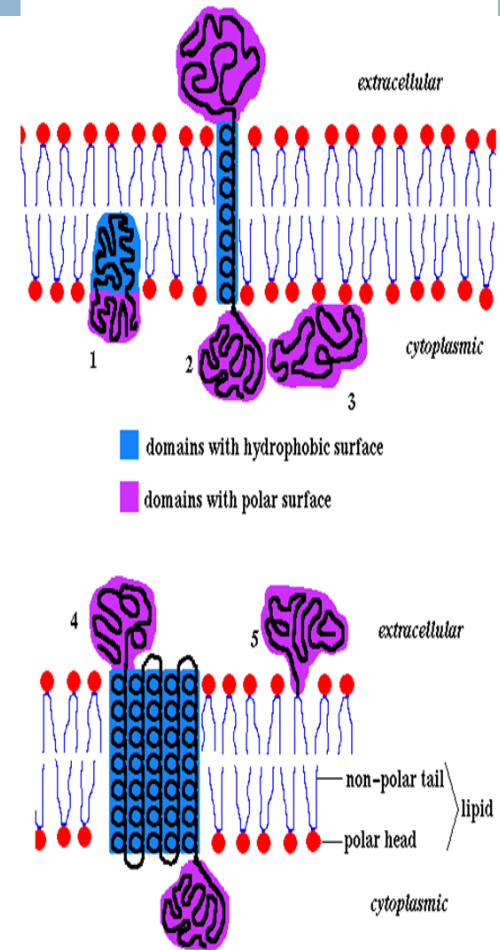
Proteins float in the membrane like ships on the surface of the sea: the fluid-mosaic model.

1. Peripheral membrane proteins are bound to one surface of the membrane.

Some attached to the cell membrane by a fatty acid covalently attached to one of the protein's amino acids. Others are attached by stretches of hydrophobic amino acids of the protein's surface

2. Integral membrane proteins are embedded in the membrane by one or more stretches of hydrophobic amino acids. Many of these proteins transport molecules in and out of the cell.

Proteins in the plasma membrane



2. Cytoplasm

Cytoplasm: A cellular material inside the plasma membrane. It is composed largely of water, together with proteins, nucleic acid, lipids and small amount of sugars and salts. It is thick, semitransparent and gel-like.

main component of cytoplasm are;

Ribosomes:

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. Proteins and RNA of bacterial ribosomes are significantly different from human.

Chromosome: Single, super-coiled, circular DNA, as nucleoid. Transcription and translation both occur in cytoplasm, even at same time

Plasmid:

Plasmids are small, circular/linear extrachromosomal, double-stranded, circular DNA molecules that are capable of replicating independently of the bacterial chromosome. Although plasmids are usually extrachromosomal, they can be integrated into the bacterial chromosome. They are not essential for cellular survival and they occur in both gram-positive and gram-negative bacteria, and several different types of plasmids can exist in one cell:

(1) Transmissible plasmids can be transferred from cell to cell by conjugation. They are large (MW 40–100 million), since they contain about a dozen genes responsible for synthesis of the sex pilus and for the enzymes required for transfer. They are usually present in a few (1–3) copies per cell.

(2) Nontransmissible plasmids are small (MW 3–20 million), since they do not contain the transfer genes; they are frequently present in many (10–60) copies per cell.

Plasmids carry the genes for the following functions and structures of medical importance:

(1) Antibiotic resistance, which is mediated by a variety of enzymes, such as the beta-lactamase of *S. aureus*, *E.coli*, and *K.pneumoniae*.

(2) Exotoxins, such as the enterotoxins of *E. coli*, anthrax toxin of *Bacillus anthracis*, exfoliative toxin of *S. aureus* and tetanus toxin of *Clostridium tetani*.

(3) Pili (fimbriae), which mediate the adherence of bacteria to epithelial cells.

(4) Resistance to heavy metals, such as mercury, the active component of some antiseptics.

(5) Resistance to ultraviolet light, which is mediated by DNA repair enzymes.

(6) Other plasmid-encoded products as **Bacteriocins** are toxic proteins produced by certain bacteria that are lethal for other bacteria. Two common mechanisms of action of bacteriocins are:

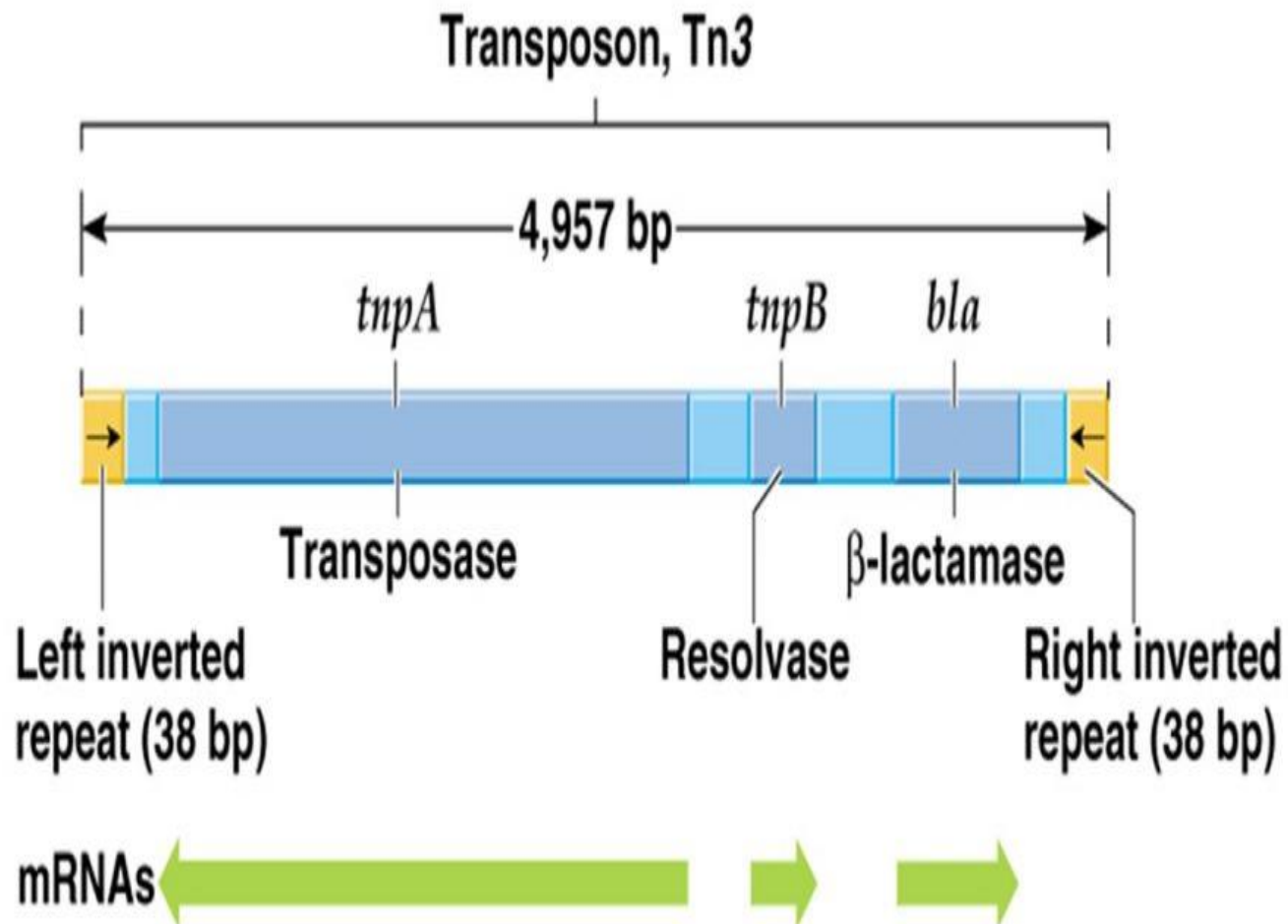
(i) degradation of bacterial cell membranes by producing pores in the membrane

(ii) degradation of bacterial DNA by DNase.

Examples of bacteriocins produced by medically important bacteria are **colicins** made by *E. coli* and **pyocins** made by *Pseudomonas aeruginosa*. The medical importance of bacteriocins is that they may be useful in treating infections caused by antibiotic-resistant bacteria.

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.
- Transposons typically have four identifiable domains.
- On each end is a short DNA sequence of **inverted repeats (IR)**, which are involved in the integration of the transposon into the recipient DNA. The second domain is **the gene for the transposase**, which is the enzyme that mediates the excision and integration processes. The third region is the gene for the repressor that regulates the synthesis of both the transposase and the protein encoded by the fourth domain, which, in many cases, is an **enzyme mediating antibiotic resistance**





Inclusions bodies: are aggregates of various compounds that are normally involved in storing energy reserves or building blocks for the cell. Inclusions accumulate when a cell is grown in the presence of excess nutrients and they are often observed under laboratory conditions.

- **Endospores:** these are dormant cells, formed when certain genera (mainly *Clostridium* and *Bacillus*) find themselves facing adverse conditions such as lack of nutrients, drying, presence of toxic materials, etc. Once formed, endospores can withstand extreme conditions and survive for apparently unlimited periods of time.
- Spores can also survive very high or low temperatures and high UV radiation for extended periods. This makes them difficult to kill during sterilization. They can survive for thousands of years
- Contain calcium ions, Dipicolinic acid DPA
- **Functions:** Identification of Bacteria, Pathogenesis and Resistance
- **Sporulation or sporogenesis** is the process of endospore formation.
- **Germination** is the return of the endospore to the vegetative state

Formation of bacterial spores



1. Bacterial chromosome replicates. One copy plus a little cytoplasm are isolated in a small area of the cell as the plasma membrane forms a partition called the spore septum.
2. Spore septum becomes a double-layered membrane that surrounds the chromosome and bit of cytoplasm and this is now called the forespore. This is inside the original cell.
3. Thick layers of peptidoglycan are produced between the two membrane layers of the spore septum.
4. A thick protein spore coat forms around the outside membrane.

5. Water in the cytoplasm of the spore is removed throughout the process, leaving very little in the cytoplasm. Metabolic reactions cease. This cytoplasm will contain high levels of dipicolinic acid and calcium ions.

6. When the endospore is complete, the vegetative cell that formed it will rupture and release the endospore. While it is still contained in the vegetative cell, the endospore will be located in a characteristic part of the cell

-Terminal,

-Subterminal,

-Centrally

Formation of a bacterial spore

