Bacterial Structure and Classification

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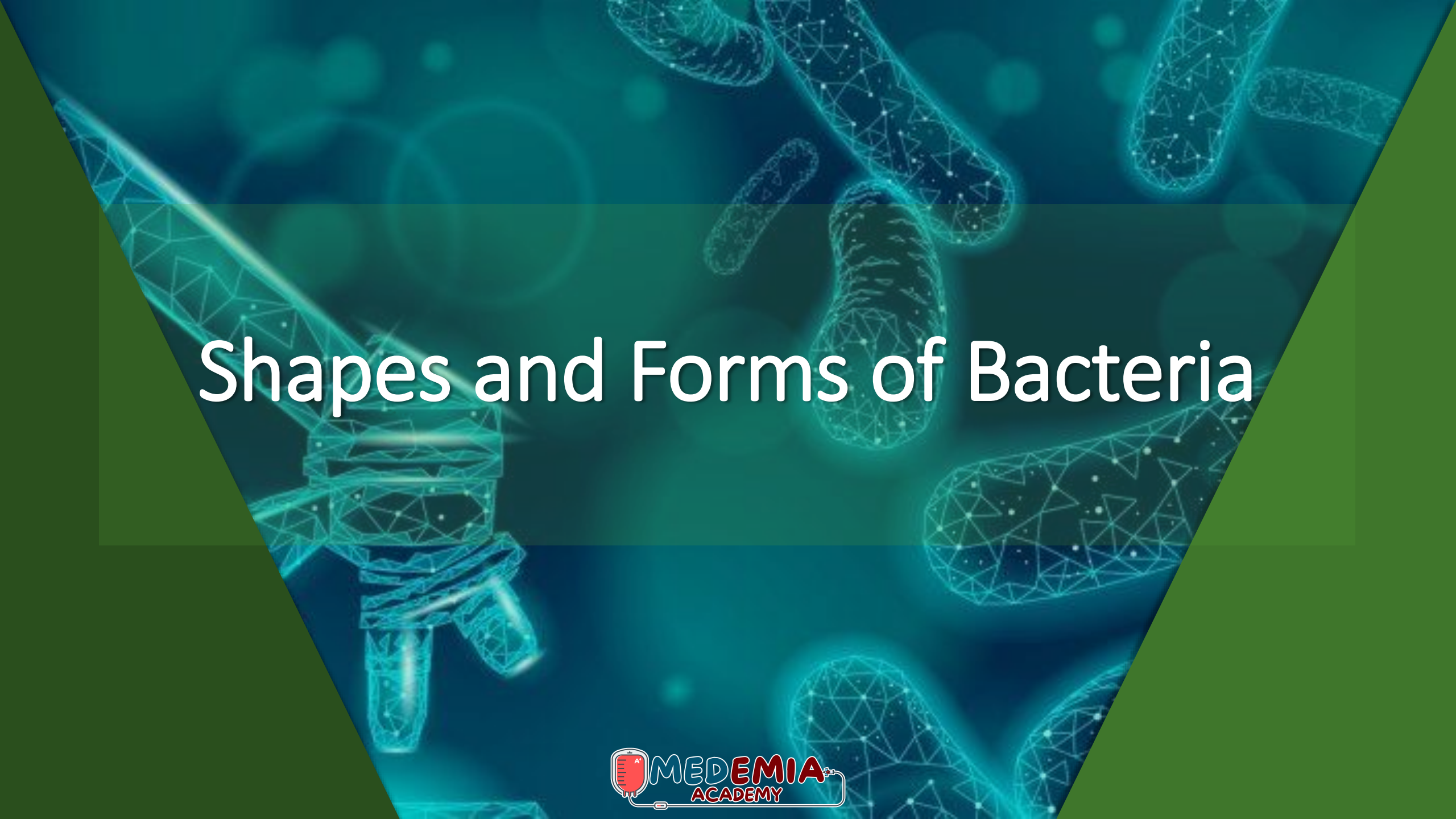

Shapes and Forms of Bacteria

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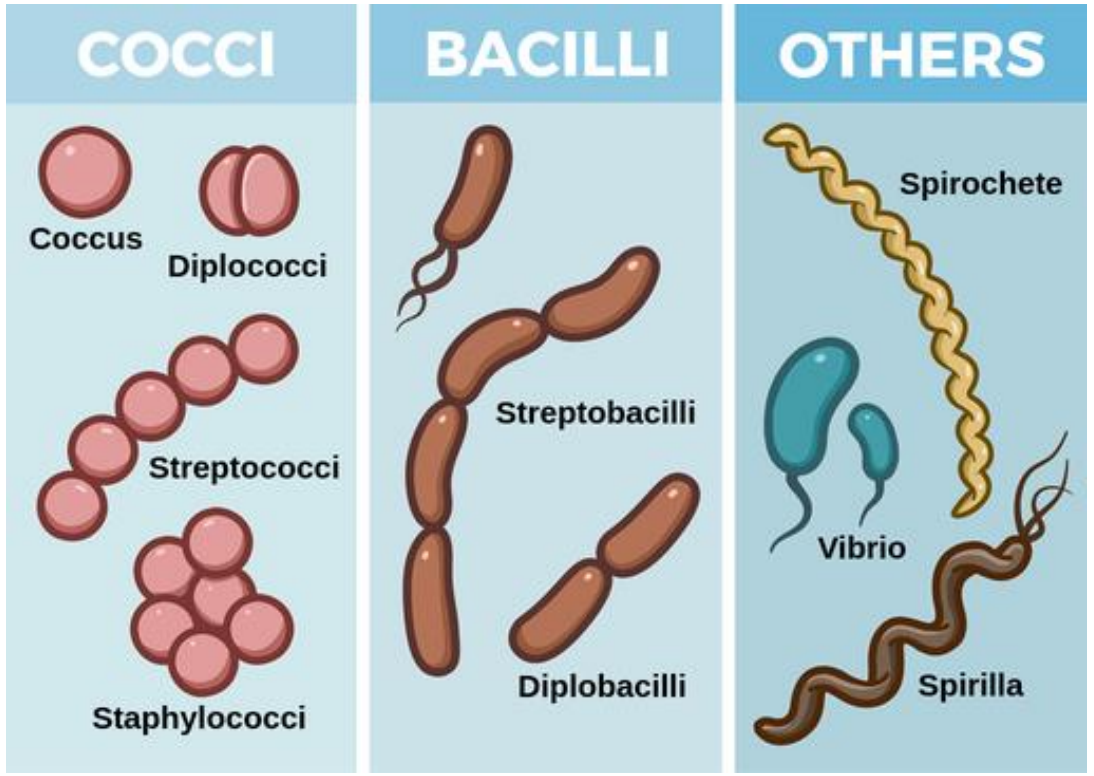
Overview of Shapes of Bacteria

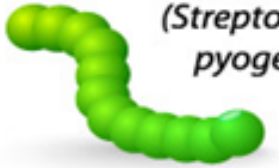
Greek		English
Cocci		Spherical
Coccobacilli		In between
Bacilli		Rod-shaped
Curved bacilli	Vibrio	Coma-shaped
	Spirillum	Spiral or helical
Spirochaeta		Corkscrew-like
Branching filaments		



1. Cocci (Spherical)

- Cocci has originated from a greek word; kokkos = seed.
- (0.5µ -1.25µ in diameter)
- **On the basis of arrangements cocci are classified to**
  - **Micrococci**: appears singly.
  - **Diplococcus**: appear in a pairs of cells.
  - **Streptococci**: appear in rows of cells or in chains.
  - **Staphylococci**: arrange in irregular clusters like bunches of grapes
  - **Tetracoccus**: arrange in a sequence of four.
  - **Sarcinae**: arrange in cuboidal or in a different geometrical.

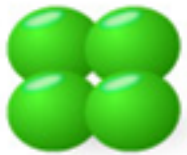
Diplococci *(Streptococcus pneumoniae)*



Streptococci *(Streptococcus pyogenes)*

Staphylococci *(Staphylococcus aureus)*

Tetrad



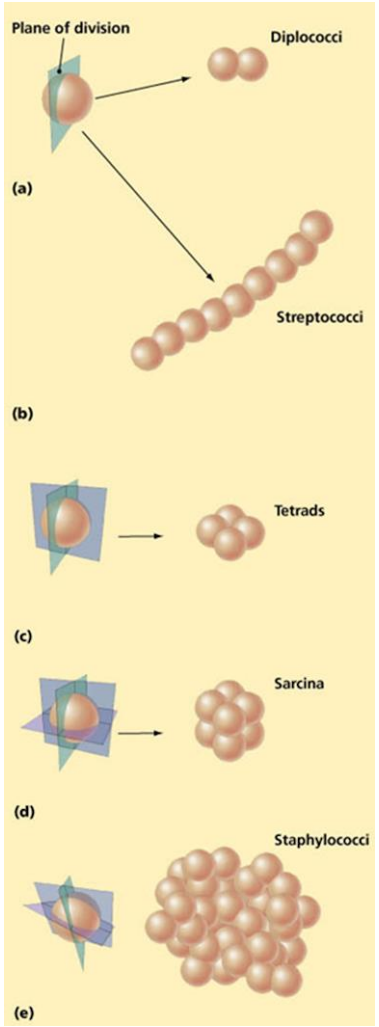
Why do bacterial cells have different arrangement?

❖Plane of Division:

- The plane in which a bacterial cell divides influences its arrangement.
- Bacteria can divide in one, two, or three planes, leading to different structural patterns
- **Single plane**: Division in one plane produces chains (e.g., Streptococcus).
- **Two planes**: Division in two planes results in a sheet-like arrangement (e.g., Diplococcus or Neisseria).
- **Three planes**: Division in three planes forms clusters (e.g., Staphylococcus)

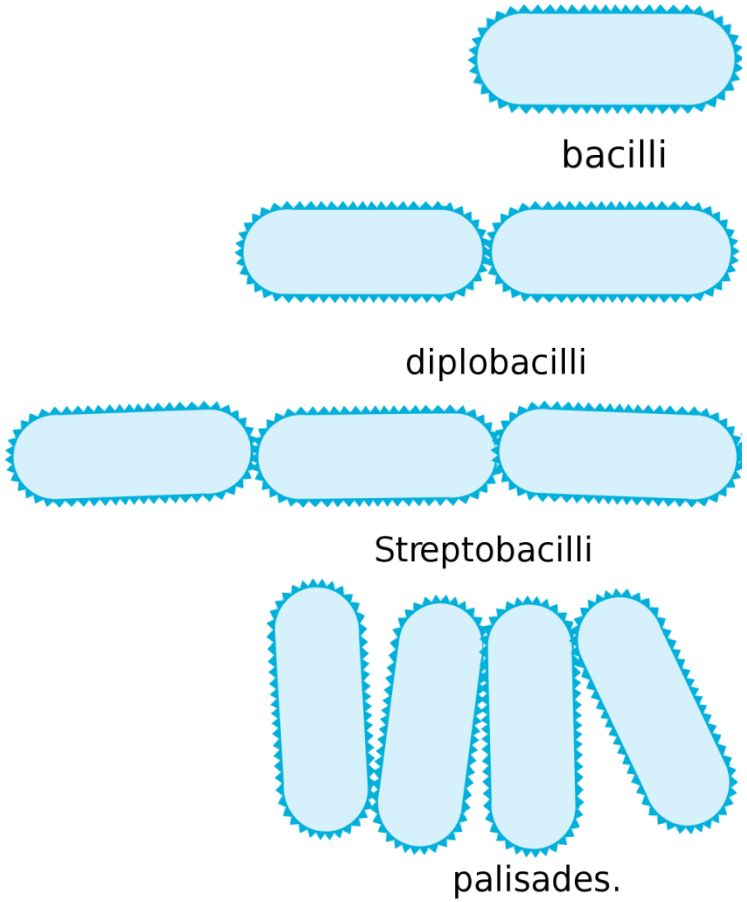
❖Daughter Cell Attachment:

- After binary fission, whether the daughter cells separate or remain attached determines bacterial arrangement
  - **Free Separation**: If the cells separate after division, individual cells are seen (e.g., E. coli).
  - **Partial Separation**: If the daughter cells stay attached, different groupings form, like chains (e.g., Streptococcus) or clusters (e.g., Staphylococcus).
  - **Complete Attachment**: Some bacteria, like Streptomyces, form long filamentous chains because the cells don't separate after division.



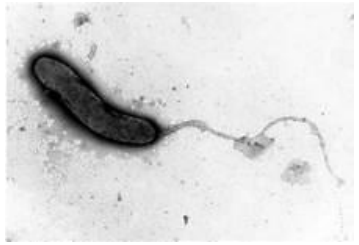
2. Bacilli (Rods)

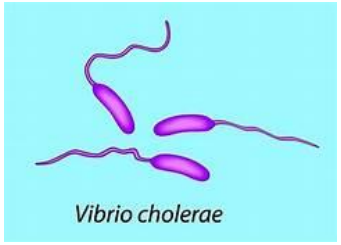
- From greek word, bacilli means rod or stick.
- There ends are rounded flat or pointed.
- 0.5-1.2µ in diameter and 3- 7µ in length.
- Flagellated or non-flagellated.
- **They may be of following types**
  - **Monobacillus**: arrange singly.
  - **Diplobacillus**: present in a group of two.
  - **Streptobacillus**: in chains.
  - **Palisade**: Very rare



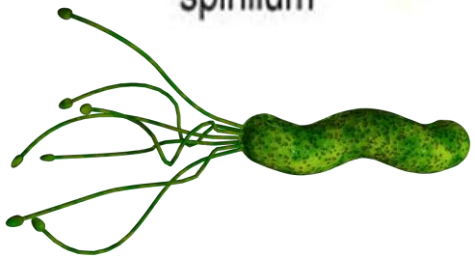
Shapes of Bacteria cont.

3. **Vibrio or Coma**
   - They bear flagella at their end.
   - 1.5-1.7µ in diameter and upto 10µ in length
   - e.g. Vibrio cholarae.

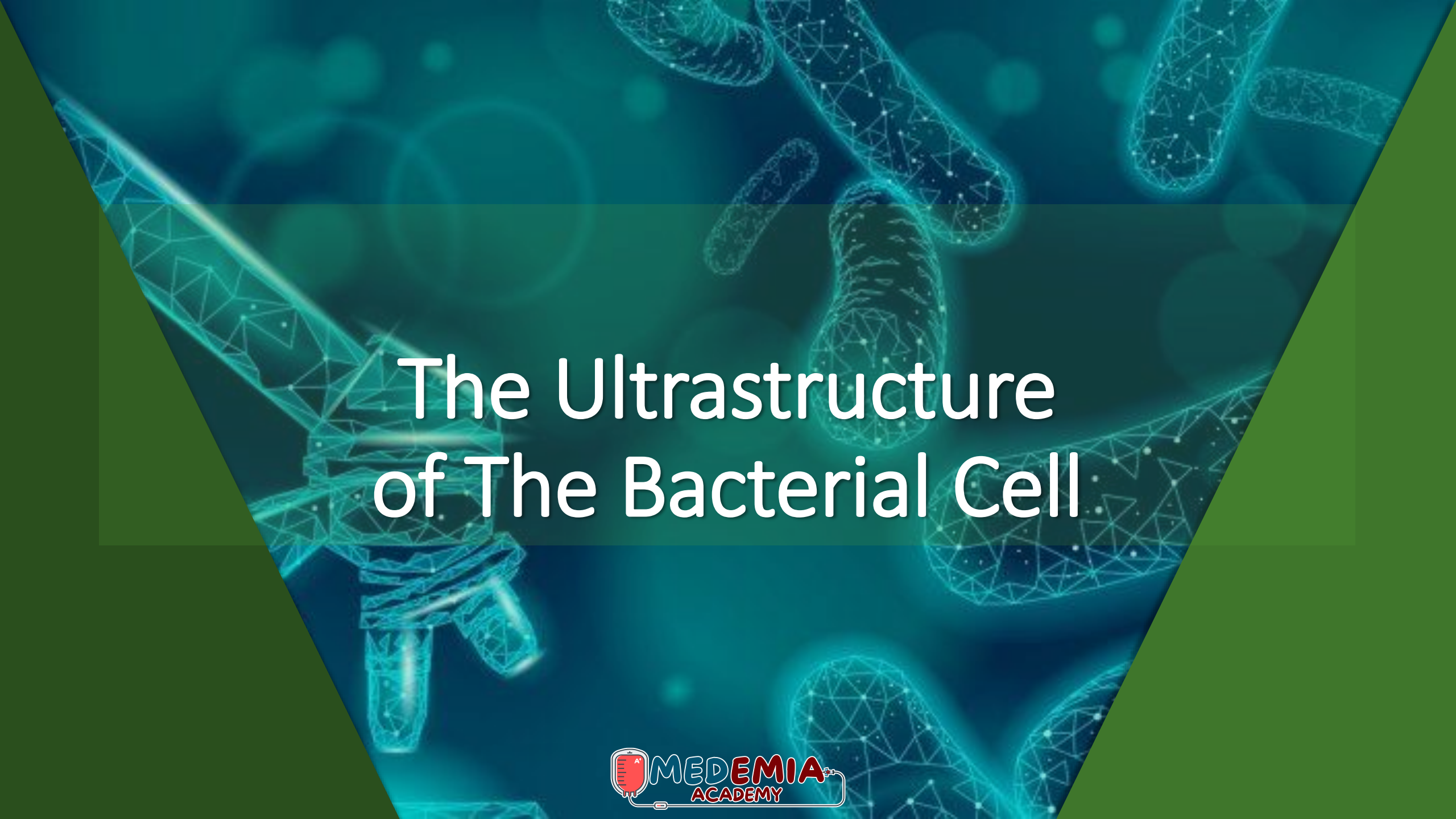




4. **Spiral or Helical**
   - From greek word; spira means coiled.
   - A single spirillum has more than one turn of helix.
   - 10-50µ in length and 0.5 - 3µ in diameter.
   - They are flagellated



5. **Spirochaeta**
   - These bacteria appear like a corkscrew.
   - Their length is more as compared to their diameter.
   - Their body is more flexible.



The Ultrastructure of The Bacterial Cell

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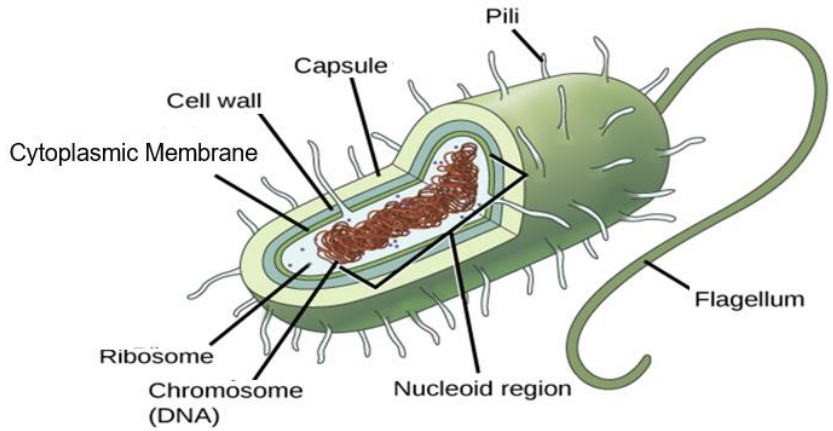
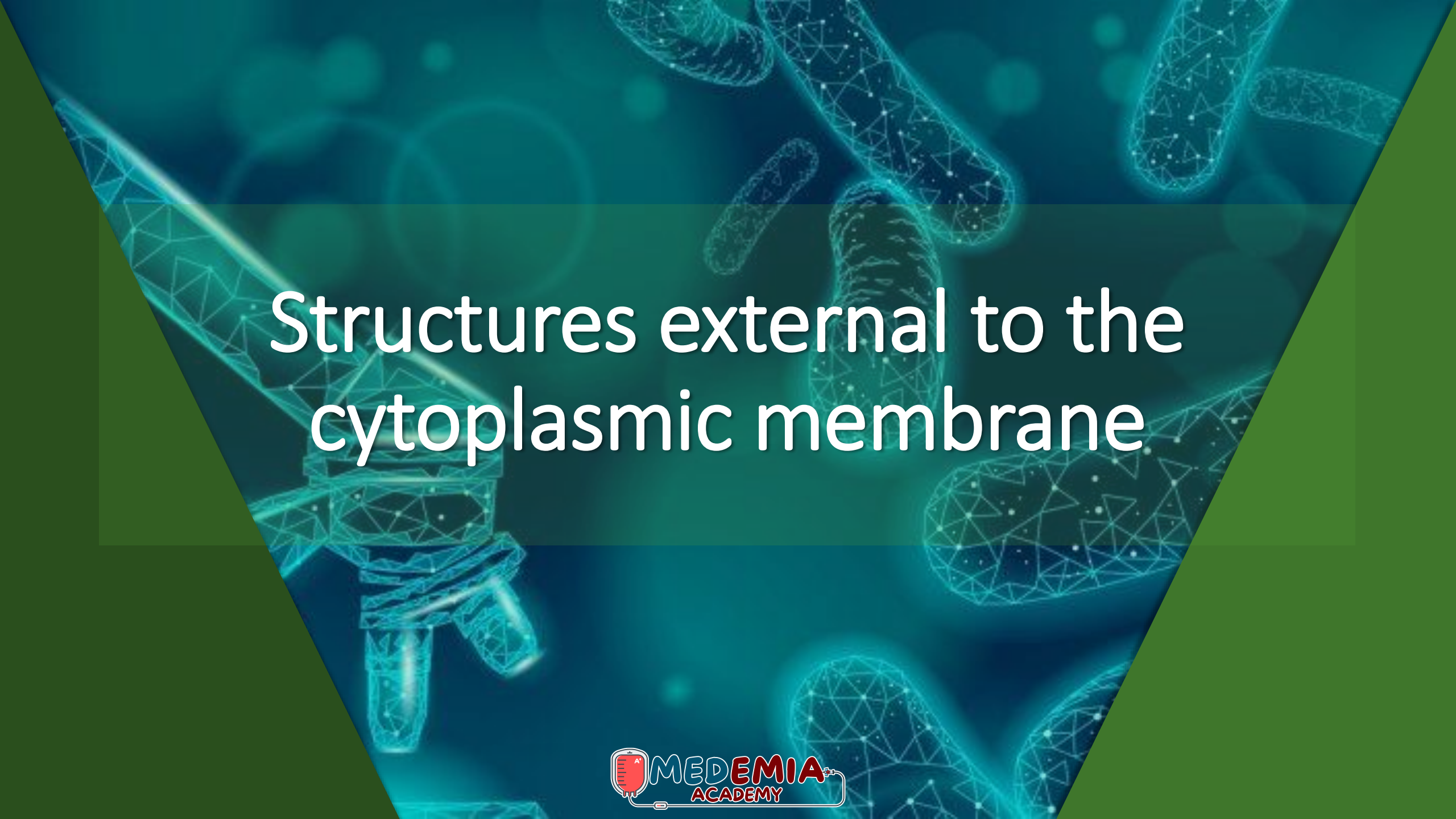
The Ultrastructure of The Bacterial Cell

Structures external to the cytoplasmic membrane	Structures internal to the cell wall
1. Cell wall 2. Flagella 3. Pili 4. Fimbriae 5. Capsule 6. Lipopolysaccharides (LPS)	1. Cytoplasmic Membrane 2. Mesosomes 3. Ribosomes 4. Cytoplasm 5. Inclusion Bodies 6. Chromosome (DNA) 7. Plasmid 8. Episome



Structures external to the cytoplasmic membrane



1. The cell wall

❖Functions

- Very rigid structure and provide definite shape to the cell
- Preventing the cell from expanding and eventually bursting because of uptake of water
- Resistant to extremely high pressure.
- Essential for the growth and division of bacteria
- Cell wall protects against osmotic lysis

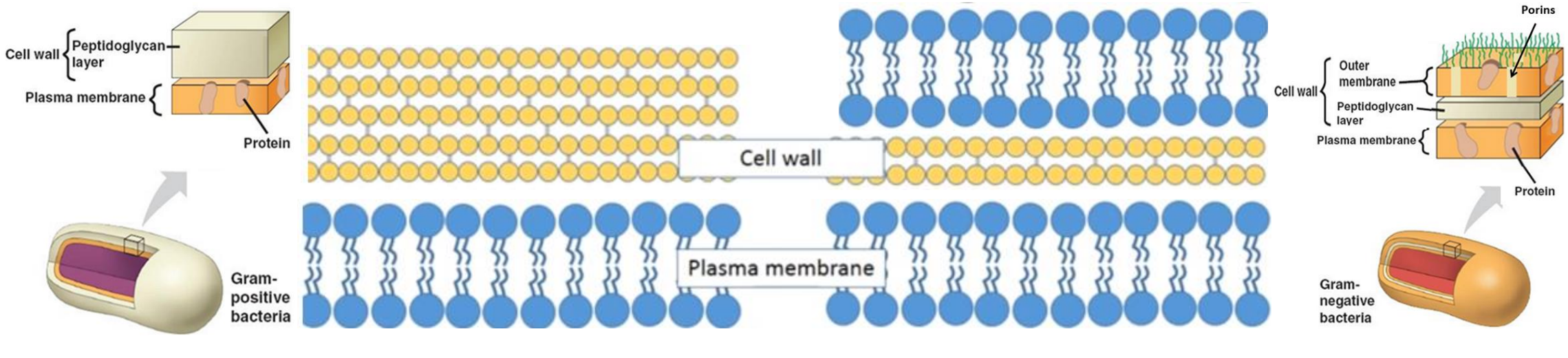
❖Gram staining steps

1. **Fixation**: Heat-fix the bacterial smear on the slide.
2. **Primary Stain**: Apply crystal violet stain for 1 minute.
3. **Mordant**: Add iodine solution to form a crystal violet-iodine complex.
4. **Decolorization**: Wash with alcohol or acetone for a few seconds (removes stain from Gram-negative bacteria).
5. **Counterstain**: Apply safranin to stain Gram-negative bacteria for 1 minute.

- **Results**: Gram +ve bacteria appear purple/blue, and Gram -ve bacteria appear pink/red.

The difference between Gram +ve & -ve cell wall

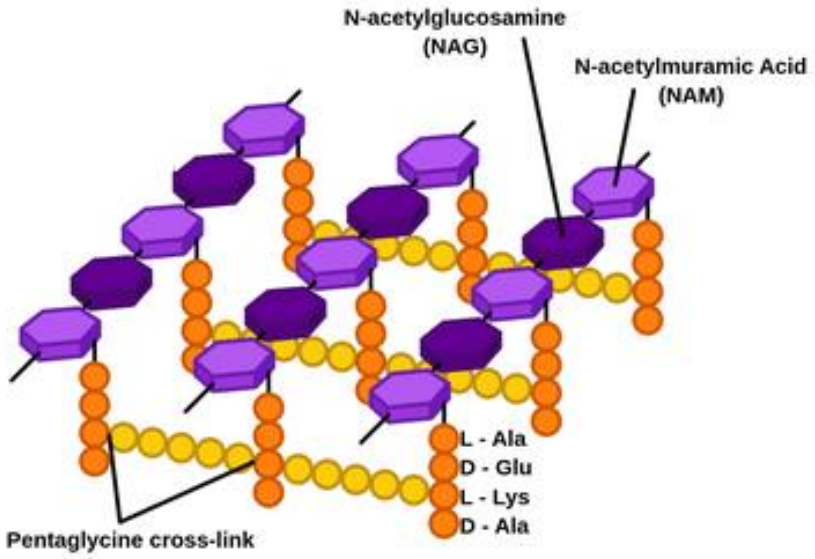
Gram positive	Gram negative
• Inner most plasma membrane • Thick peptidoglycan cell wall	• Inner most plasma membrane • Thin peptidoglycan cell wall • Another outer plasma membrane
More easily treatable with antibiotics	Harder to treat with antibiotics
Stain purple/violet after Gram Stain.	Stain red/pink after Gram Stain
Peptidoglycan forms 40-80% of the cell dry weight.	Peptidoglycan forms 5-10% of the cell dry weight.

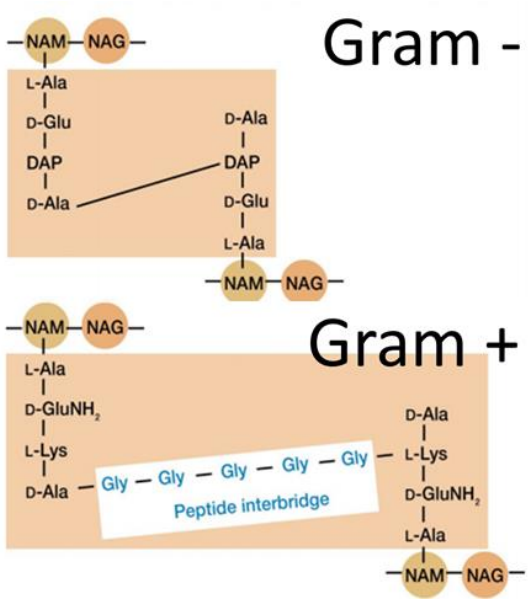


1. The cell wall

❖Peptidoglycan

- It is a rigid mesh made up of ropelike linear polysaccharide chains made up of repeating disaccharides of N-acetylglucosamine (NAG) and N-acetylmuramic acid (NAM)
- Tetrapeptide attached to NAM.

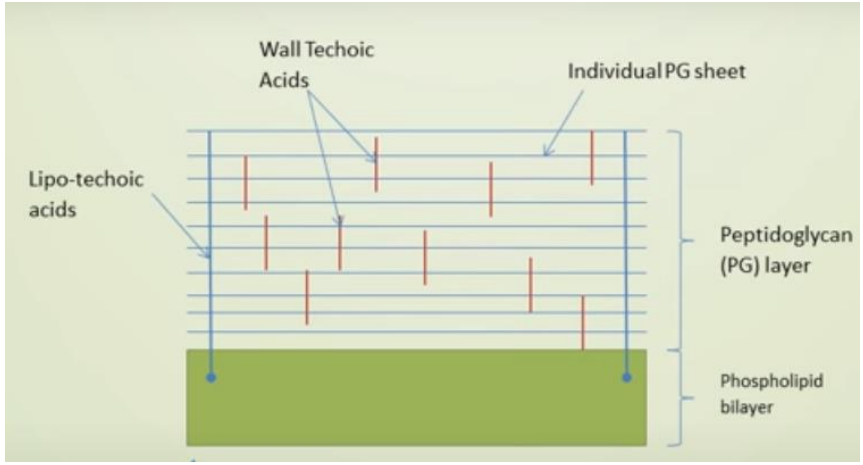


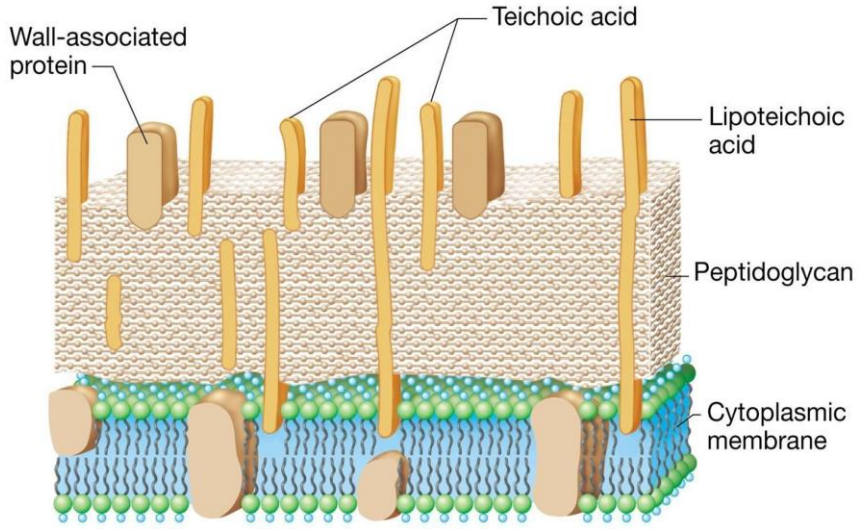


1. The cell wall

❖Teichoic and Lipoteichoic acids

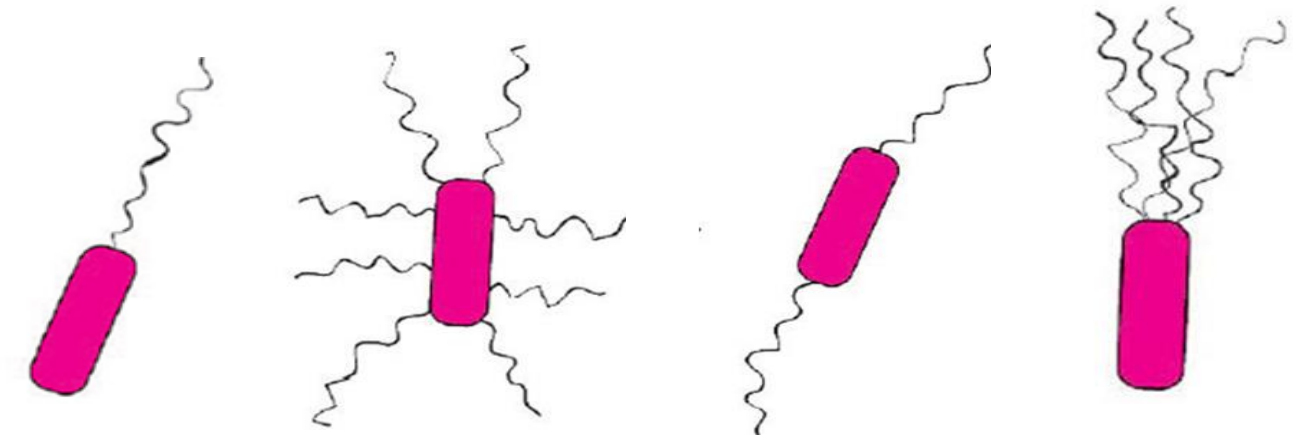
- **Teichoic acids**: copolymers of glycerol phosphate or ribitol phosphate and carbohydrates linked via phosphodiester bonds.
- **Lipoteichoic acids (LTA)**: Long chains of ribitol or glycerol phosphate
- **Functions**
  - Anchor peptidoglycan layers to the plasma membrane
  - Attachment to other bacteria and to specific receptors on mammalian cell surfaces.





2. Flagella

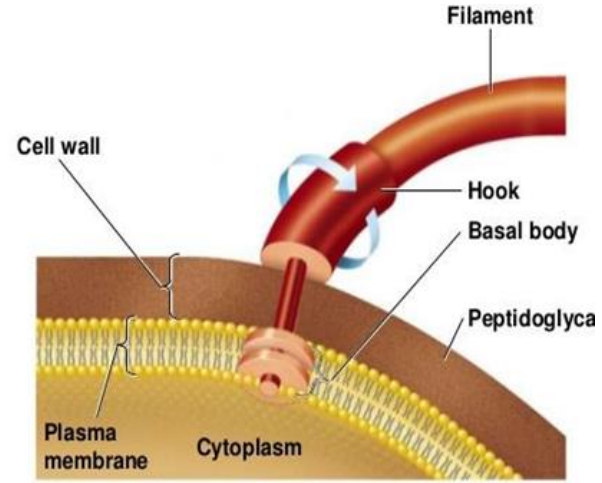
- They are flexible, whip like appendage (singular flagellum).
- Measures 4-5 µ long.
- They are made up of protein flagellin (MWt, 40,000)
- The location of flagella varies in various bacteria.
- The bacteria which lack flagella are referred as atrichous.
- Bacteria can be divided into following types based on the location of flagella.



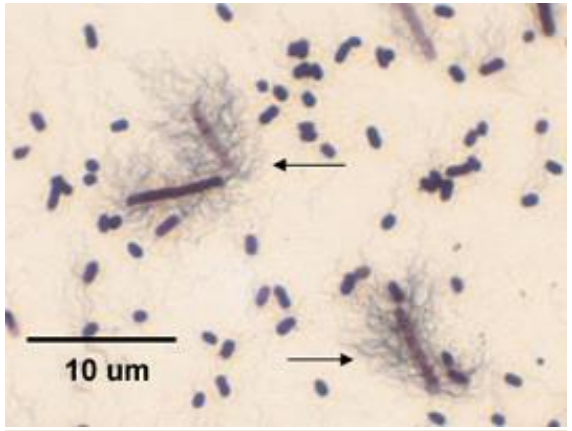
Monotrichous **Peritrichous** **Amphitrichous** **Lophotrichous**

2. Flagella

- **Each bacterial flagellum is structurally differentiated into three parts**
  - Basal body
  - Hook
  - Main filament or shaft
- **Flagella stain**



Rosanalin dye

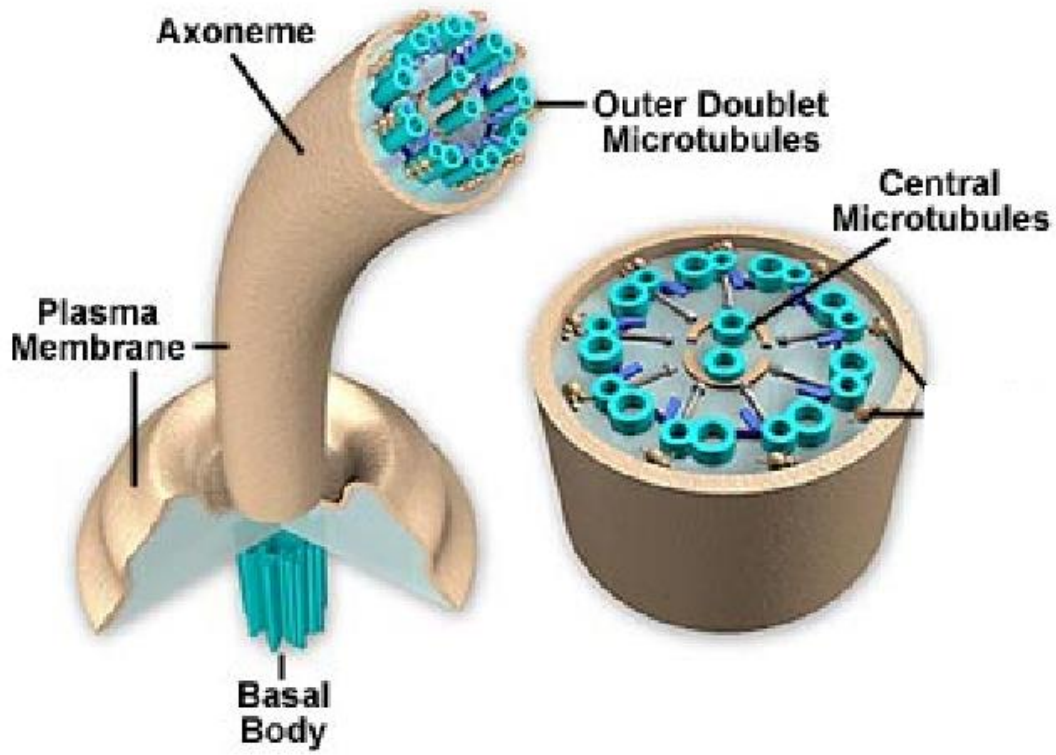


Silver nitrate + ferric tannate

2. Flagella

❖Ultrastructure of flagellum

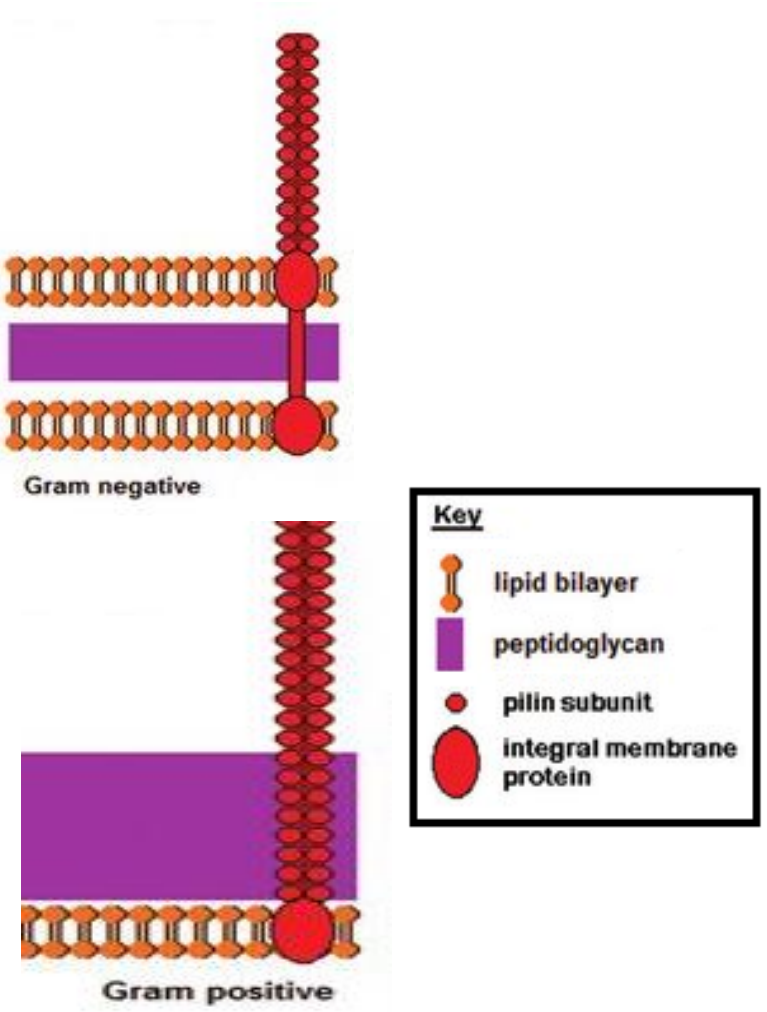
- Flagella are membrane bound cylinders about 0.2 µm in diameter.
- The strands called axoneme.
- The axoneme consists of 9 pairs of microtubule doublets arranged in a circle around 2 central tubules.
- This is called 9+2 pattern of microtubules.



Ultrastructure of Cilia and Flagella

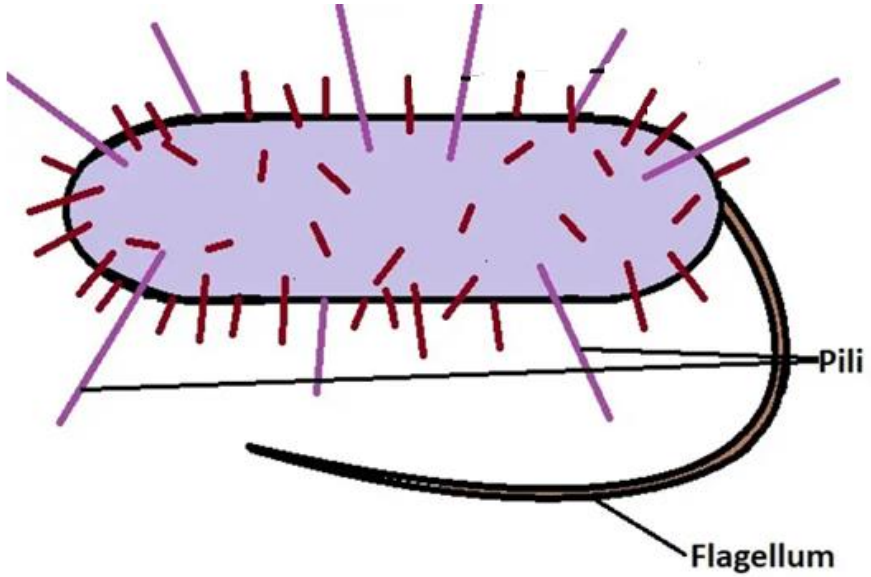
3. Pilli

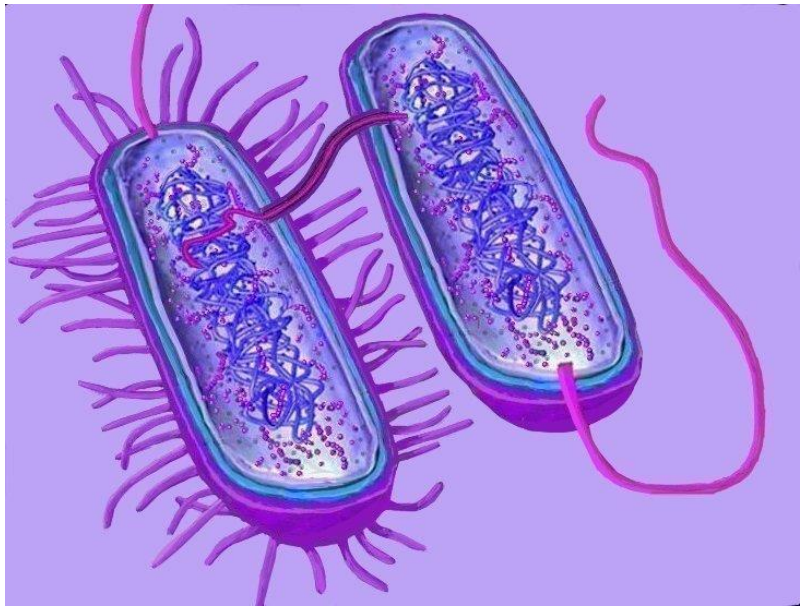
- **Definition**: hair like appendages present on the surface of most of the gram negative bacteria, but can be found in Gram-positive bacteria
- They are smaller than flagella, have no role in the motility of bacteria.
- A single bacterial cells bears about 100-500 pili which are arranged peritrichously.
- There origin is from cytoplasm and penetrate through the peptidoglycan layers of the cell wall.
- **Two types**: Somatic pili and sex pili or conjugate pili



3. Pilli

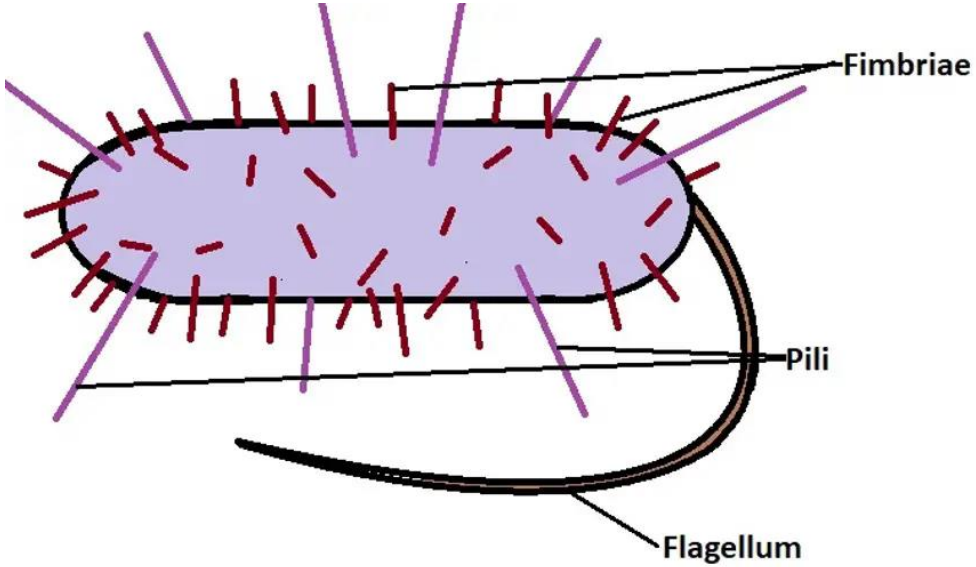
Somatic pili	Sex pili
• Each bacterial cell bears about 100 somatic pili. • Function: is to help the bacterium for attachment to a substratum.	• Also known as conjugate pili and F pili • Allow the transfer of DNA between bacteria, in the process of **bacterial conjugation**. This can result in dissemination of genetic traits, such as antibiotic resistance, among a bacterial population

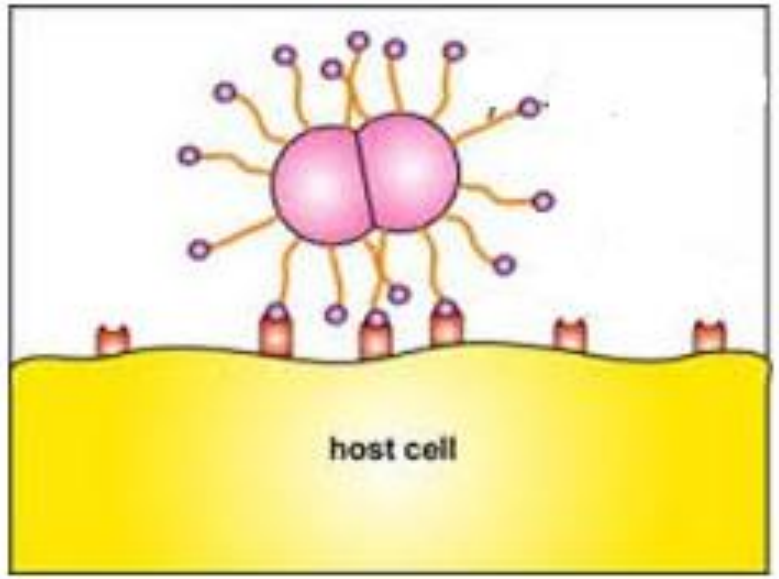




4. Fimbriae

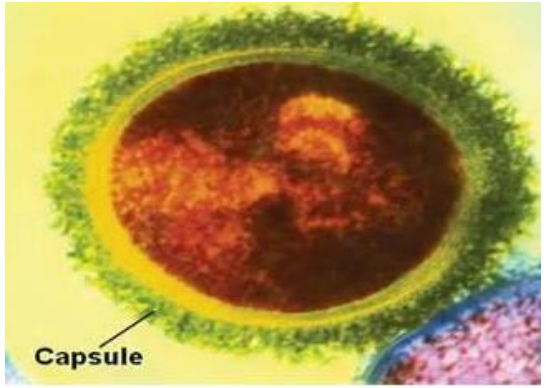
- **Definition**: a short pilus that is used to attach the bacterium to a surface. They are sometimes called "attachment pili".
- Fimbriae are either located at the poles of a cell, or are evenly spread over its entire surface.

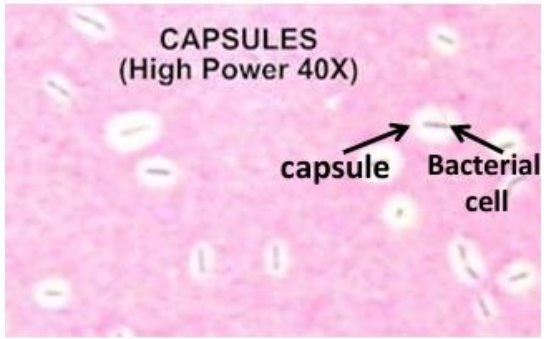


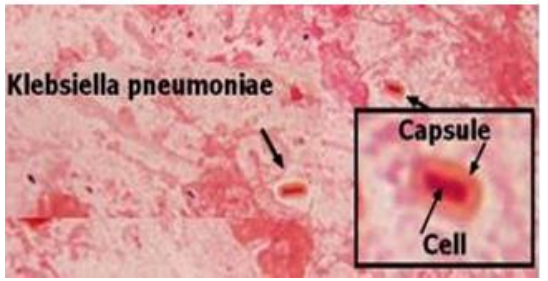


5. Capsule

- It consists of a network of fine strands
- **Divided into two groups**
  - **Macrocapsule**: It is about 0.2 µm thick and can be seen under a light microscope
  - **Microcapsule**: It can't be seen under a light microscope but can be demonstrated immunologically
- **Chemical composition**
  - They are made up of di- or polysaccharides or polypeptides
  - The polysaccharide may be homo polysaccharide or heteropolysaccharide
- **Functions**
  - Protection against temporary drying by binding water molecules
  - Antiphagocytic



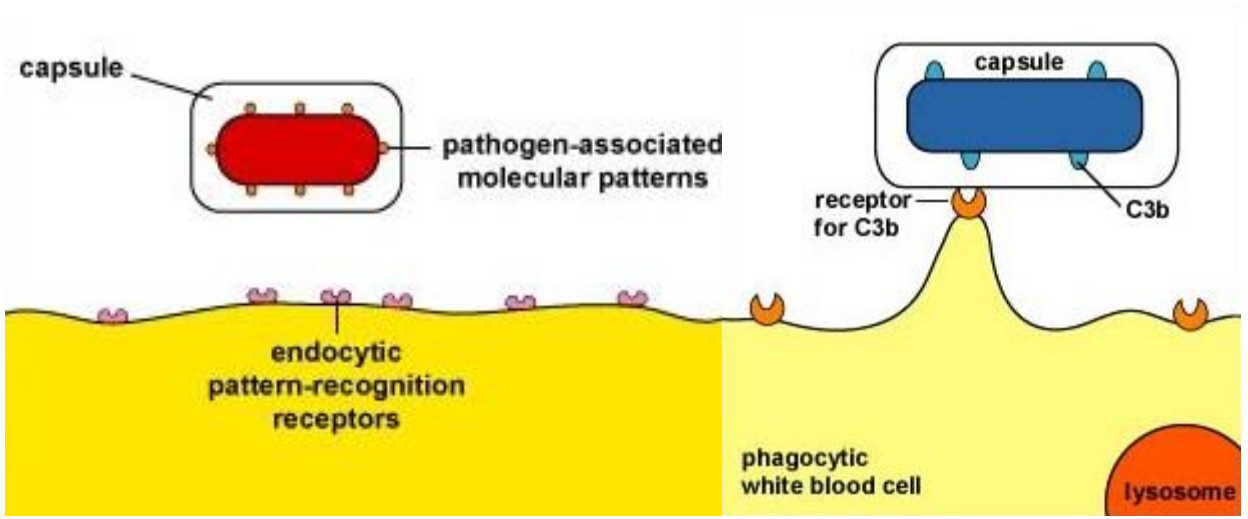




5. Capsule

❖Antiphagocytic effect of capsule

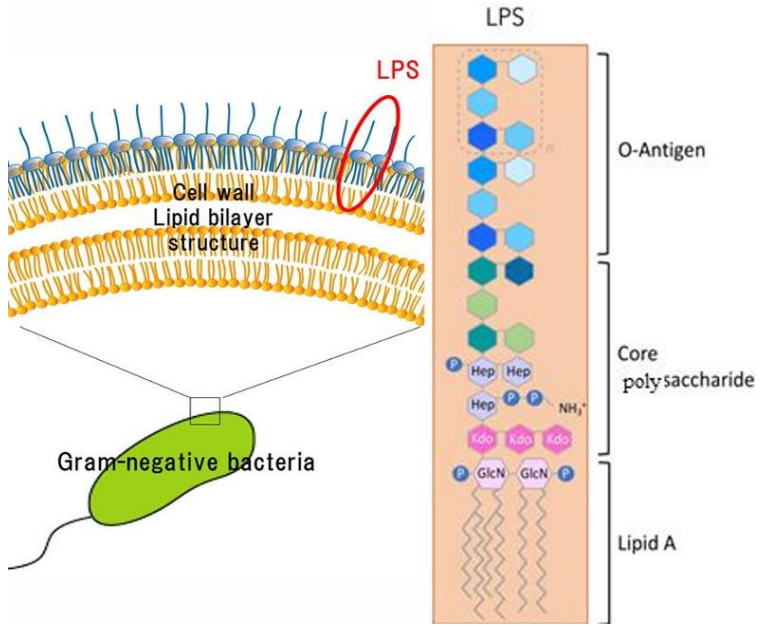
- Capsules can resist attachment by blocking pathogen-associated molecular patterns (PAMPs) — molecules like peptidoglycan, teichoic acids, lipopolysaccharides, mannans, and glucans, commonly found in microbial cell walls — from binding to pattern-recognition receptors on the surface of phagocytes, which are involved in endocytosis.



6. Lipopolysaccharides (LPS)

- Found only in the outer membrane of **Gram-negative bacteria**
- Composed of three covalently linked parts

Lipid A	Core polysaccharide	O-antigens
Firmly embedded in the membrane	Located at the membrane surface	Extend like whiskers from the membrane surface into the surrounding medium
Helps stabilize the outer membrane structure	Contributes to the negative charge on the cell surface	Protection from host defenses



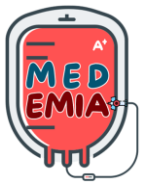
6. Lipopolysaccharides (LPS)

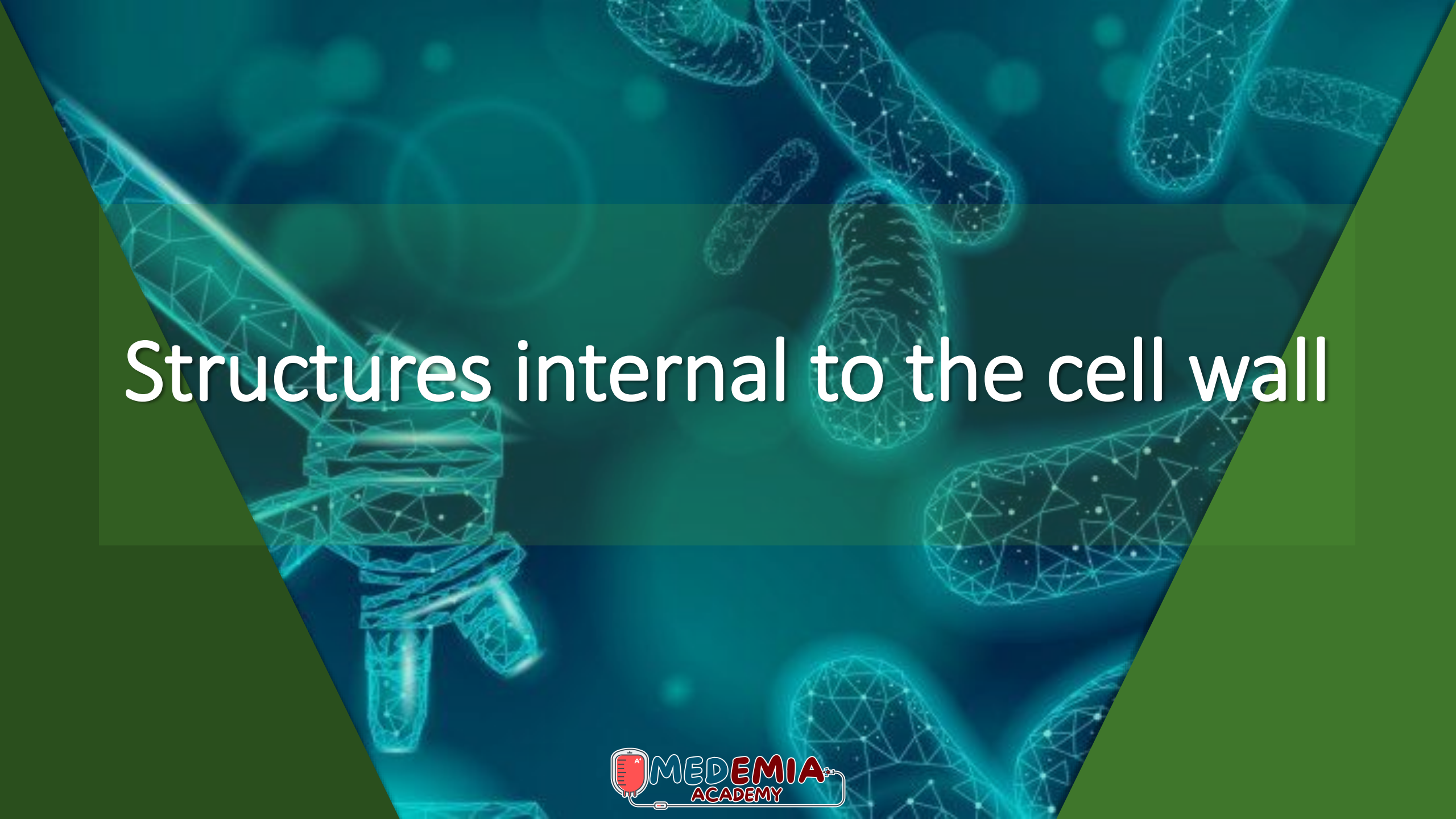
❖ **Notes**

- **O antigens** attributable to many **antigenic properties** of gram -ve bacteria
- **Lipid A** acts as an **endotoxin**
  - Lipid A released when cells lyse
  - Activating white cells, especially macrophages and monocytes
  - **Causes systemic effects**: Fever, Shock, Blood coagulation, Weakness, Diarrhea, Inflammation, Intestinal Hemorrhage, Fibrinolysis

Endotoxins vs. Exotoxins

	Endotoxins	Exotoxins
Definition	Lipopolysaccharide-protein complexes, produced at the time of cell death	polypeptide proteins excreted by few species of bacteria
Location	Part of the cells and located on chromosomal genes	Released from the cells and located on extrachromosomal genes (e.g. plasmids)
Toxicity	Endotoxin is moderately toxic	Exotoxin is highly toxic
Source	Produced after the disintegration of the gram-negative bacteria	Produced in the living gram positive bacteria and gram-negative bacteria
Boiling	It does not get denatured on boiling	It gets denatured on boiling
Diseases	Meningococcemia, sepsis by gram -ve rods	Botulism, Diphtheria, Tetanus
Effects	General symptoms are fever, diarrhea, vomiting, etc.	Cytotoxin, enterotoxin or neurotoxin with defined action on cells or tissues.
Neutralization	Cannot be neutralized by antibodies	Can be neutralized by antibodies
Vaccines	No effective vaccines are available	Effective vaccines are available
Examples	E.coli, Shigella, V. cholera, S. Typhi	S. aureus, S. pyogenes, B. anthracis, B. cereus





Structures internal to the cell wall

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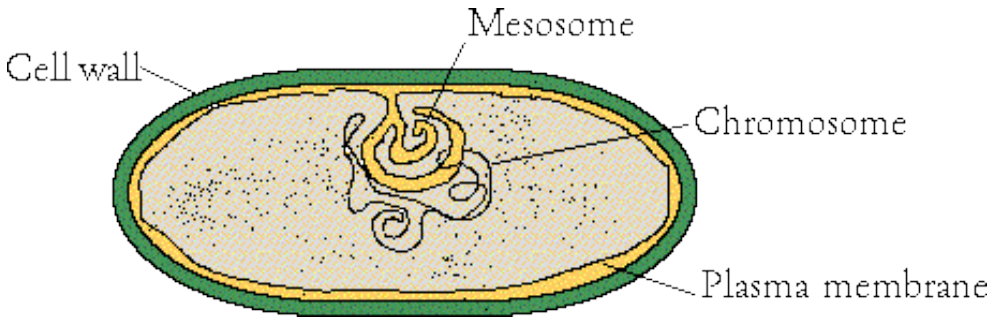
Structures internal to the cell wall

1. **Cytoplasmic Membrane**
   - Immediately below the cell wall is cytoplasmic membrane.
   - Similar in both gram + ve and-ve bacteria
2. **Mesosomes**
   - The mesosome was thought to increase the cell's surface area, aiding the cell in cellular respiration
   - This is analogous to cristae in the mitochondrion in eukaryotic cells, which are finger-like protrusions and help eukaryotic cells undergo cellular respiration. A site for oxidative phosphorylation



Structures internal to the cell wall

3. Inclusion Bodies

- Granules of organic or inorganic material that are stocked by the cell for future use

Inclusion	Composition	Function
Glycogen	Poly-glucose	Reserve carbon and energy source
Poly-betahydroxybutyric acid(PHB)	Lipid	Reserve carbon and energy source
Poly-phosphates	Polymers of PO_4	Reserve phosphate, possibly high-energy PO_4
Sulfurglobules	Elemental S	Reserve energy and or electrons
Magnetosomes	Magnetite (iron oxide)	Provide orientation in magnetic field
Gasvesicles	Protein shells inflated with gases	Provide buoyancy in aquatic environments
Parasporal crystals	Protein	Produced by endospore forming Bacilli-toxic to insects

Structures internal to the cell wall

4. Episome vs. Plasmid

- Plasmid and episome are two types of DNA elements which exist independently of the genome
- The main difference between plasmid and episome is that plasmid does not integrate into the genome, whereas episome can integrate into the genome