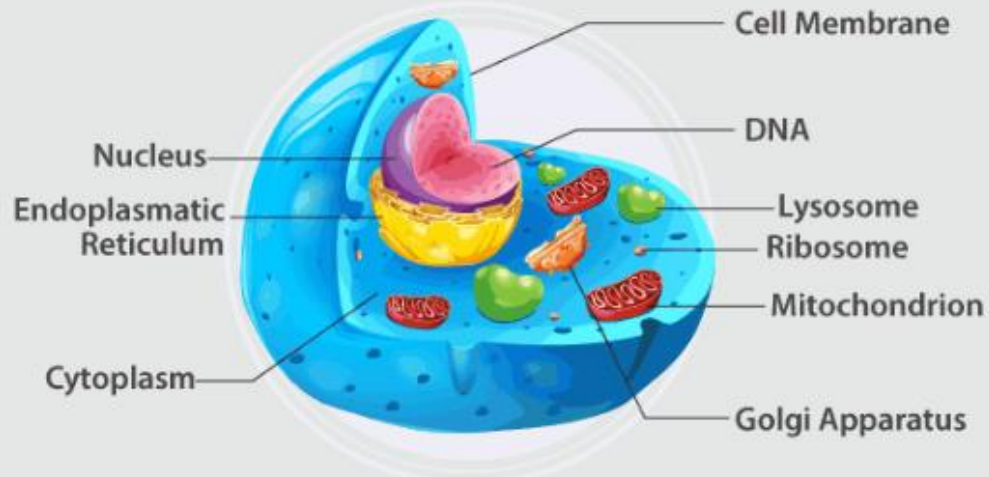
Microbial World
Part I

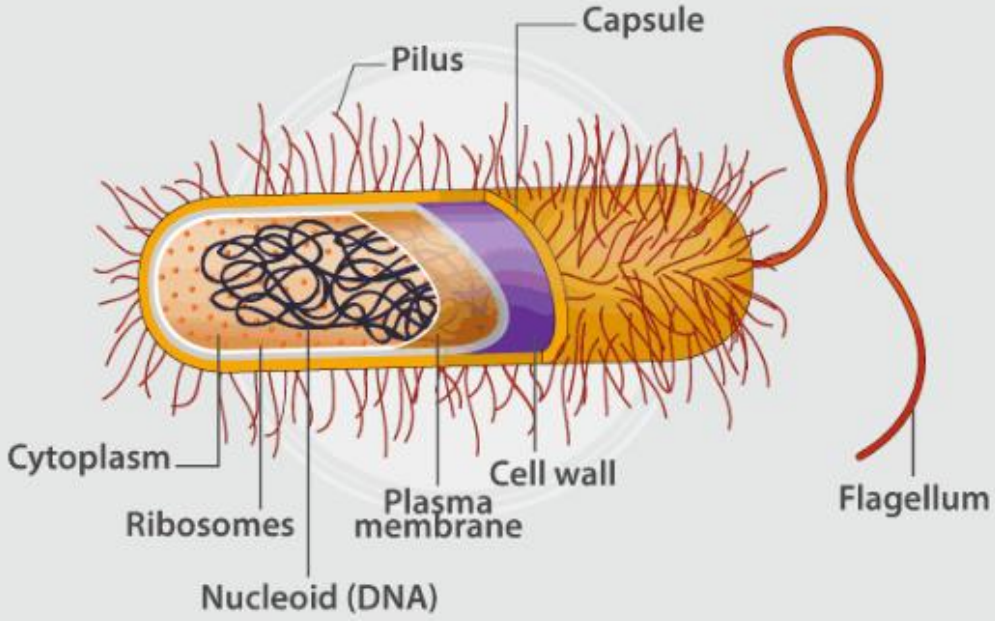
B. Sc. BOTANY

SEM I

PROKARYOTIC CELL VS EUKARYOTIC CELL

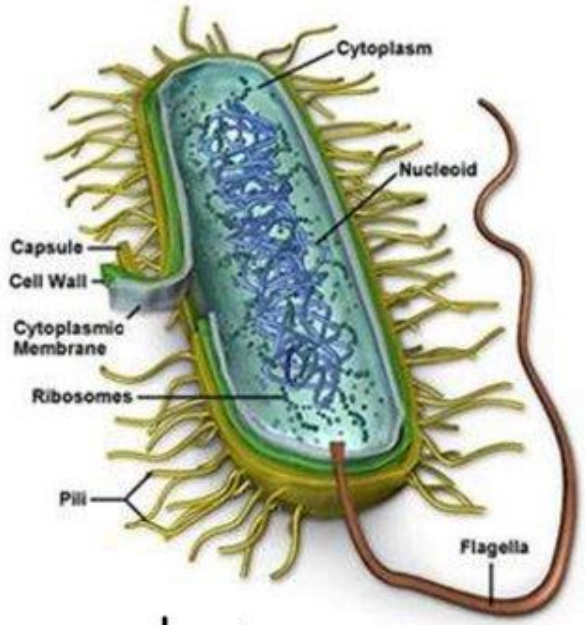


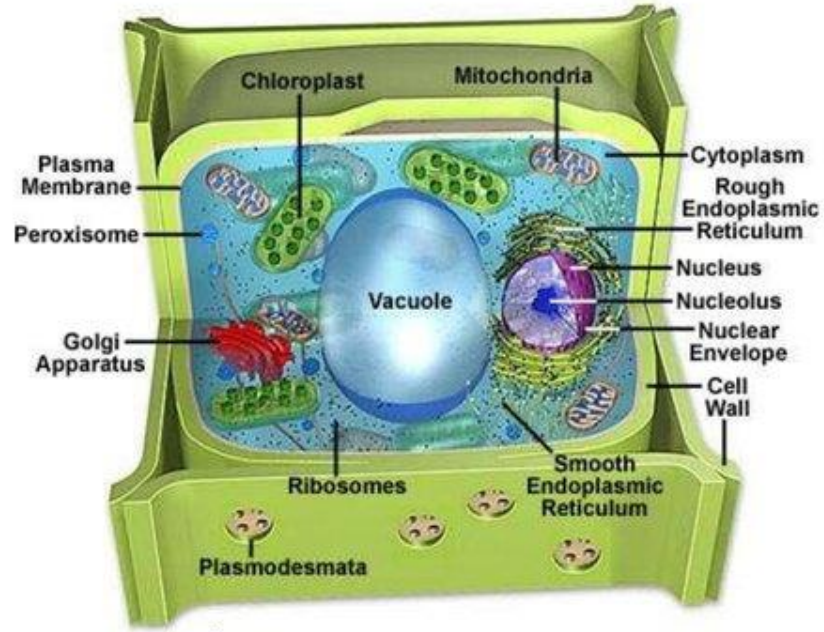
Eukaryotic Cell



Prokaryotic Cell

Prokaryotic vs. Eukaryotic

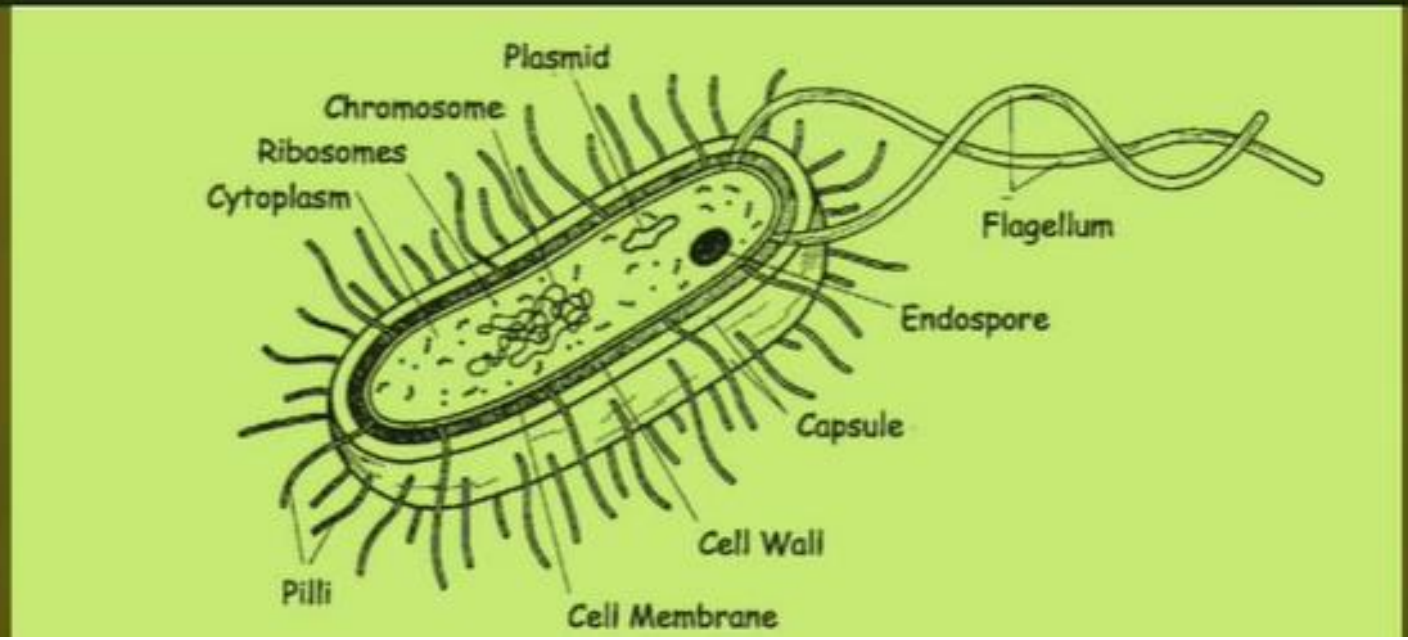




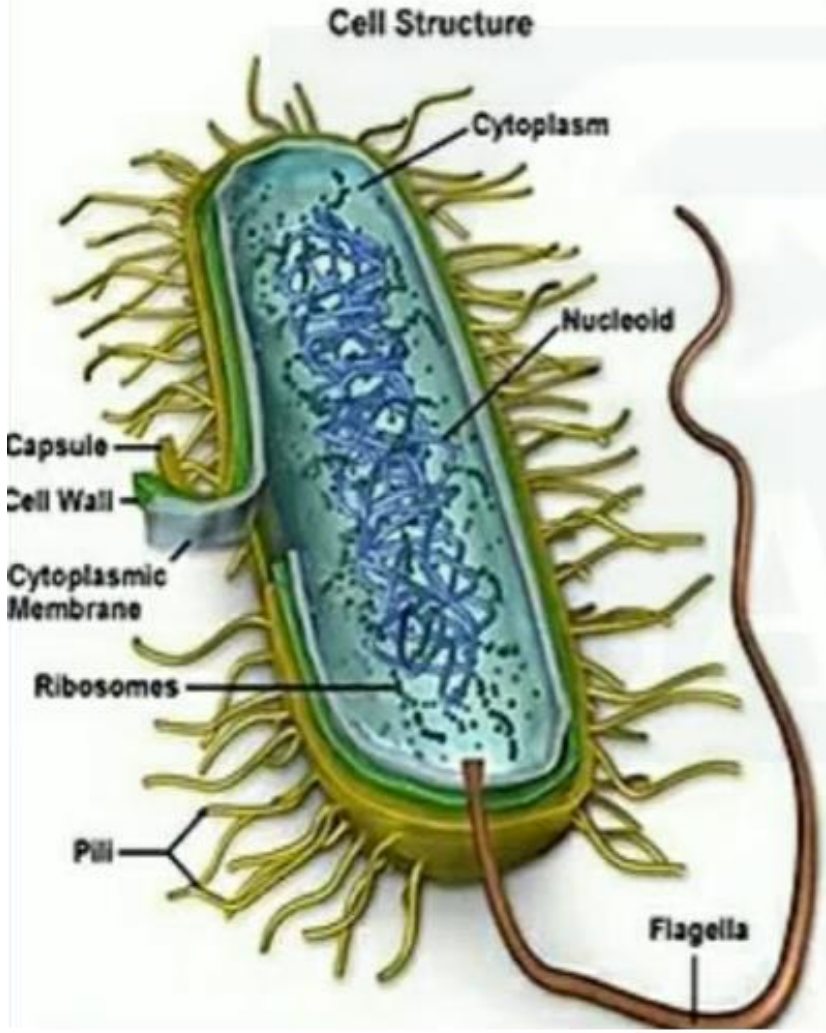
- no nucleus
- no membrane enclosed organelles
- single chromosome
- no streaming in the cytoplasm
- cell division without mitosis
- simple flagella
- smaller ribosomes
- simple cytoskeleton
- no cellulose in cell walls
- no histone proteins

- nucleus
- membrane enclosed organelle
- chromosomes in pairs
- streaming in the cytoplasm
- cell division by mitosis
- complex flagella
- larger ribosomes
- complex cytoskeleton
- cellulose in cell walls
- DNA bound to histone proteins

STRUCTURE OF TYPICAL BACTERIAL CELL



What is Bacteria?



- Single celled prokaryote
- No nucleus (nucleoid region instead)
- Very few (“no”) organelles
- Has a cell wall, cell membrane, ribosomes, cytoplasm
- Has circular chromosome and plasmid(s)

INTRODUCTION

- A bacterial cell shows various parts and these parts have specific structure and functions.
- Some structures are present in that particular species and hence that structure are characteristic feature of that species.

Various parts are as follows

1. Cell wall
2. Cell membrane
3. Mesosoma's
4. Capsule
5. Flagella
6. Pila
7. Nuclear material
8. Ribosomes

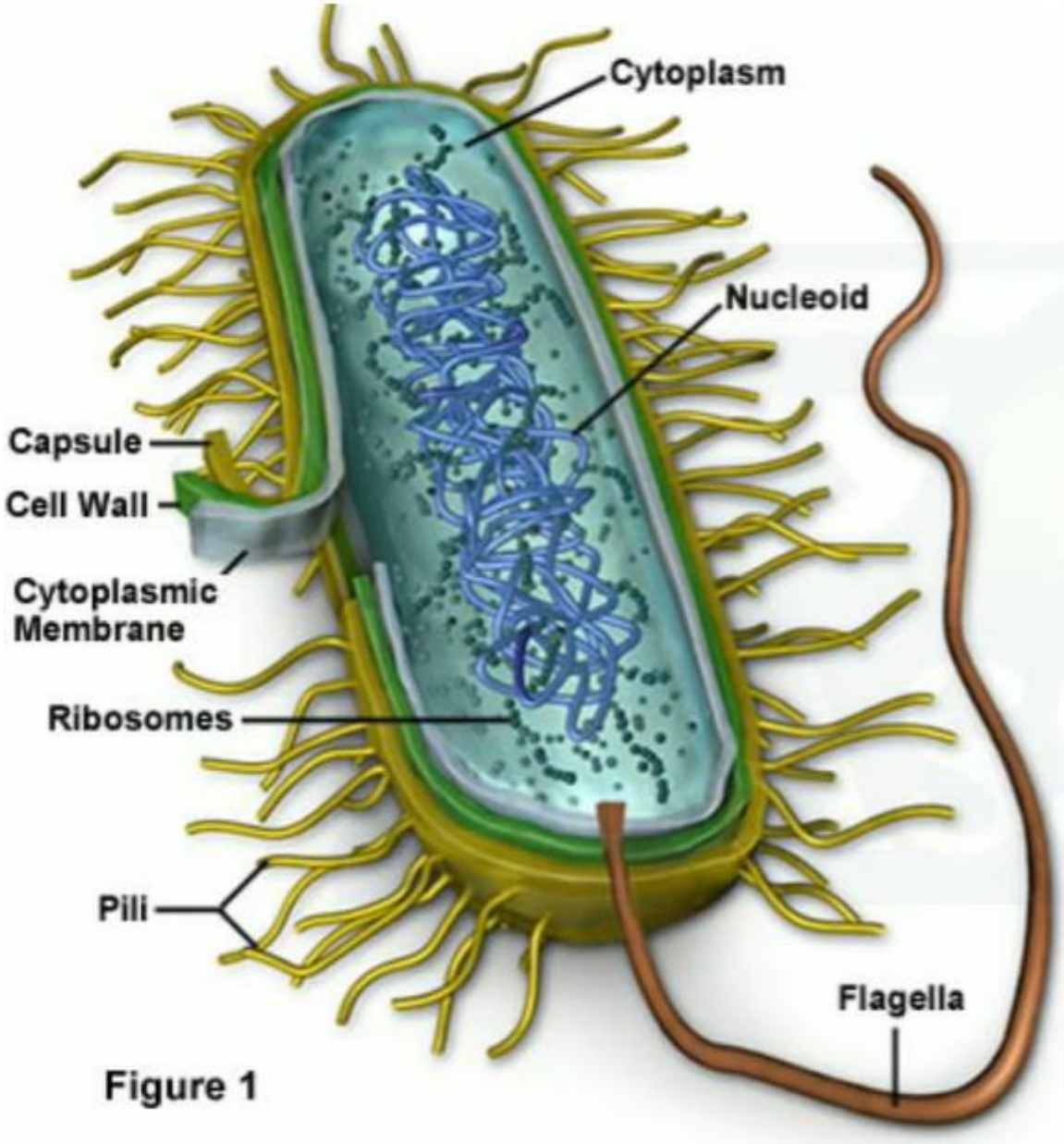
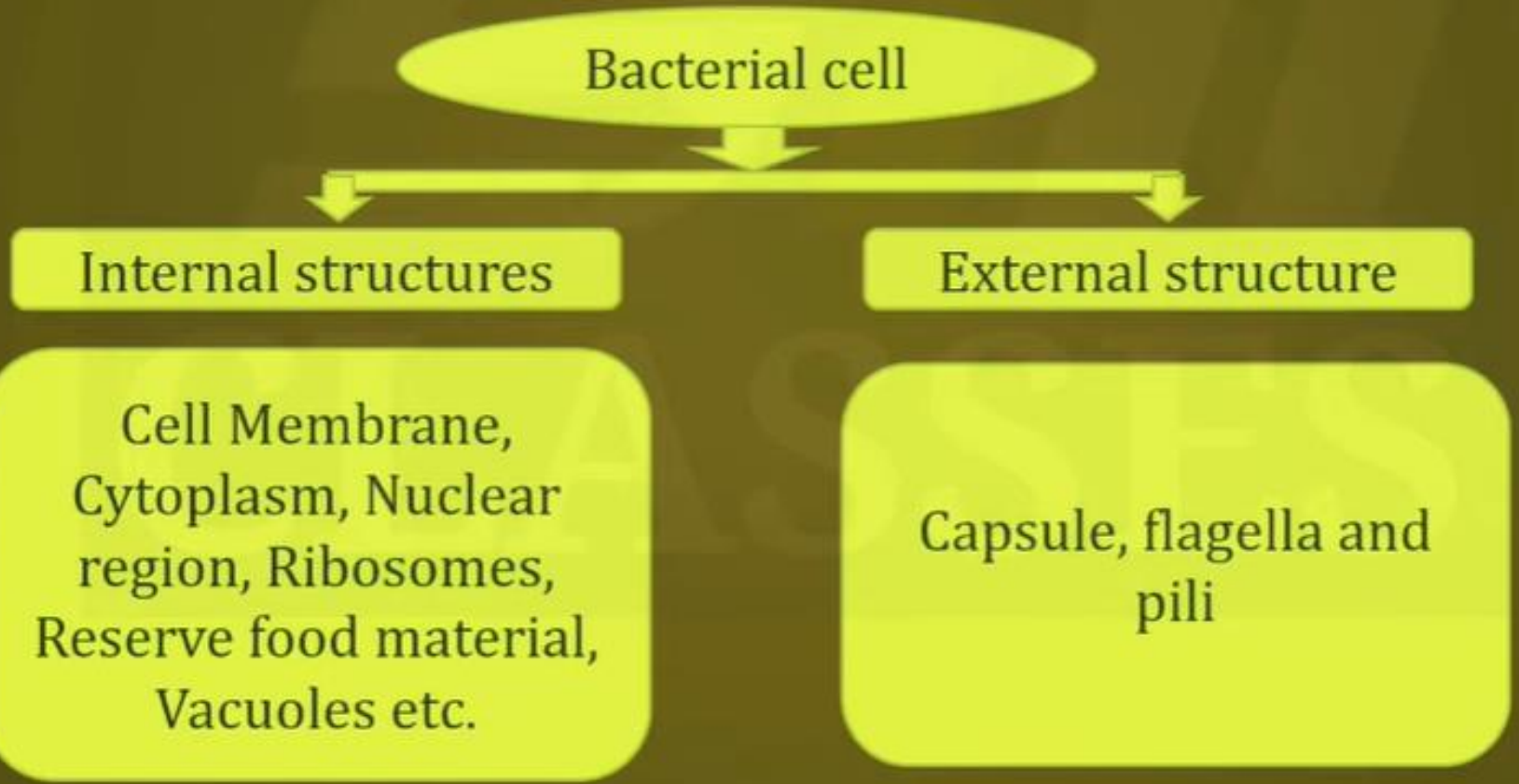


Figure 1

DIAGRAM :- BACTERIAL CELL

BACTERIAL CELL

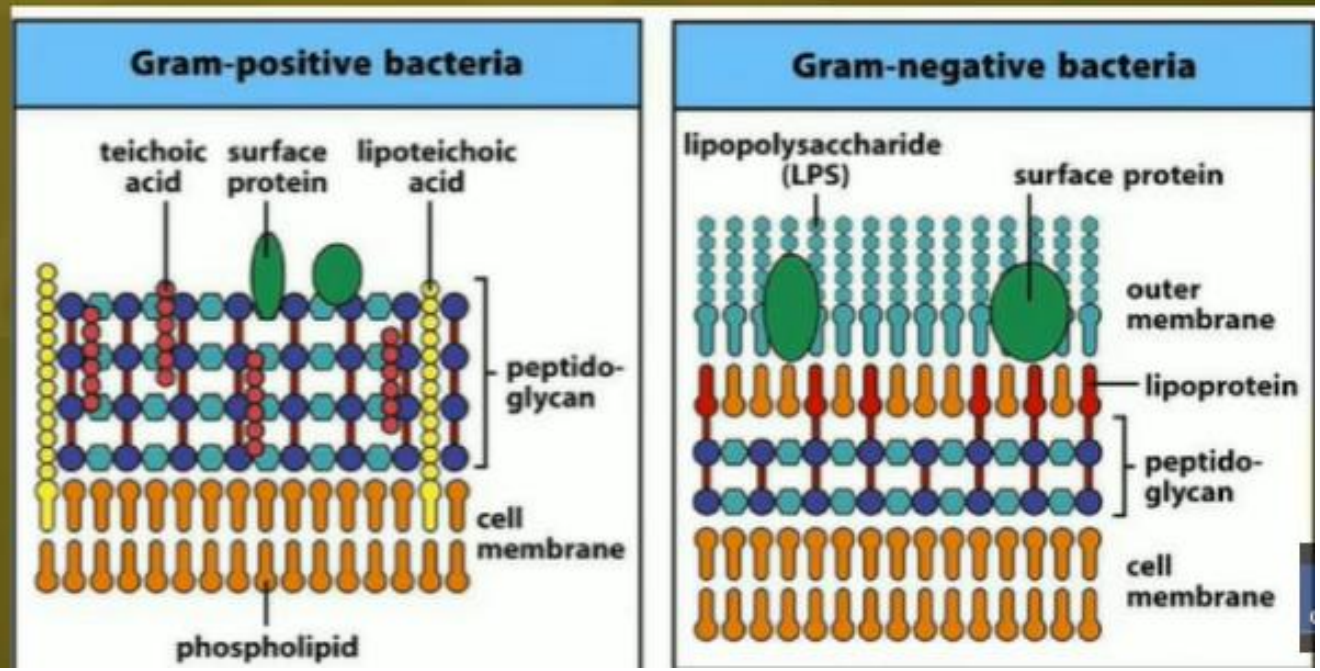
Bacterial cell is made up of various internal as well as external anatomical structure.



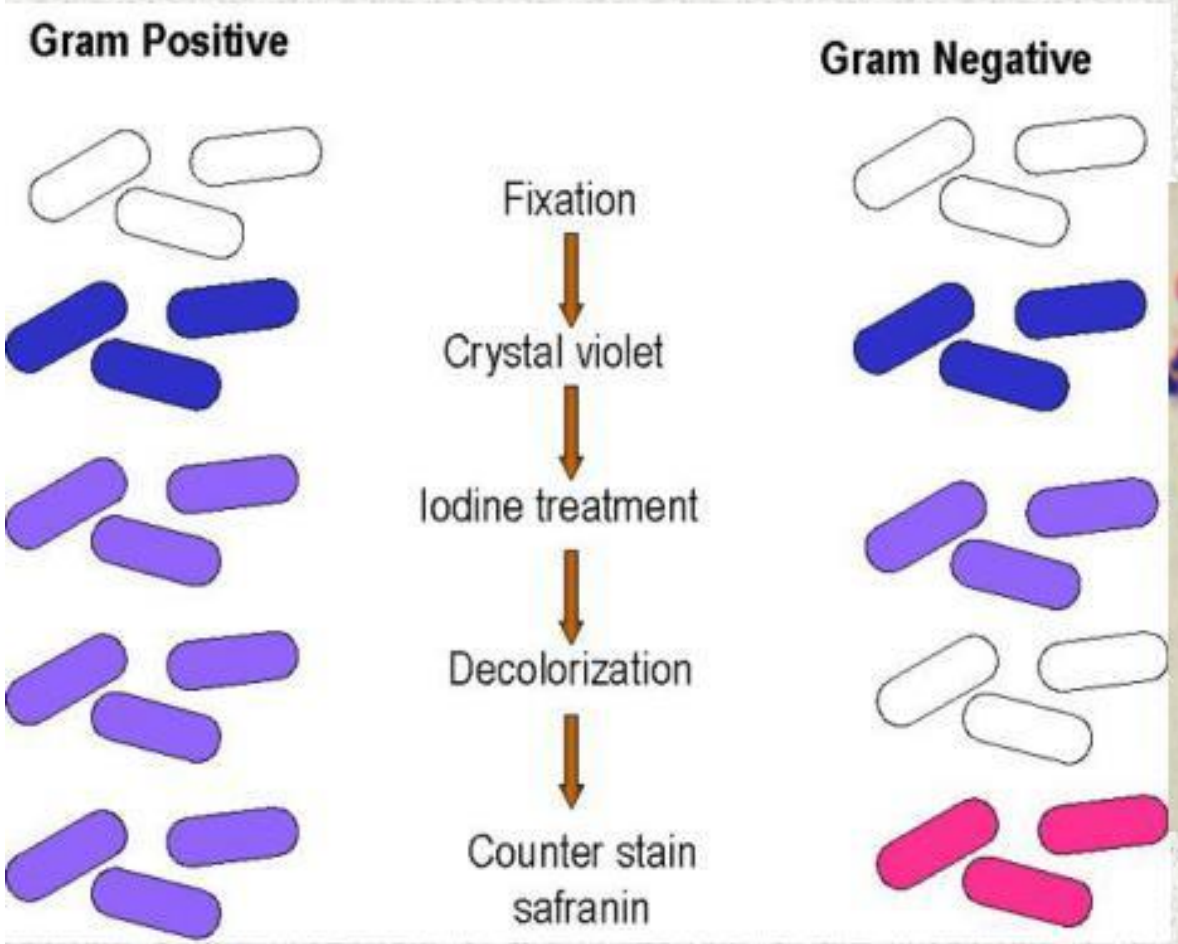
1. Cell wall

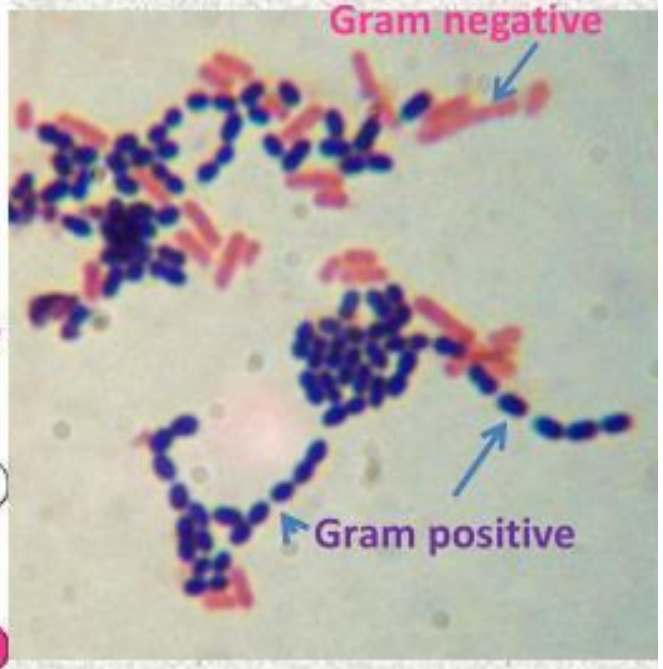
- The cell wall is the outer covering of bacterial cell in absence of capsule.
- The cell wall is rigid in nature which imparts a proper shape to bacteria.
- Cell wall encloses all internal parts of the cell.
- On the basis of typical structure, composition and Gram staining the bacterial cells are classified into

1. Gram Positive Bacterial cell
2. Gram Negative Bacterial cell



Gram Staining Procedure

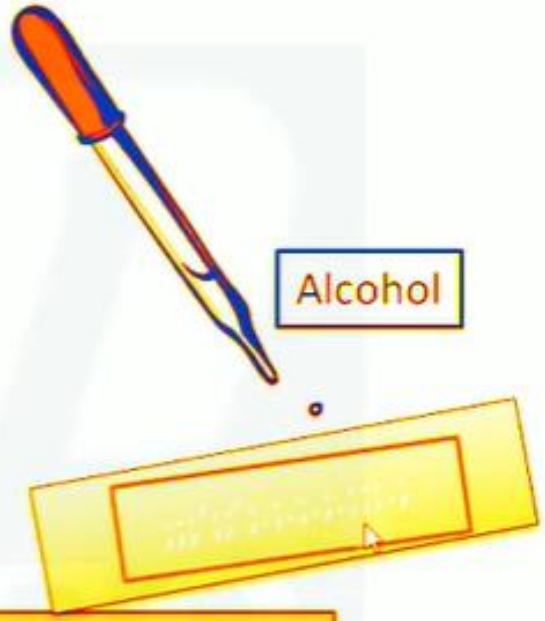




Difference No: 1-Why this name?

Hans Christian Joachim Gram

Danish Bacteriologist



Gram positive

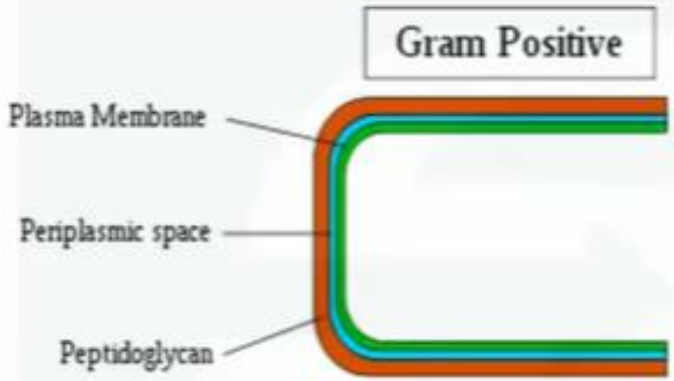
✓The bacteria that retain the colour of crystal violet even after alcohol treatment is the Gram positive

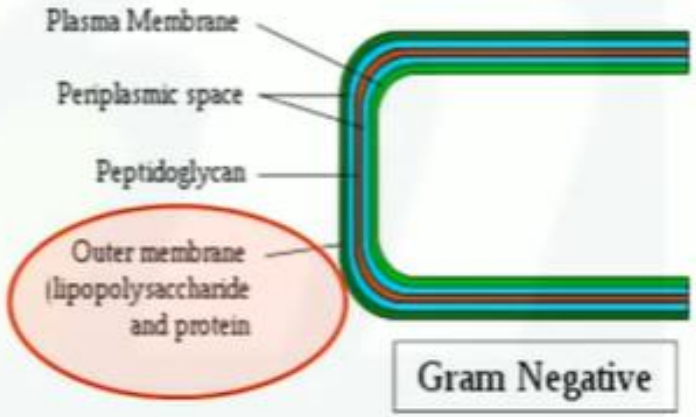
Gram negative

✓The bacteria that lose the colour of crystal violet on alcohol treatment is the Gram negative

Differential staining is due to the difference in cell wall composition of Gram positive and Gram negative bacteria

Difference No: 2- Cell Wall layers?





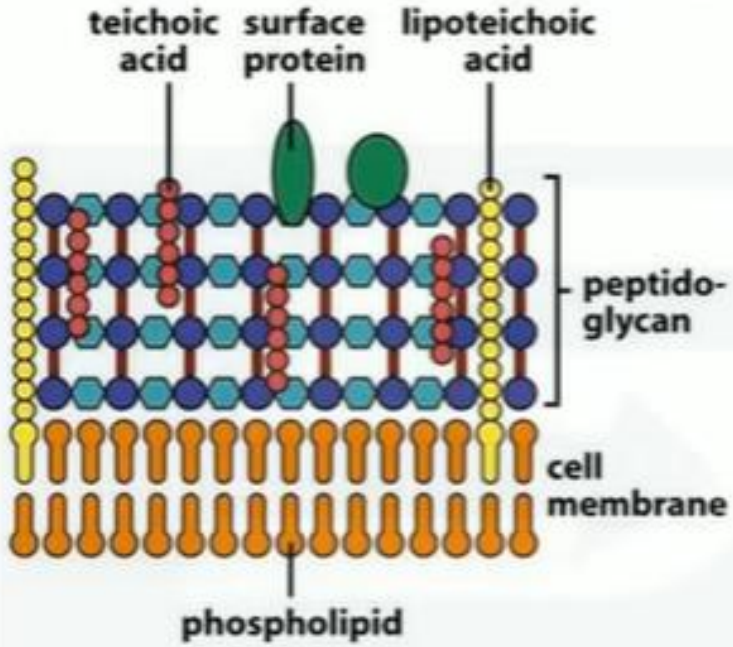
Gram positive

- ✓Outer membrane is absent
- ✓Thick peptidoglycan wall

Gram negative

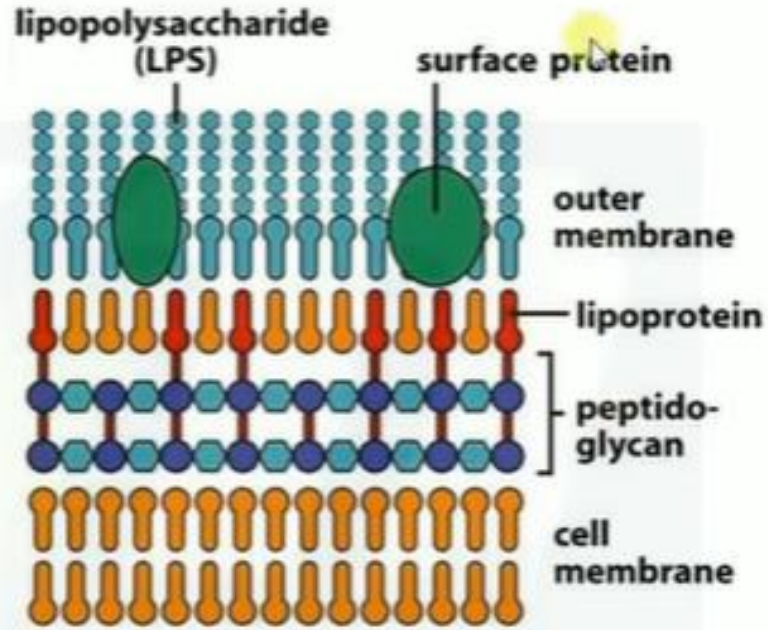
- ✓Outer membrane made up of lipo polysaccharide and protein is present
- ✓Thin peptidoglycan wall

Difference No: 3- Cell wall composition?



Gram positive

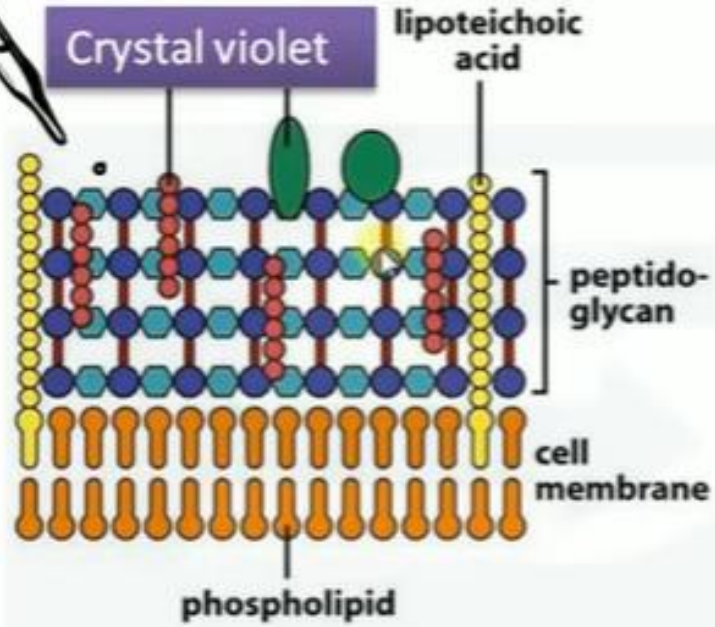
- ✓Teichoic acid is present
- ✓Lipid content is very low

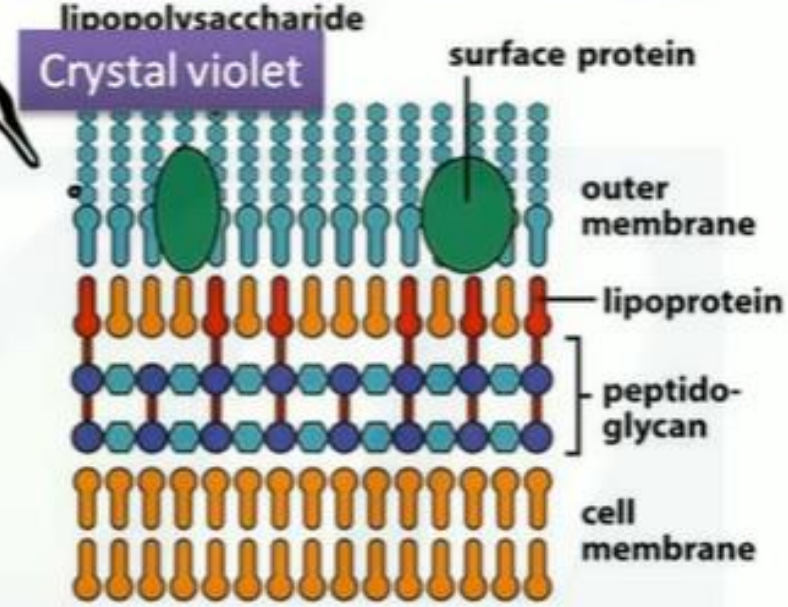


Gram negative

- ✓Teichoic acid is absent
- ✓Fair amount of lipid in the outer membrane

Difference No: 3- How Gram stain works?

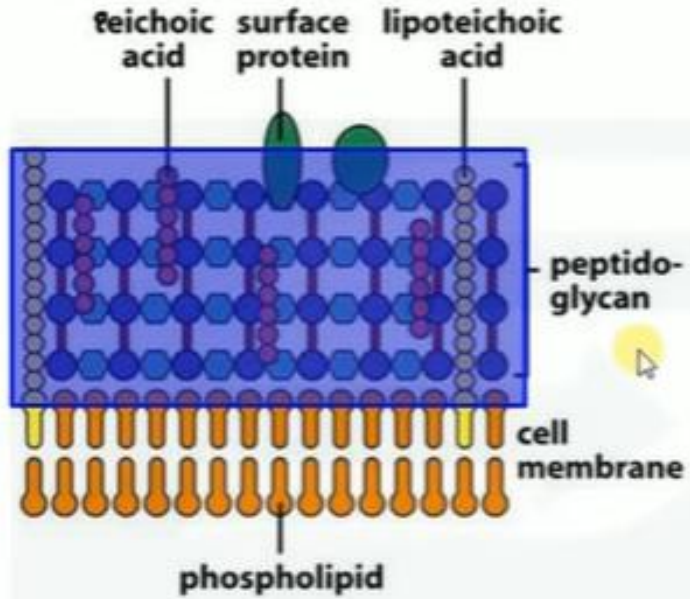




Gram positive	Gram negative

Diffe[illegible] 3- How Gra[illegible]n works?

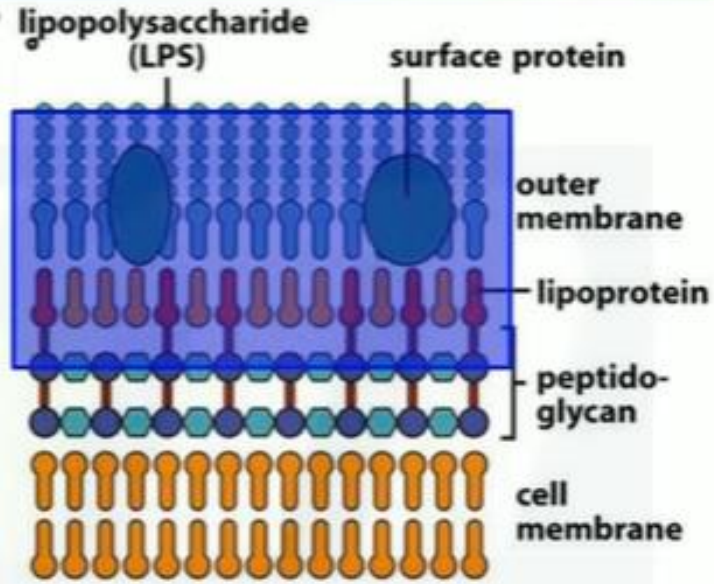
Iodine



Gram positive

✓Adding crystal violet-turns violet

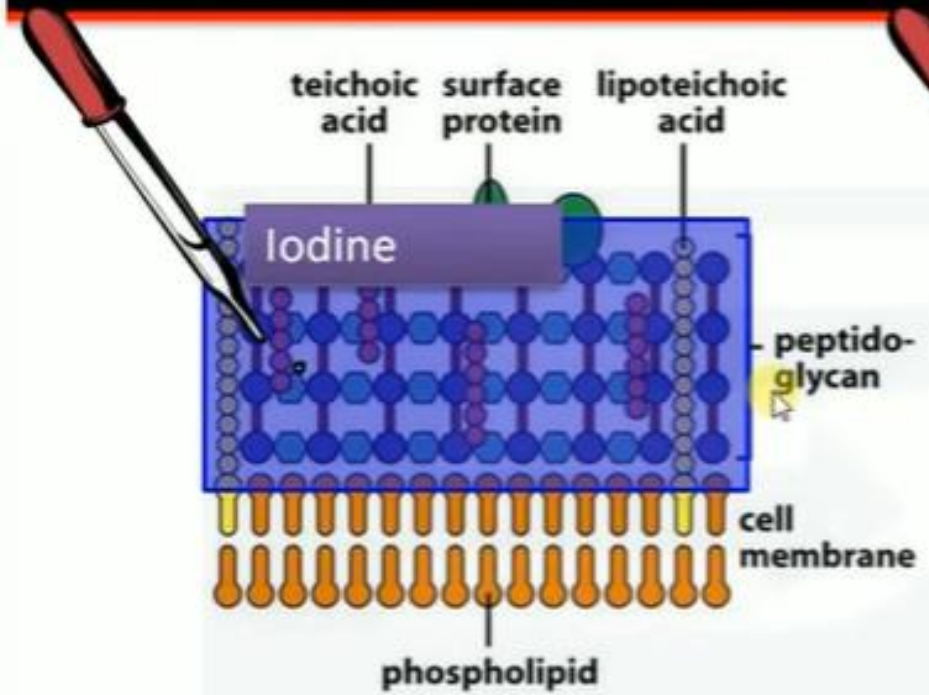
Iodine

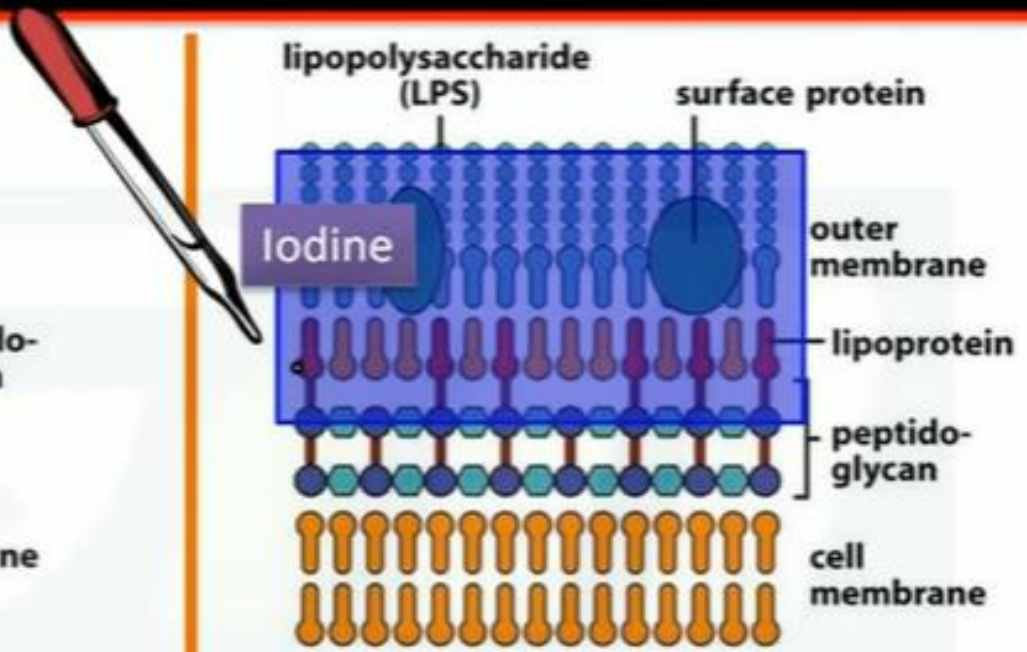


Gram negative

✓Adding crystal violet-turns violet

Difference No: 3- How Gram stain works?





Gram positive

✓Adding crystal violet-turns violet

Gram negative

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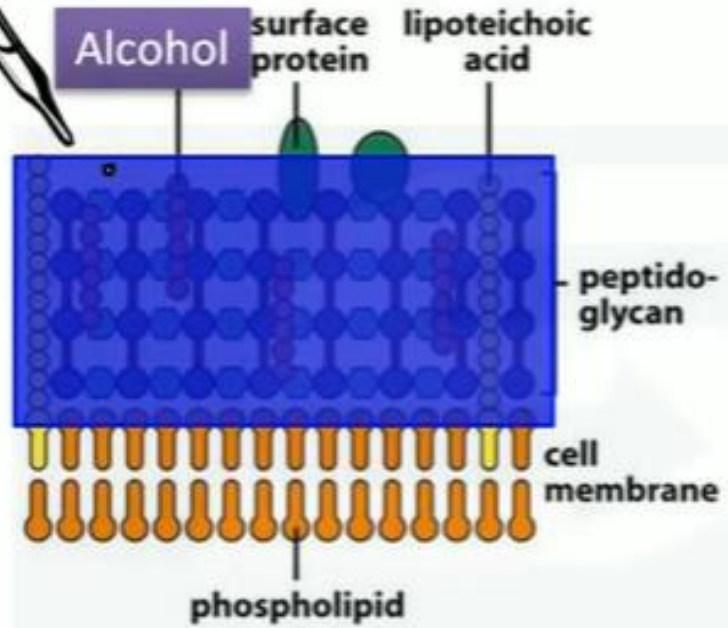
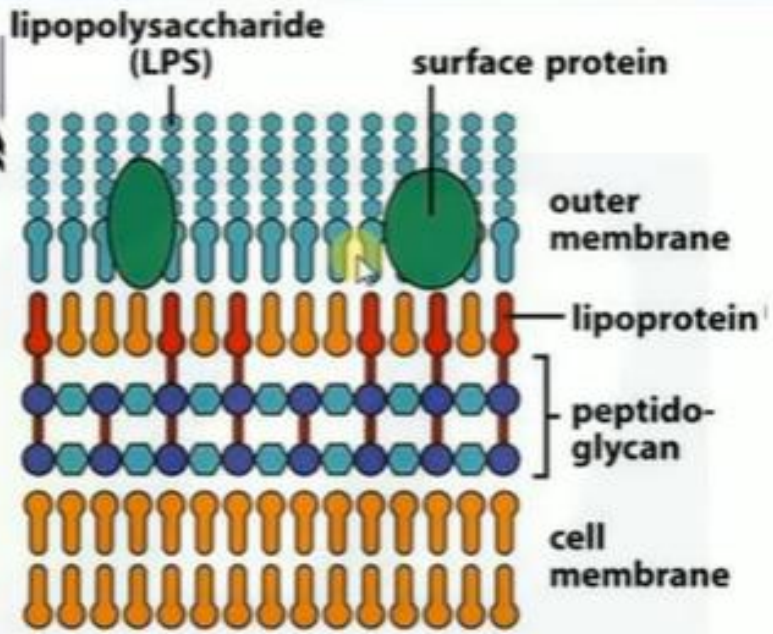
Difference No: 3- How Gram stain works?



Gram positive

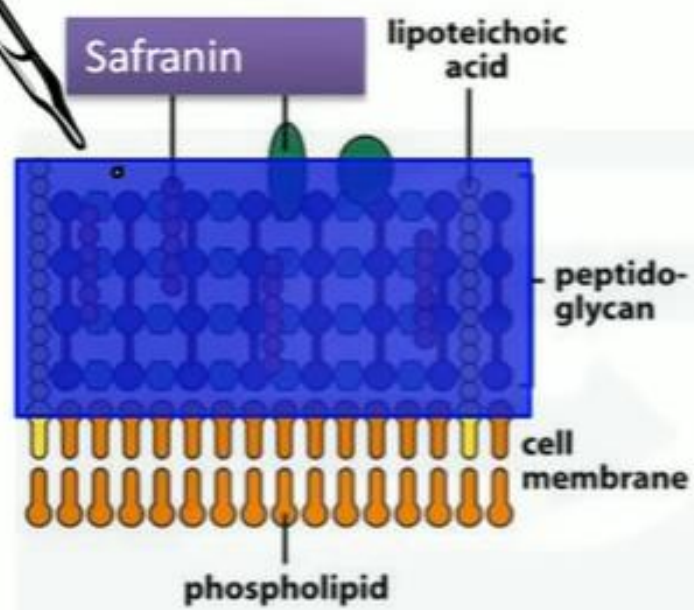
✓Adding crystal violet-turns violet



Gram negative

✓Adding crystal violet-turns violet

Difference No: 3- How Gram stain works?



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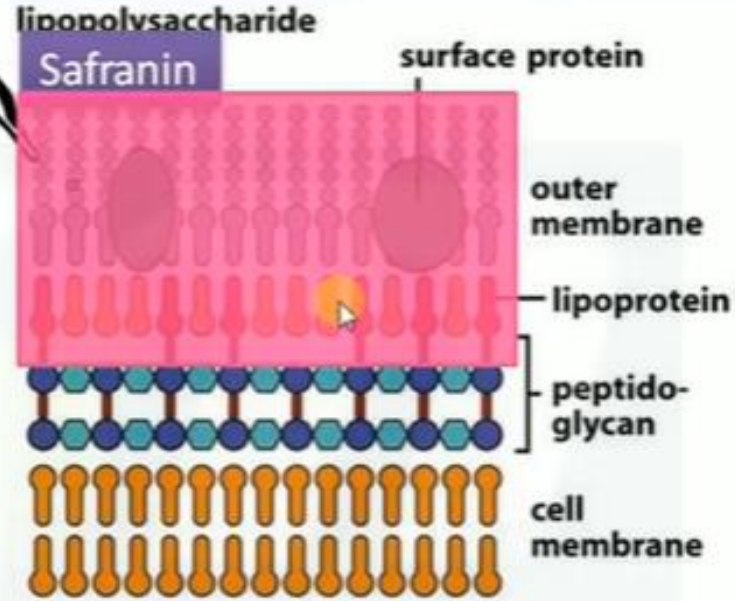

Gram negative

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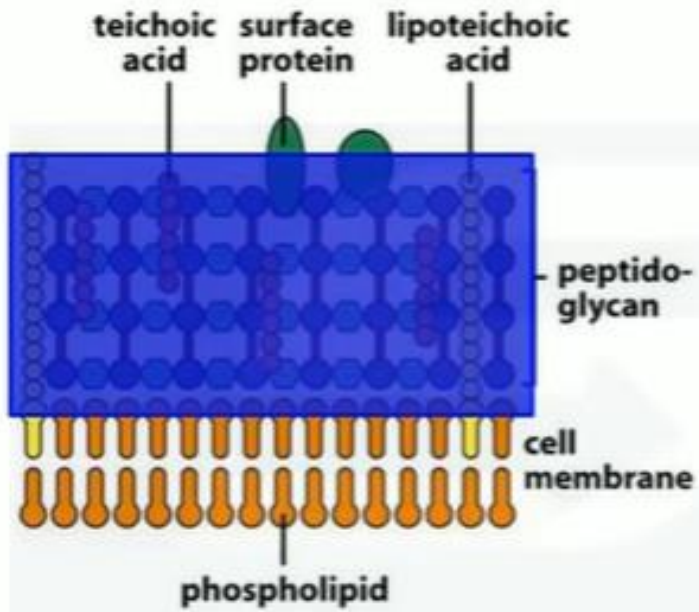
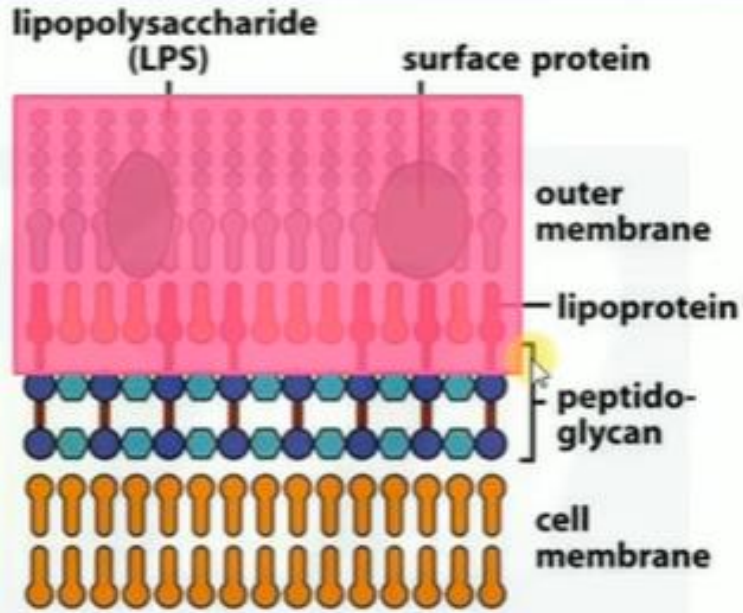
Difference No: 3- How Gram stain works?



Gram positive

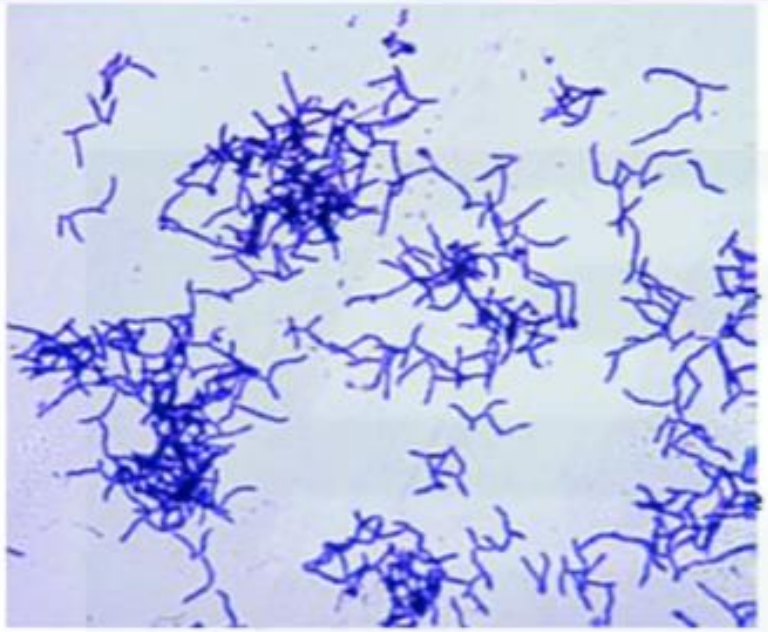
✓Adding crystal violet-turns violet
✓Adding Alcohol Gram +ve bacteria retains color of crystal violet as lipid content is very low on the membrane. Stain has firmly bound to peptidoglycan wall

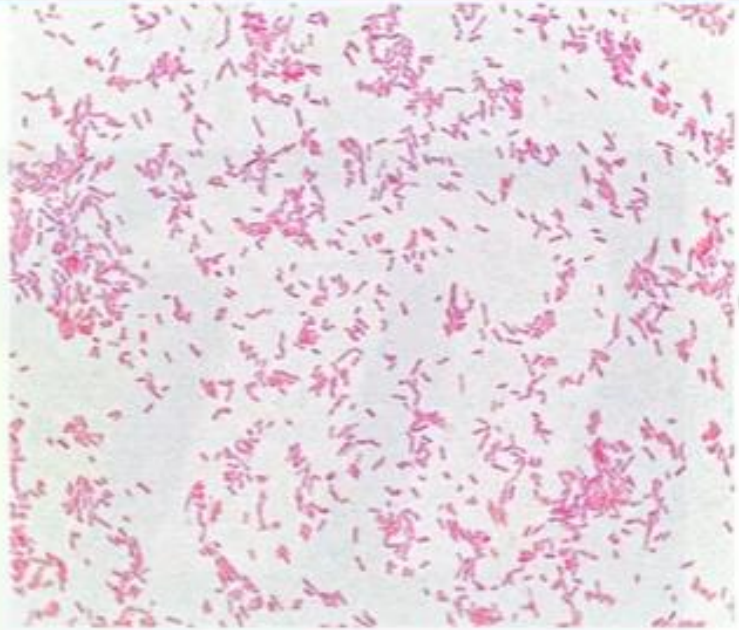


Gram negative

✓Adding crystal violet-turns violet
✓Adding Alcohol, Gram -ve bacteria loses color of crystal violet as crystal violet bound lipid containing outer membrane gets dissolved in alcohol.
✓Counter stain with safranin to see

Difference No: 3- How Gram stain works?





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Gram negative

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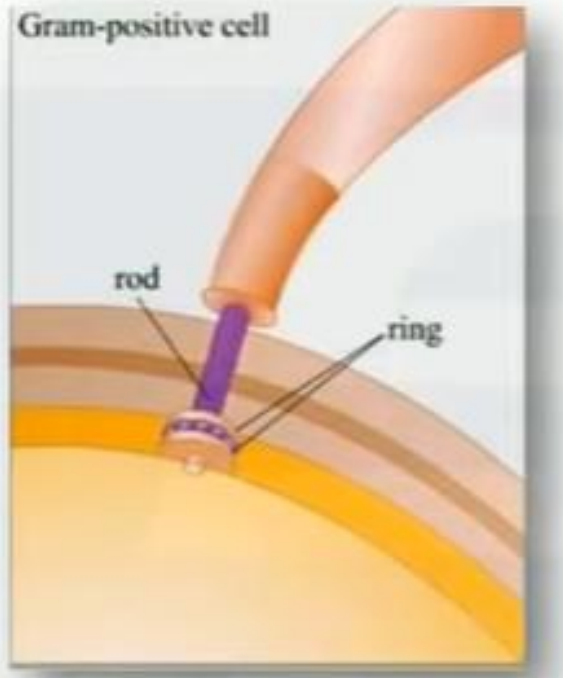
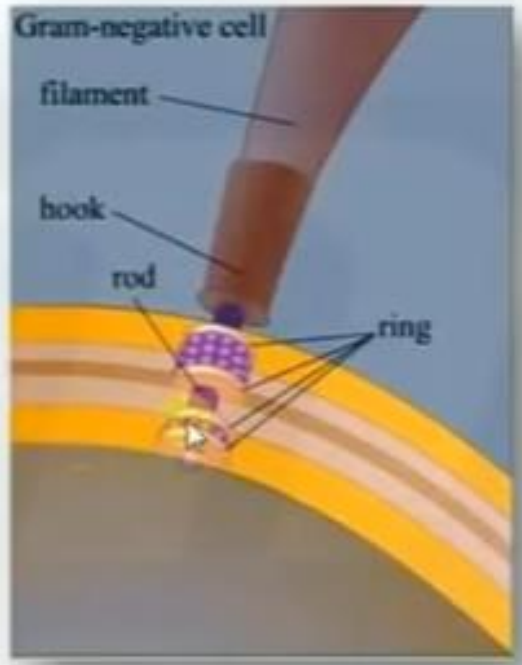
✓Counter stain with safranin to see

Difference No: 4: Flagella?



Gram positive

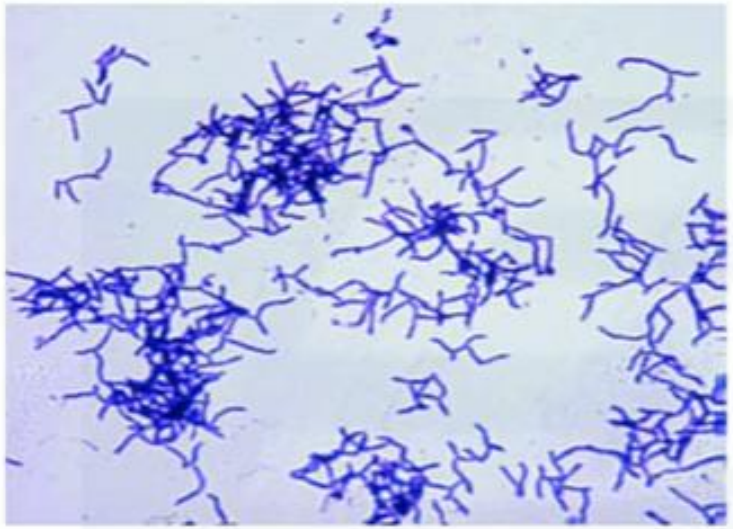
✓Basal body has two rings



Gram negative

✓Basal body has four rings

Difference No: 5: Pathogenicity?



Actinomyces

Gram positive

✓Very few bacteria are pathogenic

Examples:

- *Actinomyces*
- *Enterococcus*
- *Lactobacillus*

Escherichia coli

Gram negative

Majority of pathogenic bacteria are Gram negative.

Examples:

- *Escherichia coli*
- *Salmonella*

1. Cell wall

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- The cell wall is rigid in nature which imparts a proper shape to bacteria.
- Cell wall encloses all internal parts of the cell.
- On the basis of typical structure, composition and Gram staining the bacterial cells are classified into

1. Gram Positive Bacterial cell
2. Gram Negative Bacterial cell

2. Cell Membrane

- Cell membrane is a thin membrane beyond the cell wall and a membrane covering the cytoplasm.
- It is called cell membrane or cytoplasmic membrane or plasma membrane.
- It is a bilayered structure made up of phospholipids and proteins.

3. Mesosoma's

1. Mesosoma are chemically invasions of cell membrane made up of phospholipid bilayer and proteins.
2. Mesosoma's are mostly seen in Gram positive bacteria as well as rarely observed in gram negative bacteria due to small size.

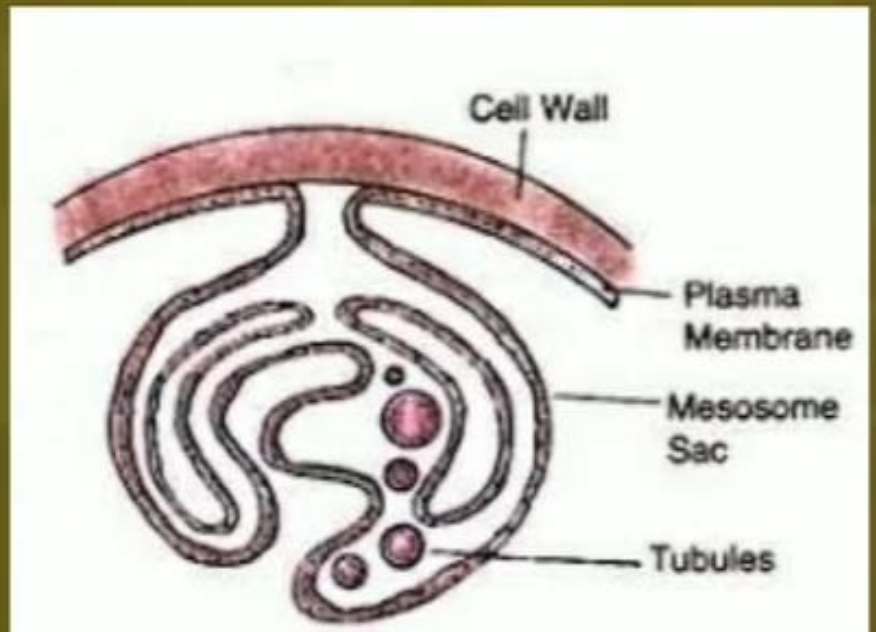

Fig. 4.15 : The bacterial mesosome (diagrammatic)

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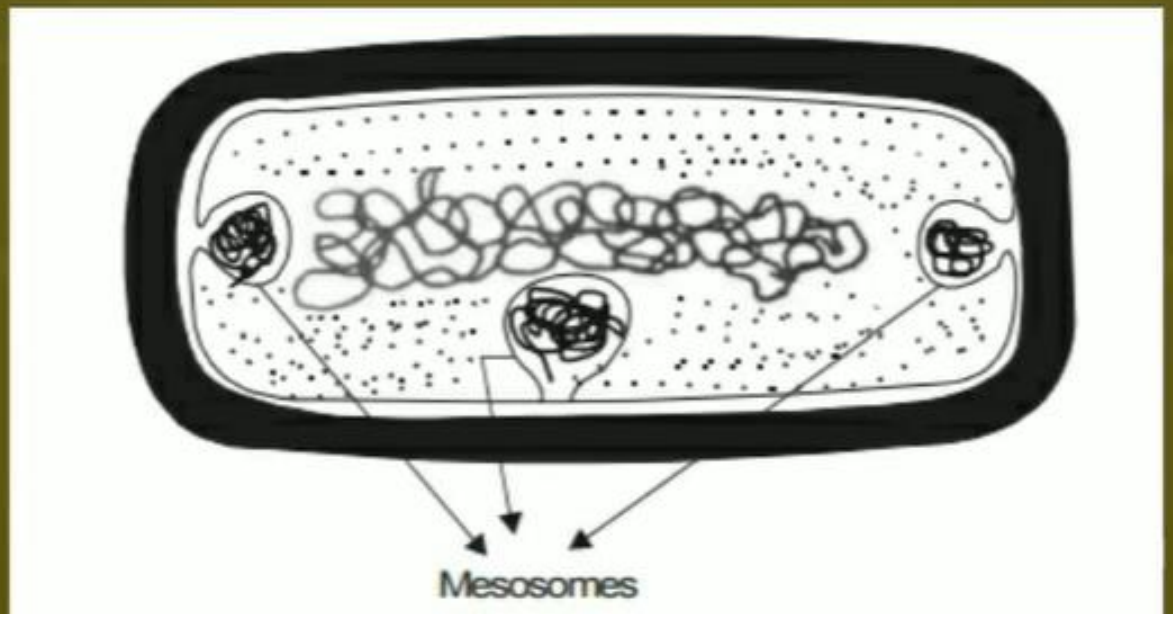
3. On the basis of location mesosoma's basically are of two types – Central mesosoma's and peripheral mesosoma's.



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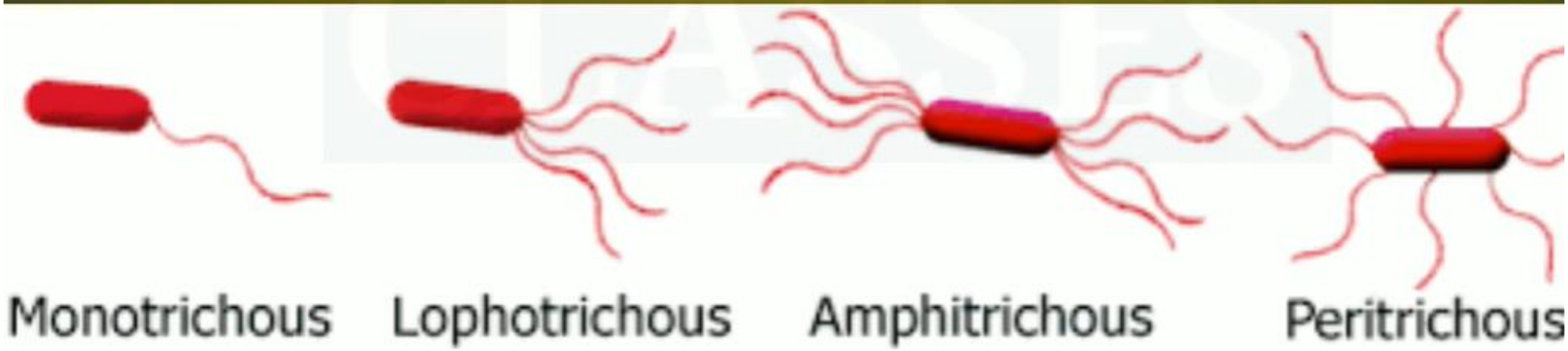
4. Capsule

1. The outer most slimy, gummy coating surrounding the cell wall is called as capsule.
2. It increases virulence of bacterial cell as it acts as a protective covering.
3. Micro-organism having capsule are called as capsulated bacteria.
4. On the basis of thickness capsules are of two types and they are Macro-capsule and micro-capsule.

5. Flagella

- Flagella is one of the important locomotory organ. Micro – organism containing flagella are called as flagellated micro-organism.
- Diameter of flagella ranges from 10 to 12 nm and length ranges from 20 micron to 200 micron.
- On basis of arrangement flagella are differentiated as monotrichous, lophotrichous, Amphitrichous and peritrichous.



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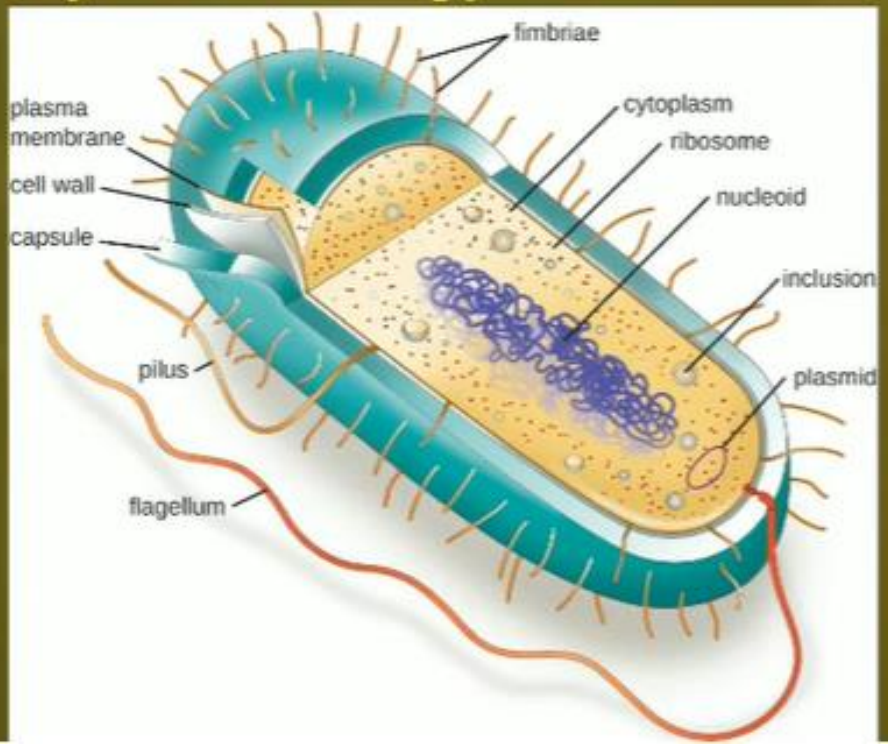
- On basis of arrangement flagella are differentiated as monotrichous, lophotrichous, Amphitrichous and peritrichous.

6. Pili

- Pili are the small, thin and straight appendages present on the surface of bacteria.
- Diameter of pili ranges from 3 to 25 nm and length ranges up to 12 micro.
- Pili serve as a site for attachment of bacteriophage.

7. Nuclear material

- Bacterial cells are prokaryotic in nature and its nuclear material is not enclosed in nuclear membrane.
- Nuclear material of bacteria is called as nucleoid, bacterial chromosome or chromatid body.
- Nuclear material of bacteria is a long molecule of DNA approximately about 3000 micron . They have one copy of chromosome so called haploid.



7. Nuclear material

- Bacterial cells are prokaryotic in nature and its nuclear material is not enclosed in nuclear membrane.
- Nuclear material of bacteria is called as nucleoid, bacterial chromosome or chromatid body.
- Nuclear material of bacteria is a long molecule of DNA approximately about 3000 micron . They have one copy of chromosome so called haploid.

8. Ribosomes

- Ribosomes are small, tiny units distributed evenly in cytoplasm.
- Ribosomes may be free or in chain form linked to mRNA molecules. Such ribosomes are called as polysomes.
- Bacterial ribosome is 70 'S' type. Size of ribosome ranges from 16 to 18 nm.
- Ribosomes are composed of 60 % or rRNA and 40 % of protein.

CLASSIFICATION OF BACTERIA ON BASIS OF SHAPE

Summarizing Classification of Bacteria on the basis of

1) Pathogenicity
2) Shape / Morphology
3) Arrangement
4) Differential Staining
5) Gaseous Requirement / Growth Requirements
6) Locomotory Organ i.e. Flagella
7) Spore
8) Mode of Nutrition
9) Temperature Requirements
10) Optimum pH for growth
11) Salt requirement

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

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

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

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

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:

Arrangements of Cocci

- **Monococcus:**– they are also called micrococcus and represented by single, discrete round Example: *Micrococcus flavus*.

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:

Arrangements of Cocci

- **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*.

Diplococci

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:

Arrangements of Cocci

- **Streptococcus:** – here the cells divide repeatedly in one plane to form chain of cells. Example: – *Streptococcus pyogenes*.

Streptococci

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:

Arrangements of Cocci

- **Tetracoccus: –**

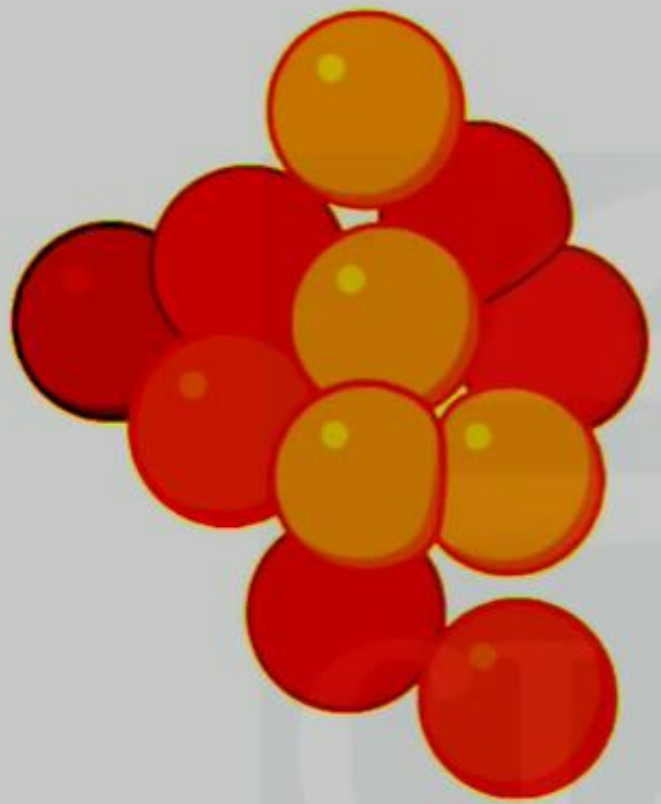
- Tetrad bacteria are arranged in a group of four cells that remain attached and grow in the attachment after cell division.
- This arrangement results when the cells divide into two planes.
- Examples: *Aerococcus, Pediococcus, and Tetragenococcus.*

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:

Arrangements of Cocci

- **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*.

Staphylococci



- This type includes bacteria that are arranged in grape-like clusters.
- This results from cell division in both the planes and are characterized by organisms which are immotile and Gram-positive.
- Examples: *Staphylococcus epidermidis, Staphylococcus haemolyticus, Staphylococcus aureus, Staphylococcus capitis.*

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

Arrangement of Bacilli

Diplobacilli

- As in Diplococci, Diplobacilli also exists in pairs.
- After cell division, the two cells do not divide and grow in an attached arrangement.
- Examples: *Coxiella burnetii, Klebsiella rhinoscleromatis, Moraxella bovis*.

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

Arrangement of Bacilli

Streptobacilli

- In this group, bacteria are arranged in chains.
- This results from cell division in a single chain.
- Examples: *Streptobacillus moniliformis, Streptobacillus Levaditi, Streptobacillus felis, Streptobacillus hongkongensis.*

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

Arrangement of Bacilli

Coccobacilli

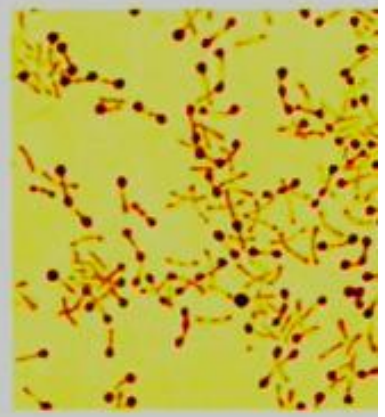
- As the name suggests, coccobacilli resemble both cocci as well as bacilli.
- These are shorter in size and thus, appear stumpy.
- Examples: *Chlamydia trachomatis, Haemophilus influenza, Gardnerella vaginalis*.

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

4. Palisades

Arrangement of Bacilli

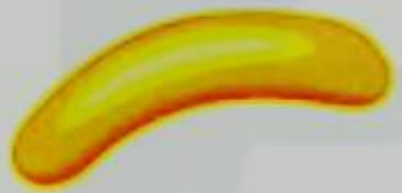
Palisades



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 diphtheriae*

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



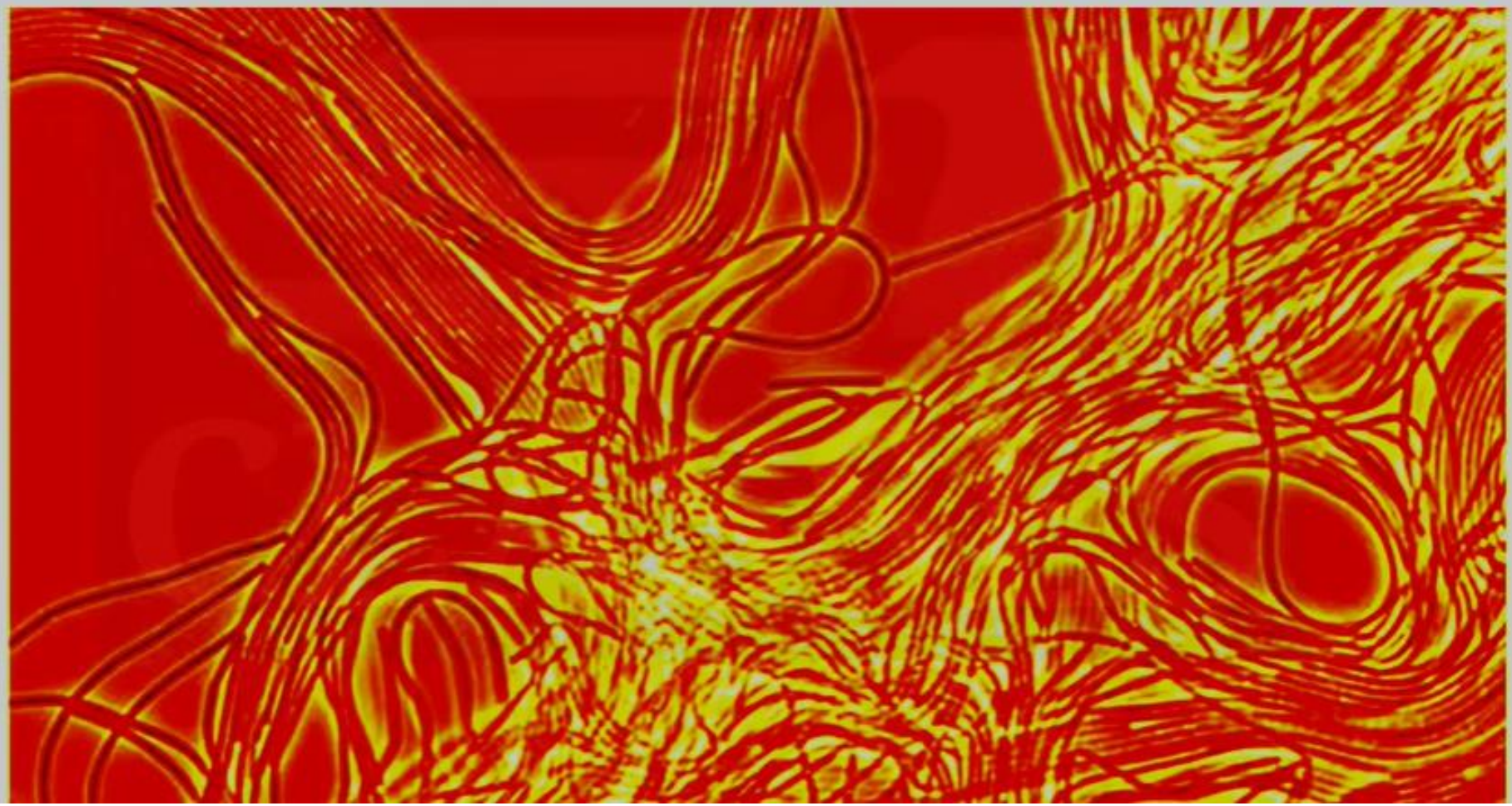
Vibrio

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

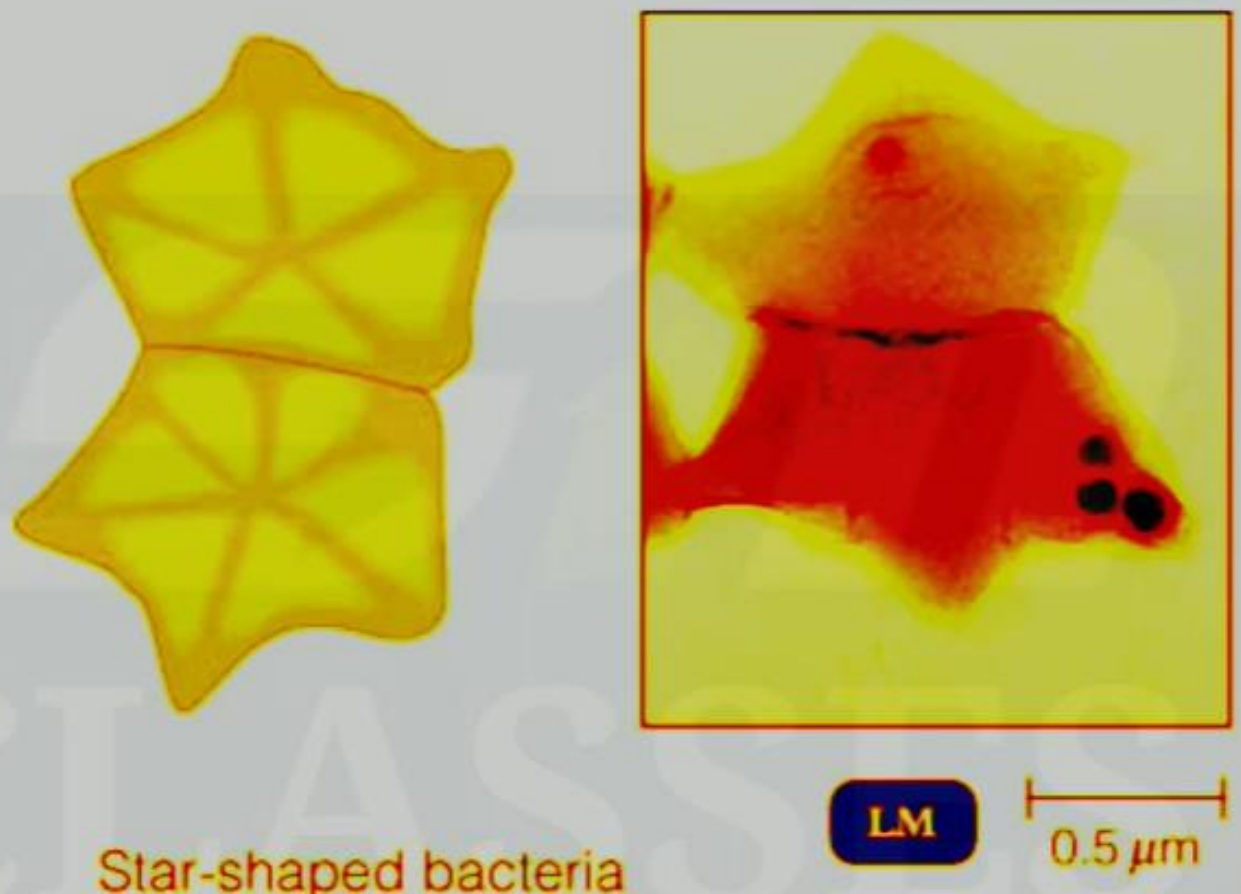
Spirillum

Others Shapes and Arrangements of Bacteria

1. Filamentous Bacteria



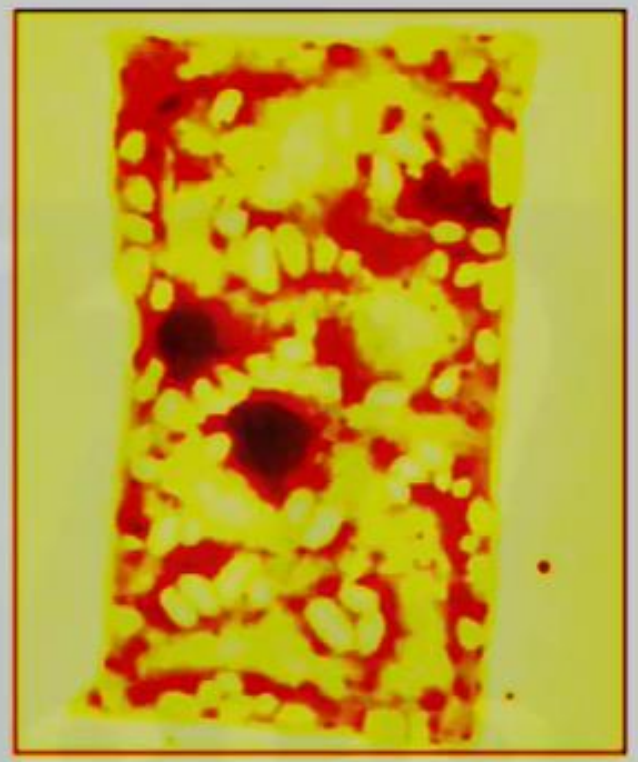
2. Star Shaped Bacteria



Star-shaped bacteria

Example: *Stella*

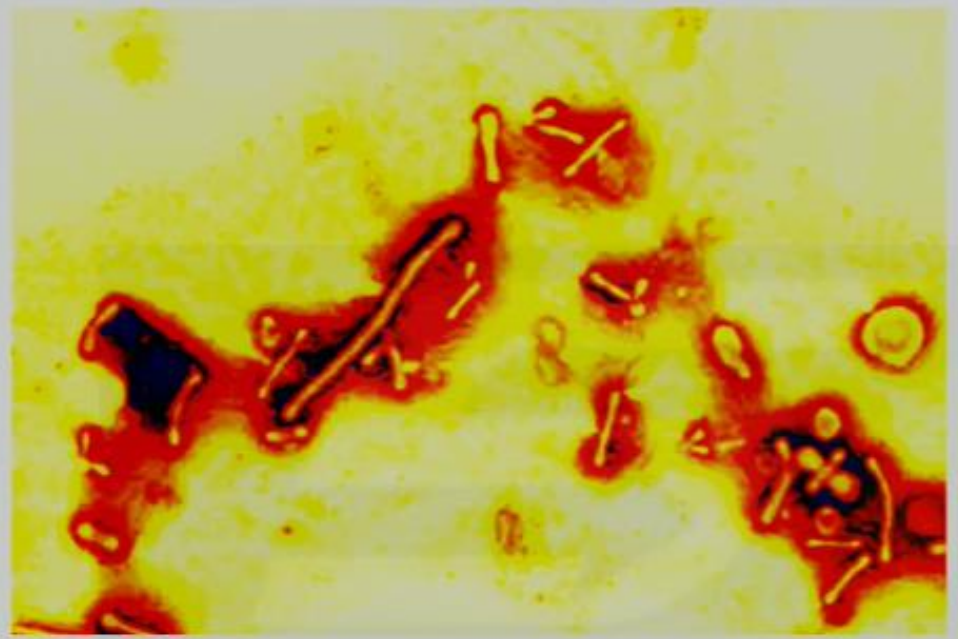
3. Rectangular Bacteria



Rectangular bacteria

- Examples: *Haloarcula* spp *(H. vallismortis, H. marismortui)*

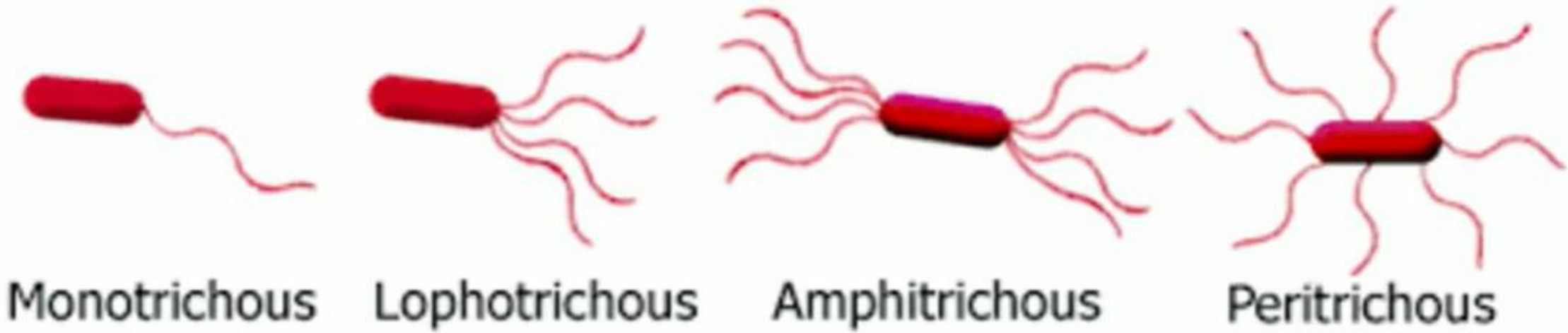
4. Pleomorphic Bacteria



These bacteria do not have any characteristic shape unlike all others described above. They can change their shape. In pure cultures, they can be observed to have different shapes.

Examples: *Mycoplasma pneumoniae, M. genitalium,* etc.

Classification Of Bacteria on the basis of Flagella



On the basis of flagella (threadlike locomotor appendages extending outward from the plasma membrane and cell wall) the bacteria can be classified into 5 categories:

Bacteria are also classified on basis of their Locomotory Organ i.e. Flagella

Bacteria which possess one or more flagella are called as Motile bacteria

Non motile bacteria are without flagella

Non motile bacteria without flagella are called **Atrichous Bacteria**

Motile bacteria are further classified as

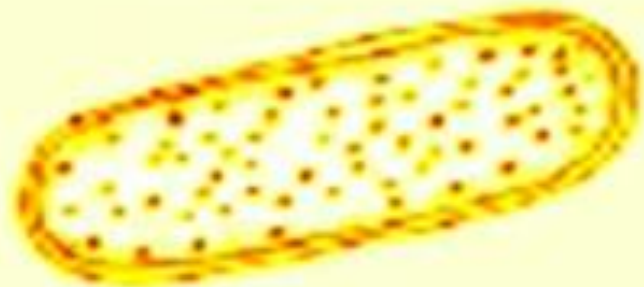
Monotrichous bacteria

Amphitrichous bacteria

Lophotrichous bacteria

Peritrichous bacteria

1) Atrichous: – These bacteria do not have flagella (*trichous means hair).*
Example: *Corynebacterium diptherae*



2) Monotrichous: – One flagellum is attached to one end of the bacteria cell.
Example: – *Vibro cholerae.*

Monotrichous

3) Lophotrichous: -(*lopho means tuft)* Bunch of flagella is attached to one or both end of the bacteria cell. Example: *Spirillum*

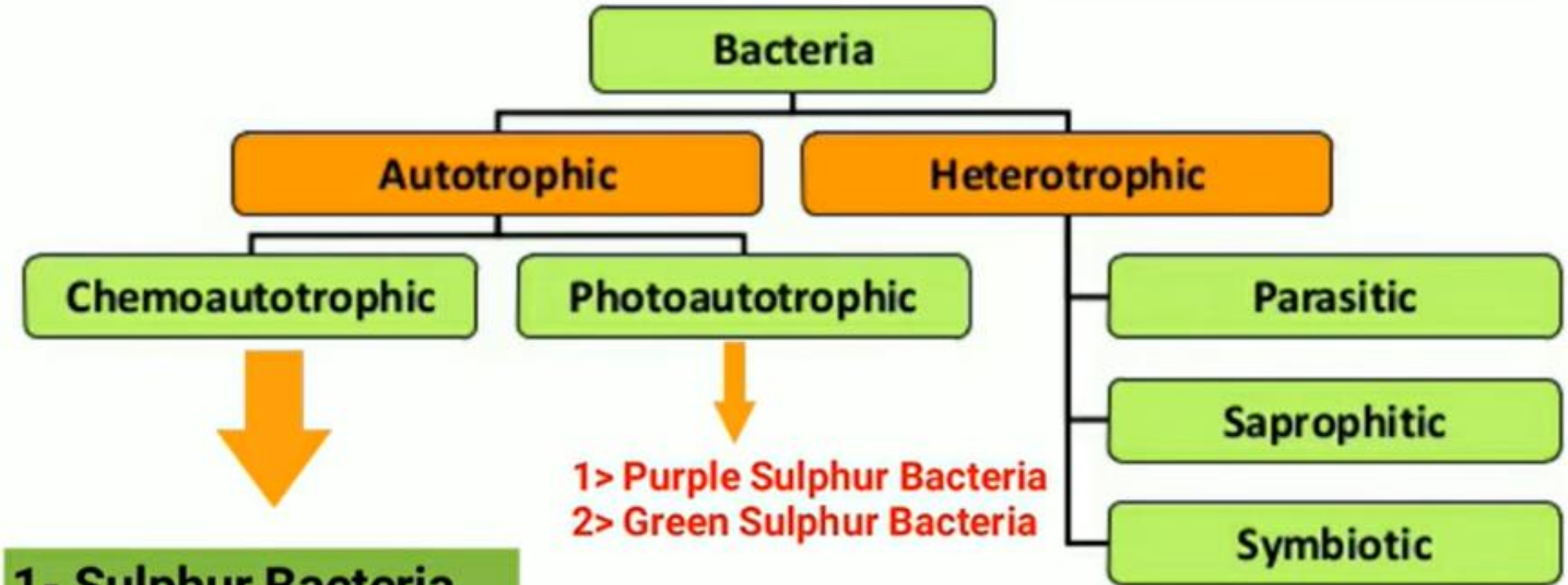
4) Amphitrichous: -(*amphi means on* both sides) flagella arising from both end of the bacteria cell.
Example: *Rhodospirillum rubrum*

Amphitrichous

5) Peritrichous : - (*peri means* around)The flagella are evenly distributed surrounding the entire bacterial cell. Example: *Bacillus.*

Peritrichous

Nutrition



1- Sulphur Bacteria
2- Methane Bacteria
3- Hydrogen Bacteria
4- Carbon Bacteria
5- Nitrifying Bacteria
6- Iron Bacteria

What are photosynthetic bacteria?

Much like the name suggests, these micro-organisms are special types of bacteria that contain light absorbing pigments and reaction centers which make them capable of converting light energy into chemical energy.

Cyanobacteria contain chlorophyll while other forms of bacteria contain bacteriochlorophyll. Although bacteriochlorophyll resembles chlorophyll, it absorbs light of a longer wavelength than chlorophyll. Bacteriochlorophyll a is the most common form of bacteriochlorophyll but other forms include b, c, d, e, f and g.

Cyanobacteria contain chlorophyll while other forms of bacteria contain bacteriochlorophyll. Although bacteriochlorophyll resembles chlorophyll, it absorbs light of a longer wavelength than chlorophyll. Bacteriochlorophyll a is the most common form of bacteriochlorophyll but other forms include b, c, d, e, f and g.

Bacteria that contain bacteriochlorophyll do not use water as an electron donor and therefore do not produce oxygen. This is known as anoxygenic photosynthesis. Cyanobacteria perform photosynthesis using water as an electron donor in a similar manner to plants. This results in the production of oxygen and is known as oxygenic photosynthesis.

Oxygenic photosynthesis

$$6CO_2 + 12H_2O + \text{light energy} \longrightarrow C_6H_{12}O_6 + 6O_2 + 6H_2O$$

carbon dioxide — water — glucose — oxygen — water

Anoxygenic photosynthesis

$$CO_2 + 2H_2A + \text{light energy} \longrightarrow [CH_2O] + 2A + H_2O$$

carbon dioxide — electron donor* — carbohydrate — water

*$H_2A = H_2O$, H_2S, H_2, or other electron donor

[2]Photosynthetic bacteria

- These include all the three , coccal bacillary and spirillum irorms .
- all are anaerobes which grow in light and are usually found in sulphur spiring where hydrogen sulphide is normally present .
- the two common examples of photosynthetic bacteria are the purple sulphur bacteria and green sulphur bacteria.

Purple Sulphur Bacteria:

These bacteria have the pigment bacteriochlorophyll located on the intracytoplasmic membrane i.e., thylakoids. These bacteria obtain energy from sulfur compounds e.g., *Chromatiiun. Theopedia rosea, Thiospirilium*.

Chemical equation for anoxygenic photosynthesis in purple sulfur bacteria

$$H_2S + CO_{2+} light\ energy \rightarrow S + CH_2O$$

$$12H_2S + 6CO_2 \rightarrow 12S + C_6H_{12}O_6 + 6H_2O$$

Green Sulphur Bacteria:

These bacteria use hydrogen sulfide (H_2S) as hydrogen donor. The reaction takes place in the presence of light and pigment termed as bacteriovirdin or bacteriopheophytin or chlorobium chlorophyll e.g., *Chlorobium limicola, Chlorobacterium* etc.

2. Chemotrophs:

- Those bacteria gain energy from chemical compounds.
- They cannot carry out photosynthesis.

Sulphomonas (Sulphur bacteria):

These bacteria obtain energy by oxidation of elemental sulphur or H_2S, e.g., *Thiobacillus, Beggiatoa*.

- Elemental Sulphur Oxidising Bacteria: Denitrifying sulphur bacteria oxidize elemental sulphur to sulphuric acid e.g., *Thiobacillus denitrificans*
  $2S + 2H_2O + 3O_2 \rightarrow 2H_2SO_4 + 126$ kcal.
- Sulphide Oxidizing Bacteria: These bacteria oxidizes H_2S and release the sulphur e.g., *Beggiatoa*.
  $2H_2S + 4O_2 \rightarrow 2H_2O + 2S + 141.8$ cal

Hydromonas (Hydrogen bacteria)

- These convert hydrogen into water, e.g., *Bacillus pantotrophus, Hydrogenomonas*.

  $2H_2 + O_2 \rightarrow 2H_2O + 55$ kcal.

  $4H_2 + CO_2 \rightarrow 2H_2O + CH_4 + Energy$

Ferromonas (Iron bacteria):

- These bacteria inhabit water and obtain energy by oxidation of ferrous compounds into ferric forms. e.g., *Thiobacillus ferroxidans, Ferro bacillus, Leptothrix*.

  $4FeCo_3 + 6H_2O + O_2 \rightarrow 4Fe(OH)_3 + 4CO_2 + 81$ kcal.

Methanomonas (Methane bacteria):

- These bacteria get their energy by oxidation of methane into water and carbon dioxide.

Nitrosomonas (Nitrifying bacteria):

- These bacteria get their energy by oxidation of ammonia and nitrogen compounds into nitrates.
- Nitrosomonas oxidises NH3 to nitrites. NH3 + ½O2 ® H2O + HNO2 + Energy
- Nitrobacter converts nitrites to nitrates. NO2 + ½O2 ® NO2 + Energy

(B) Heterotrophic bacteria:

The heterotrophic bacteria obtain their-ready made food from organic substances, living or dead. These are of three types:

(i) Saprophytic bacteria.

(ii) Parasitic bacteria.

(iii) Symbiotic bacteria.

(i) Saprophytic bacteria:

These bacteria obtain their food from the dead organic decaying substances such as leaves, fruits, vegetables, meat, animal faeces, leather, humus etc. They secrete enzymes to digest the food and absorb it. The enzymes secreted break down the complex compounds into simpler soluble compounds, which are easily absorbed. Examples are Bacillus acidi lacti, Acetobacter etc.

(ii) **Parasitic bacteria:**

These bacteria obtain their food from the tissues of living organisms, the hosts. They may be harmless or may cause serious diseases. The disease-producing bacteria are pathogenic which cause various diseases in plants and animals. Examples are Bacillus typhosus, B. anthracis, B.tetani. B. diplheriae, B. tuberculosis, B. pneumoniae, Vibrio cholerae, Pseudomonas citri etc.

(iii) **Symbiotic bacteria:**

These bacteria live in close association with other organisms as symbionts. They are beneficial to the organisms. The common examples are the nitrogen-fixing bacteria, e.g., Bacillus radicicola, B. azotobacter, Rhizobium, Ctostridium etc. Rhizobium spp.,B. radicicola and B. azotobacter live inside the roots of leguminous plants and form bacteria nodules for fixation of nitrogen from the air.

THANK YOU