

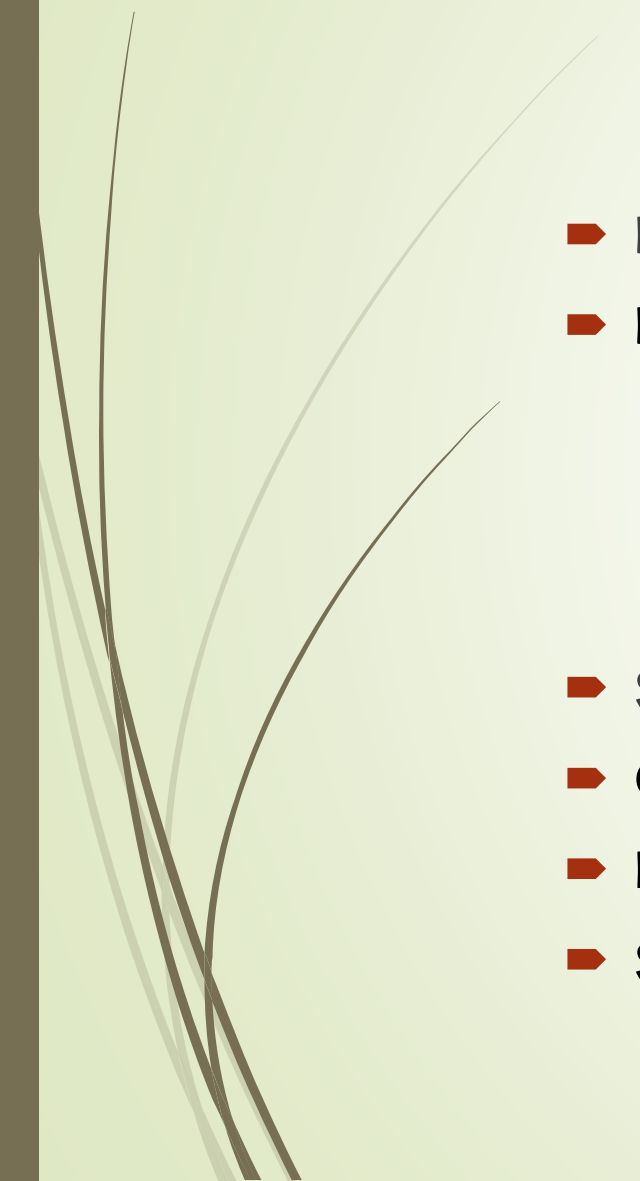
B Pharm, 3rd Semester
PHARMACEUTICAL MICROBIOLOGY
BP 303 (T)
Unit I
Structure of Bacteria



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Bacteria

- ❖ **Prokaryotic Cell**
- ❖ **Unicellular Organism**
- ❖ **Size range 0.75 μm -5 μm (microscopic size)**
- ❖ **Found everywhere on earth also in extreme environment like hot springs, sea, ocean, soil, rocks within earth crust, air etc**
- ❖ **They have special and specific characteristic features that helps them to survive in a specific environments, such as streams, ponds, lakes, rivers, oceans, hot-springs, gastrointestinal tract (GIT), roots of plants, and even in oil wells etc.**
- ❖ **They are both beneficial and harmful(cause disease)**
- ❖ **Reproduce by binary fission**

Prokaryota/Monera

		Similarity	Differences	Examples
Monera	Eubacteria(major group)	Unicellular, Prokaryotic	<ul style="list-style-type: none">• Cell wall of peptidoglycan,• Found everywhere on earth, can not live in extreme environment• Both helpful & harmful for humans	E.coli, Cyanobacteria
	Archaeobacteria(minor group)	Unicellular, Prokaryotic	<ul style="list-style-type: none">• Cell wall of other material,• Live in extreme environment (Hostile)• None infect humans	Halobacter, Methanococcus

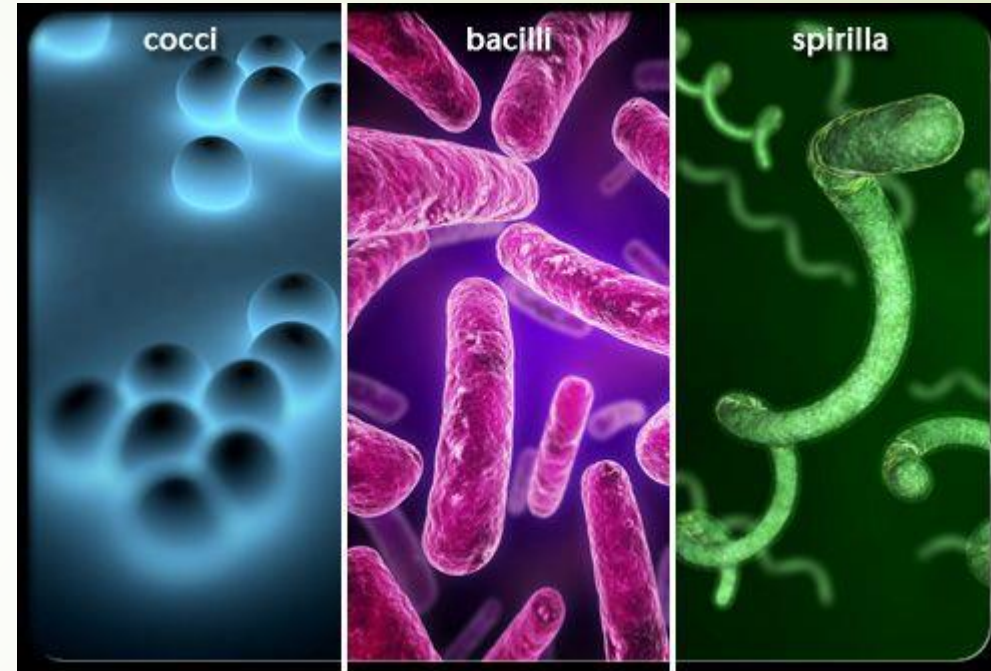
Bacteria Classification: Based on shape & Arrangement

❖ Based on shape –

1. **Cocci** are round cells,
2. **Bacilli** (or bacillus for a single cell) are rod-shaped.
3. **Spirilla** (or spirillum for a single cell) are curved, spiral or twisted

❖ Based on arrangement

Clusters, tetrads, sarcina, pairs, chains



<https://in.pinterest.com/pin/288863763578125688/>

Bacteria Classification: Based on Bacterial Arrangement of Cocci

Based on planes of division, Cocci (or coccus for a single cell) can appear in several distinct arrangements:

➤ **Diplococci-** Pairs of cocci

Eg. *Neisseria gonorrhoeae*

➤ **Streptococci-** rows or chains of cocci

Eg. *Enterococcus faecalis*, *Lactococcus*

➤ **Tetrads-** four cells arrangement in a square

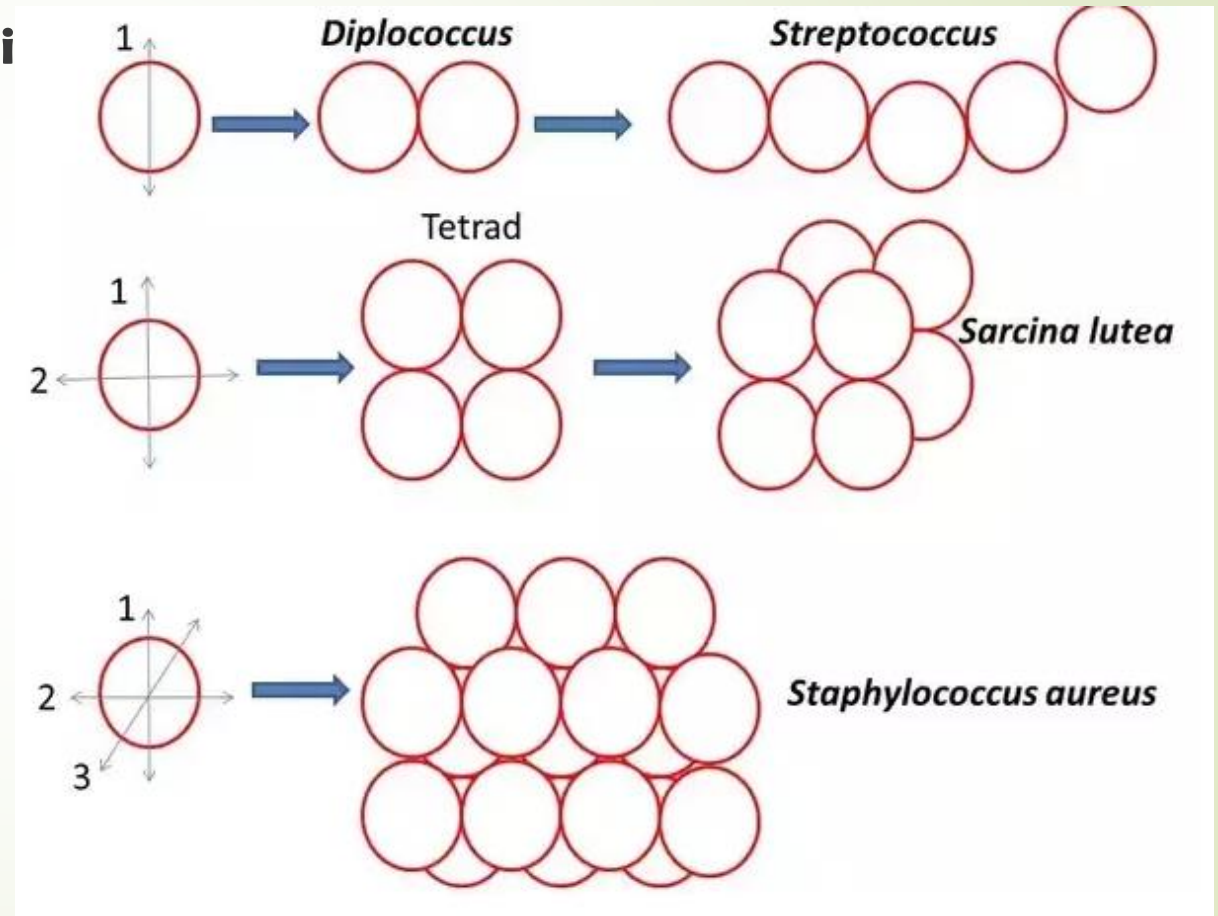
Eg. *Micrococcus*

➤ **Staphylococci-** grapelike clusters of cells

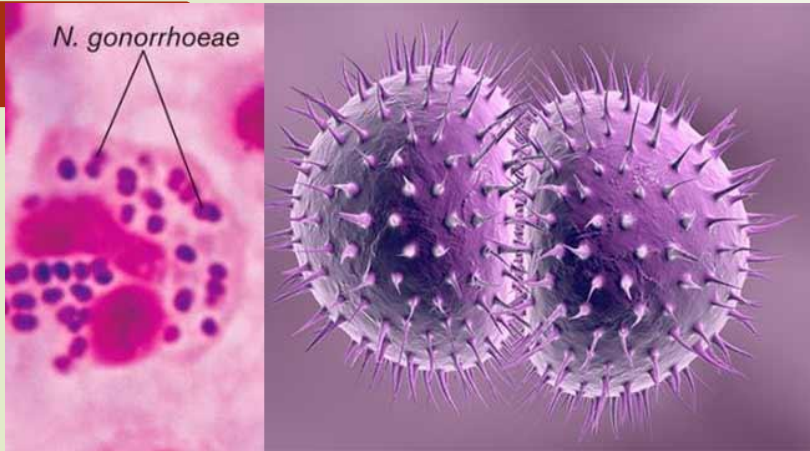
Eg. *Staphylococcus aureus*

➤ **Sarcinae-** packets of eight or more cells

Eg. *Sarcina lutea*



Diplococci-Eg. Neisseria gonorrhoeae



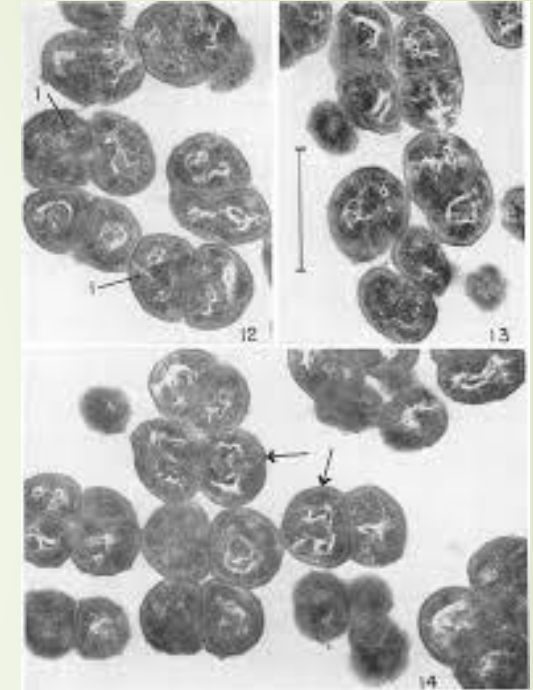
<https://microbenotes.com/habitat-and-morphology-of-neisseria-gonorrhoeae>

Streptococci-Lactococcus lactis



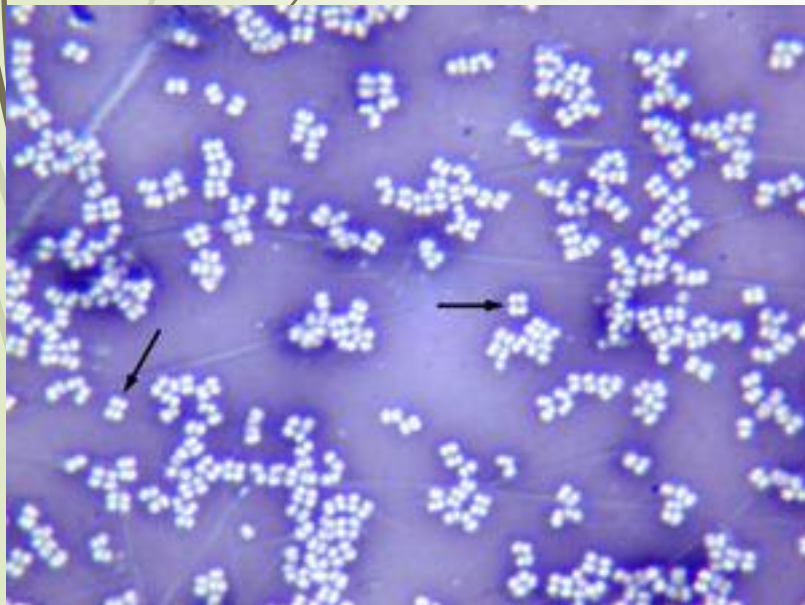
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Sarcinae-Sarcina lutea



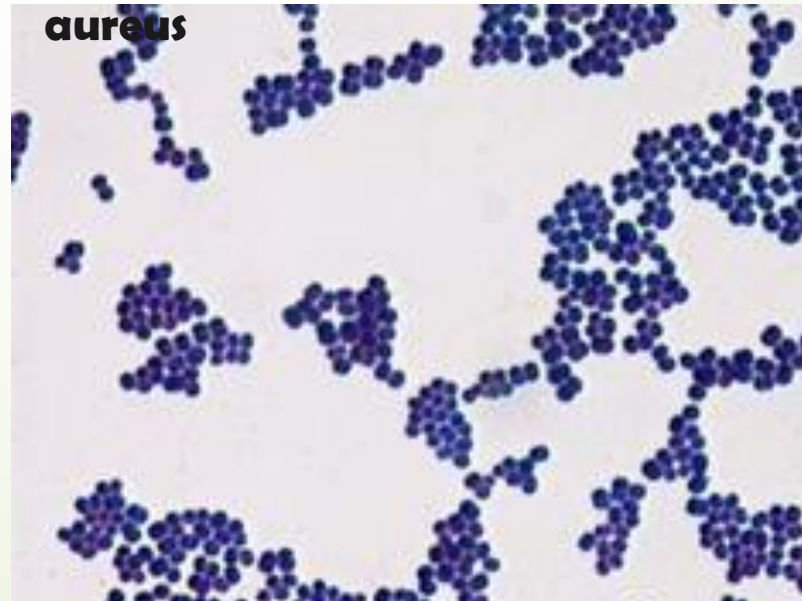
<https://jb.asm.org/content/jb/79/1/132.full.pdf>

Tetrads-Micrococcus



<https://microbewiki.kenyon.edu/index.php/Micrococcus>

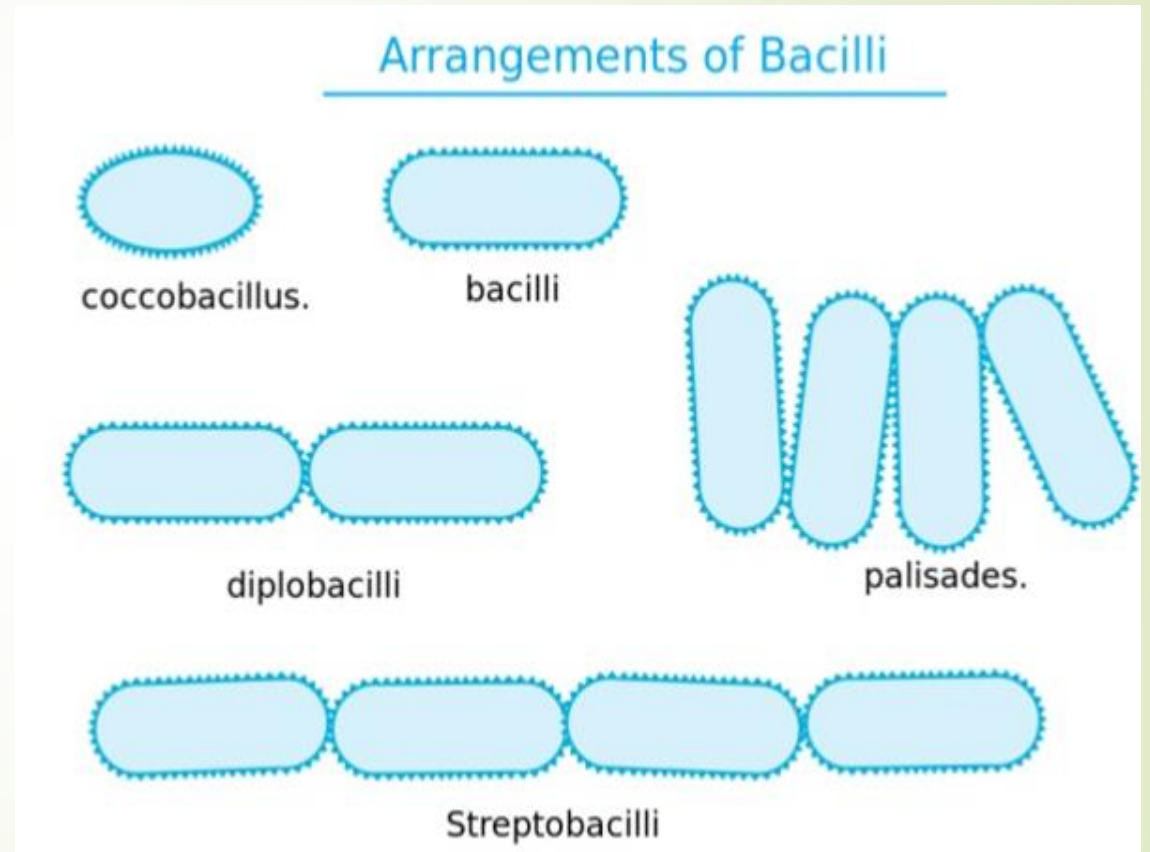
Staphylococci-Staphylococcus aureus



<https://in.pinterest.com/ldntexas/staphylococcus-aureus/>

Bacteria Classification: Based on Bacterial Arrangement of Bacilli

- **Monobacillus:** single rod-shaped cell remains after dividing. Eg.
- **Diplobacilli:** cells remain in pairs after dividing.
- **Streptobacilli:** rods arranged in chains after dividing.
- **Palisades:** rods arranged side-by-side instead of end-to-end that are partially attached.
- **Coccobacillus:** slightly oval shape rods that resemble both coccus and bacillus bacteria.



https://en.m.wikipedia.org/wiki/File:Arrangement_of_bacilli_bacteria.svg

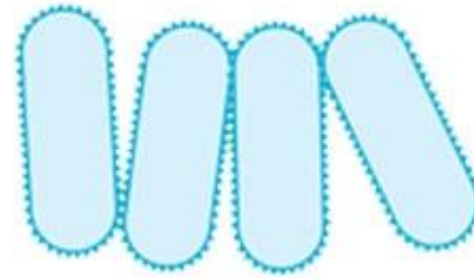
Bacteria Classification:



Coccobacillus



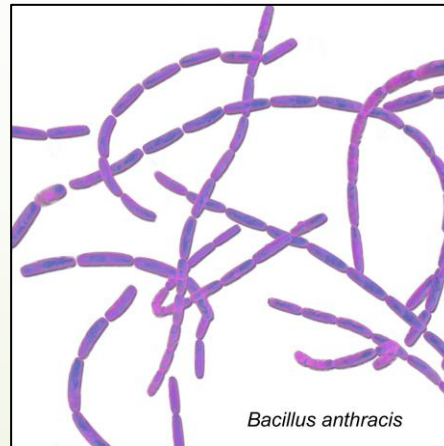
SEM 1 μ m



Palisades



Streptobacilli

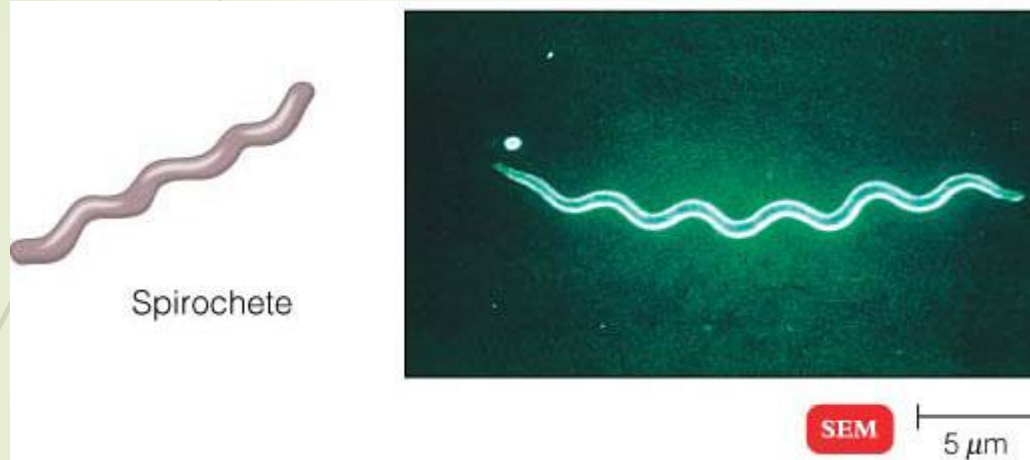


Bacillus anthracis

https://commons.wikimedia.org/wiki/File:Bacillus_Anthraxis.png

Bacteria Classification based on shape: Spirilla

Twisted shaped



Curved Shaped




Spiral shaped

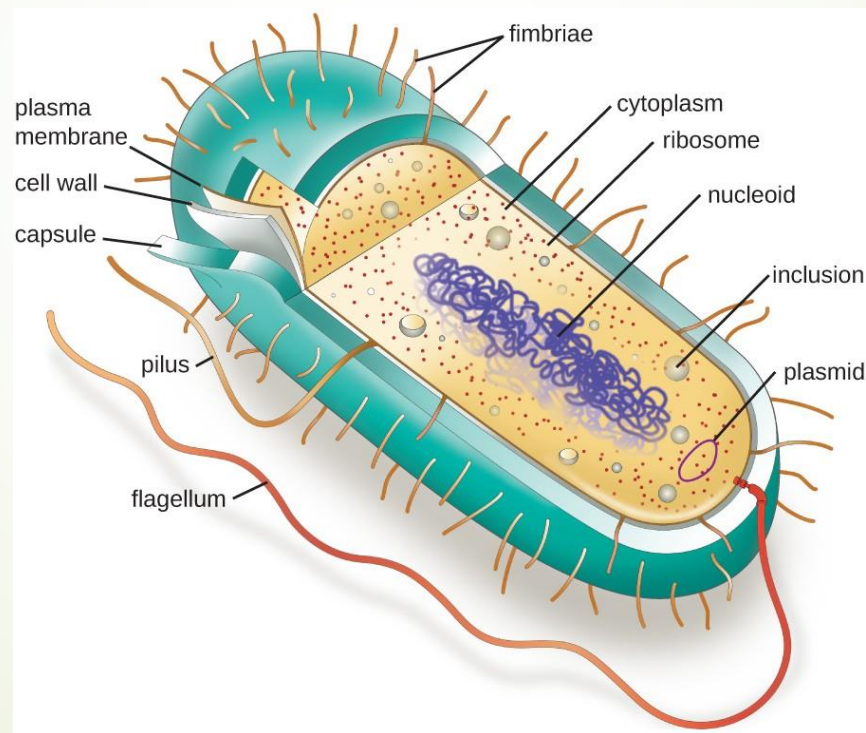




Other shapes of Bacteria

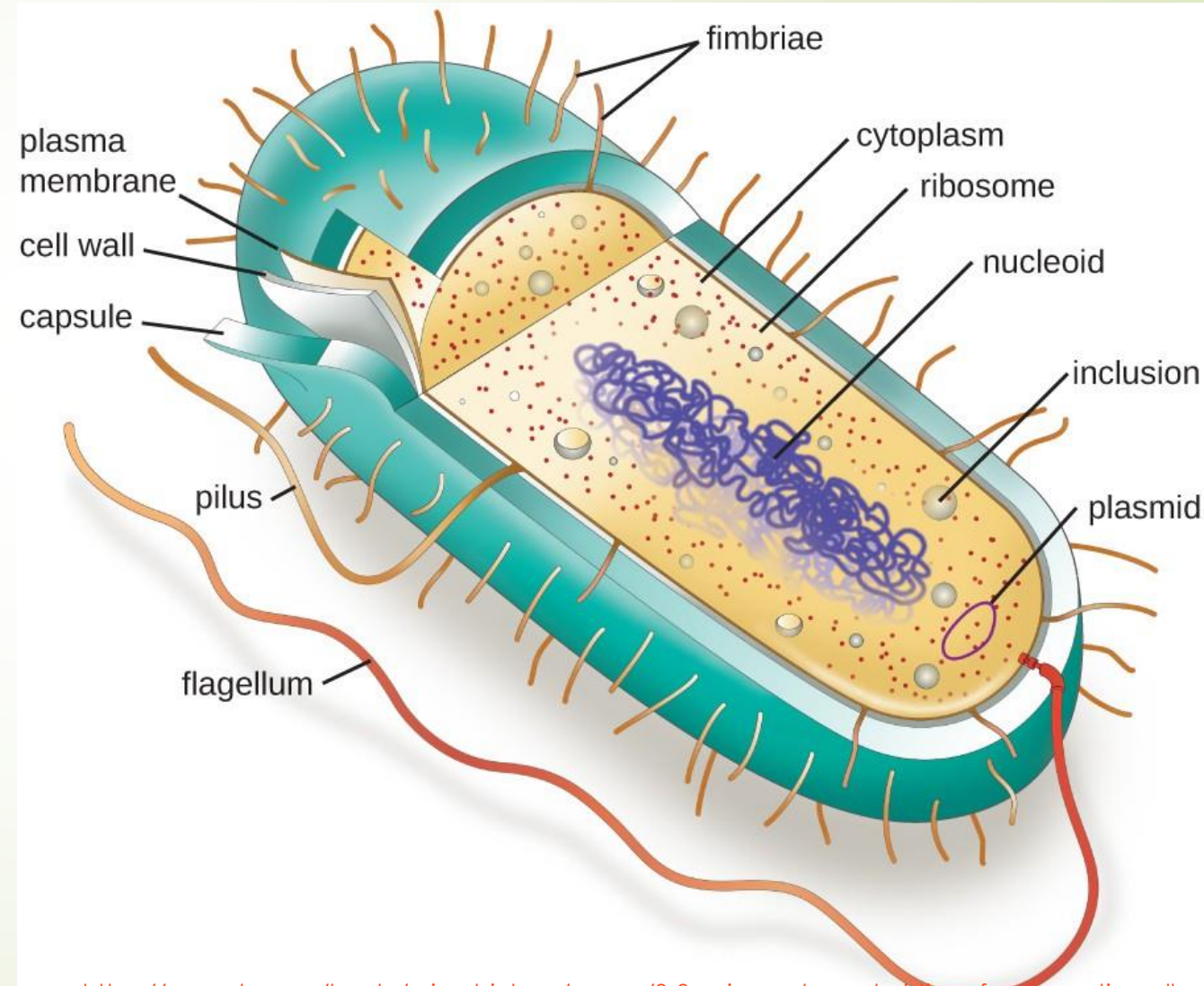
- **Pleomorphic is the ability to change or alter the size and shape under the stress of pressure of environmental factors. One example is *Mycoplasma pneumonia*, which is the causative agent of pneumonia**
- 

Structure of Bacteria



Structure of Bacteria

- **Structure External to Cell Wall-**
 - **Flagella,**
 - **Pili,**
 - **Capsule, microcapsule, Slime, Sheaths**
- **Cell Wall**
- **Structure Internal to Cell Wall-**
 - **Cytoplasmic Membrane,**
 - **Cytoplasm/Protoplasm/Spheroplasm**
 - **Mesosome**
 - **Ribosomes**
 - **Nucleoid**
 - **Plasmid**
 - **Cytoplasmic Inclusion**



Structure External to Cell Wall: Flagella

- **Flagella are hair like helical appendages that protrude through cell wall present in motile bacteria.**
- **Function- provide motility and found only in motile bacteria**
- **Composition-Flagellin protein**

Types of Flagellar Arrangement



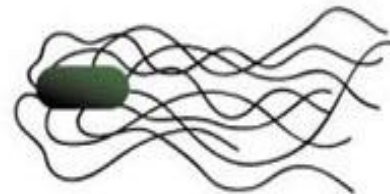
Polar/ Monotrichous – single flagellum at one pole



Lophotrichous – tuft of flagella at one pole



Amphitrichous – flagella at both poles



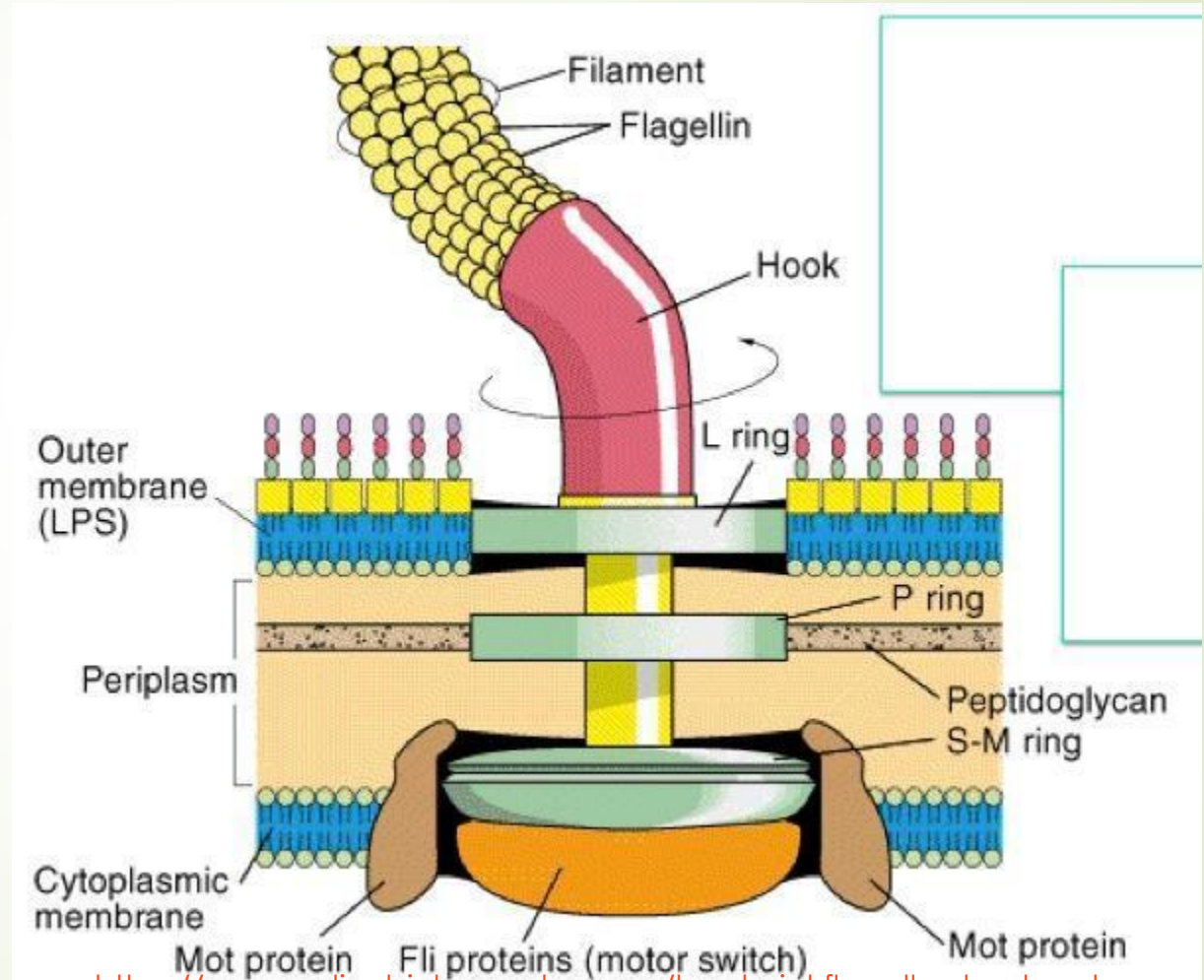
Peritrichous – flagella all over



Amphiloophotrichous – tuft of flagella at both ends

Structure of Flagella

- ➔ **Basal body anchors flagella into cytoplasmic membrane and permits it to rotate. It consists of rings include: L-ring: Outer ring is affix in lipopolysaccharide layer, P-ring: fastened to peptidoglycan layer, C-ring: Anchored in the cytoplasm, M-S ring: Anchored in the cytoplasmic membrane**
- ➔ **Hook**
- ➔ **Filament is thin hair-like structure arising from the hook made up of flagellin protein**



<https://www.onlinebiologynotes.com/bacterial-flagella-structure-types-function/>



Structure External to Cell Wall: Pili

► **Pili-Non helical, hollow filamentous structure, thinner, shorter and more numerous than flagella. They are not involved in motility.**


Function-allow pathogenic bacteria to attached to epithelial cell of respiratory tract, GIT tract or genitourinary tract (therefore not easily washed away)and help in establishing infection.

Structure External to Cell Wall: Capsule

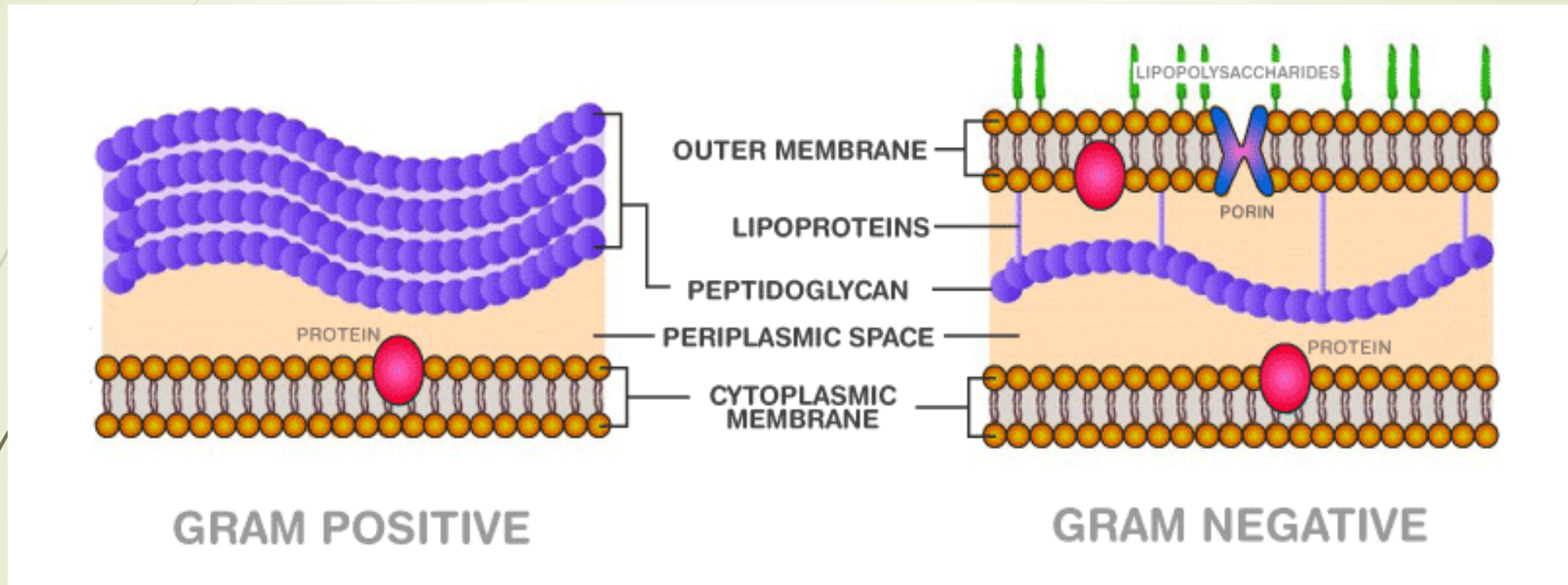
- **Capsule-** Viscous covering composed of polysaccharide
 - **Microcapsule-** Layer is thin
 - **Slime-** layer is loosely associated with the bacterium and can be easily washed off, whereas a capsule is attached tightly
 - **Sheaths-** Bacterial cell enclosed in hollow tube. Usually sheathed bacteria are found in fresh water and marine.
- **Function-** Provide protection against drying
 - **Block attachment of bacteriophages**
 - **Provide antiphagocytic property that inhibits engulfment of pathogenic bacteria by WBC**
 - **Enhance virulence**
 - **Promote attachment to the surface**



Bacterial Cell Wall

- **cell wall is very rigid wall present beneath the capsule that give specific shape to the bacteria.**
 - **Maintains osmotic integrity and protects the cell from bursting due to osmotic shock in hypotonic environment.**
 - **Bacteria are classified into two groups based on the difference in cell wall-**
 - **Gram Positive**
 - **Gram Negative**
- 

Cell wall of Gram Positive & Gram Negative Bacteria



**LPS-Lipid A (Pyrogenicity and lethal effect), Polysaccharide core and O antigen
It has toxic properties and also known as Endotoxin**

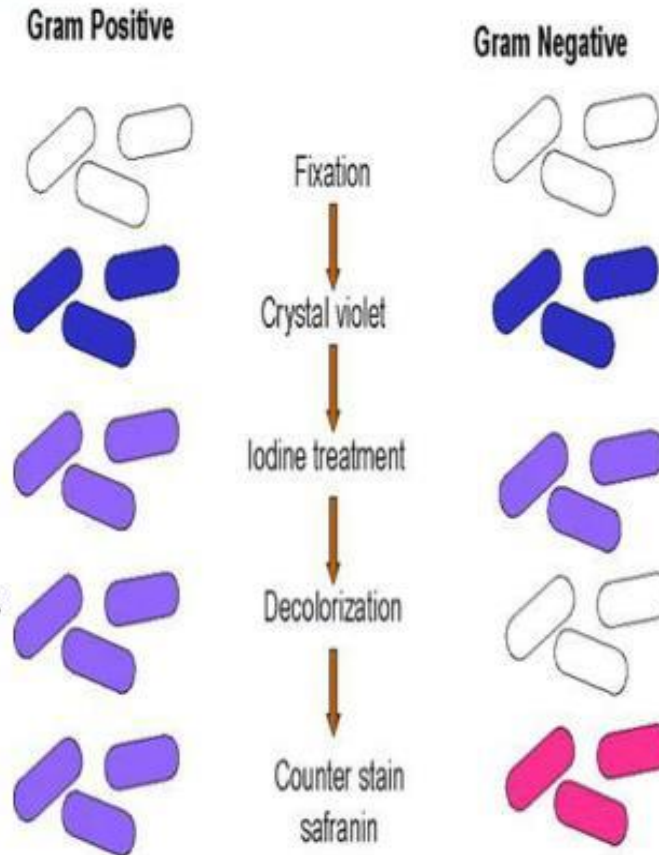
Difference between Gram Positive & Gram Negative Bacteria

Character	Gram Positive	Gram Negative
Cell wall	simple	More complicated
Thickness	Thick, homogeneous(20-25 nm)	Thin, heterogeneous(10-15nm)
Number of layers	One	Two
Chemical composition	Peptidoglycan, Teichoic acid and lipotechoic acid	Lipopolysaccharide, lipoproteins and peptidoglycan
Lipid	not present	Present(20-30%)
Peptidoglycan(Murein)	More than 50%	Less (10%)
Teichoic acid	present	Absent
Porins protein	Absent	Present
Lipopolysaccharide	Absent	Present
Toxin	Exotoxin	Exotoxin or Endotoxin
Antibiotic effect	More susceptible	More resistant(because their cell wall is impenetrable)
Examples	Staphylococcus, Streptococcus	Escherichia, Salmonella

Gram Stain

Principle of staining technique:

1. Primary stain:- Crystal Violet
2. Mordant(fixes the dye):- Iodine
3. Decolorizing agent:- Alcohol/Acetone
4. Counter stain;- Safranin



This technique was proposed by Christian Gram 1884



Gram Staining Technique

- **Gram-positive and gram-negative bacteria are classified based on their ability to hold the gram stain.**
- **Gram-positive bacteria, retains the gram stain and show a visible violet colour upon the applying crystal violet mordant(iodine),ethanol(alcohol) and safranin.**
- **The gram-negative bacteria are de-stained because of the alcohol wash and attain the stained of counterstain such as safranin and appear as pink.**



Cell Wall Exceptions

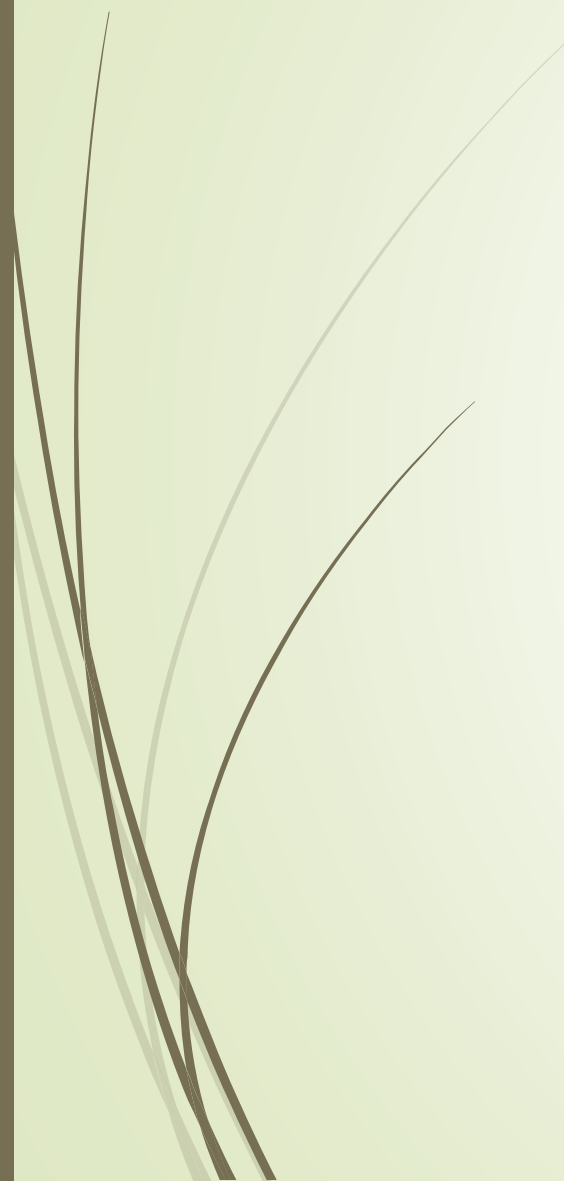
- **Mycoplasma lack a rigid cell wall and is smallest known organisms with smallest genomes**
- **Mycoplasma are pleomorphic and exhibit different shapes- cocci, short rods, short spirals, and sometimes doughnut shape**
- **Mycoplasma pneumoniae cause pneumonia in humans also as parasites of animals**

Cell Wall Exceptions: Bacteria with chemically unique cell walls

- **Acid-Fast Cells** Mycobacterium species Gram + type of cell wall Unique lipid Mycolic acid – waxy substance
- **Rickettsia** Cell wall contains diaminopimelic acid lacks teichoic acid. It is obligate intracellular pathogens cause (Rickettsia rickettsii) Rocky Mountain spotted fever, Rickettsia prowazekii – epidemic typhus, Coxiella burnetii – Q fever
- **Chlamydia** – Cell wall contains an outer lipopolysaccharide membrane but lacks peptidoglycan, most common sexually transmitted disease,

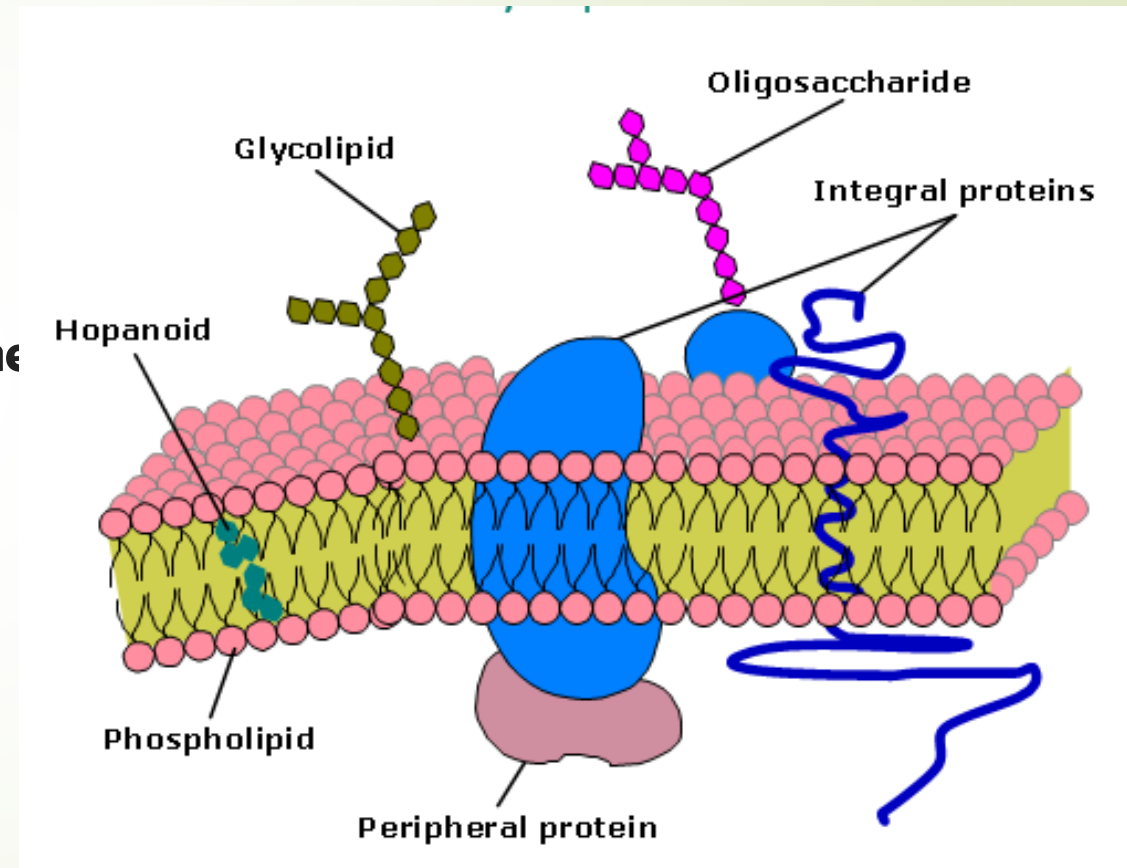


Structure Internal to Cell Wall

- **Cytoplasmic Membrane,**
 - **Cytoplasm/Protoplasm/Spheroplasm**
 - **Mesosome**
 - **Ribosomes**
 - **Nucleoid**
 - **Plasmid**
 - **Cytoplasmic Inclusion**
- 

Cytoplasmic Membrane/Cell Membrane/Plasma Membrane


- composed of a phospholipid (20-30%) bilayer and proteins (60-70%) and encloses the contents of the bacterial cell
- Thickness-7.5nm
- Have two types of proteins
- Integral Proteins (can be removed only by membrane destruction)
- Peripheral Proteins (can be removed by mild treatment)
- It contain several permease enzymes responsible for transportation of nutrients and chemicals in and outside the cell
- Also contain enzyme involved in respiration and metabolism



<https://in.pinterest.com/pin/510454938984775618/>



Cytoplasm & Protoplasm

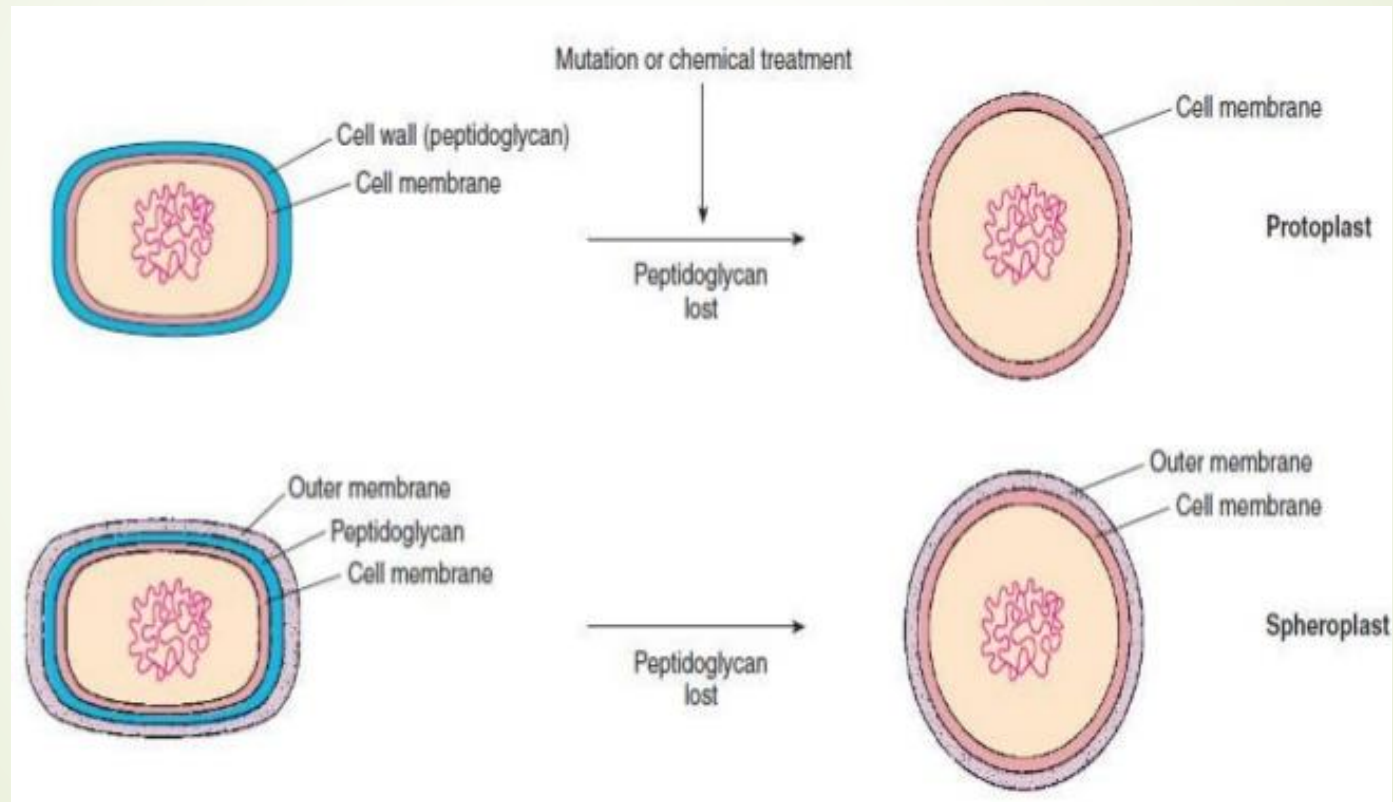
- **Protoplasm-** Cell material consisting of proteins, ribosomes, water soluble contents, nucleoid, plasmid etc. of bacteria are bounded with cytoplasmic membrane.
 - **Cytoplasm-** Cytoplasm of bacterial cells is gel-like that contains the nucleoid, ribosomes, various macromolecules and small molecules in water solution.
- 

Protoplasm/Spheroplasm

In Isotonic condition if

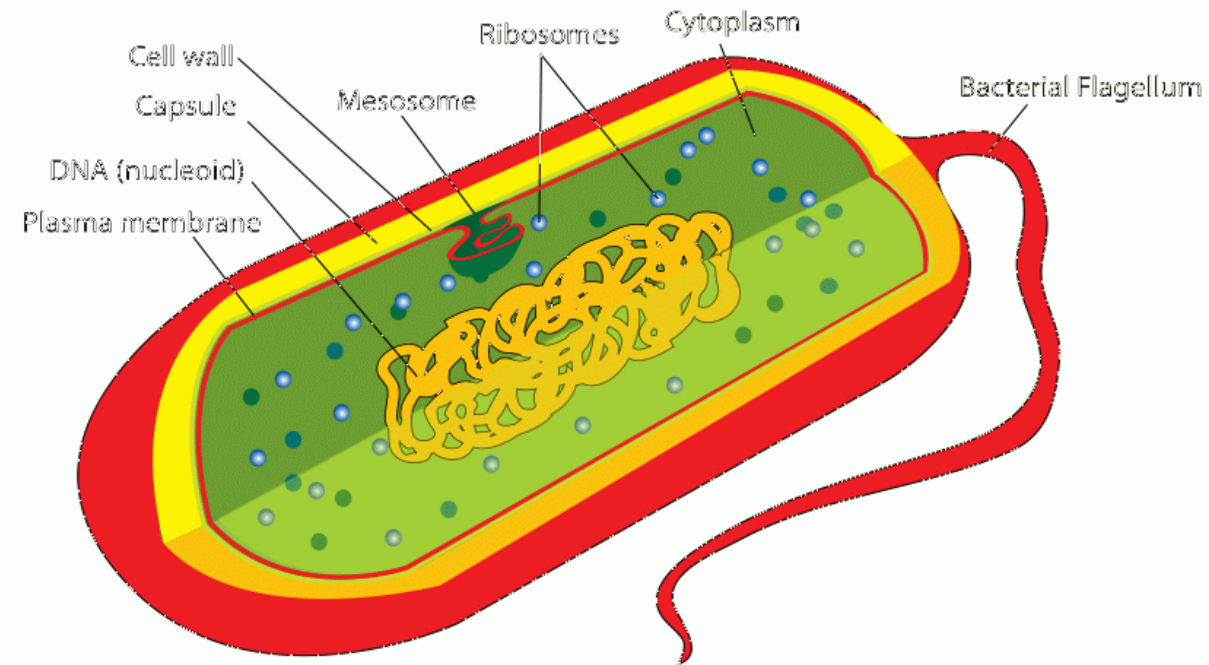
- Gram Positive bacteria Lysozyme/Penicillin → Protoplasm
- Gram Negative bacteria Lysozyme/Penicillin → Spheroplasm(two membranes)
- Enzyme **Lysozyme** dissolve the peptidoglycan of cell wall and
- **Penicillin** Inhibits the synthesis of peptidoglycan cell wall

Protoplast/Spheroplast

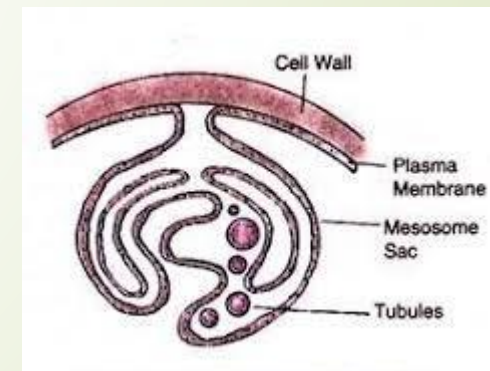


Mesosome

- Mesosomes are formed due to the infolding of plasma membrane,
- these are rich in enzymes that helps to perform functions like cellular respiration, DNA replication, sporulation (in sporulating bacteria) and photosynthesis in photosynthetic bacteria
- Responsible for export of enzymes.



<https://in.pinterest.com/pin/529454499918570283/>



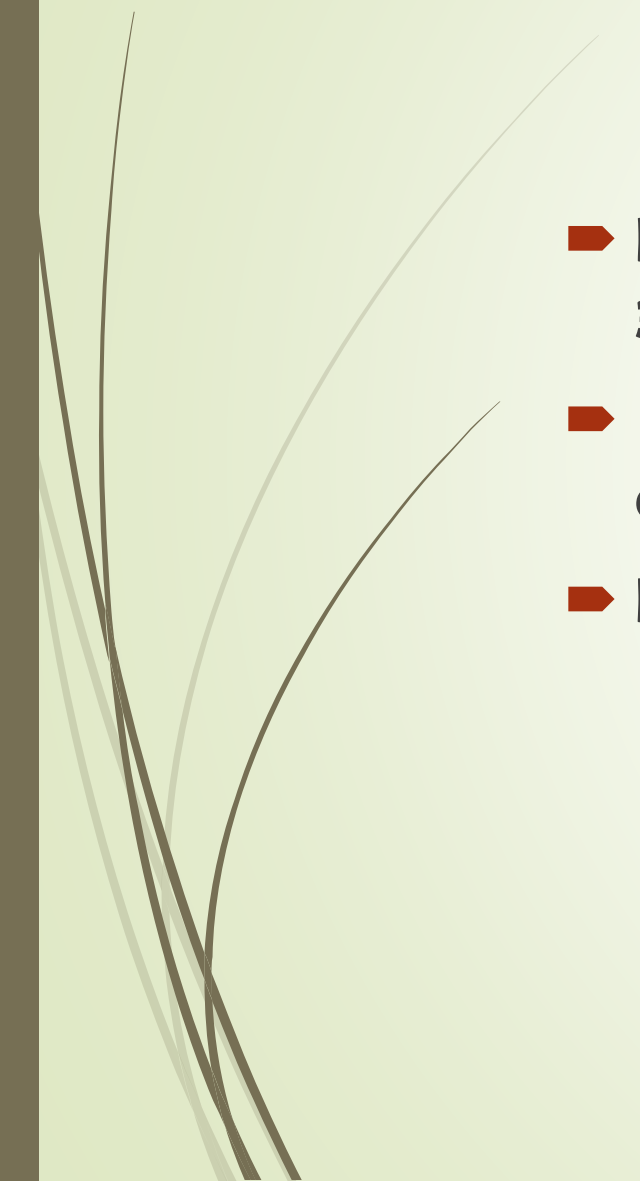
<https://www.quora.com/What-is-a-mesosome-in-a-prokaryotic-cell>

Nucleoid & Plasmid

- ➔ **Single-celled prokaryotes do not contain nuclei. Therefore, the genetic material (DNA) of such microorganism exists as nucleoid, which is without a membrane enclosing.**
- ➔ **Nucleoid is bacterial single circular DNA that is located in the cytoplasm is called the nucleoid.**
- ➔ **Bacteria also contain smaller circular DNA molecules called plasmids. Plasmids naturally exist in bacterial cells.**
- ➔ **Genes carried in plasmids provide bacteria with genetic advantages, such as antibiotic resistance.**



Ribosomes

- **Ribosome is 70S in size composed of a 50S (large) subunit and 30S (small) subunit.**
 - **Eucaryotic ribosome is 80S in size and is composed of a 60S and a 40S subunit.**
 - **Involved in protein synthesis**
- 

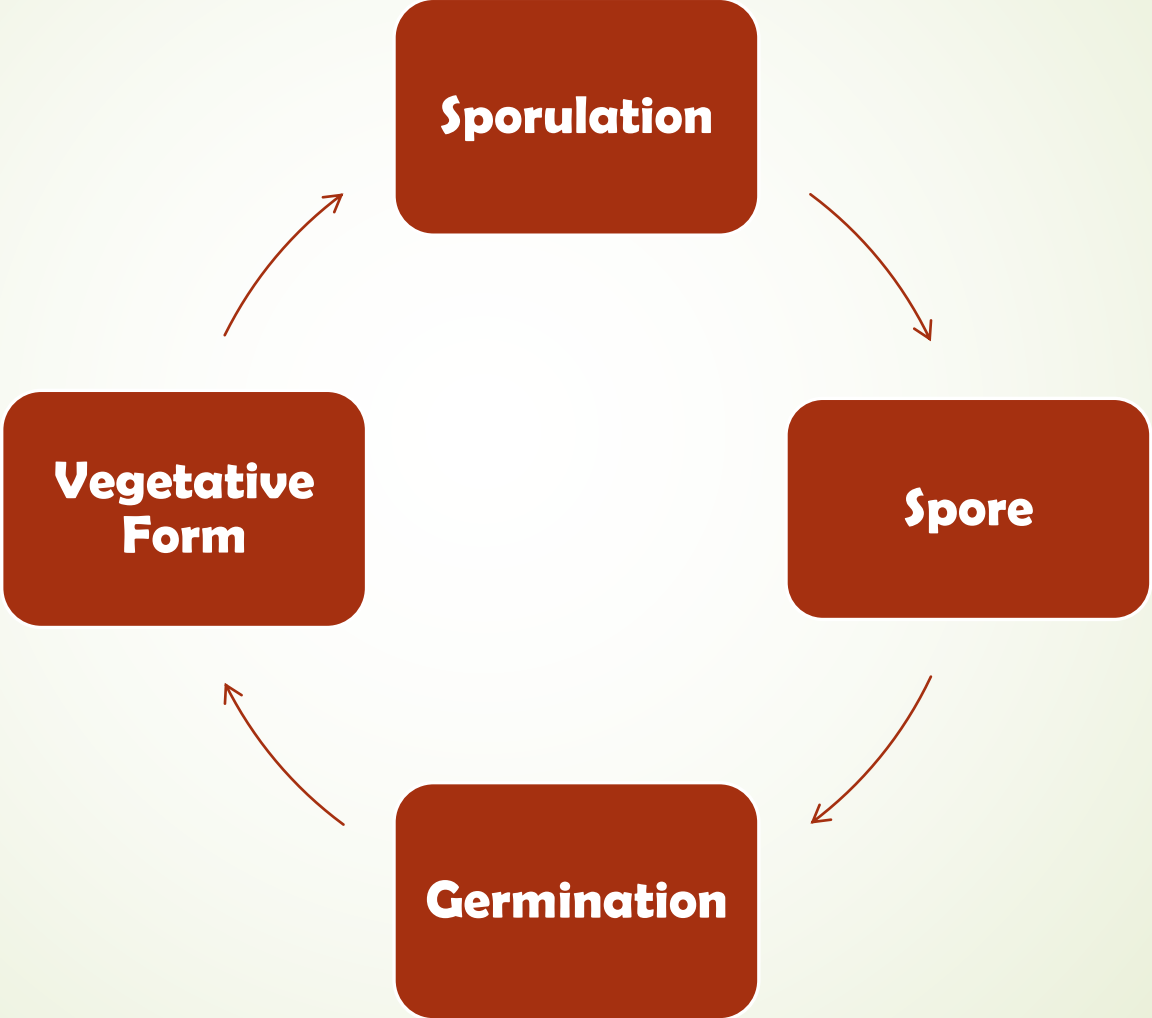
Cytoplasmic Inclusion

- **Cytoplasmic Inclusion are concentrated deposition of certain substance**
- **bacteria always do not live in favorable condition that contain large amounts of nutrients at all times.**
- **Bacteria have several methods of nutrient storage that are employed in times of plenty, for use in times of want.**
- **For example, many bacteria store excess carbon in the form of polyhydroxyalkanoates or glycogen.**
- **Some microbes store soluble nutrients, such as nitrate in vacuoles.**
- **Sulfur is most often stored as elemental (S₀) granules which can be deposited either intra- or extracellularly. Sulfur granules are especially common in bacteria that use hydrogen sulfide as an electron source.**
- **Cytoplasmic inclusion can be viewed using a microscope, that are surrounded by a thin non-unit membrane to separate them from the cytoplasm.**

Cytoplasmic Inclusion


Inclusion	Composition	Function	Identification
Volutin / Metachromatic Granules	Inorganic Phosphates/Polyphosphates	Reserve phosphate, possibly high-energy PO₄	Gives reddish purple colour with methylene blue
Polyβhydroxybutyrate (PHB)	Carbon	Reservoir of energy	Stained by lipid soluble dye Nil blue
Glycogen/Starch Granules	Carbon	Reservoir of energy	Stain brown with Iodine
Sulphur	Sulphur	Reserve energy and or electrons	
Cynophycine	Organic Nitrogen material		
Gas vesicles	protein shells inflated with gases	Provide buoyancy in aquatic environments	

Sporulation

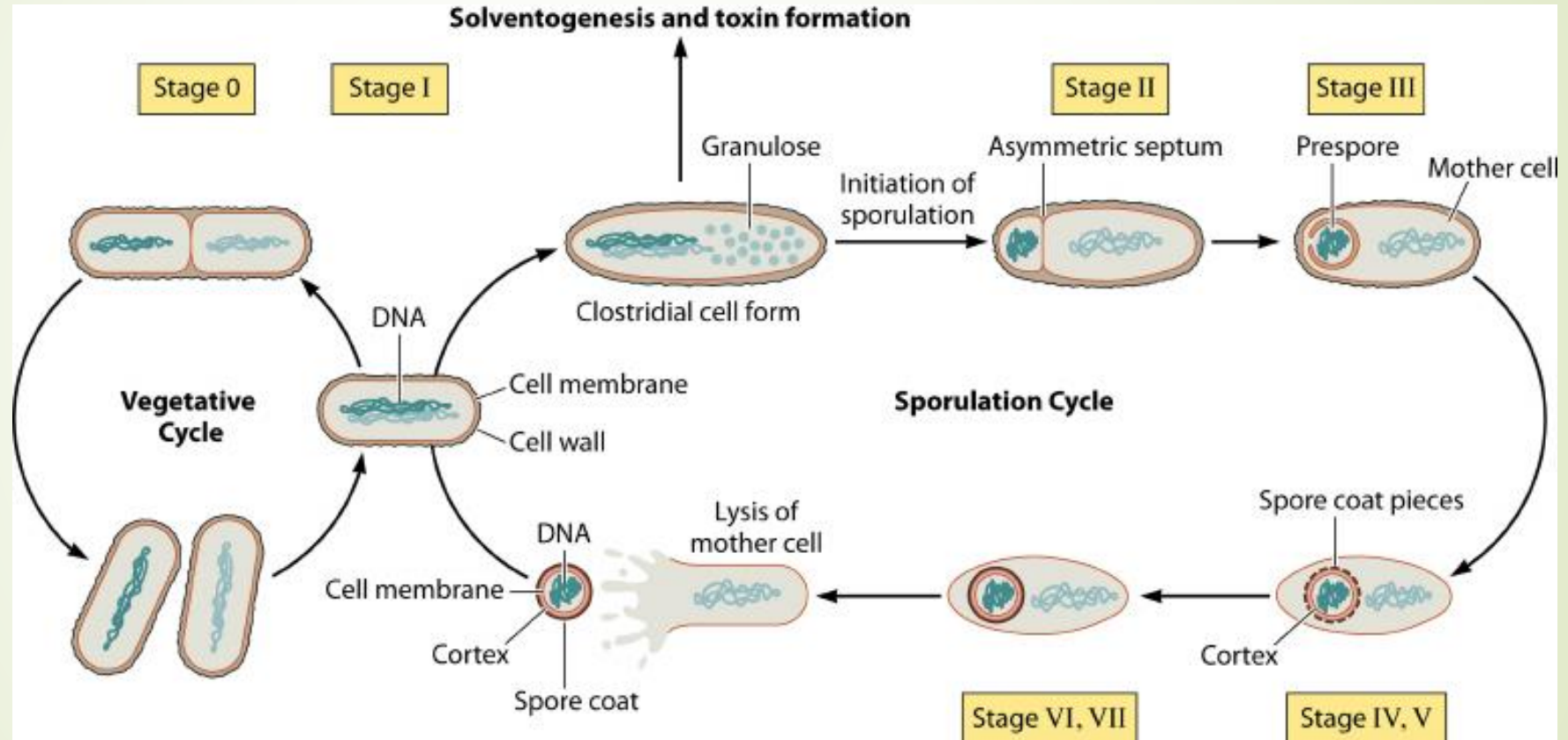




Spores

- ▶ **Are metabolically dormant form**
 - ▶ **Under favorable conditions they undergo germination and produce vegetative cell(metabolically active form)**
 - ▶ **Certain species of bacteria including *Bacillus* and *Clostridium* produce spores within cell they are called Endospores and some produce external to the cell that are called Exospores.**
- 

Endospore formation



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