- PG course (M. V. Sc.)
- Date: 21 January, 2021

VMC 601: BACTERIOLOGY II

Topic: Cellular organization & chemical characteristics of eukaryotic and prokaryotic cells

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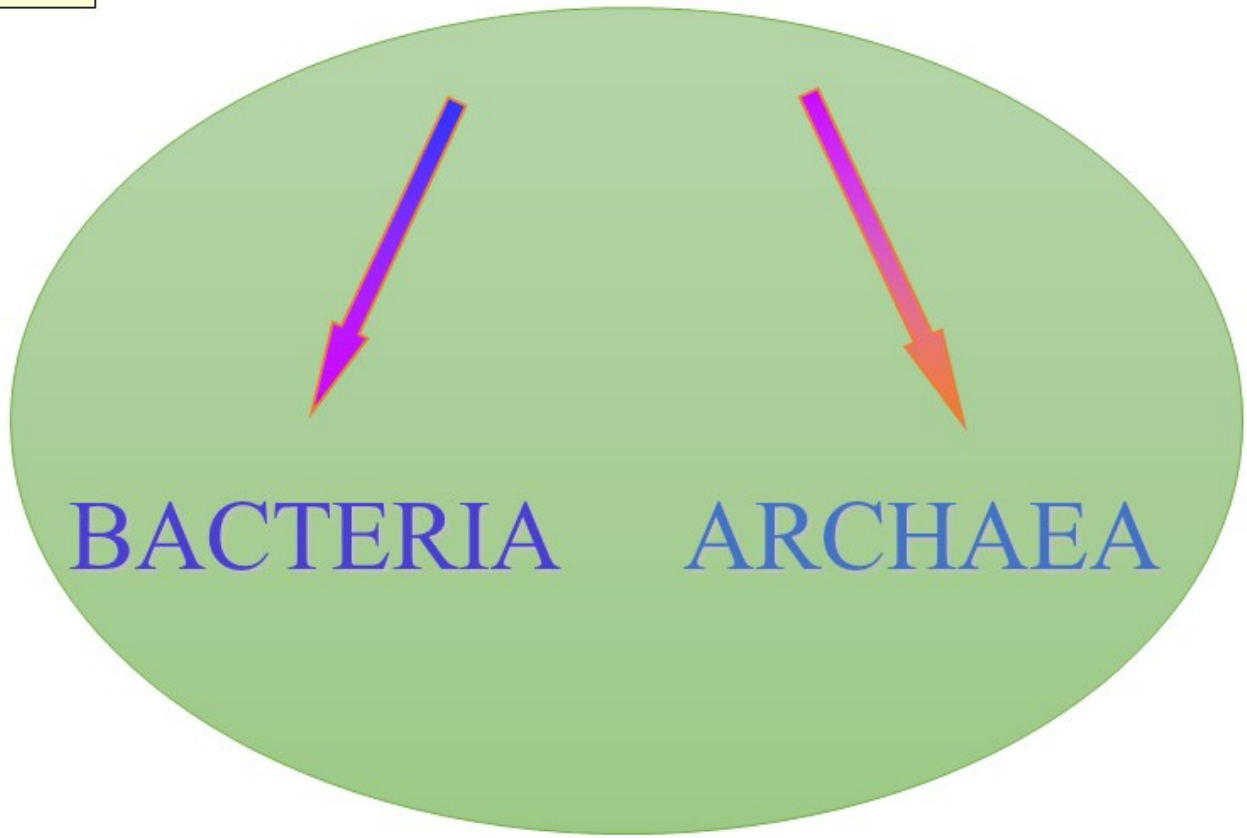
EUKARYOTES

PROKARYOTES



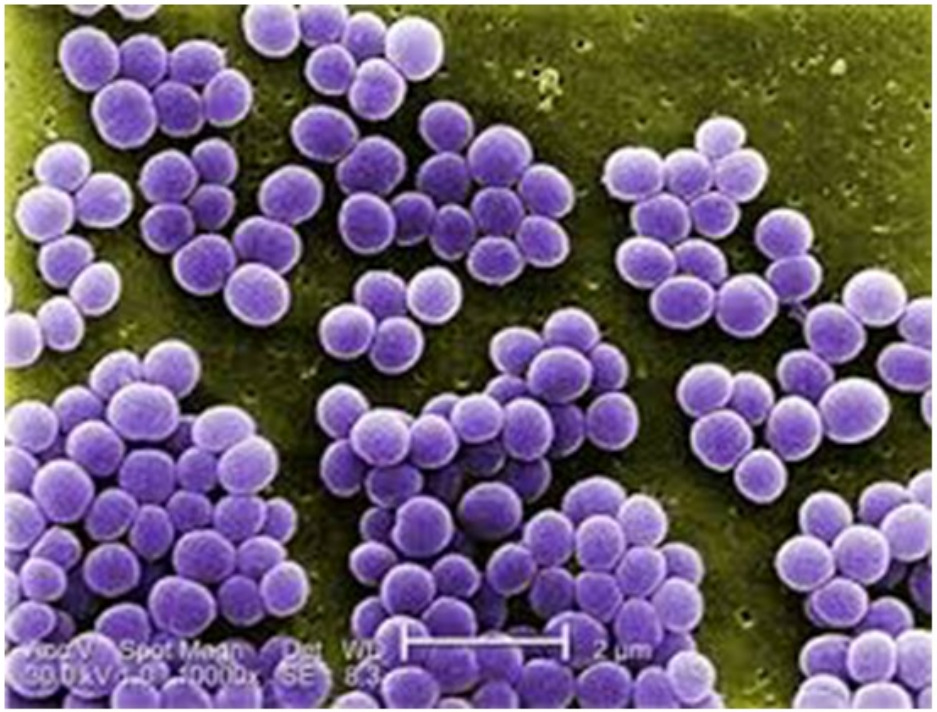
Cell: the smallest unit of life

Discovery of Cells

- 1665- Robert Hooke was the first to identify and name cells.
- 1674- Anton van Leeuwenhoek made better lenses and observed cells in greater detail.
- 1838- Mathias Schleiden noted that plants are made of cells
- 1839- Theodor Schwann concluded that all living things are made of cells
- 1855- Rudolf Virchow proposed that all cells come from other cells

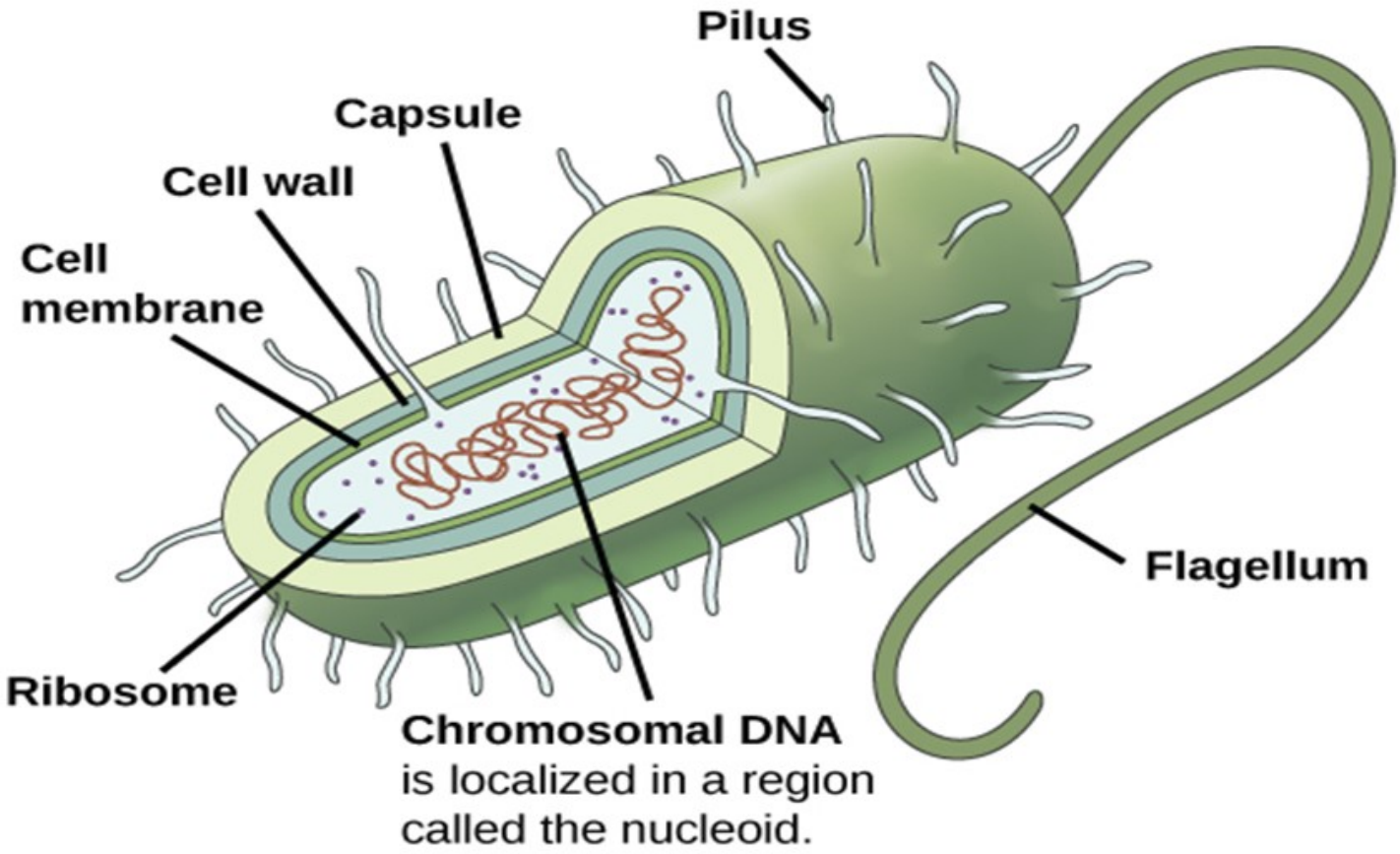
Prokaryotic cells

- Simple cells
- No nucleus
- Ex: bacteria



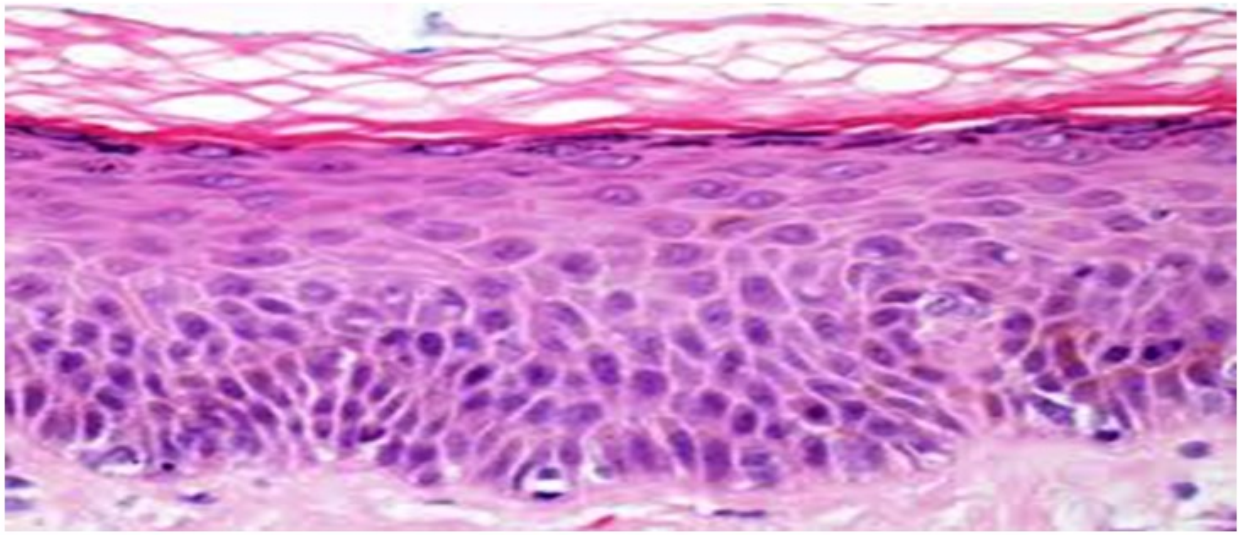
Staphylococcus aureus

Prokaryotic Cell

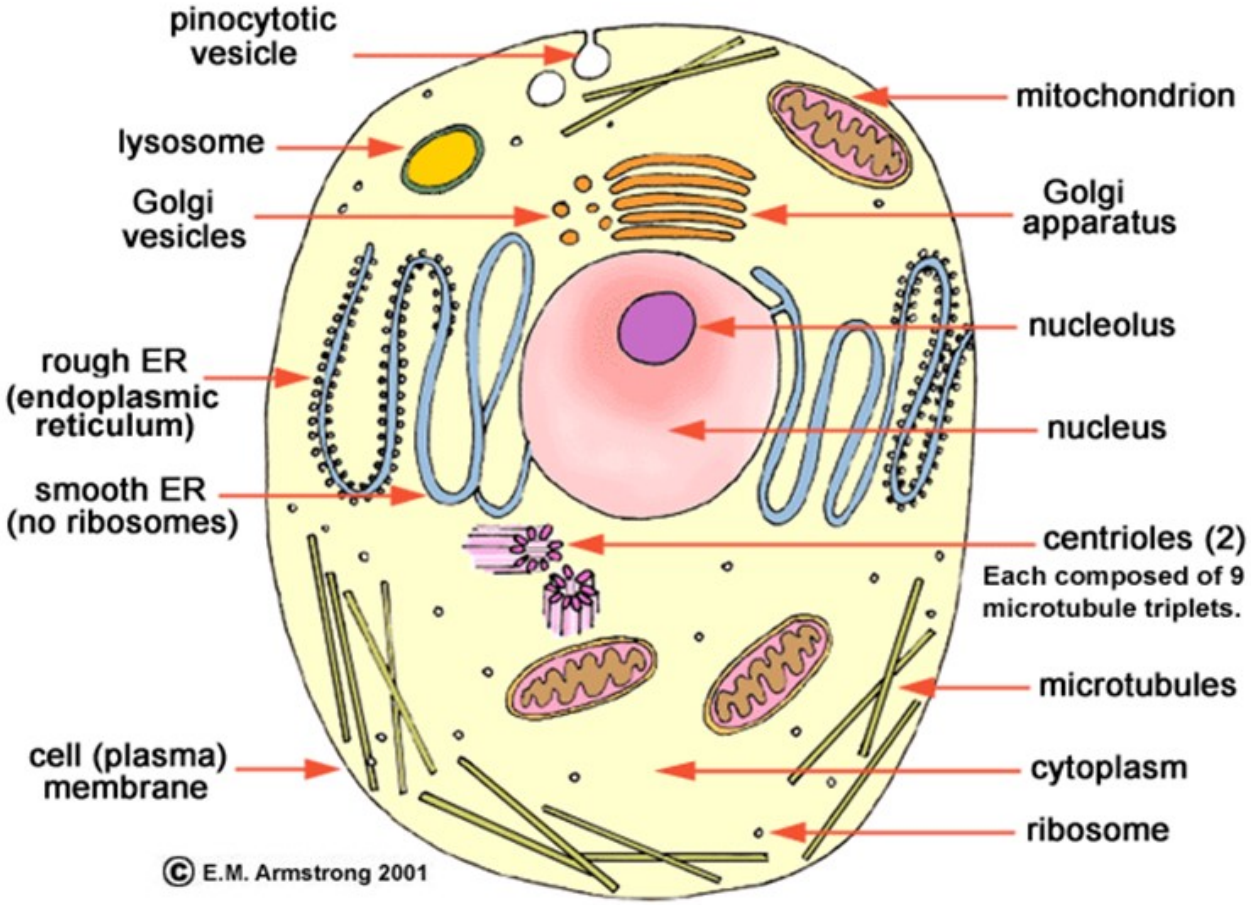


Eukaryotic Cells

- More complex
- Have a true nucleus
- Make up all living cells other than bacteria



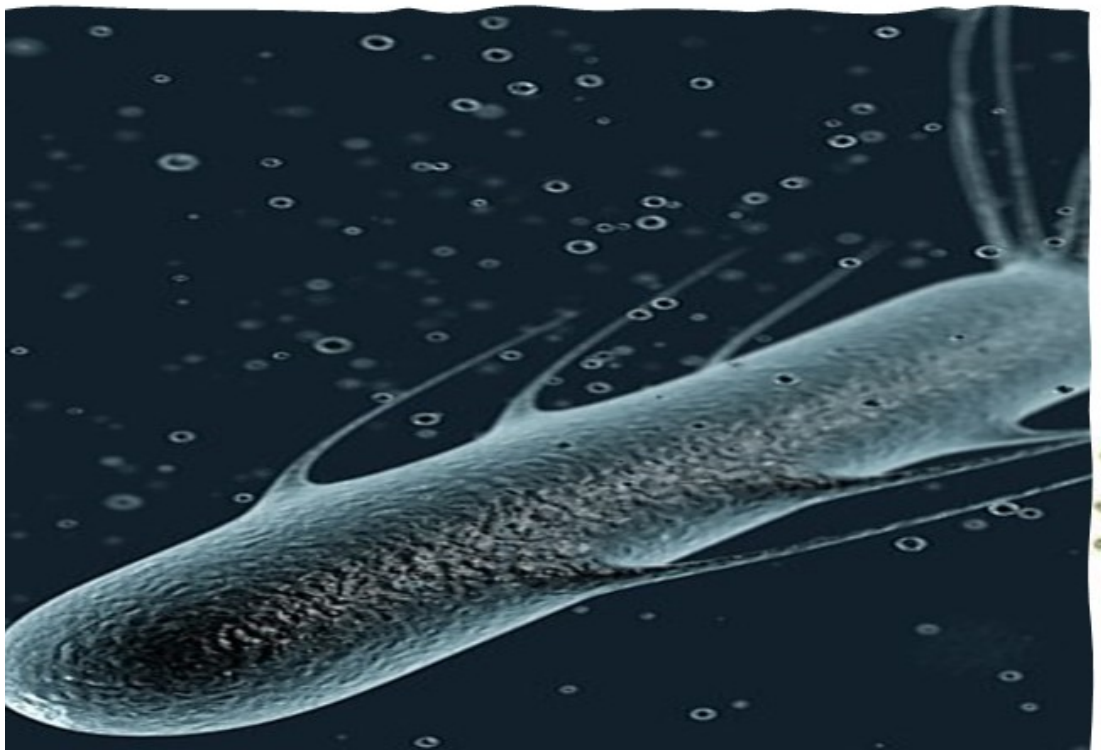
Eukaryotic Cell

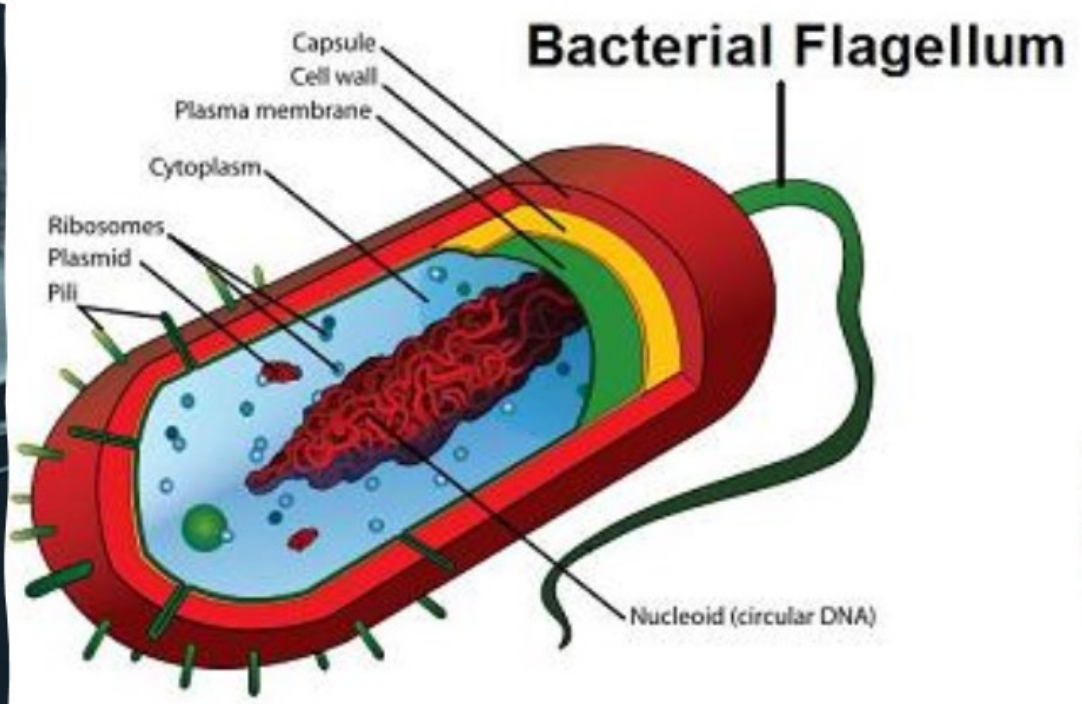


Similarities and differences between the Prokaryotic and Eukaryotic Cells

	Prokaryotic cells	Eukaryotic cells
Cell size	1-10 micrometers	10-100 micrometers
Cell membrane?	Yes	Yes
Membrane-bound organelles?	No	Yes
Have nucleus?	No	Yes
Have cytoplasm?	Yes	Yes
Have DNA	Yes, in cytoplasm	Yes, in nucleus
Examples	Bacteria	Fungi, plants, animals

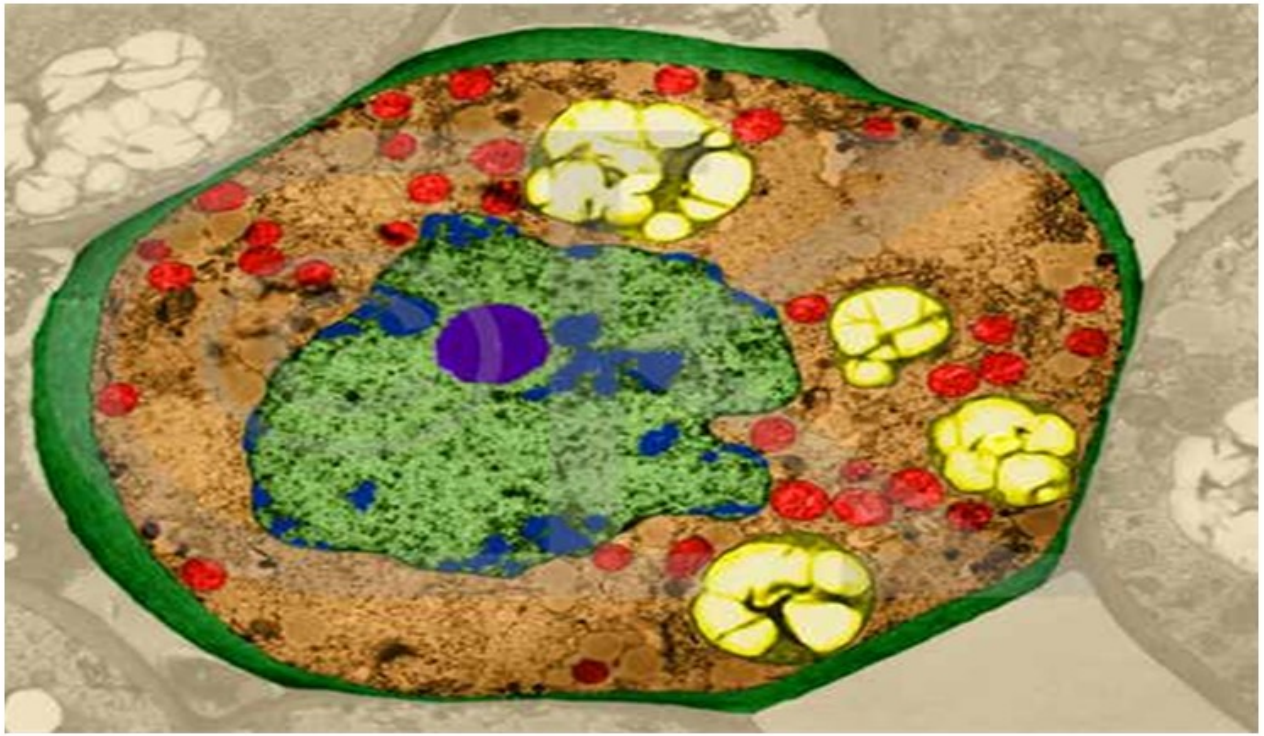
Flagella: long hairlike filaments used by some prokaryotes to move





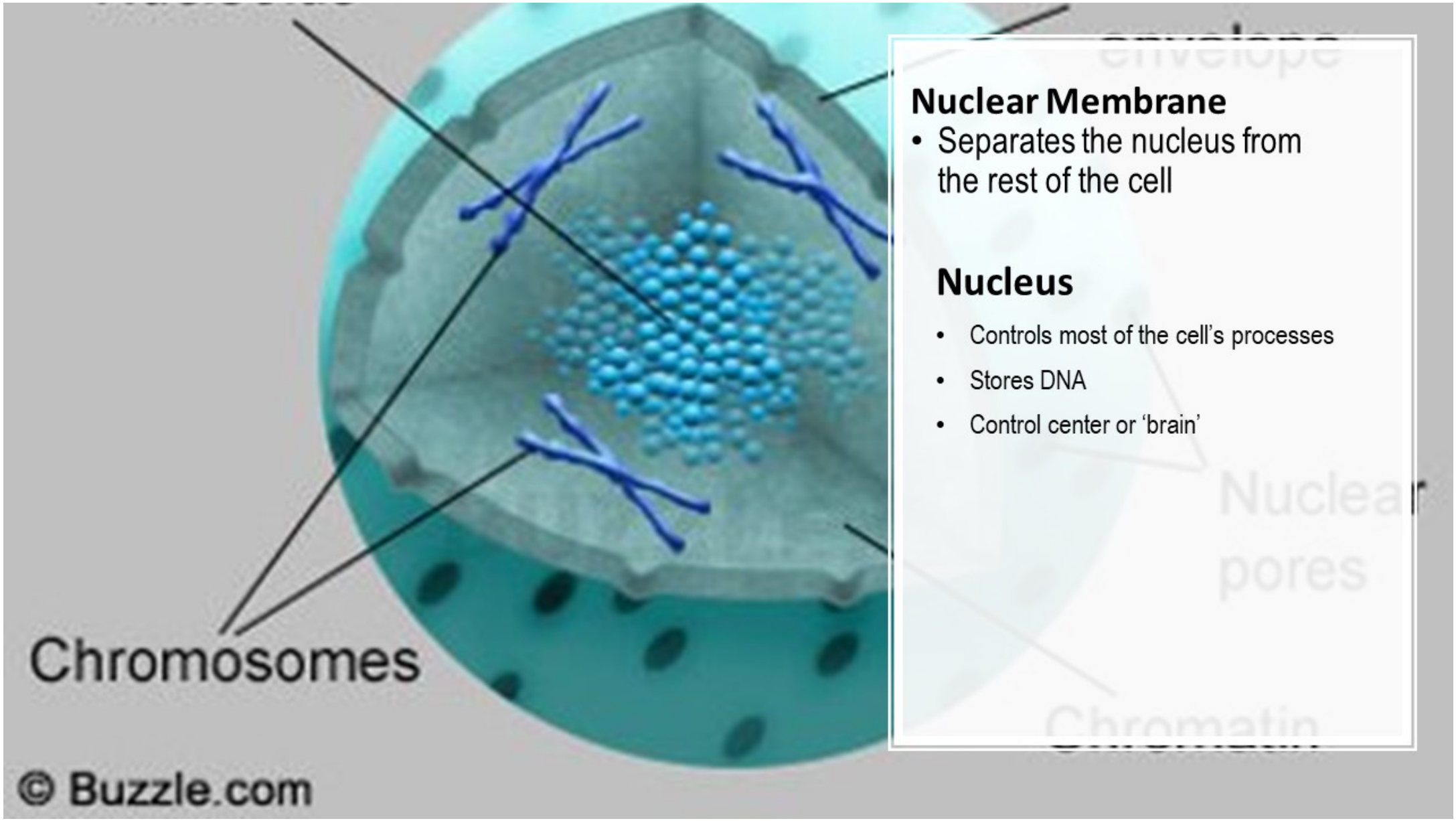
Cell Organelles

- Specialized cell parts that carry out many different processes and functions.



Cell membrane

- Barrier around the cell that controls what goes in and out
- Security Guard



Nuclear Membrane

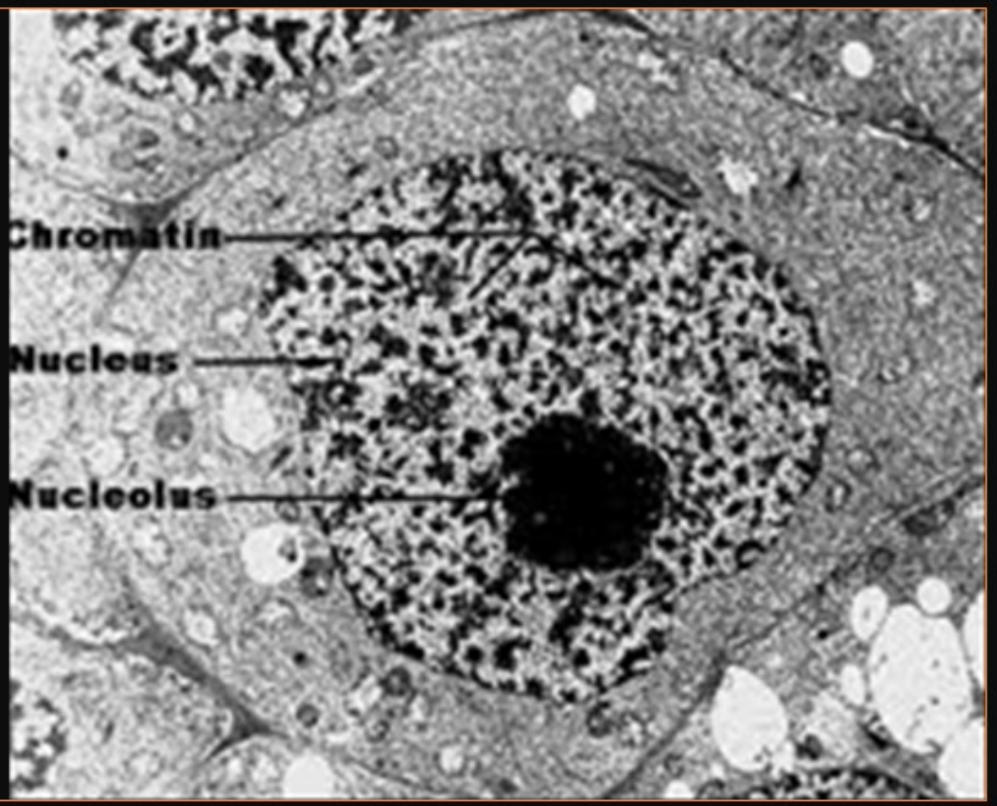
- Separates the nucleus from the rest of the cell

Nucleus

- Controls most of the cell's processes
- Stores DNA
- Control center or 'brain'

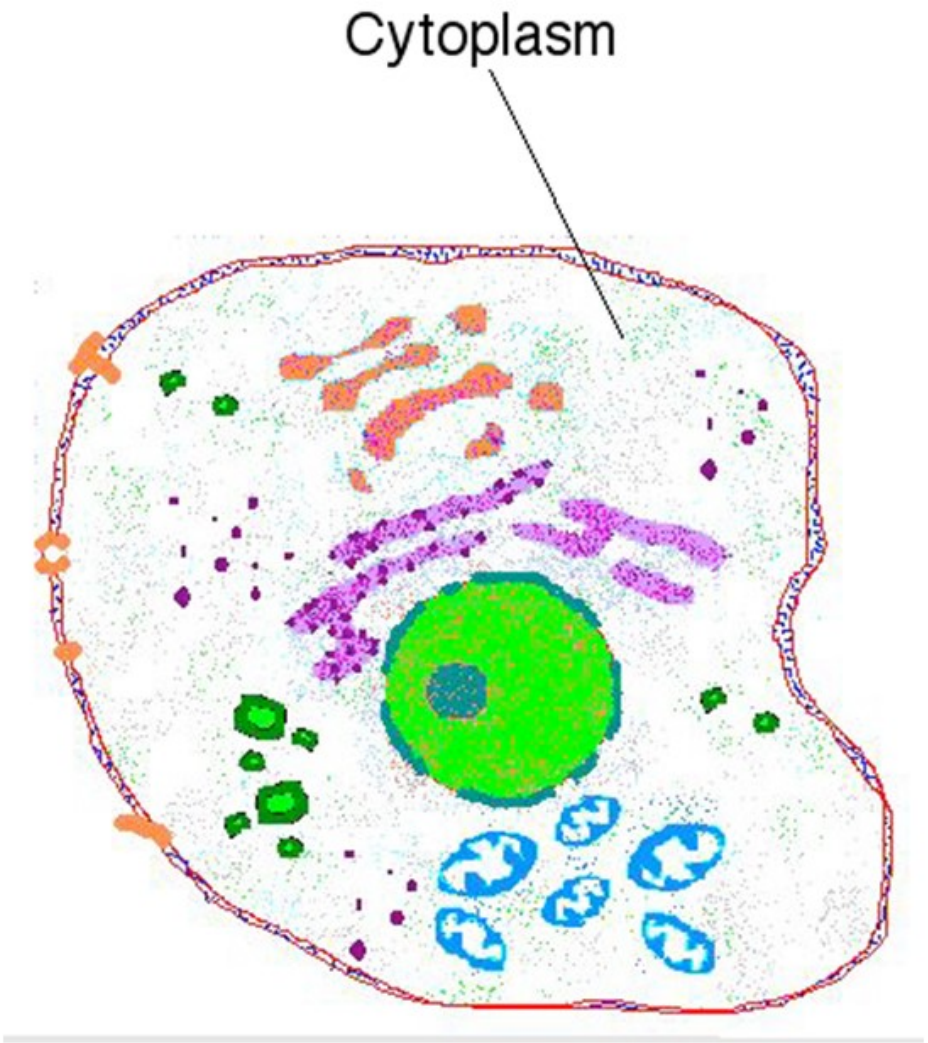
Nucleolus

Darker portion inside the nucleus that produces ribosomes

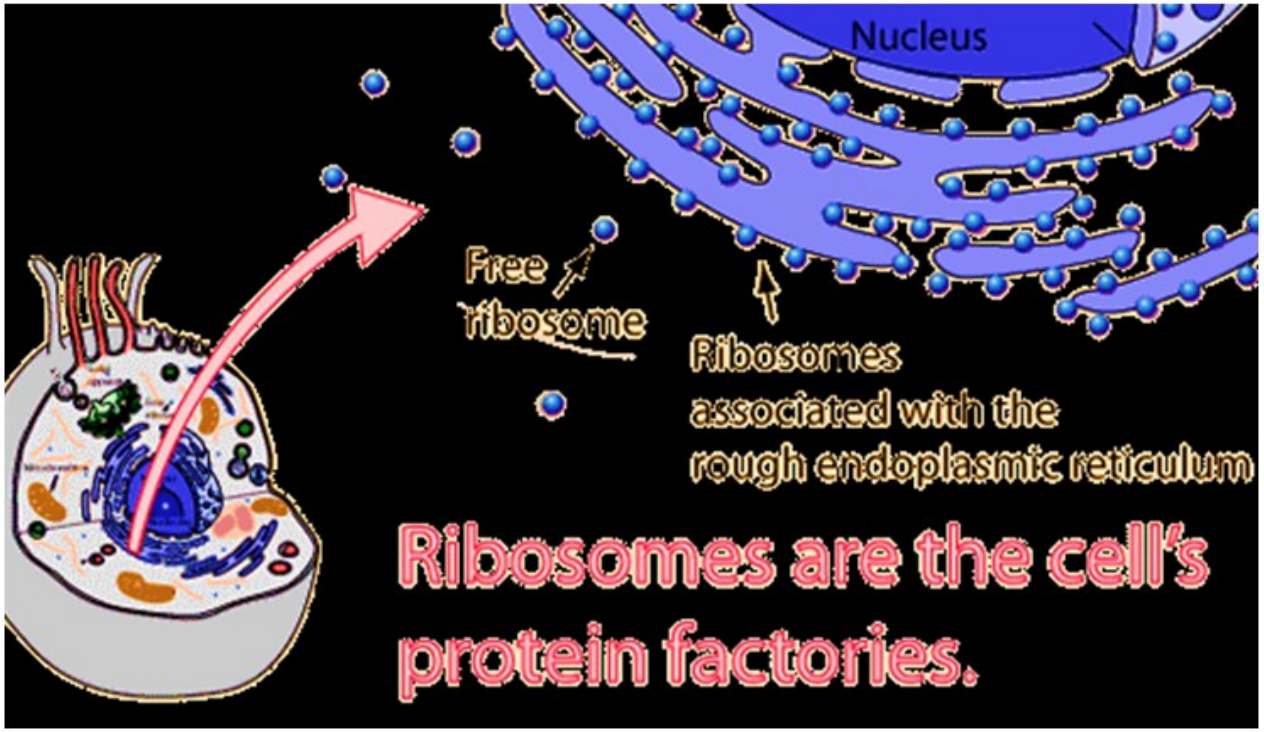


Jelly-like fluid inside the cell where metabolic processes occur

Cytoplasm (cytosol)



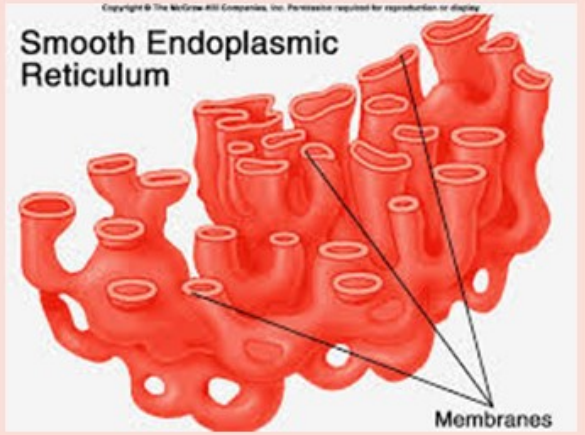
Ribosome

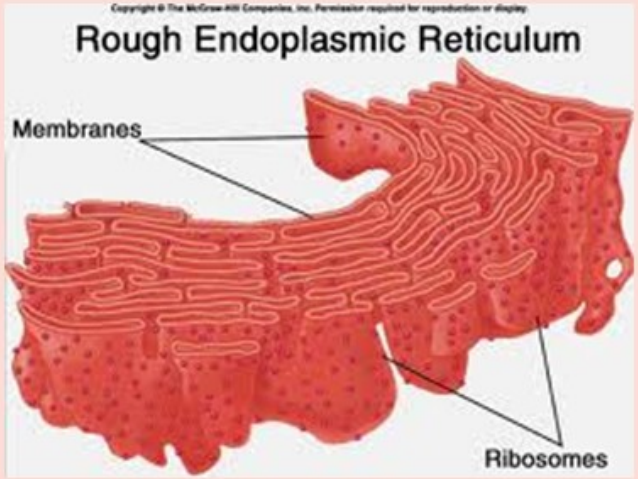


- Small organelles that float in the cytoplasm or on the ER that build proteins
- Cell workers

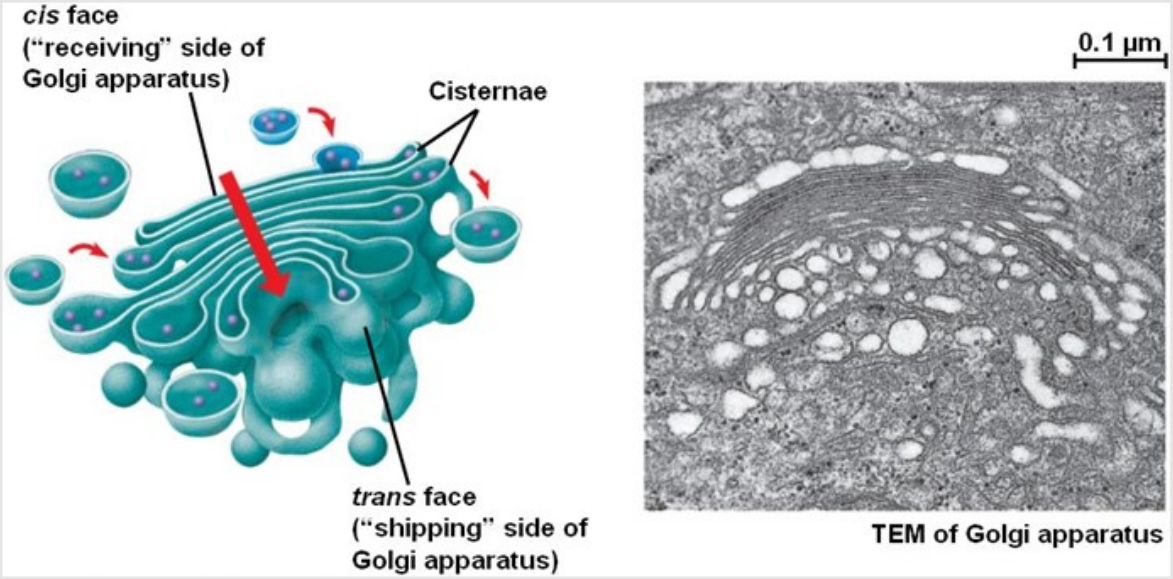
Endoplasmic Reticulum

- Produces and transports materials such as proteins
- Assembly line



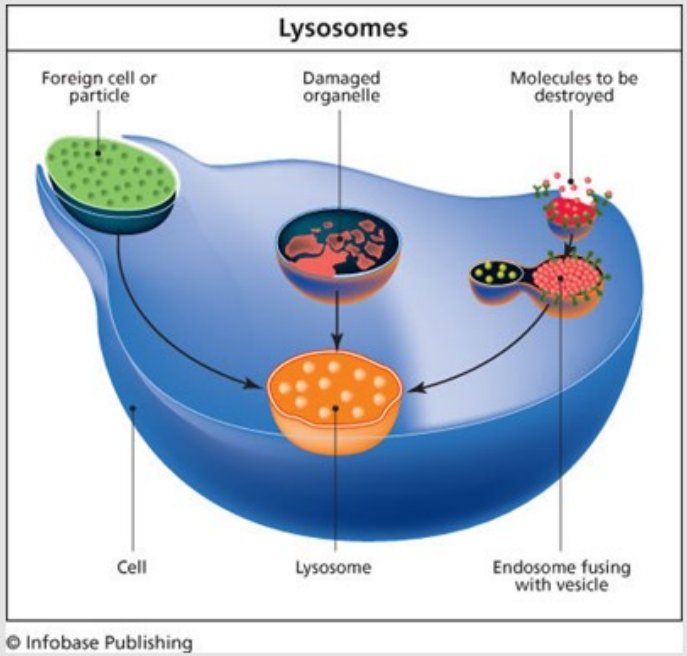


Golgi Apparatus
(Golgi body)



- Packages and distributes proteins and lipids
- Shipping and handling department

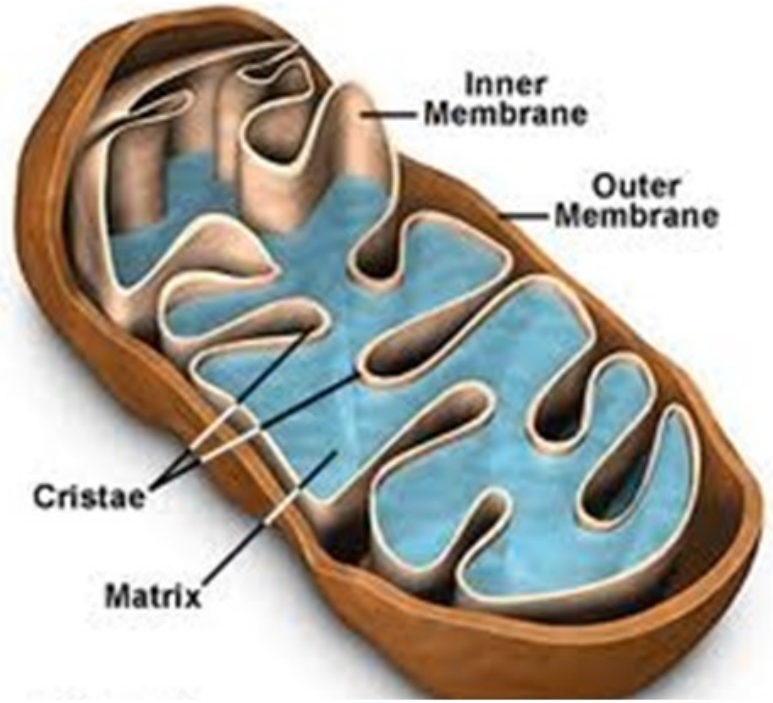
Lysosome

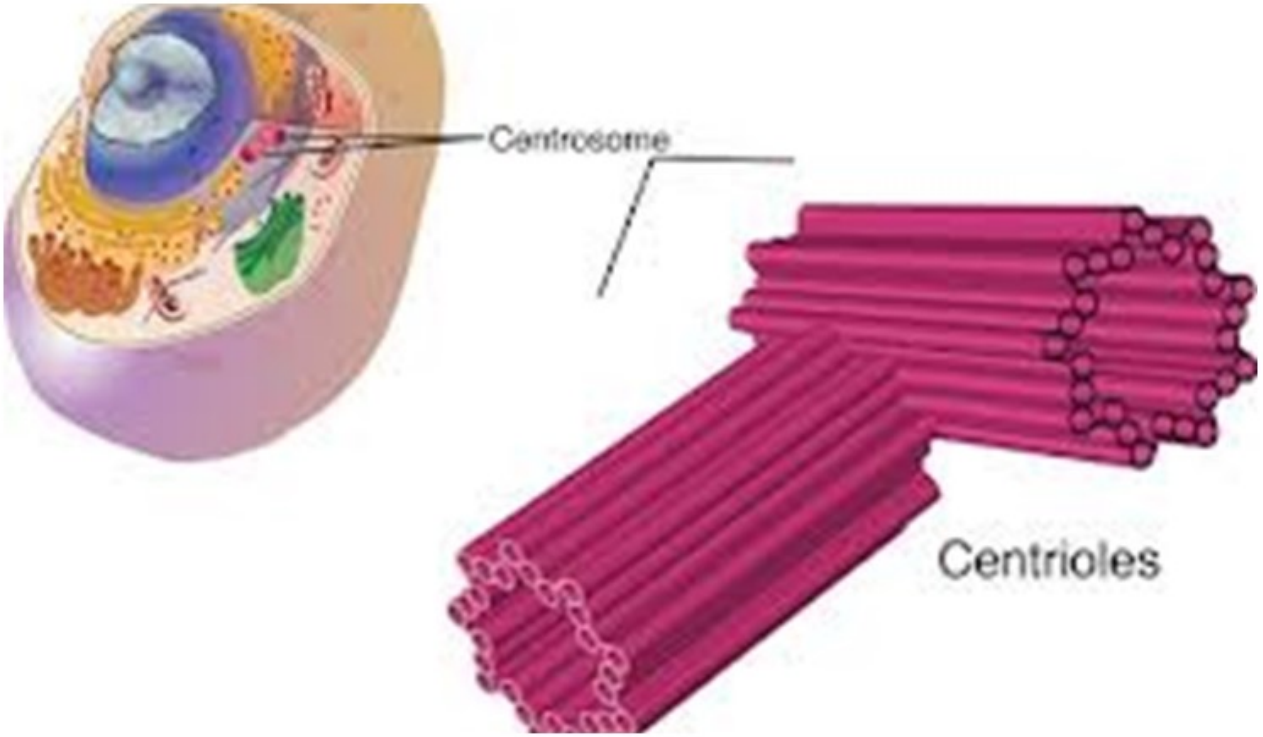


- Stores enzymes and removes worn-out organelles. Mainly in animal cells.
- Waste disposal unit

Mitochondria

- Provides energy for the cell
- Powerhouse or powerplant

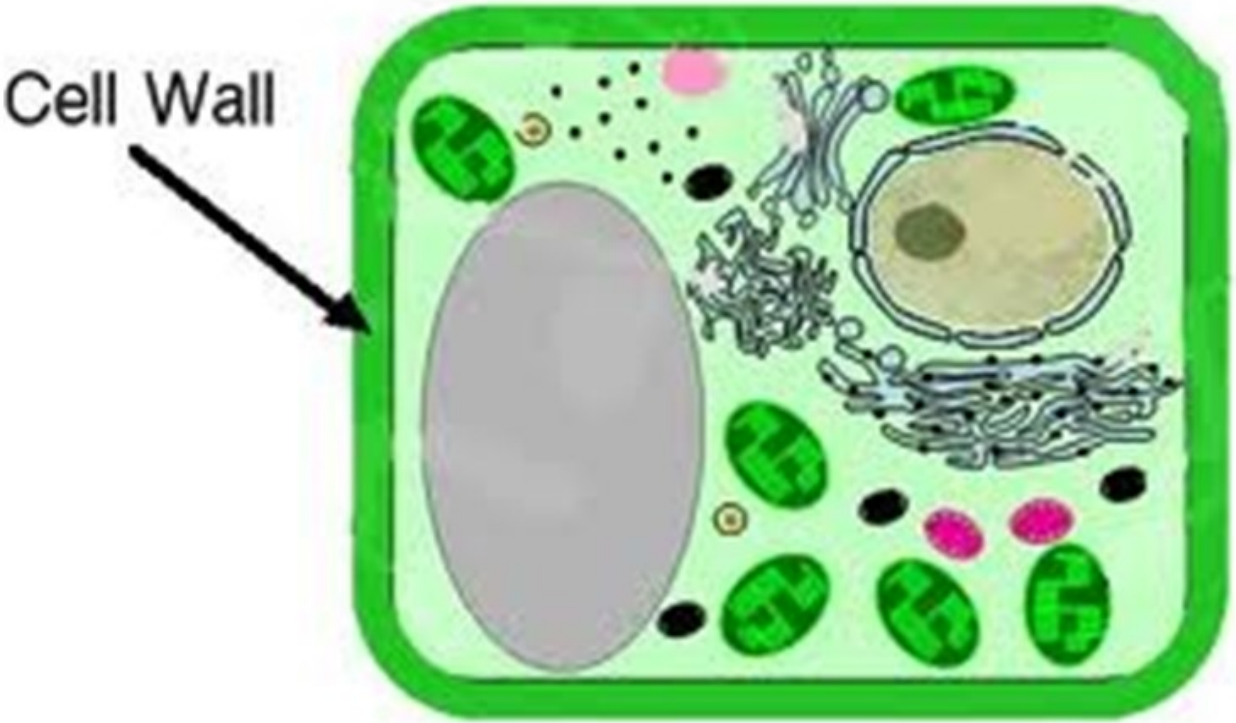




Centrioles

- Only found in animal cells that are important for cell division

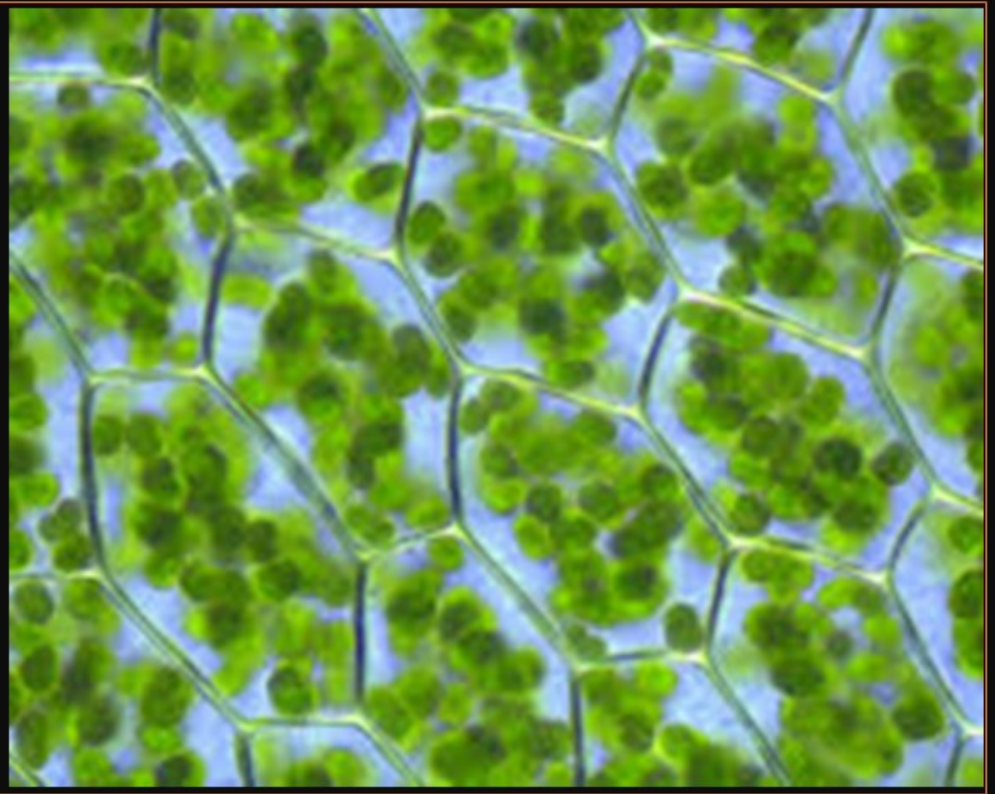
Cell wall



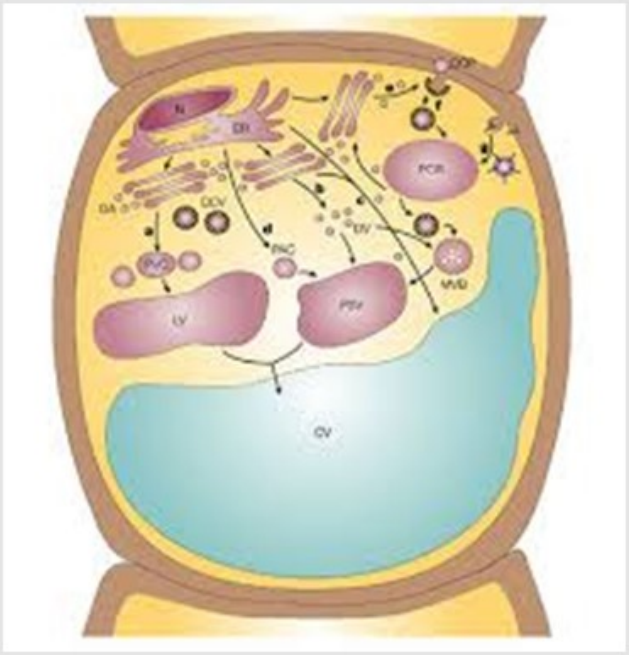
- Found only in plant and fungus cells.
- Provides extra shape, support and protection.

Chloroplast

Found only in plant cell. They contain chlorophyll used for photosynthesis



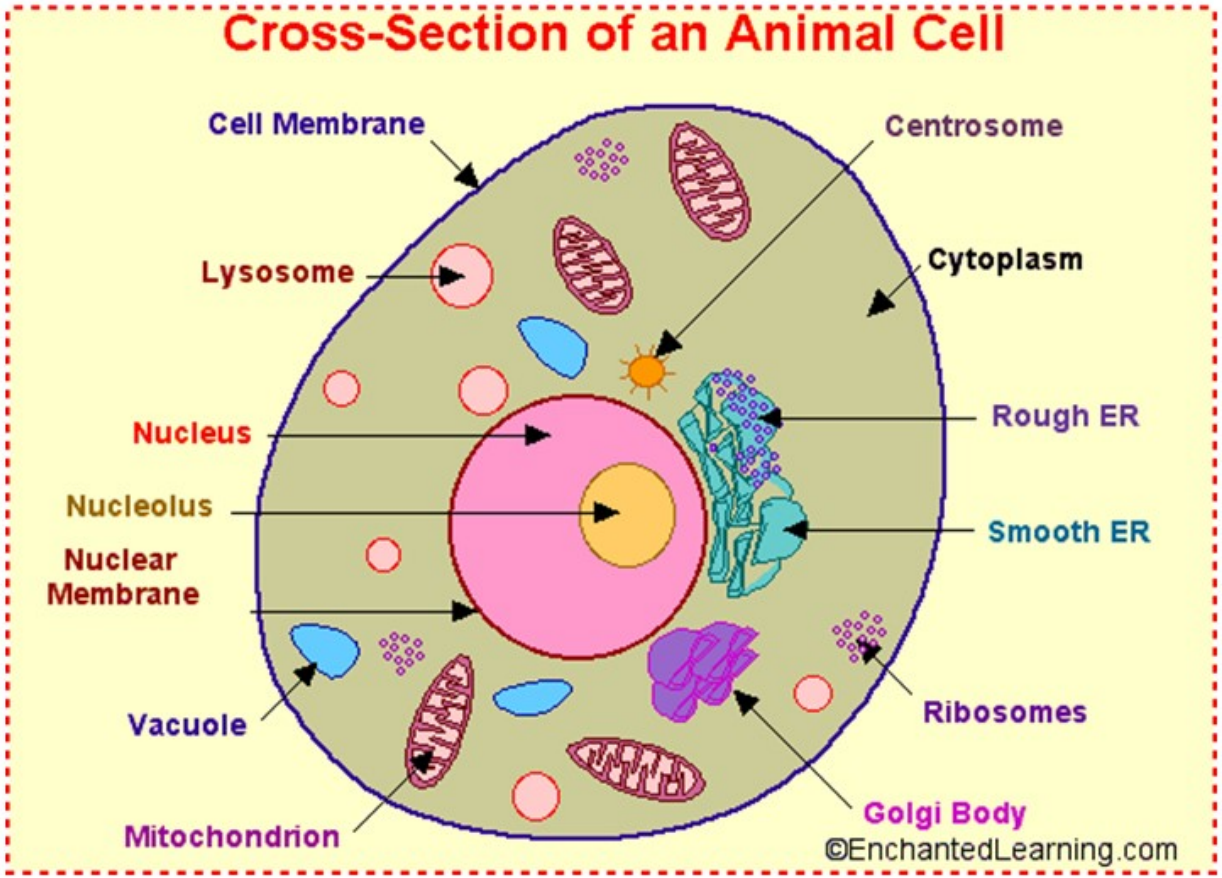
Vacuole



- Stores water, salts, and wastes. Plants have larger ones
- Storage unit

Differences Between Plant and Animal Cells

	Plant Cells	Animal Cells
Have a Cell Membrane, Nucleus, Mitochondria, Ribosomes, Golgi apparatus, and Endoplasmic Reticulum?	YES	YES
Have a Cell Wall?	YES	NO
Have Lysosomes?	NO (rarely)	YES
Have Vacuoles?	YES	None or Small
Have Chloroplasts?	YES	NO


Cross-Section of an Animal Cell
Cell Membrane
Centrosome
Lysosome
Cytoplasm
Nucleus
Rough ER
Nucleolus
Smooth ER
Nuclear Membrane
Vacuole
Ribosomes
Mitochondrion
Golgi Body
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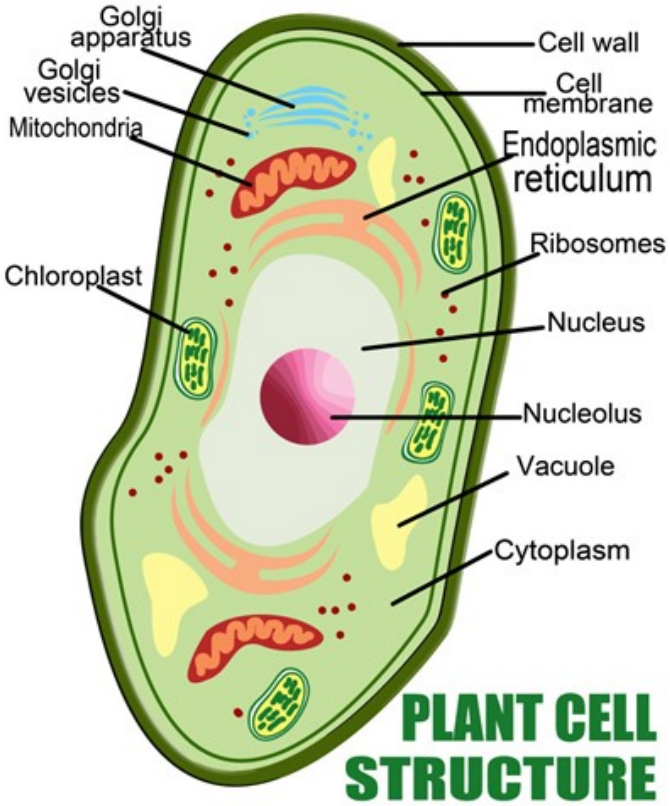

Golgi apparatus
Golgi vesicles
Mitochondria
Chloroplast
Cell wall
Cell membrane
Endoplasmic reticulum
Ribosomes
Nucleus
Nucleolus
Vacuole
Cytoplasm
PLANT CELL STRUCTURE

Prokaryotes (Bacteria)

Eubacter **"True" bacteria**

- **human & animal pathogens**
- **clinical or environmental**
- **one kingdom**

Archaea **"Primitive" Bacteria**

- **Environmental organisms**
- **second kingdom**

Definition

Bacteria : **is a heterogeneous** group of uni-cellular organisms about 1-8 µm in diameter

Prokaryotic (has a primitive nucleus):

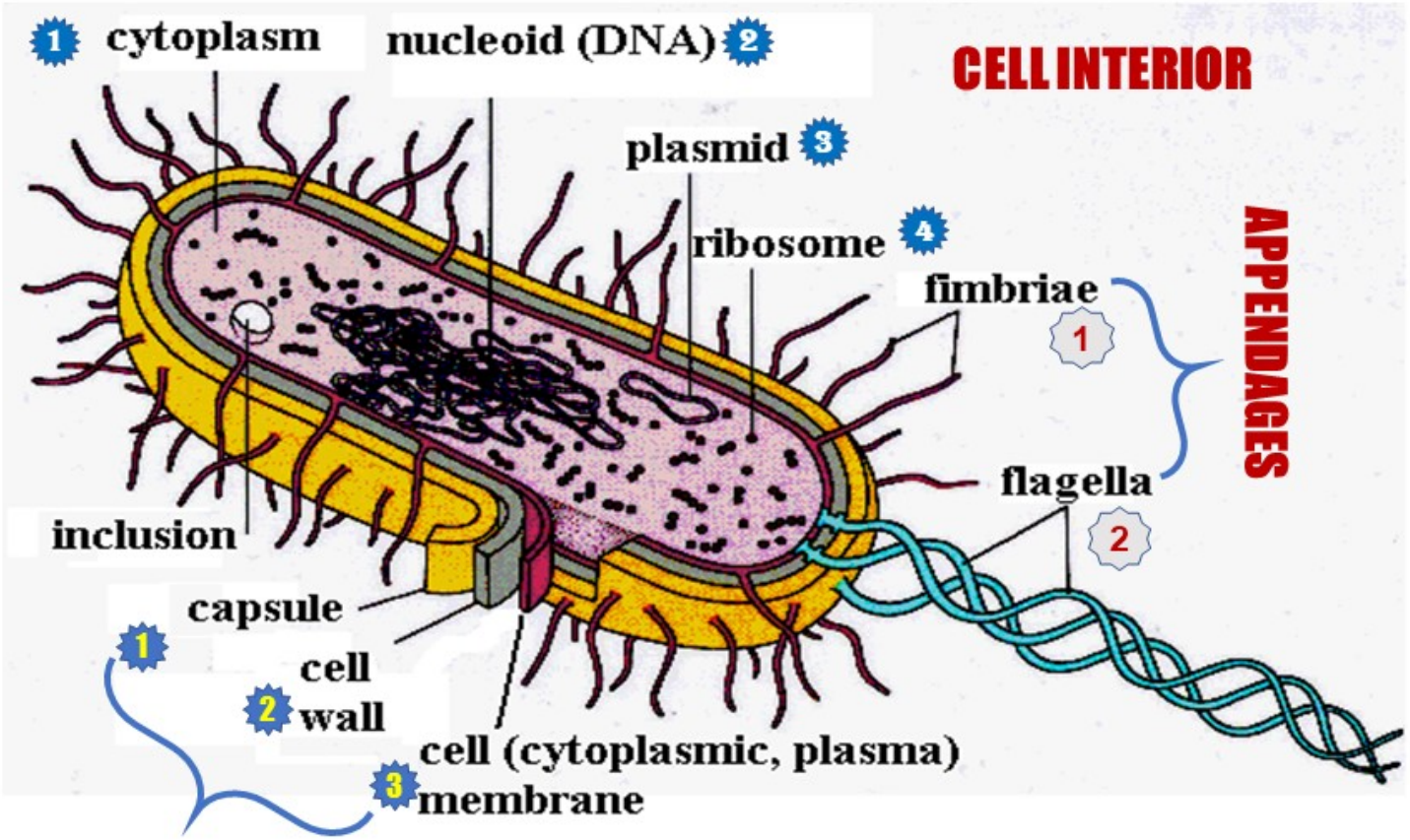
- **one chromosome(haploid) / cell**
- no nuclear membrane
- no mitochondria
- no sterols
- no 80 S Ribosome

Plasmids: extra piece of **DNA.**

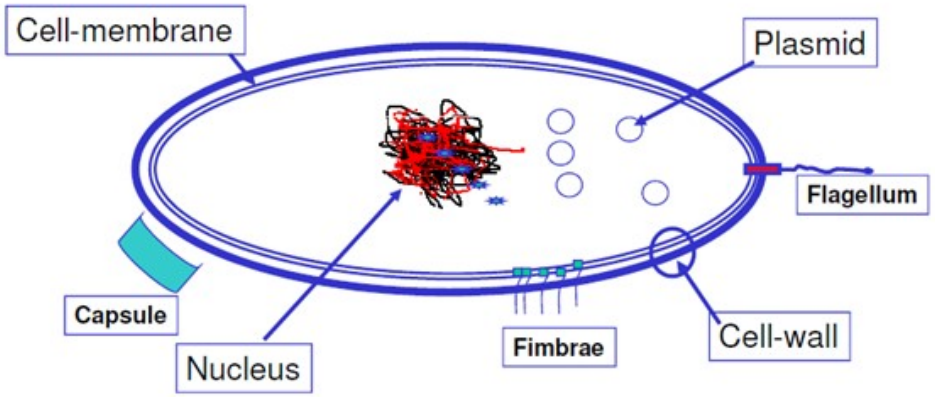
Size of Bacteria

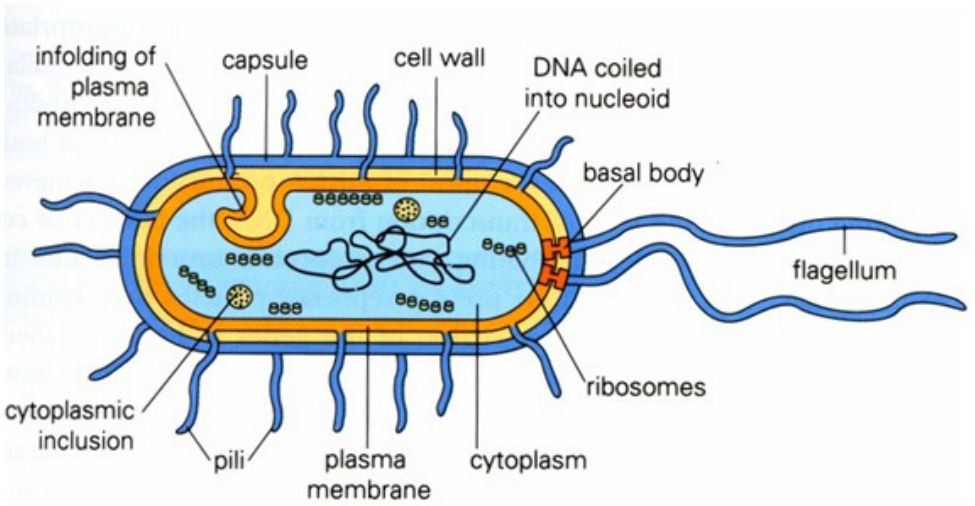
- Average bacteria 0.5 - 2.0 µm in diameter.
  - RBC is 7.5 µm in diameter.
- Surface Area ~12 μm^2
- Volume is ~4 μm^3
- Surface Area to Volume is 3:1
- Typical Eukaryote Cell SA/Vol is 0.3:1
- Food enters through SA, quickly reaches all parts of bacteria
- Eukaroytes need structures & organelles

Overview of prokaryotic cell.



Structure of bacteria





Structures of bacteria

Shapes :

Spherical / Oval.....**Cocci**

Very short Bacilli.....**Coccobacilli**

Rods.....**Bacilli**

Tapered end.....**Fusiform**

Club-shaped / Curved....**Vibrio**

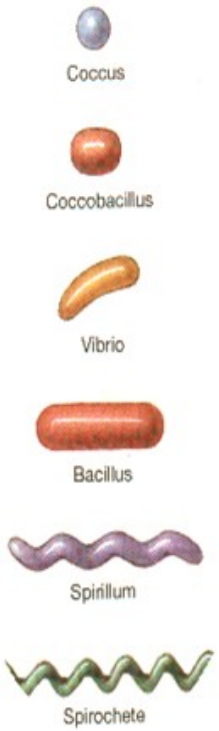
Helical / Spiral... .....**Spirochaetes**

Shapes of bacteria

Coccus
- Chain = Streptoccus
- Cluster = Staphylococcus

Bacillus
- Chain = Streptobacillus

Coccobacillus
Vibrio = curved
Spirillum
Spirochete
Square
Star



Arrangements(1)

- Among Cocci :
- Pairs……Diplococci
- Chains……Streptococci
- Clusters…..Staphylococci
- In four…….Tetrad
- Pallisades…..*Corynebacterium*

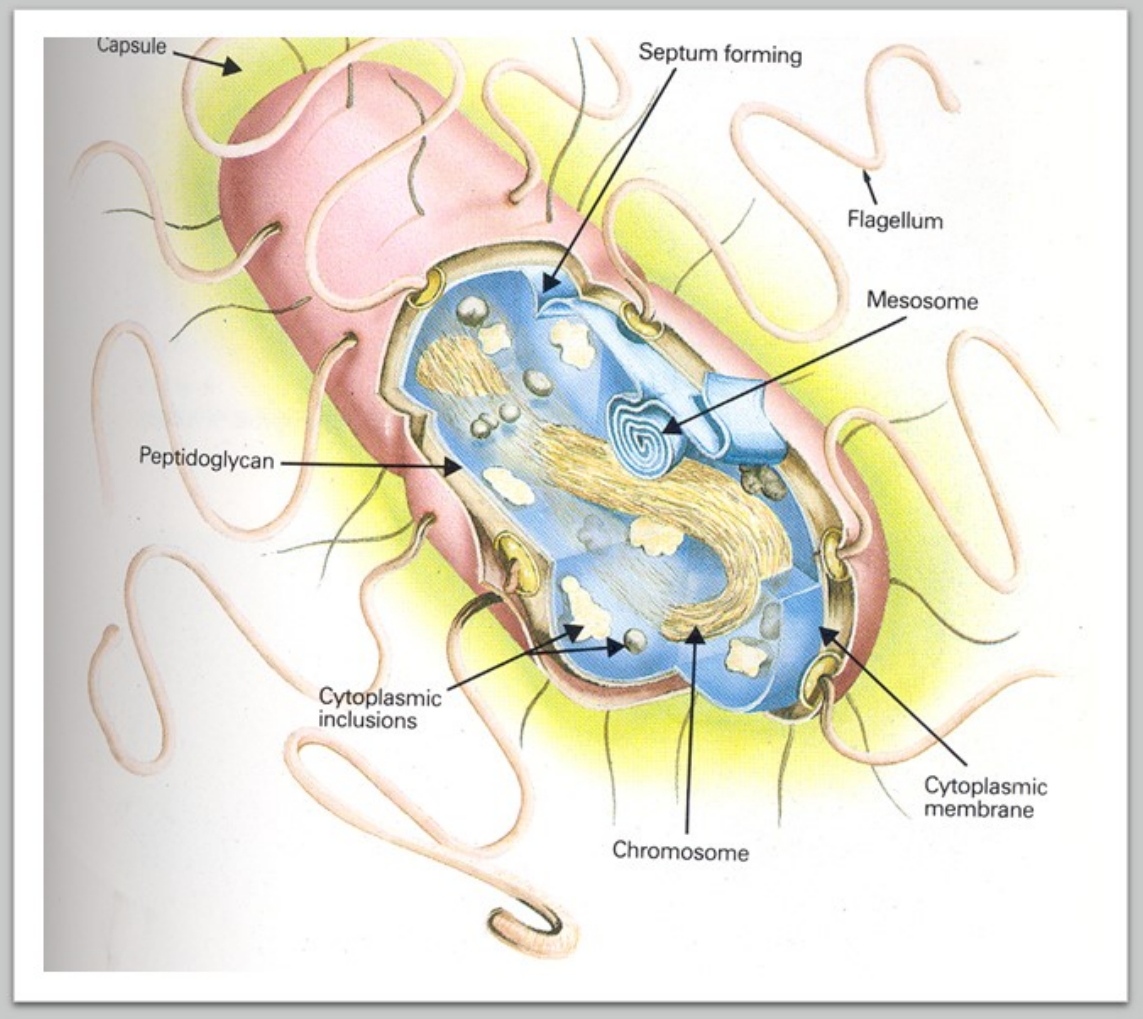
Arrangements(2)

Among Bacilli :

Pairs.....Diplococcibacilli

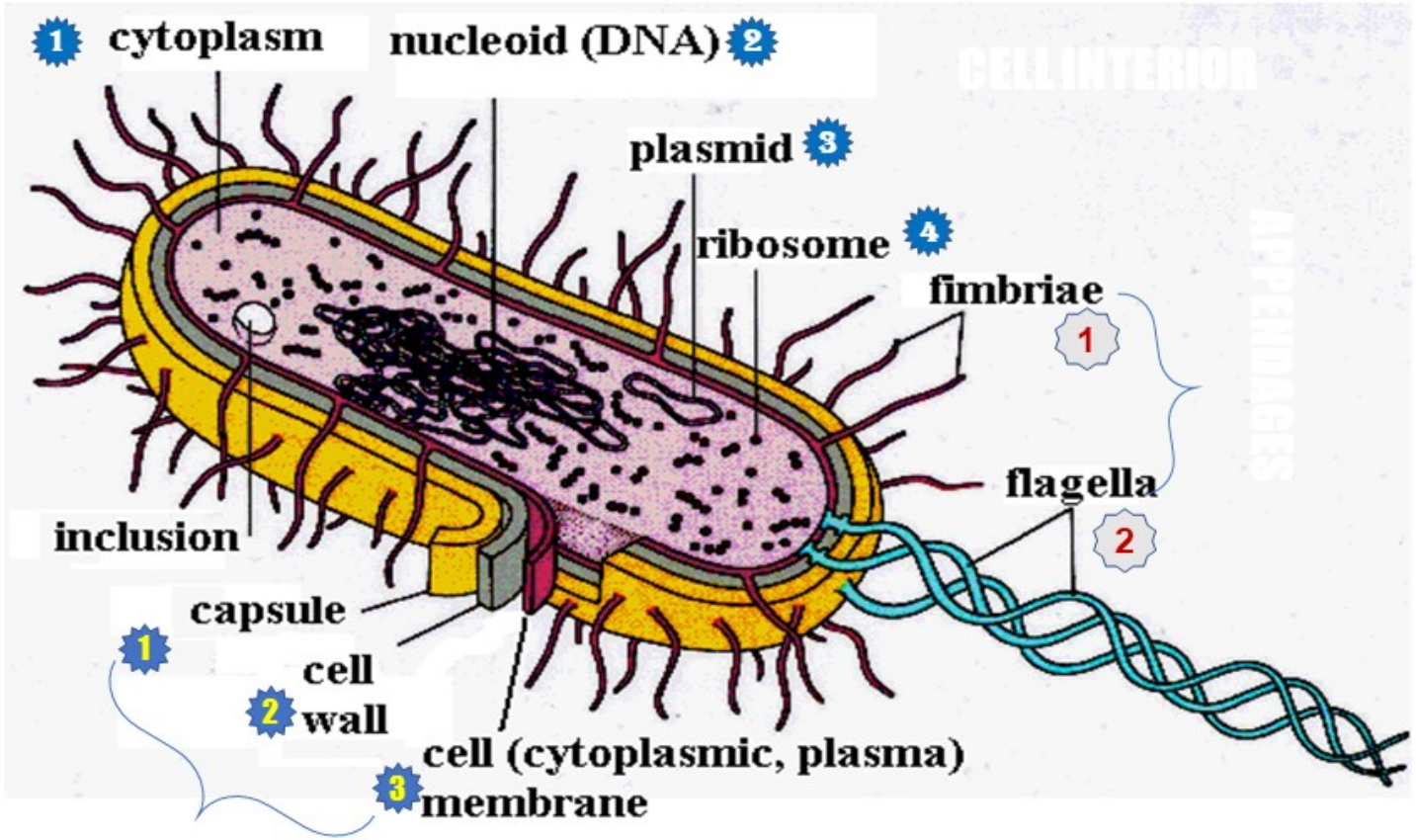
Chains.....Streptobacilli

Pallisades.....*Corynebacterium*



Major structures of bacteria cell wall / appendeges & cytosol

Overview of prokaryotic cell.



External Structures

Protrude from the cell into the environment.:

Flagella

Pili

Fimbriae

Capsule

Appendages- FLAGELLA

Some rods and spiral form have this.

a). function: motility

b). origin : cell membrane /cell wall flagella attach to the cell by hook and basal body which consists of set(s) of rings and rods

Gram - : 2 sets of ring and rods, L, P, S, M rings and rods . e.g. *E. coli*

Gram + : S, M rings and rods .**e.g. *B. megaterium***

c).Origin (continued)

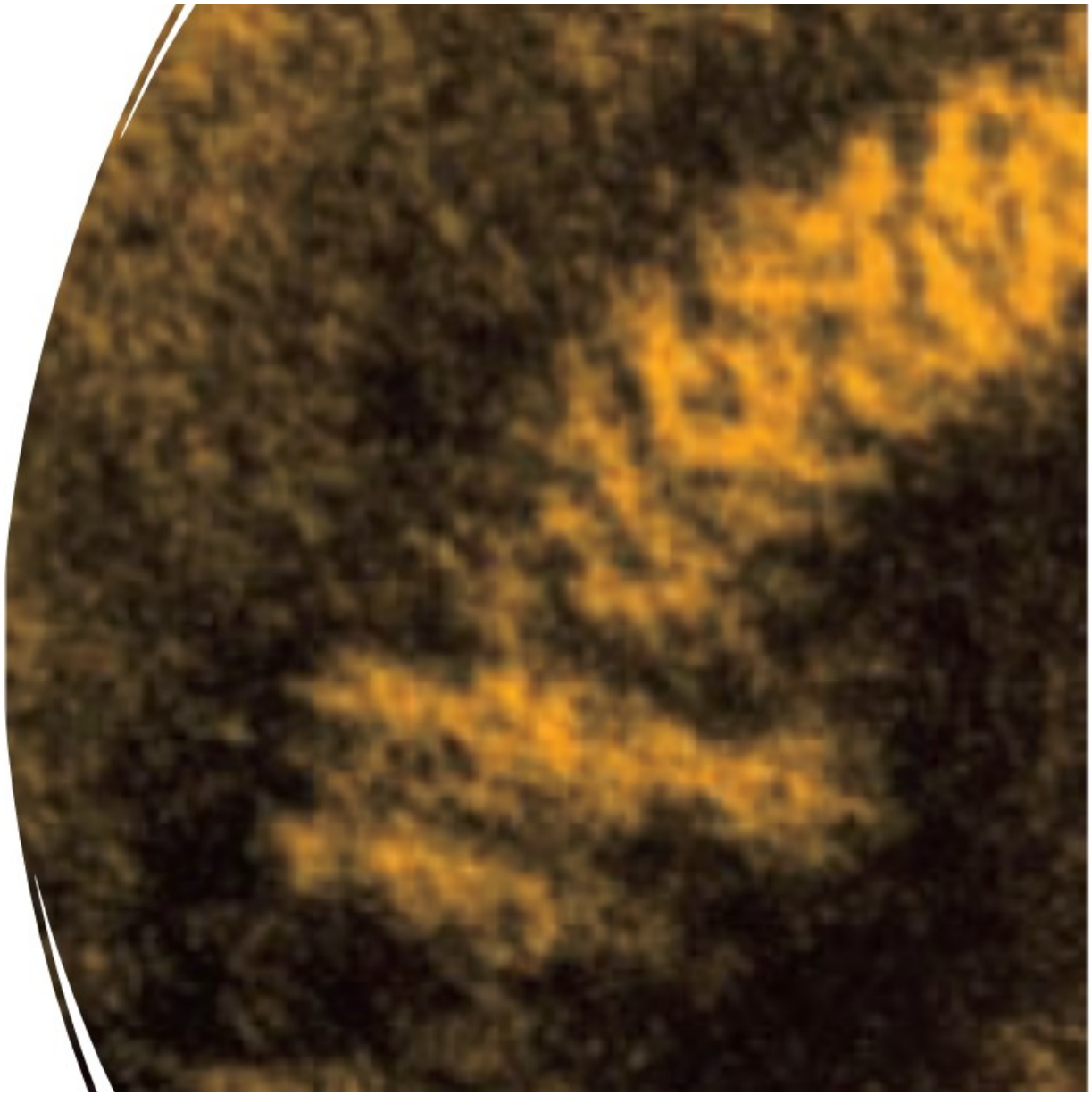
– The structure of the bacterial flagella allows it to spin like a propeller and thereby propel the bacterial cell; clockwise or counter clockwise wave like motion.

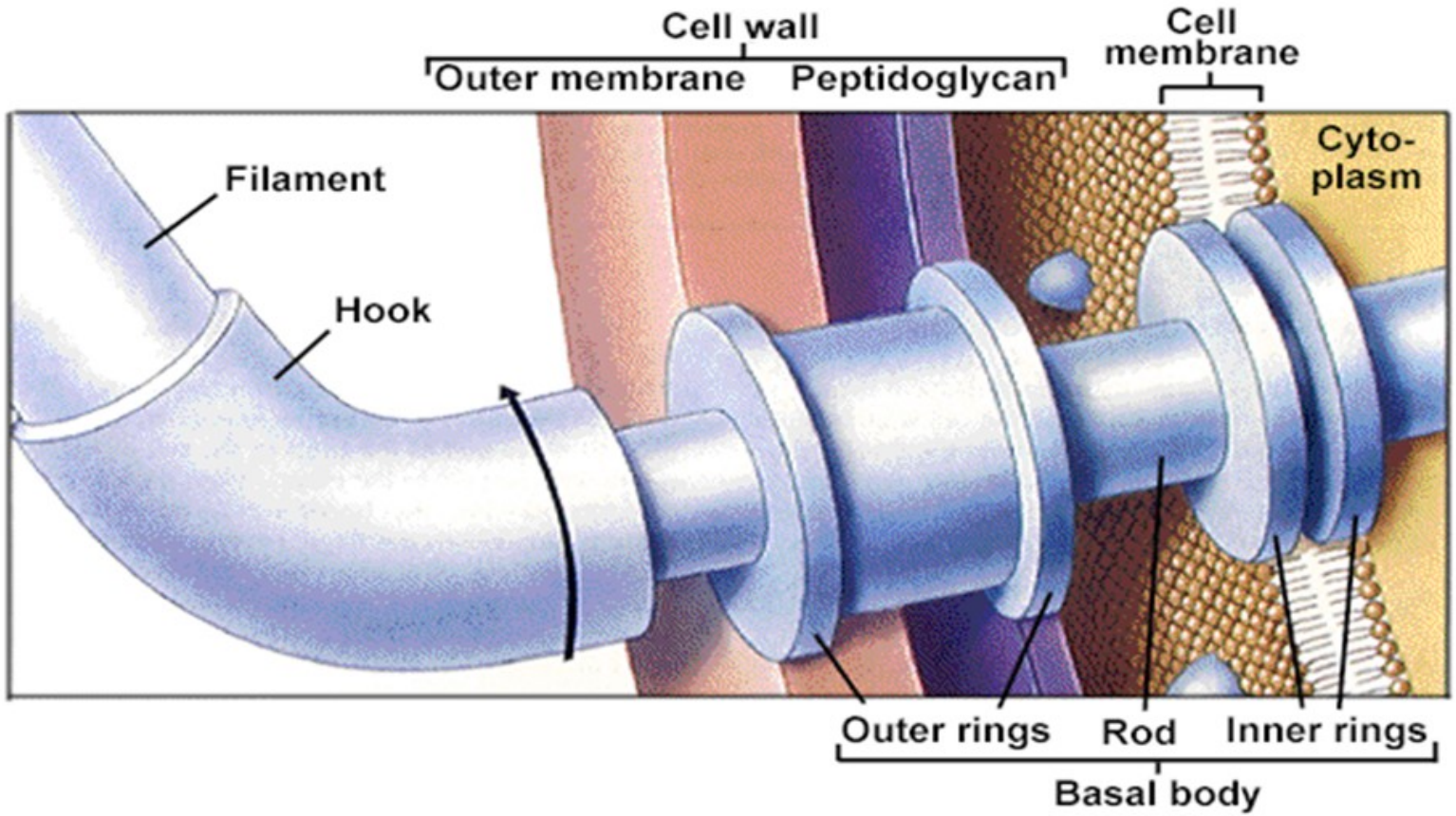
– Bacterial flagella provides the bacterium with mechanism for swimming toward or away from chemical stimuli, a behavior is knows as **CHEMOTAXIS**, chemosenors in the cell envelope can detect certain chemicals and signal the flagella to respond.

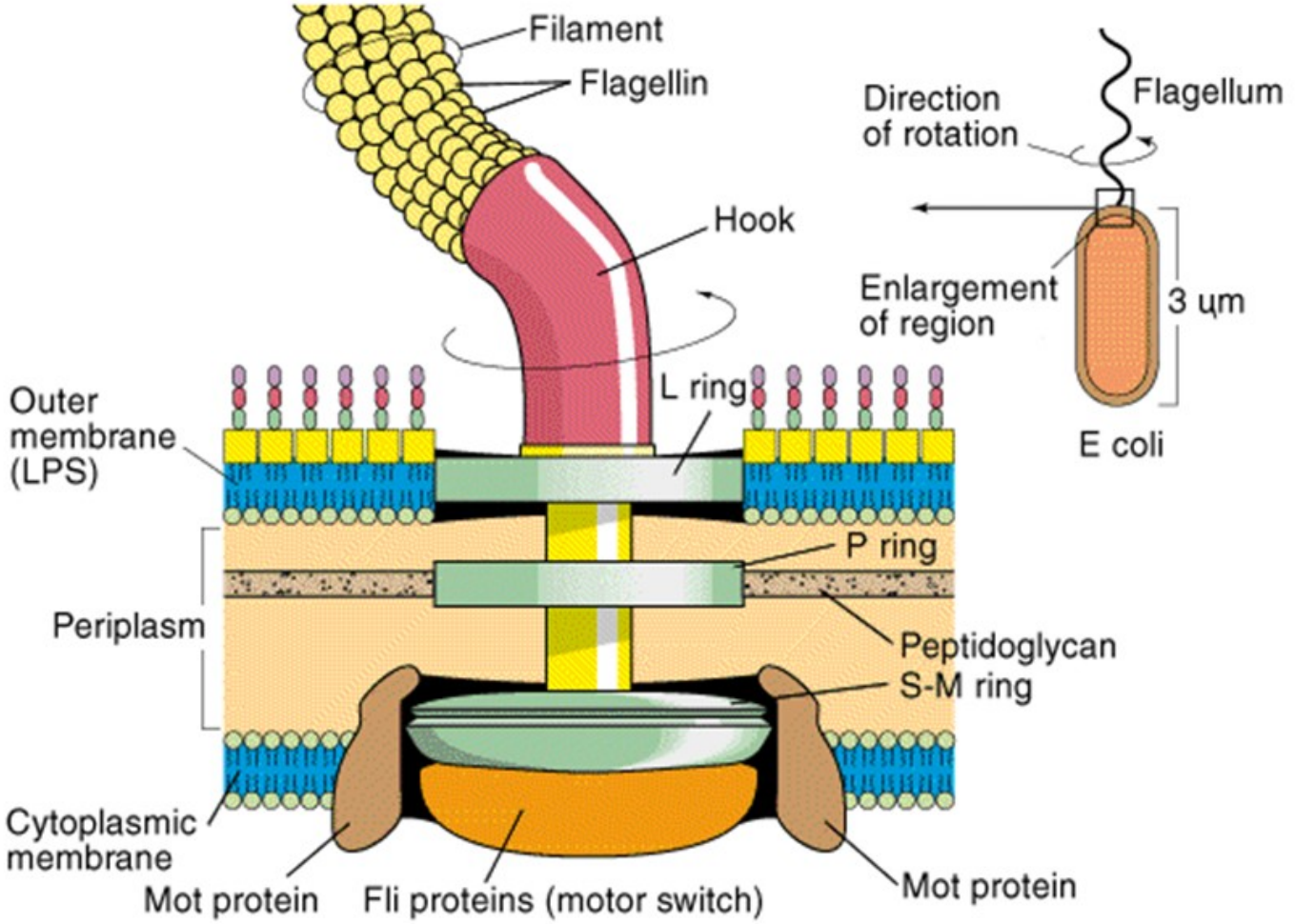
d). structure

protein in nature: subunit flagellin (globular protein)

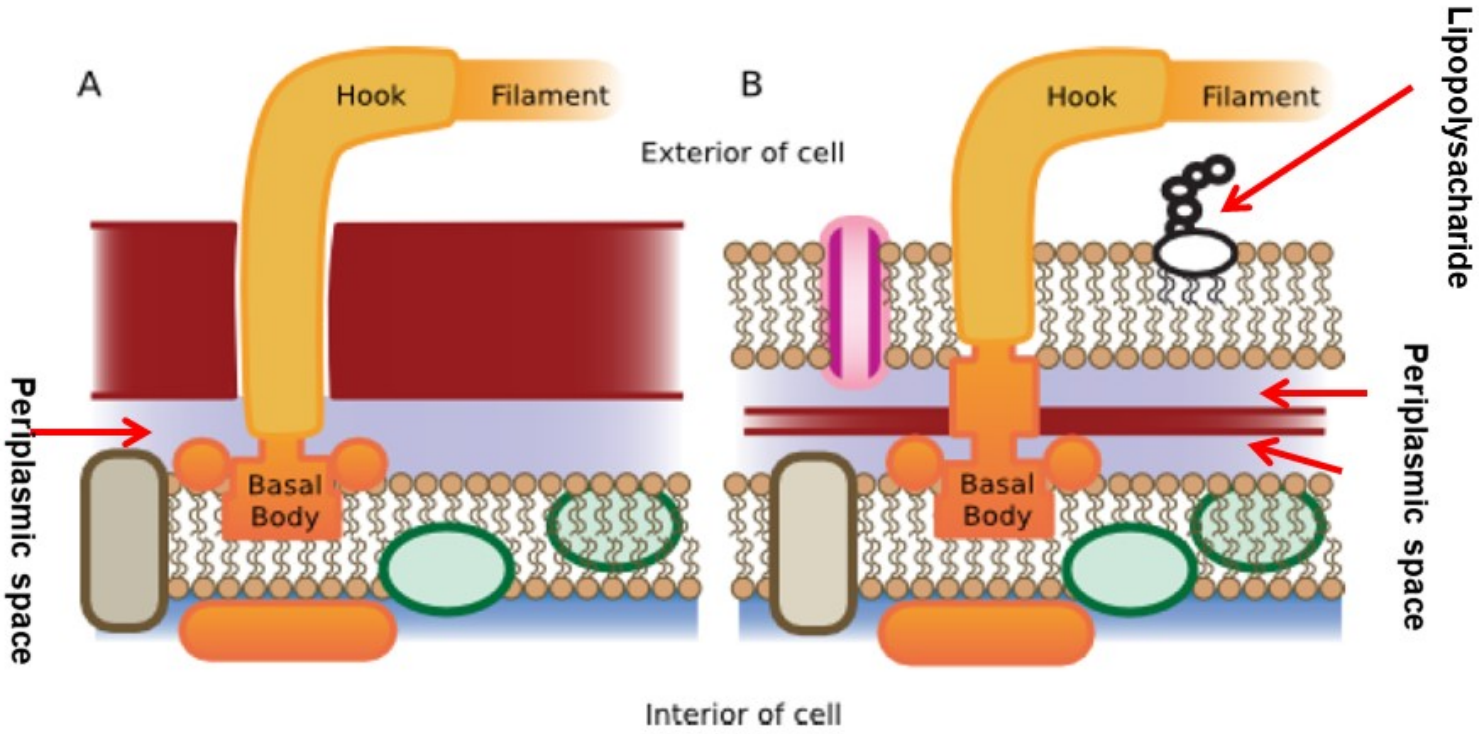
Flagella




Cell wall
Outer membrane
Peptidoglycan
Cell membrane
Cyto-plasm
Filament
Hook
Outer rings
Rod
Inner rings
Basal body


Filament
Flagellin
Hook
L ring
Outer membrane (LPS)
P ring
Periplasm
Peptidoglycan
S-M ring
Cytoplasmic membrane
Mot protein
Fli proteins (motor switch)
Mot protein
Direction of rotation
Flagellum
Enlargement of region
3 μm
E coli

Attachment of flagella in bacteria



Flagella

Motility - movement

Swarming occurs with some bacteria

- Spread across Petri Dish
- *Proteus* species most evident

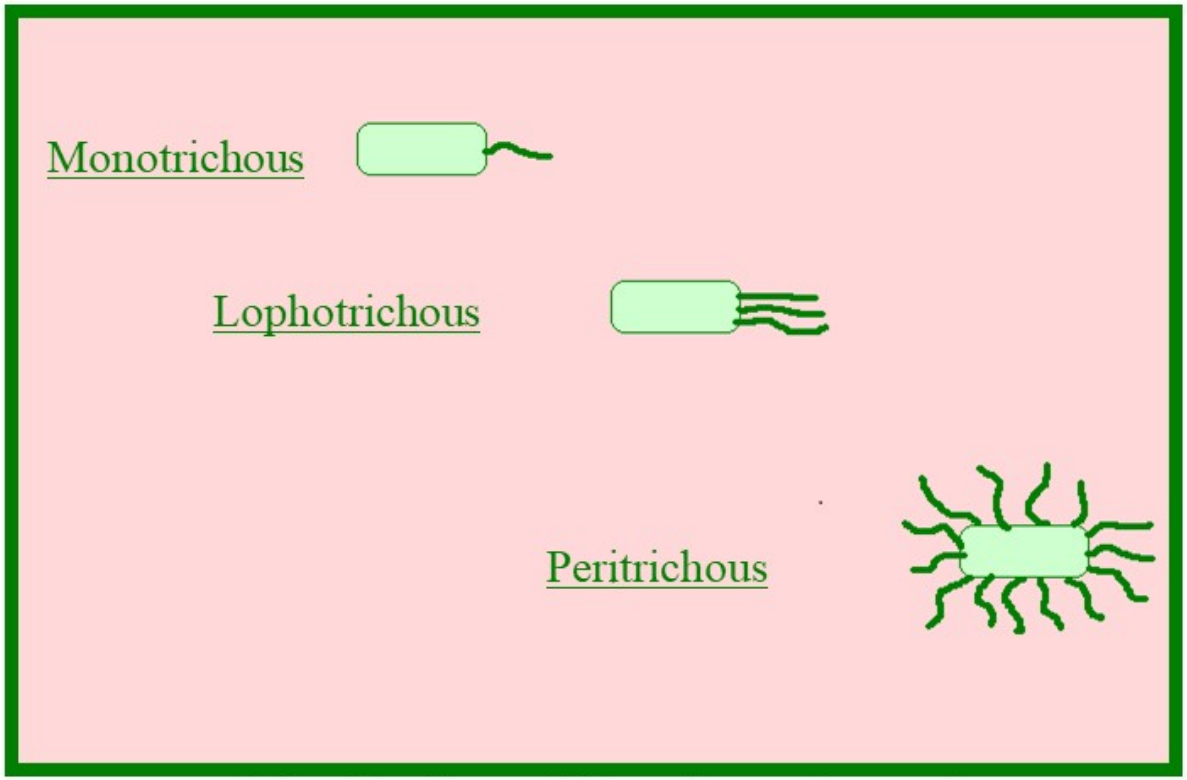
Arrangement basis for classification

- **Monotrichous**; 1 flagella
- **Lophotrichous**; tuft at one end
- **Kophotrichous**; tuft at both ends
- **Amphitrichous**; both ends
- **Peritrichous**; all around bacteria

Flagella

Helical filaments	
Composed of protein **FLAGELLIN.**	
Found in Gram positive & Gram negative bacteria.	
Distribution:	- Monotrichous
	- Amphitrichous
	- Lophotrichous
	- Peritrichous

Arrangement of spherical bacterial cells



Distribution of flagella on bacteria

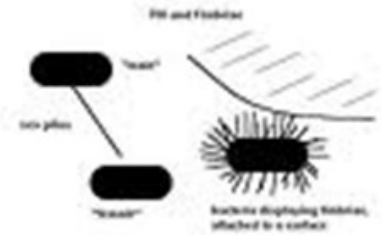
PILI

- Fine short filaments extruding from cytoplasmic membrane.
- Found on the surface of many Gram negative & Gram positive bacteria.
- Composed of protein **Pilin.**

Two classes:

❶ **Common pili** (*fimbriae*): covers the surface — responsible for: adhesion & colonization

❷ **Sex pili** : in some bacteria only, responsible for conjugation.



PILI

A . Origin:

- Cell membrane

B. Position:

- Common pili
- numerous over the cell

C. Structure

- Composed of proteins -**PILIN .**

D. Function:

- Adherence
- Gene transfer
- Prevent phagocytosis

rock Biology of Microorganisms 11/e
on Prentice Hall, Inc.

F- pilli

II. CELL SURFACE LAYER

1. **Glycocalyx**: ↗ Capsule

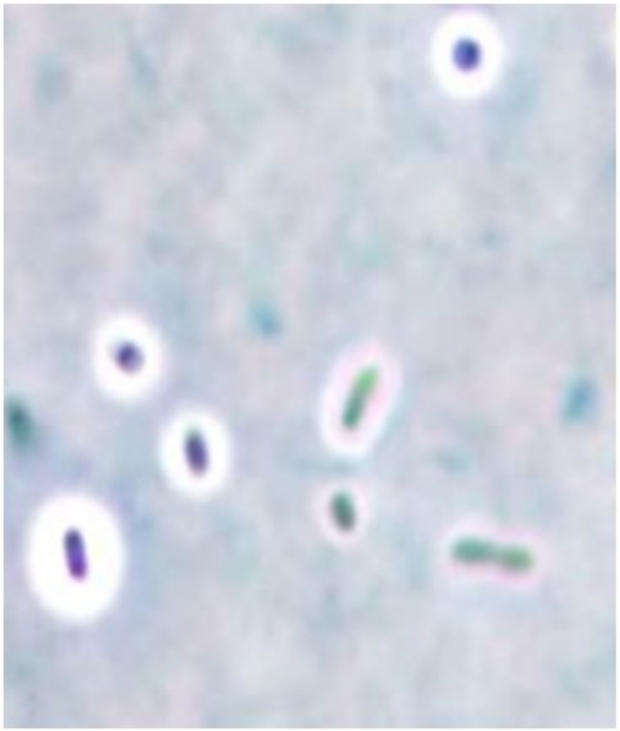
   ↘ Slime layer

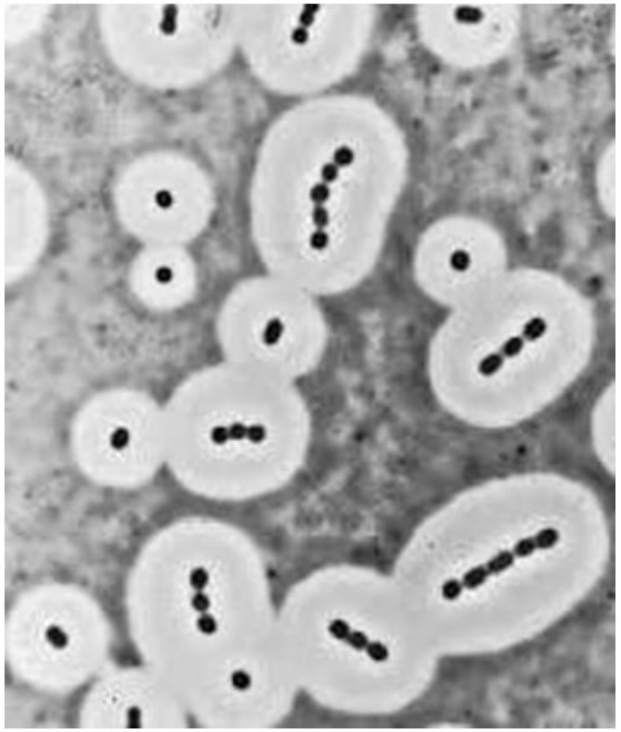
- It consists of polypeptide and polysaccharide on bacilli. Most of them have only polysaccharide.
- It is a protective layer that resists host phagocytosis. Medically important (*Streptococcus pneumonia*).

Capsule and Slime layer

- **CAPSULE** - ***well organized*** and not ***easily washed off***
- **SLIME LAYER-** ***unorganized*** material that is ***easily removed.***
- Give mucoid growth on agar plate
- *B. anthracis* has a capsule of poly-D-glutamic acid, while *S. pyogenes* made of hyaluronic acid.
- **FUNCTION** : Resistant phagocytosis(Inhibits phagocytosis) , Protect against desiccation, Attachment to surface of solid objects.
- - acts as Virulence factor in some bacteria by assessing attachment to the surfaces.

Capsule

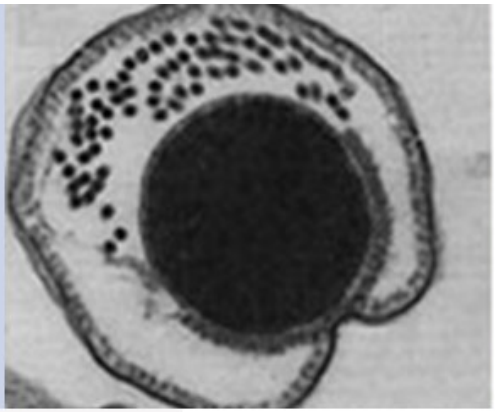
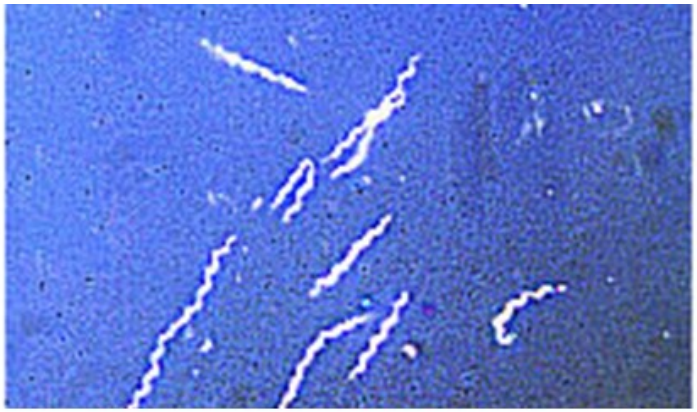
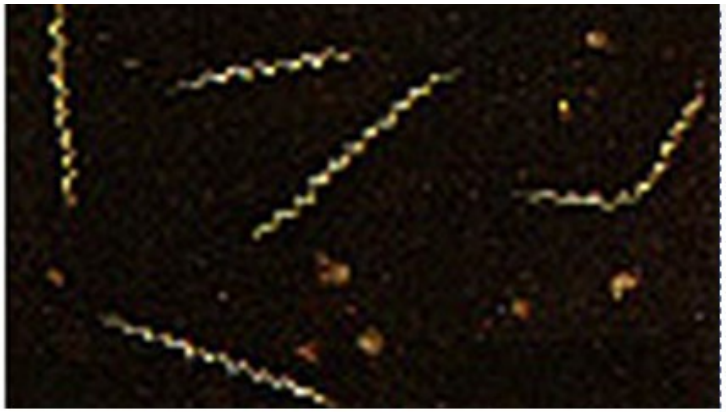




- Amorphous material surrounds bacteria.
- Usually polysaccharide
- Occasionally protein

Axial Filaments

- Present in spirochetes (*Treponema pallidum* cause syphilis)
- Function is motility – gliding motility
- Bundles of fibrils that arise at the ends of the cell

Spirochetes

- Axial filament
- Structurally similar to flagella
- Unique location under an outer membrane

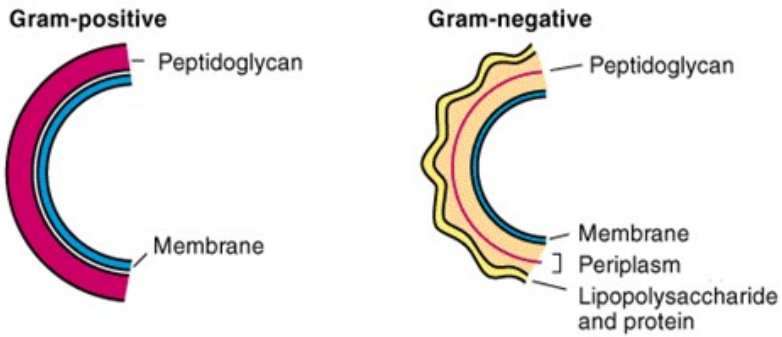
CELL WALL

- Bacteria are cells with rigid cell wall surround cytoplasmic membrane and internal structures.

Functions of cell wall:

- - Rigidity
- - Shapes bacteria
- - Protection
- -Porous / permeable to LMW molecules
- -Cell division
- - Antigenic determinants

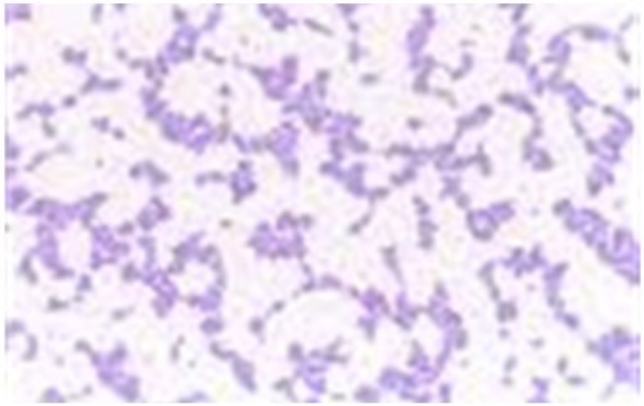
Schematic outlay of cell wall- Bacteria

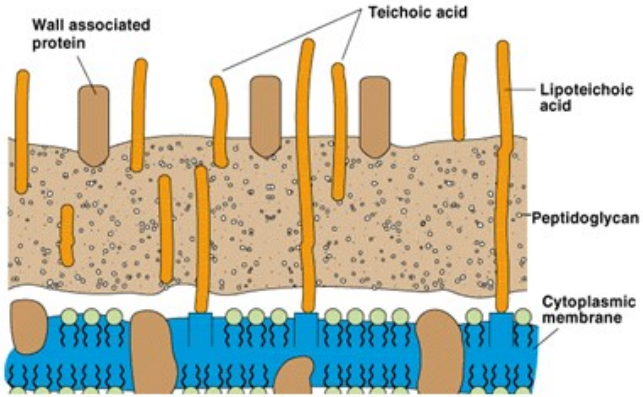


Gram Positive Cell Wall

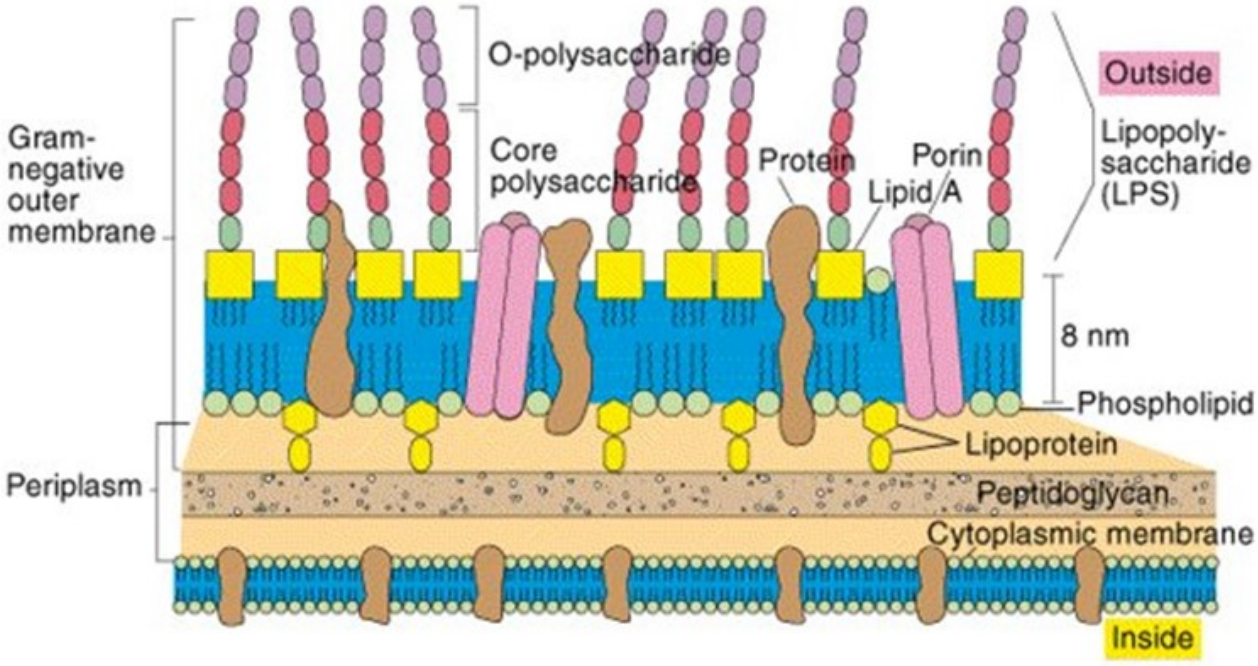
- Peptidoglycan **thicker** than Gram negative bacteria.
- Closely associated with cytoplasmic membrane.
- Techoic acid : anchors cell wall to cell membrane , epithelial cell adhesion.
- Antigens : - polysaccharides (Lancefield)

  - protein (Griffith)





Gram Negative Cell Wall



- **Thin** Peptidoglycan
- Outer membrane that contains :

  - specific proteins (porins) important in the transport of hydrophilic molecules

  - lipopolysaccharide & lipid (ENDOTOXIN)

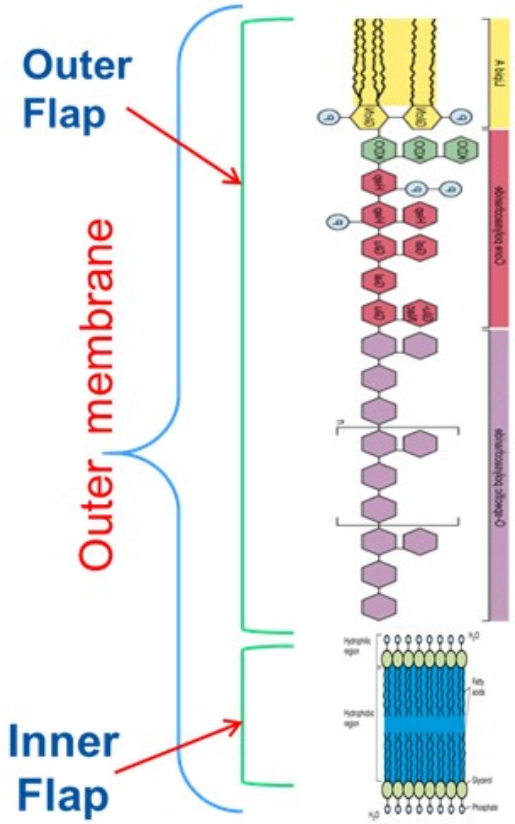
Chemical Structure of Cell Wall

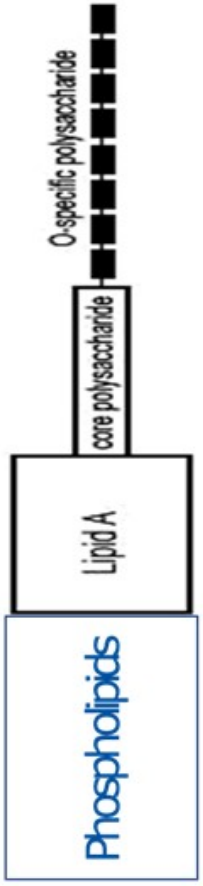
- **Peptidoglycan** :

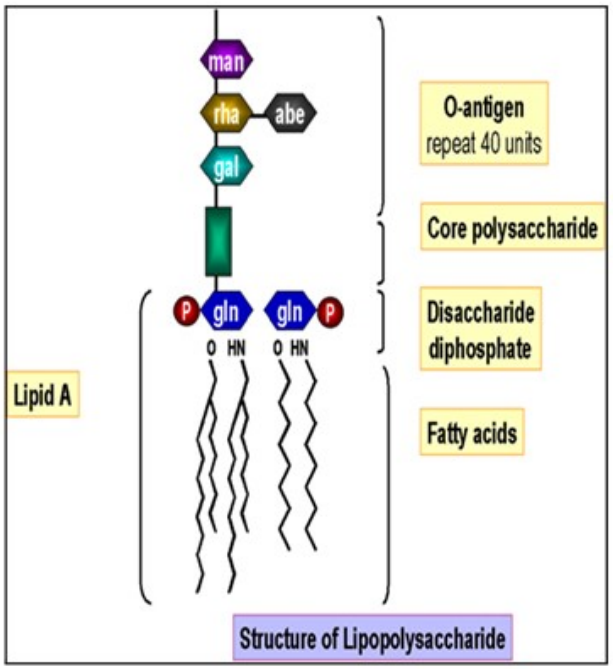
  rigid part , mucopeptide composed of alternating strands of :

  - *N- acetyl muramic acid* and
  - *N- acetyle glucosamine* linked with
  - peptide sub units.

Chemistry of LPS



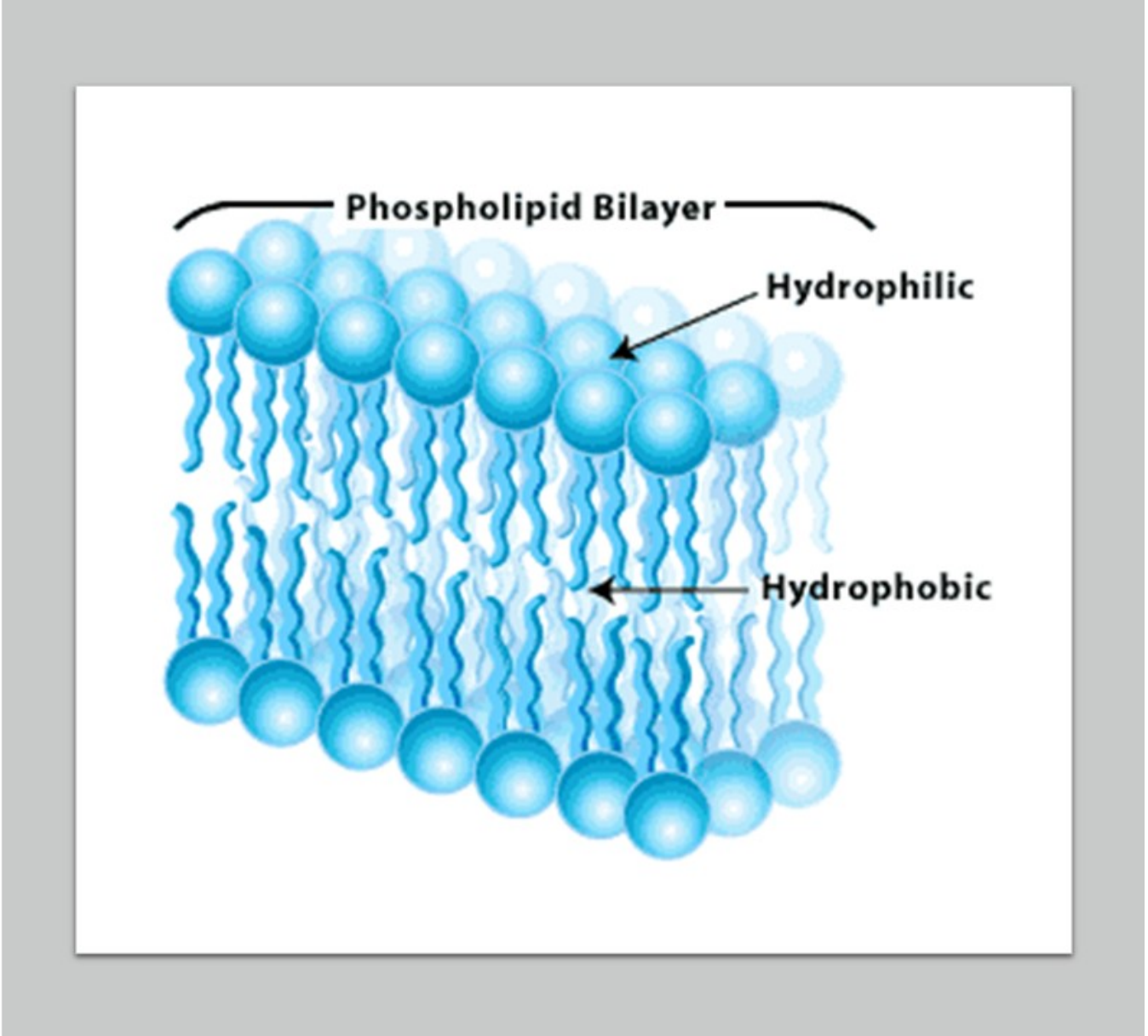


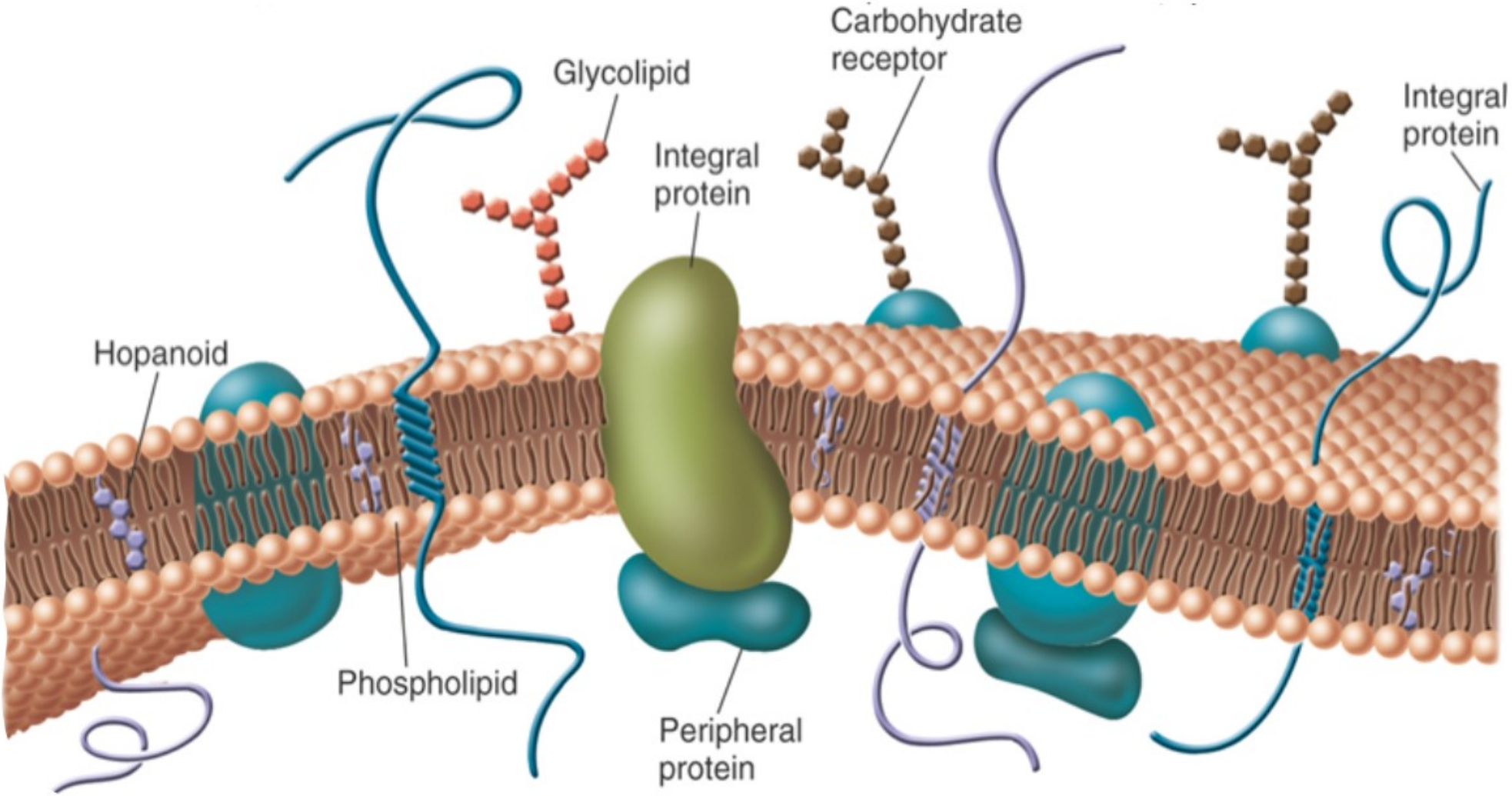


Cytoplasm membrane (cell membrane)

STRUCTURE :

- The cell membrane (often called the plasma membrane) is composed of **double layers** of **phospholipids** & **protein**.
- Phospholipids have polar heads and non-polar tails.
  - "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.
  - "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




Carbohydrate receptor
Glycolipid
Integral protein
Integral protein
Hopanoid
Phospholipid
Peripheral protein

Characteristics of Plasma membrane

- A pure phospholipid membrane only allows water, gasses, and a few small molecules to move freely through it.
- Act as semi- permeable membrane (passive diffusion)
- Site of numerous enzymes involved in active transport of nutrients and various metabolic processes

2. Cell Membrane

FUNCTION:

A. control permeability

B. transports and protons for cellular metabolism

C. contain enzymes to synthesis and transport

D. cell wall substance and for metabolism

E. secret hydrolytic enzymes

F. regulate cell division.

- Fluid mosaic model. phospholipid bilayer and protein (structure and enzymatic function). Similar to eukaryotic cell membrane but some differs. e.g.Absence of sterols such as cholesterol in Prokarotes.

Internal structures

Mesosomes : convoluted invaginations of cytoplasmic membrane.

Two types

- # Concentric
- # Lamellar

Function :

- Involved in DNA segregation during cell division & respiratory activity
- Contain receptors involved in chemotaxis
- Permeability barrier (active transport of solutes).

Core

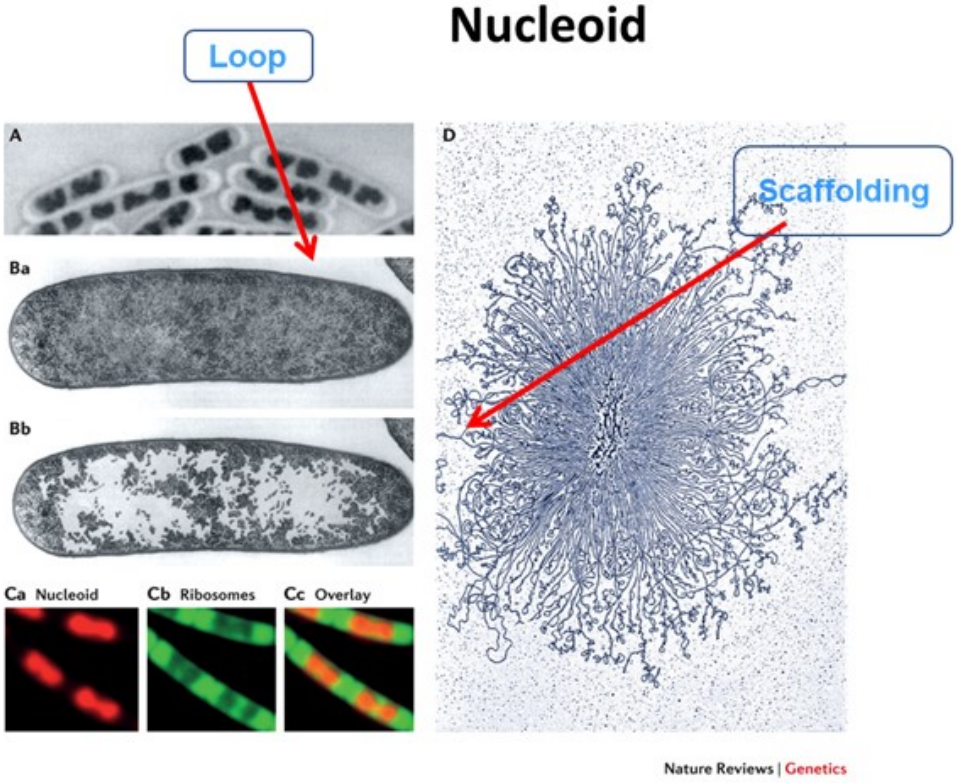
Composed of :

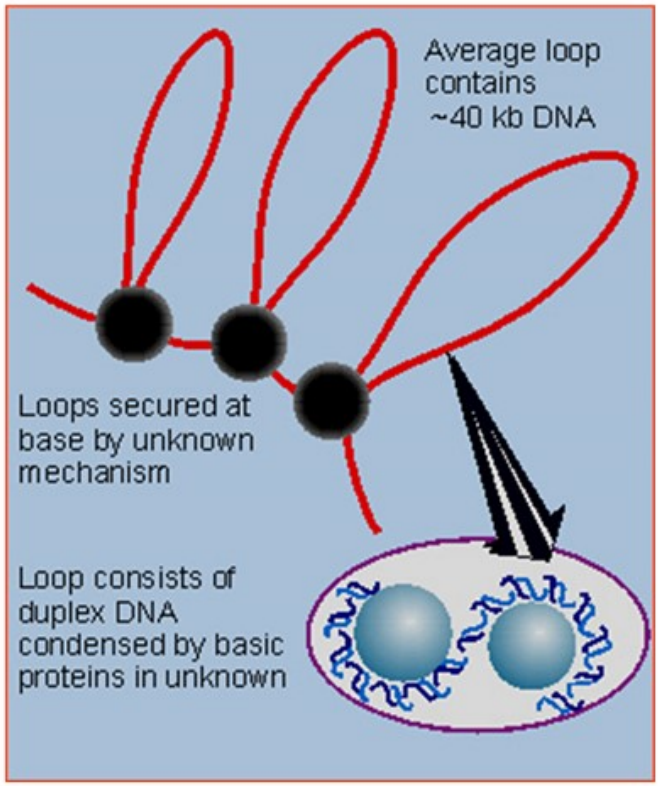
- Nucleoid
- Ribosome
- Cytoplasmic inclusions
    - Cytoplasmic inclusions:
    - Nutritional storage granules , eg.
        - Volutin
        - Lipid
        - Starch / or Glycogen

Nucleoid (nuclear body)

- Circular single stranded chromosome (bacteria genome or DNA)
- No nuclear membrane
- DNA undergoes semi-conservative replication ,bidirectional from a fixed point

Prokaryotic chromosome





BACTERIAL CHROMOSOMES

- The bacterial chromosome is found in a region called the nucleoid
- The nucleoid is not membrane-bounded
  - So the DNA is in direct contact with the cytoplasm

- Bacteria may have one to four identical copies of the same chromosome
  - The number depends on the species and growth conditions

- Bacterial chromosomal DNA is usually a circular molecule that is a few million nucleotides in length
  - *Escherichia coli* → ~ 4.6 million base pairs
  - *Haemophilus influenzae* → ~ 1.8 million base pairs

- A typical bacterial chromosome contains a few thousand different genes
  - Structural gene sequences (encoding proteins) account for the majority of bacterial DNA
  - The nontranscribed DNA between adjacent genes are termed intergenic regions

DNA-binding proteins

Prokaryotic chromosome structure

Histone-like proteins essential for DNA packaging to stabilize and constrain the supercoiling.

- **HU: a small basic dimeric protein, non-specific binding to DNA, most abundant.**
- **H-NS (protein H1): neutral monomeric, partially non-specific binding**

Site-specific DNA binding proteins important for organization of DNA domains (*RNA polymerases, IHF etc*).

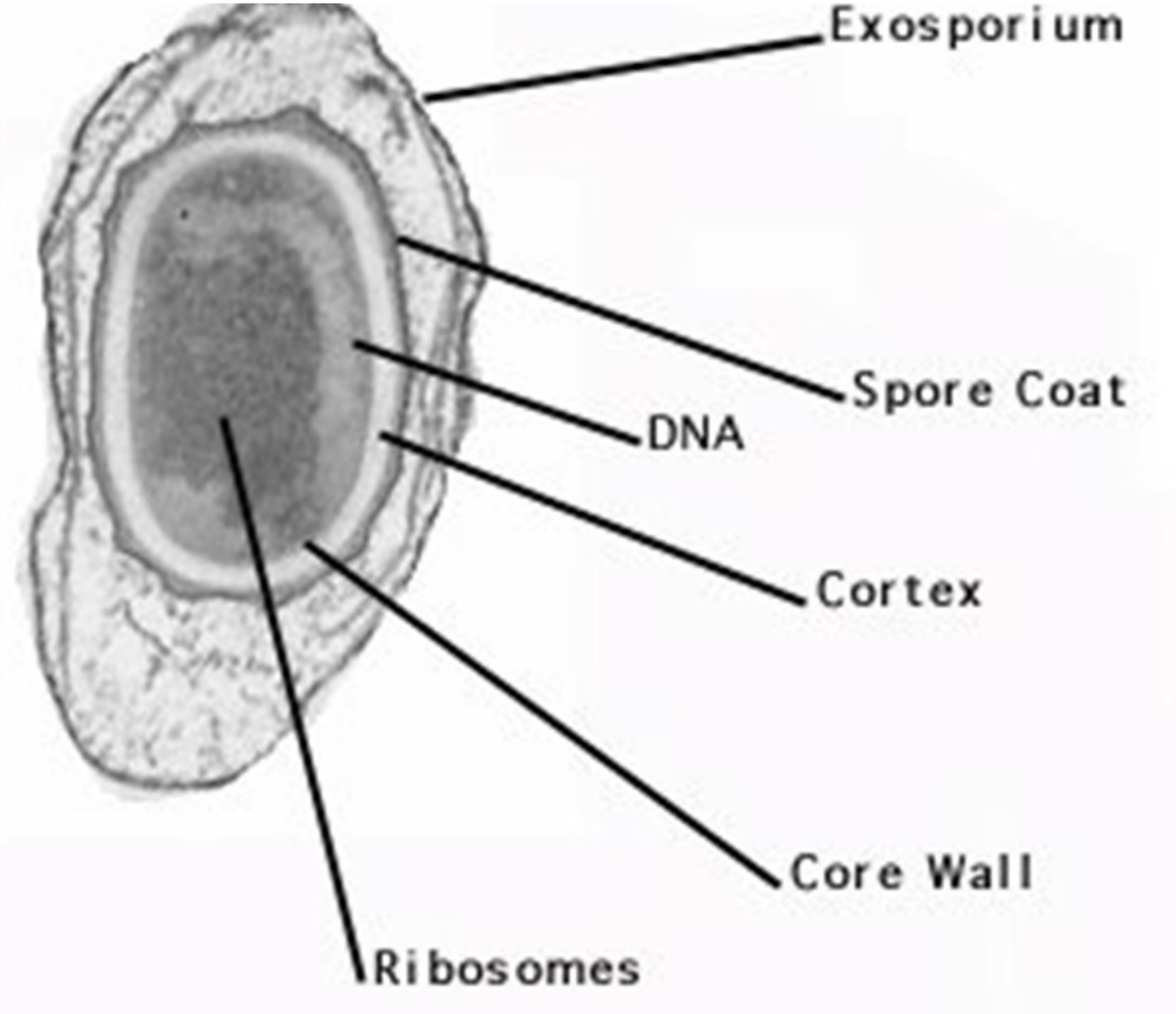
Ribosomes

- Distributed throughout the cytoplasm
- Site of protein synthesis
- Composed of RNA and protein
- Organized into 30s and 50s subunits.

Spores

- Small ,dense, metabolically inactive , non- reproductive structures produced by ***Bacillus & Clostridium***
- Enables the bacteria to survive adverse environmental conditions.
- Contain high con. of Calcium dipicolonate
- Resistant to heat, dissecation & disinfectants
- Often remain associated with the cell wall

Spore structure



Cont'd -spores

- Described as :

1- **Terminal** spores

2- **Sub-terminal** spores

3- **Central** spores

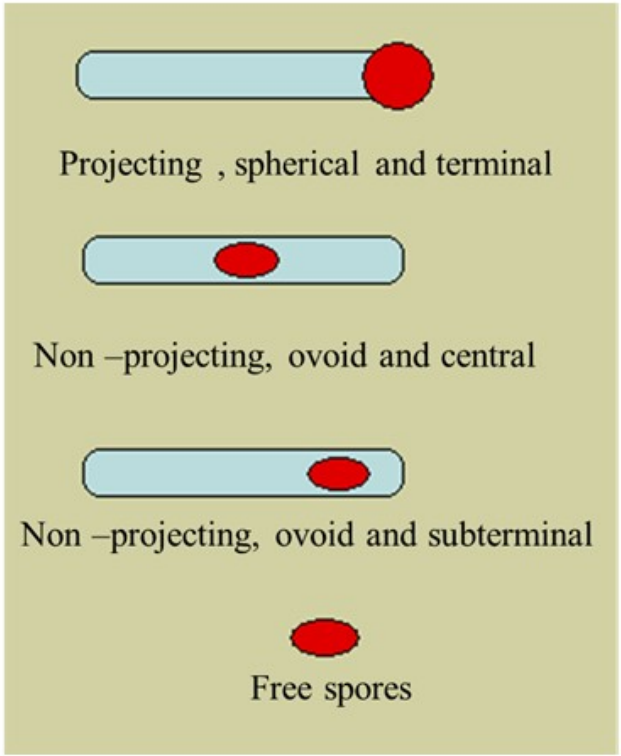
Germinate when growth conditions become favorable to produce vegetative cells.

Spore preparations used for checking the efficacy of autoclaves, e.g. *B. subtilis*, *B. sterothermophilus*.

Spore

position , size and shape

Gram's stain



IV. Special Structure

* **Endospores**

  Spore former: *Sporobactobacilli* and *Sporosarcinae* (Gram + cocci)- no medical importance.

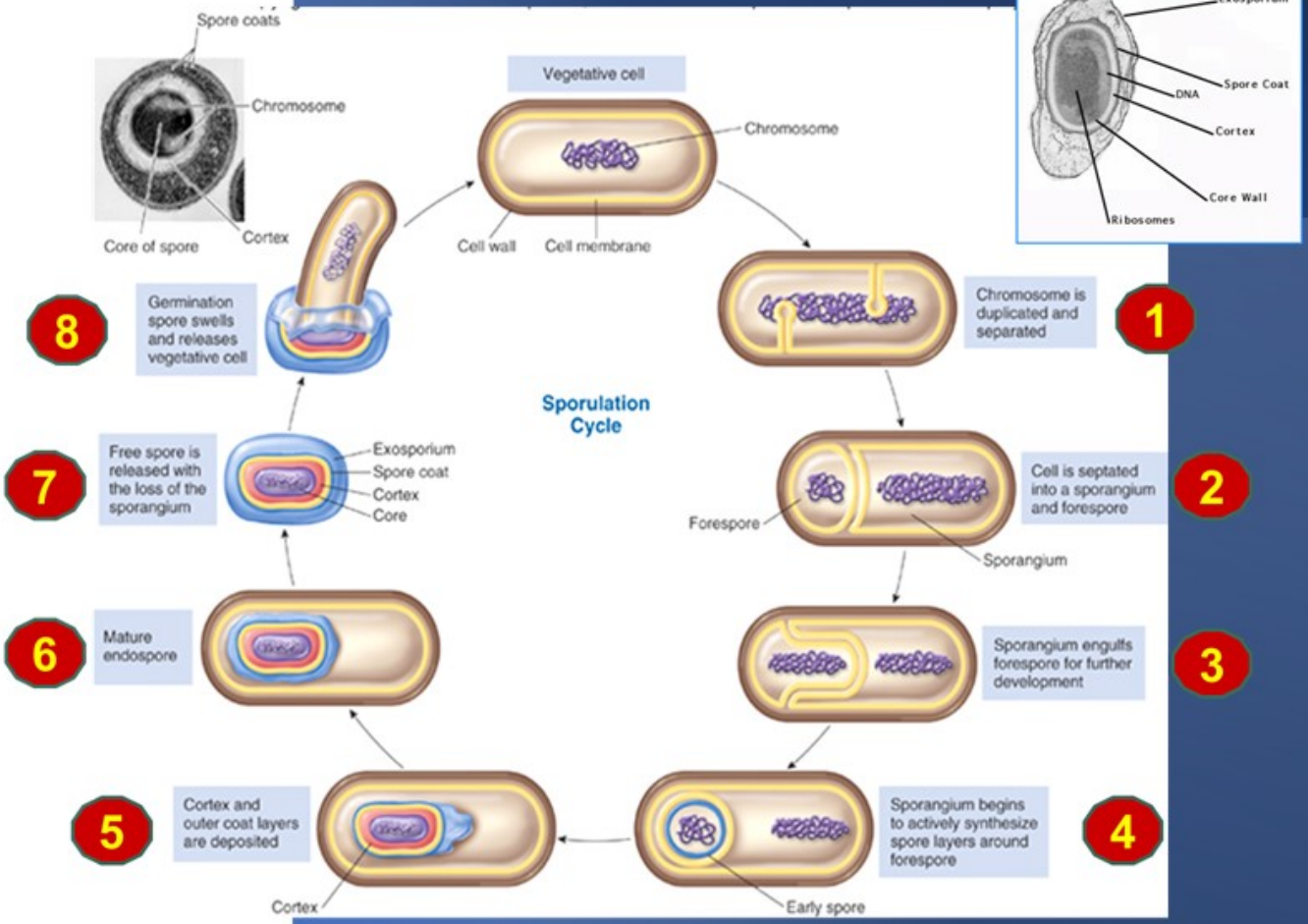
Bacillus and *Clostridium* (Gram + Rod) have medical importance.
Coxiella (Gram –ve Rod) cause Q fever.

* Position: median, sub-terminal and terminal have small water, high calcium content and dipicolinic acid (calcium dipicolinate)

- Extremely resistant to heat, UV, chemicals etc. may be due to many S containing A.A for disulfide groups.

The process of endospore formation

- After the active growth period approaching the stationary growth phase, a structure called forespore develops within the cells.
- It consists of coat, cortex and nuclear structure.


Spore coats
Chromosome
Core of spore
Cortex
Vegetative cell
Chromosome
Cell wall
Cell membrane
Exosporium
Spore Coat
DNA
Cortex
Core Wall
Ribosomes
Sporulation Cycle
1
Chromosome is duplicated and separated
2
Cell is septated into a sporangium and forespore
Forespore
Sporangium
3
Sporangium engulfs forespore for further development
4
Sporangium begins to actively synthesize spore layers around forespore
Early spore
5
Cortex and outer coat layers are deposited
Cortex
6
Mature endospore
7
Free spore is released with the loss of the sporangium
Exosporium
Spore coat
Cortex
Core
8
Germination spore swells and releases vegetative cell

The End