



**Basrah University**  
**Al-Qurna Education College**  
**Biology Department: 4<sup>th</sup> Stage**



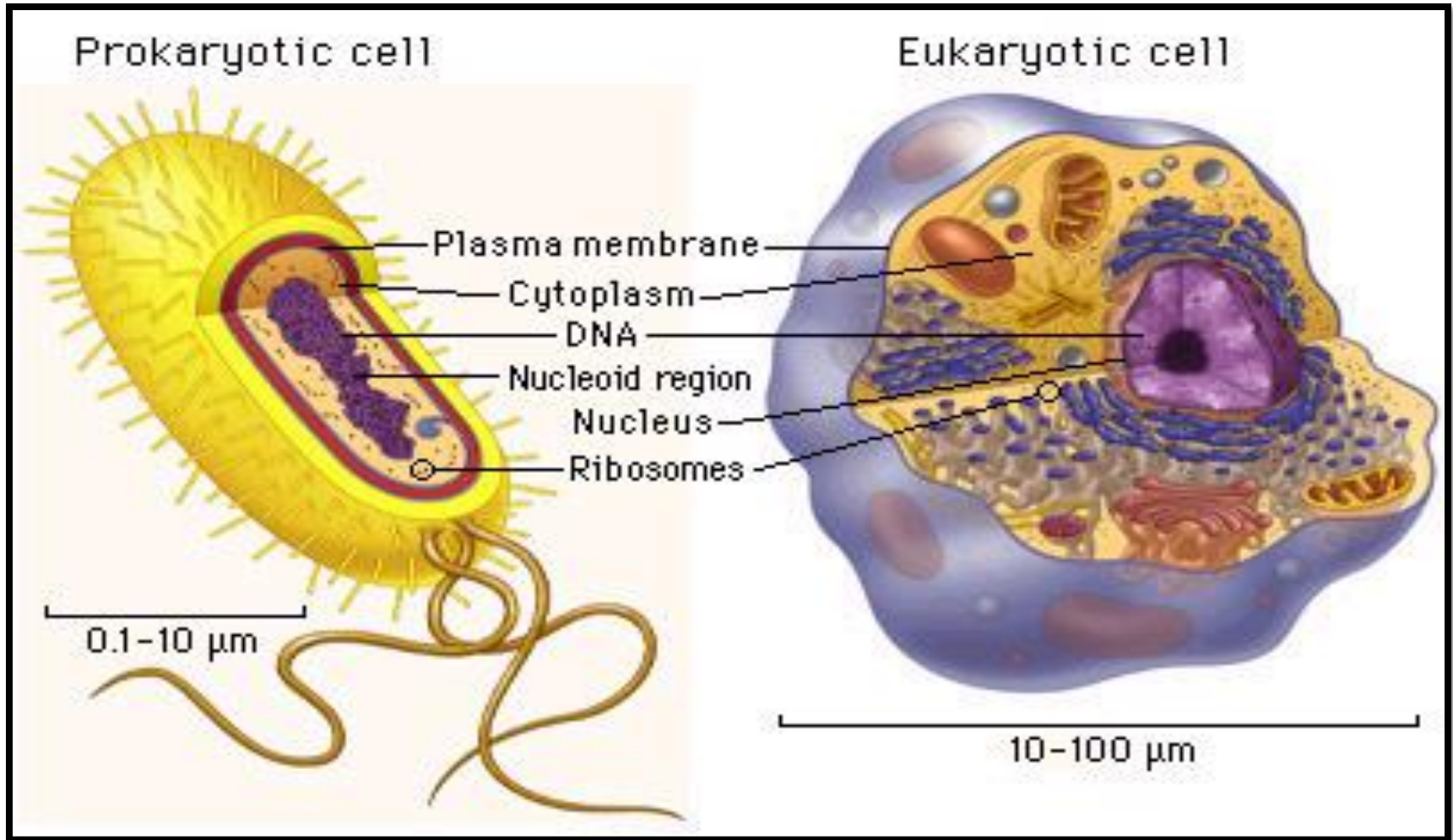
**1st Course , Lecture #.3 &#. 4**

# **Bacterial Cell ;Structure & Function**

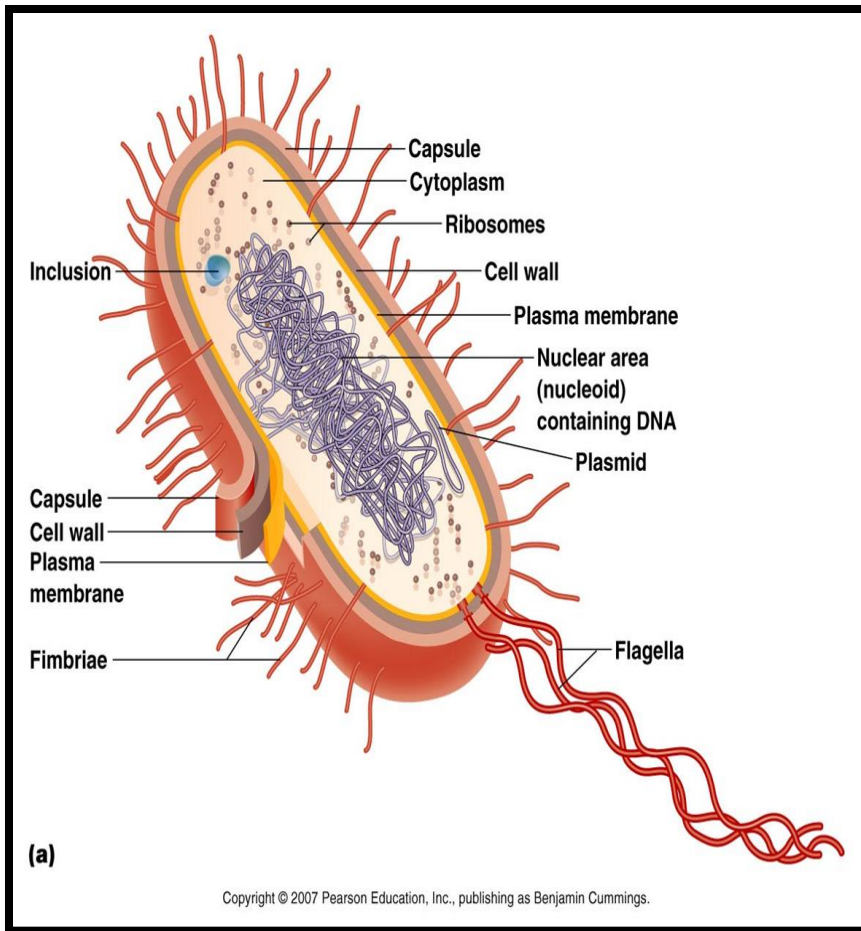
**Dr. Kawakib I. Al-Zubaidy**

**Wed. 25 Oct. 2023**

# Two Basic Types of Cells



# Definition of “prokaryotic”



- Refers to organisms, typically 1-celled, having cells which:
- lack a nucleus
- lack membrane-bound organelles
- contain 1 chromosome
- may contain extra-chromosomal DNA (plasmids)
- contain 70S Ribosomes
- contain **peptidoglycan** cell walls

# Bacterial cell size, shapes and arrangements

## ➤ Shapes of Bacteria

### 1. Coccus

Chain = Streptococcus

Cluster = Staphylococcus

### 2. Bacillus

Chain = Streptobacillus

Coccobacillus

### 3. Vibrio = curved

Spirillum

Spirochete



Coccus



Coccobacillus



Vibrio



Bacillus



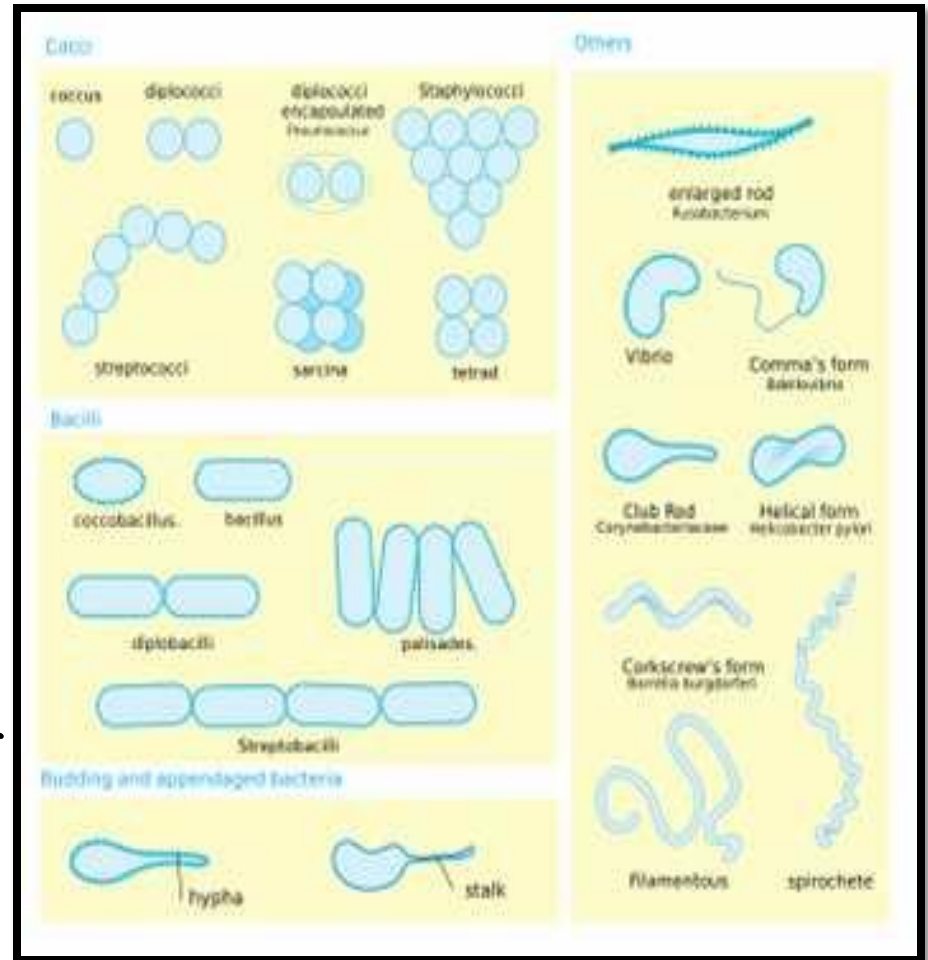
Spirillum



Spirochete

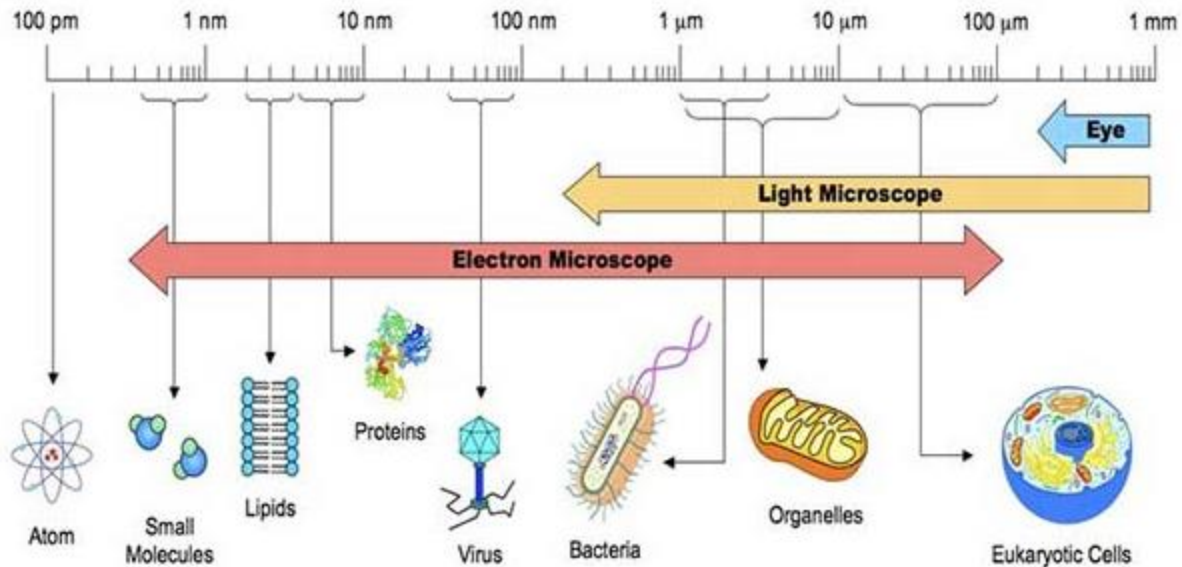
# Prokaryotes – Arrangements of Cells

- Bacteria sometimes occur in groups, rather than singly.
  - pairs (diplococci)
  - chains (streptococci)
  - packets (sarcinae)
  - clusters (staphylococci).
- Size, shape and arrangement of cells often first guide in identification of a bacterium.



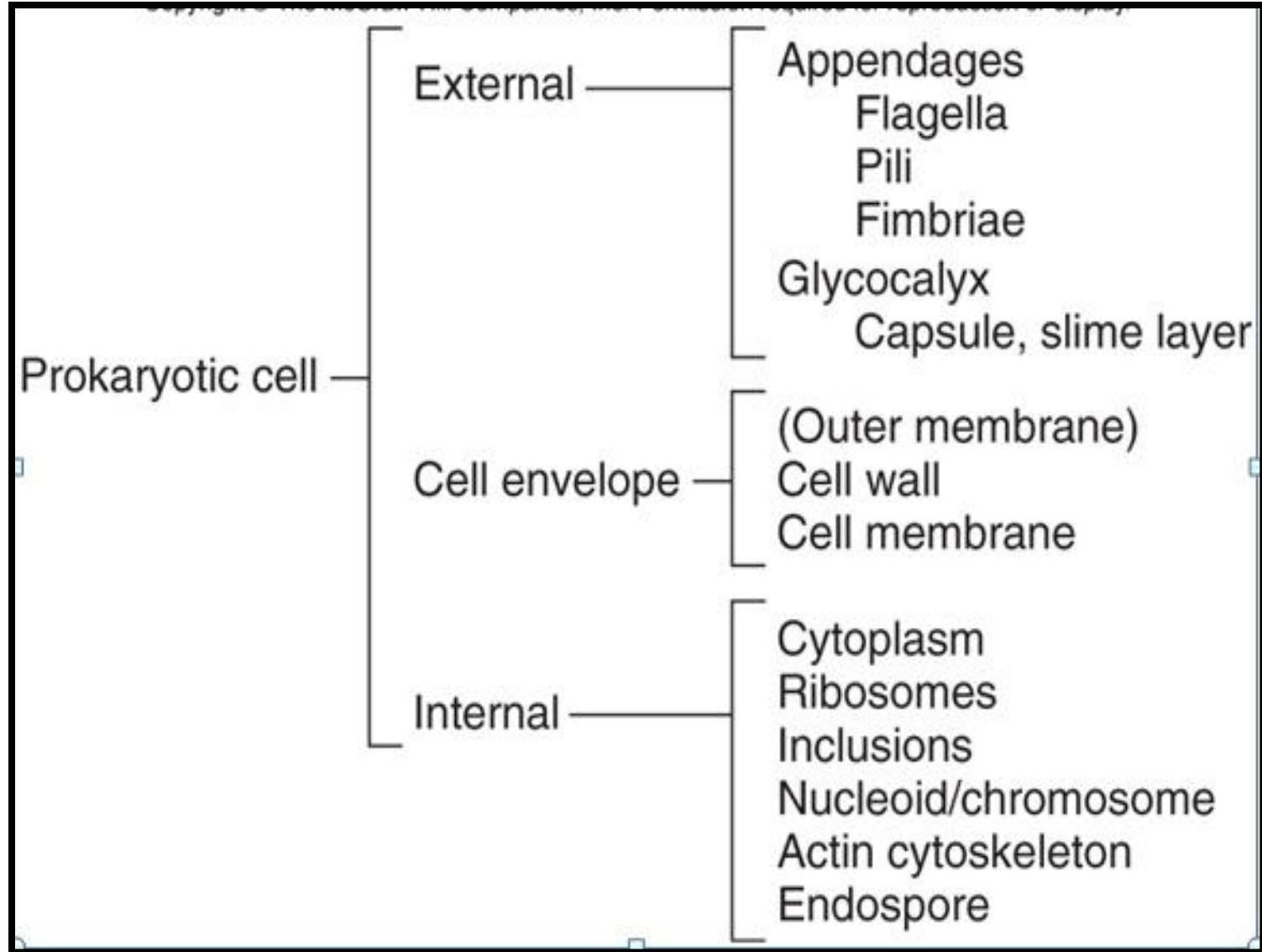
# Size of Different organisms

## Size of Bacterial Cell



The average diameter of spherical bacteria is 0.5-2.0 μm. For rod-shaped or filamentous bacteria, length is 1-10 μm and diameter is 0.25-1.0 μm.

# Prokaryotic Form and Function



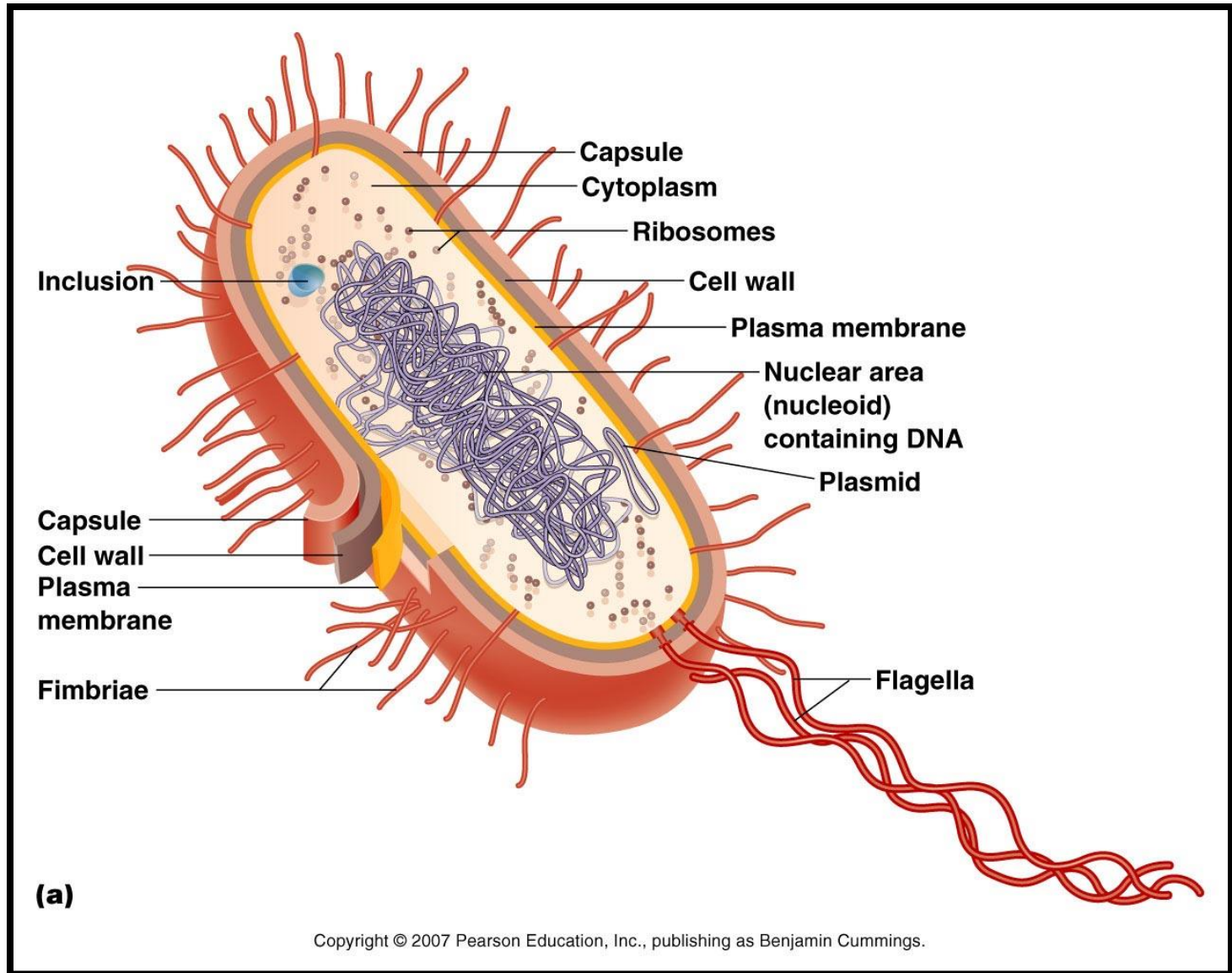
## **Bacterial cell structure ;**

organized into 3 categories :

- **Internal Structures:** Cytoplasm, nucleoid, bacterial chromosome, plasmid, ribosomes, endospores and storage granules
- **Cell envelope:** cell membrane, peptidoglycan cell wall or an outer lipid membrane (only found in Gram-negative cells)
- **External structures** (appendages & coverings): flagella, fimbriae, sex pilus and glycocalyx



# Bacterial ultrastructure



# Cell Wall

The **cell wall** is the outer most layer of the cell. In many cases the cell wall comes in direct contact with the environment.

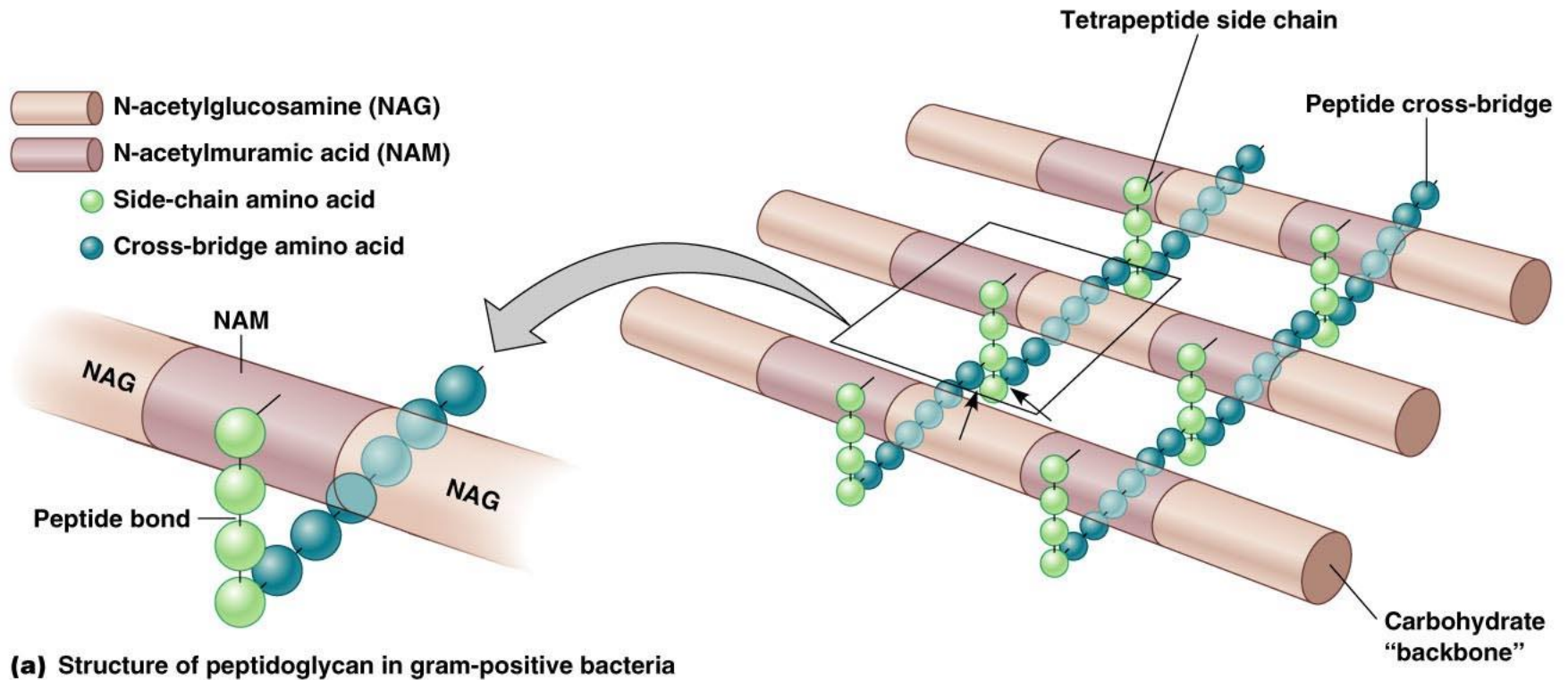
## **Function:**

1. Protection of the cell.
2. Maintains the shapes of the cell.
3. Maintains the osmotic integrity of the cell.
4. Play an essential role in cell division.

# Cell wall structure

- **Peptidoglycan**, also known as **murein**, is a polymer consisting of sugars and amino acids that forms a mesh-like layer outside the cell membrane of most bacteria forming the cell wall.
- The sugar component consists of alternating residues of  $\beta$ -(1,4) linked N-acetylglucosamine( NAG) and Nacetylmuramic acid (NAM).
- These subunits which are related to glucose in their structure are covalently joined to one another to form glycan chains.

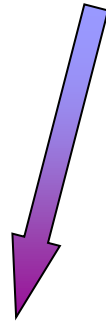
# Alternating NAM-NAG with tetrapeptide connections



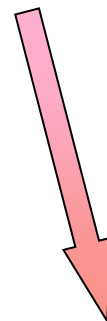
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**Hans Christian Gram;** the inventor of the Gram staining technique, in 1882 according to the chemical structure of the cell wall

# Gram Stain







**Gram Positive**

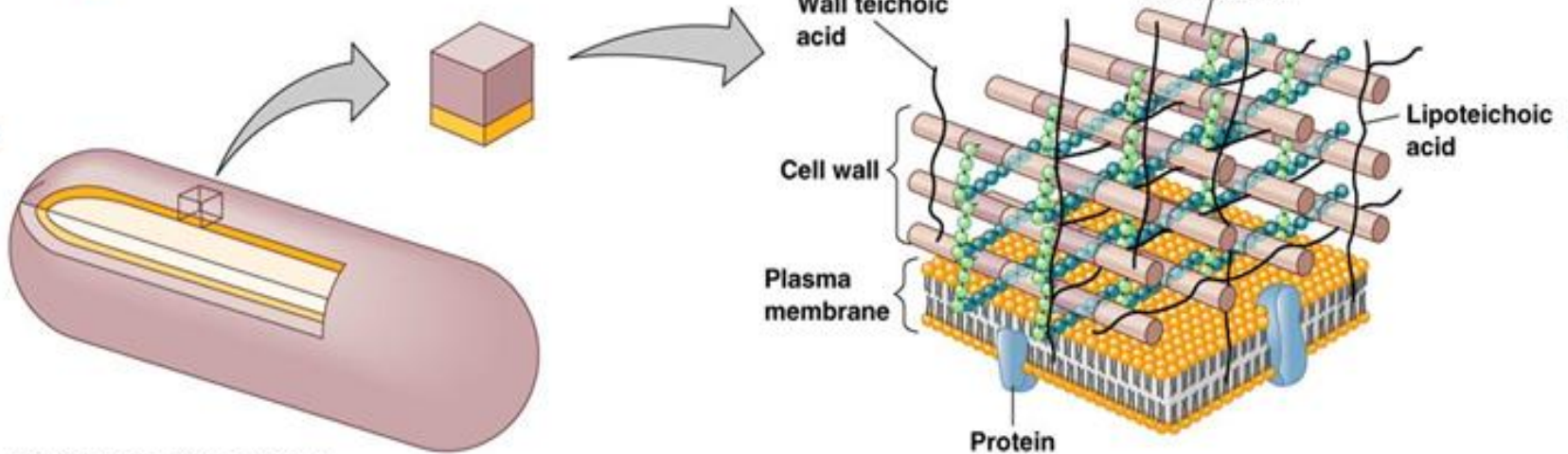


**Gram Negative**

- Gram-positive cell wall is thick homogeneous monolayer
- Gram-negative cell wall is thin heterogeneous multilayer

# Gram positive cell wall structure

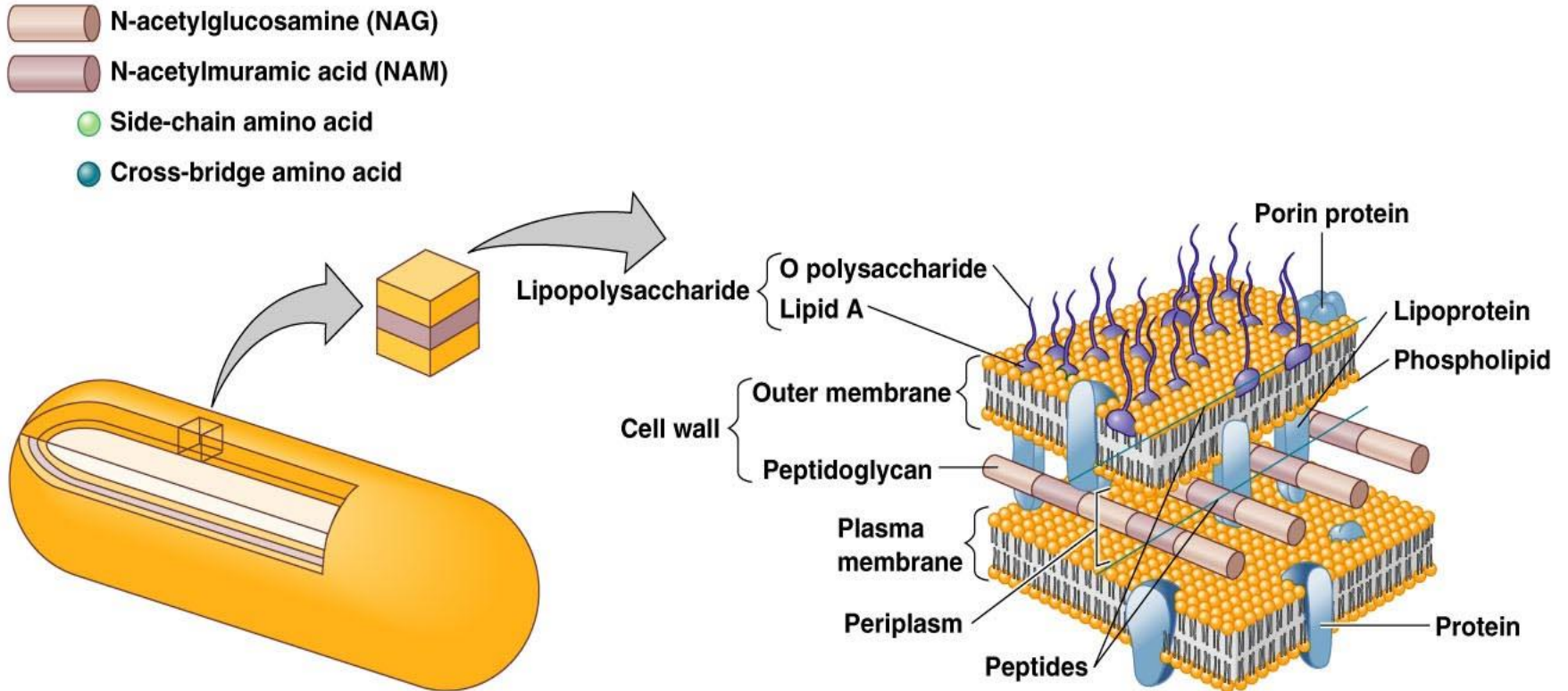
-  N-acetylglucosamine (NAG)
-  N-acetylmuramic acid (NAM)
-  Side-chain amino acid
-  Cross-bridge amino acid



**(b) Gram-positive cell wall**

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# Gram negative cell wall structure



(c) Gram-negative cell wall

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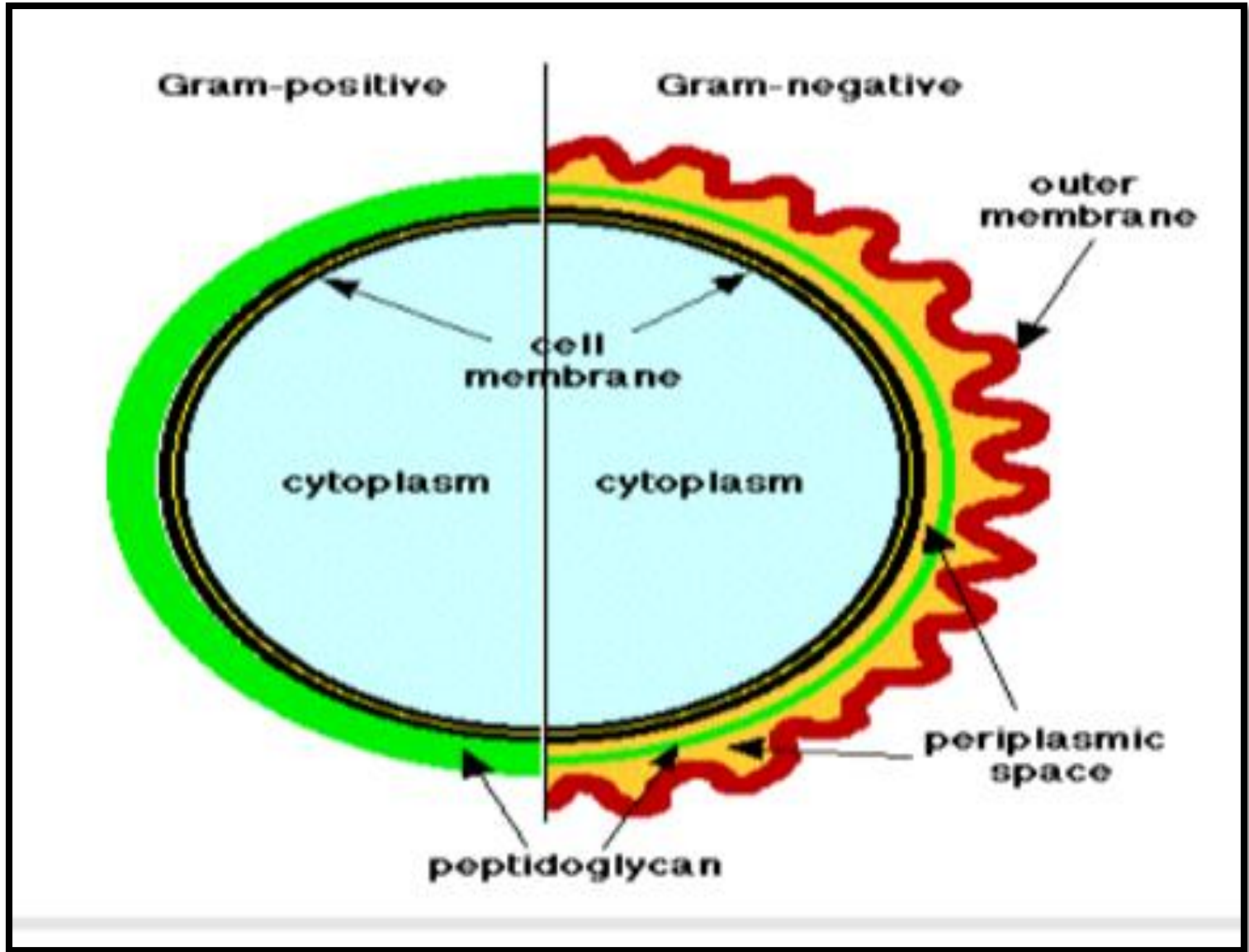
## **Gram Positive Cell wall**

- Usually thick, homogenous, composed mainly of peptidoglycan.
- It accounts for 50-90% of the dry weight of the cell wall.
- Contain large amount of teichoic acids.

## **Gram Negative Cell Wall**

- Multi layered and more complex than Gram positive cell walls.
- Peptidoglycan of gram negative bacteria is thin and comprises only 10% or less of cell wall.
- Outer membrane lies outside the thin peptidoglycan layer.





## **Periplasm:**

- The region between the cytoplasmic membrane and the outer membrane is filled with a gel-like fluid called periplasm.
- In gram negative bacteria, all secreted proteins are contained within the periplasm, unless they are specifically trans located across the outer membrane.
- Periplasm is filled with the proteins that are involved in various cellular activities, including nutrient degradation and transport.

**Lipopolysaccharide (LPS)** is consists of three parts:

- 1.Lipid A.....embedded in membrane.
- 2.Core polysaccharide.....located on the surface of membrane.
- 3.O antigens....which are short polysaccharides extended out from core.

# The Gram stain

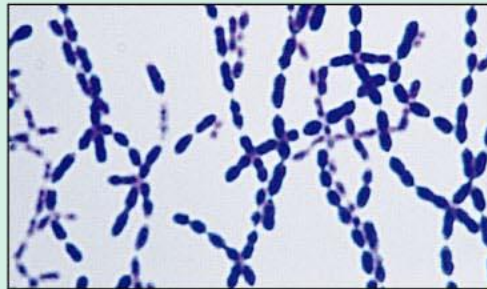
**TABLE 4.1**

**Some Comparative Characteristics of Gram-Positive and Gram-Negative Bacteria**

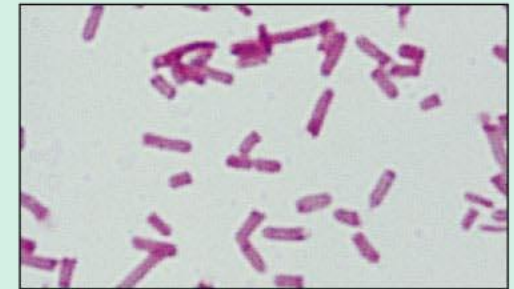
Characteristic

Gram-Positive

Gram-Negative



LM 4 μm



LM 4 μm

**Gram Reaction**

Retain crystal violet dye and stain dark violet or purple

Can be decolorized to accept counterstain (safranin) and stain pink

**Peptidoglycan Layer**

Thick (multilayered)

Thin (single-layered)

**Teichoic Acids**

Present in many

Absent

**Periplasmic Space**

Absent

Present

**Outer Membrane**

Absent

Present

**Lipopolysaccharide (LPS) Content**

Virtually none

High

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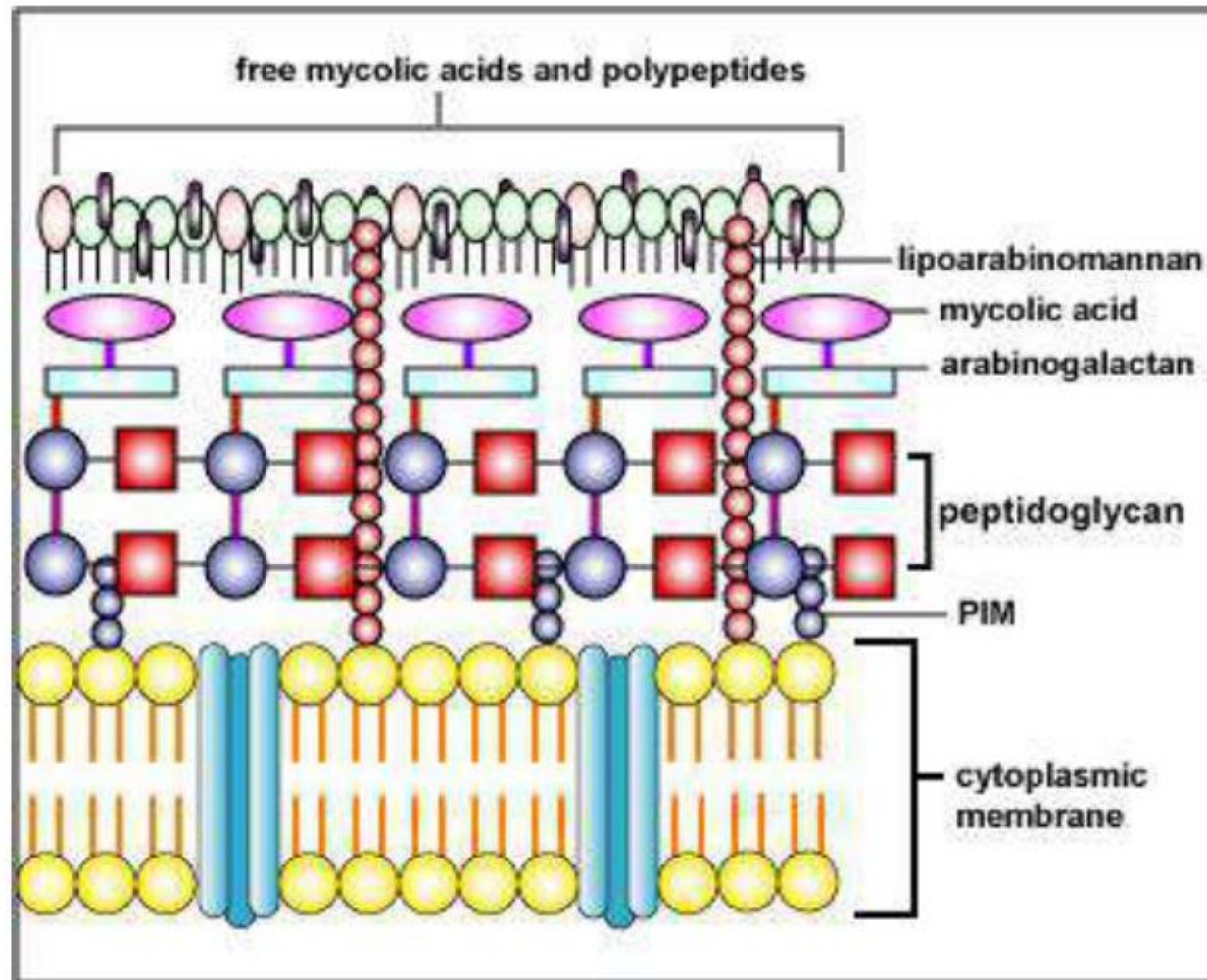
# **Acid fast and related bacteria** *(Mycobacteria, Nocardia and Corynebacteria)*

## **Acid Fast Cell Wall**

**The cell wall of acid-fast bacteria consists of:**

- **peptidoglycan layer linked to arabinogalactan**
- **arabinogalactan (D-arabinose and D-galactose) and mycolic acid layers**
- **mycolic acid layer is overlaid with a layer of polypeptides and free mycolic acids.**
- **Other glycolipids include lipoarabinomannan and phosphatidylinositol mannosides (PIM).**

# Structure of an Acid-Fast Cell Wall



# Wall-less forms

## Wall-less bacteria that don't replicate:

- **Result from action of:**
  - **enzymes lytic for cell wall**
  - **antibiotics inhibiting peptidoglycan biosynthesis**
- **non-viable**
- **spheroplasts (with outer membrane) from Gram negative bacteria**
- **protoplasts (no outer membrane) from Gram positive bacteria**

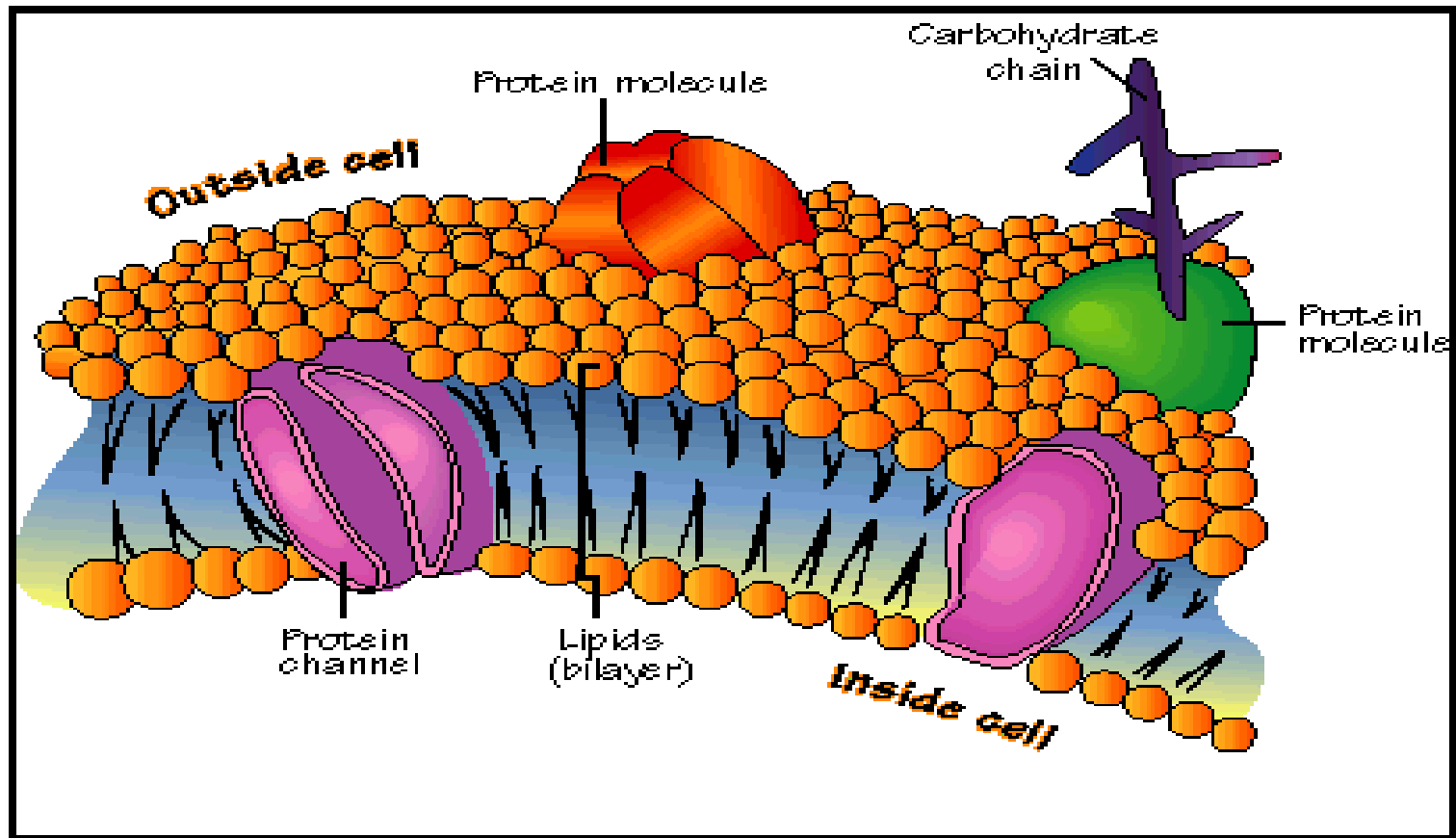
## Wall-less bacteria that replicate : L-forms

Naturally occurring wall-less bacteria: **Mycoplasmas (viable, replicate)**

# Plasma Membrane

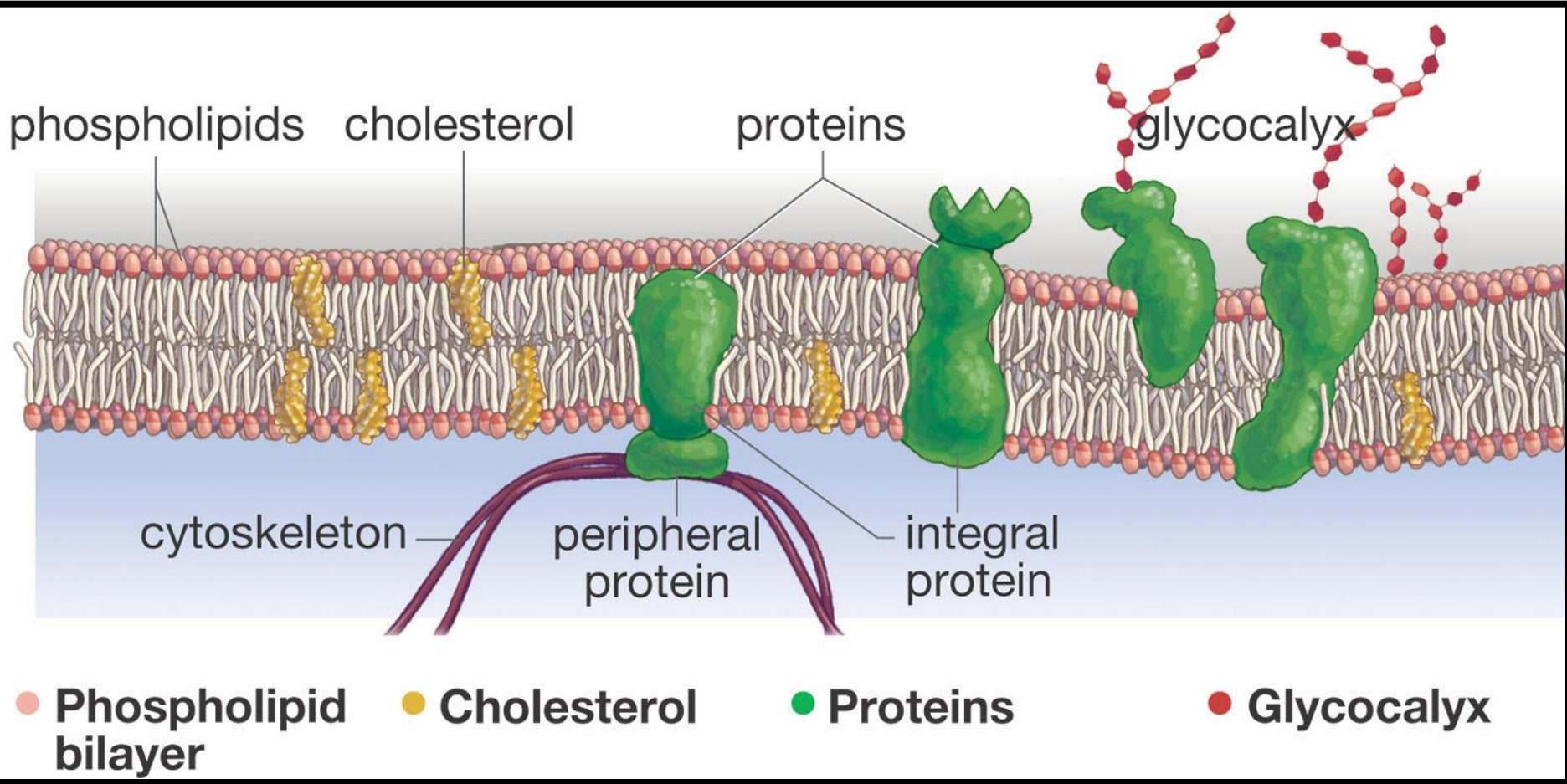
- Phospholipid bilayer surrounding the cytoplasm and regulates the flow of substances in and out of the cell.
- Consists of both lipids and proteins.
- Protects the cell from its surroundings.
- Selectively permeable to ions and organic molecules and controls the movement of substances in and out.
- numerous proteins moving within or upon this layer are primarily responsible for transport of ions, nutrients and waste across the membrane.

# Structure of the Cell Membrane

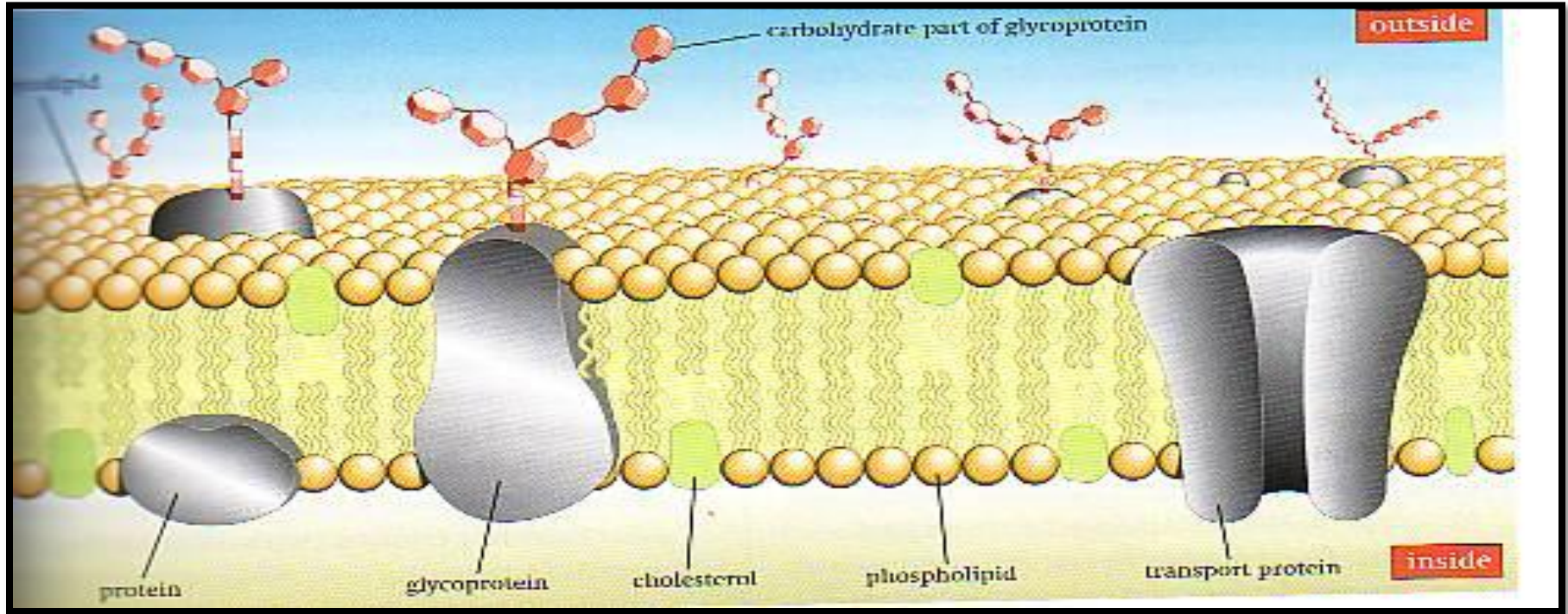




# Membrane Components



# FLUID MOSAIC MODEL



**FLUID-** because individual phospholipids and proteins can move around freely within the layer, like it's a liquid.

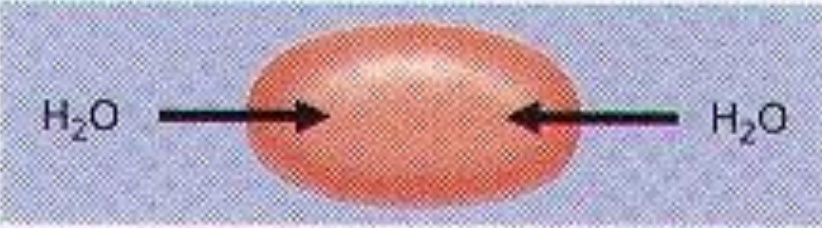
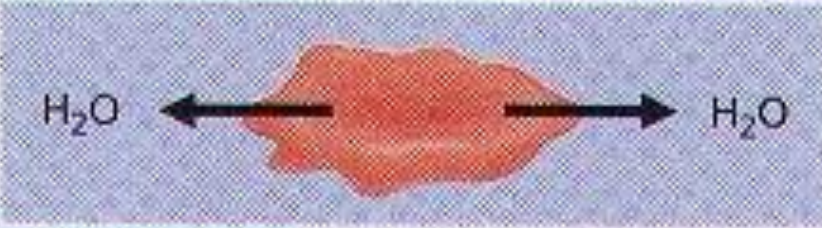
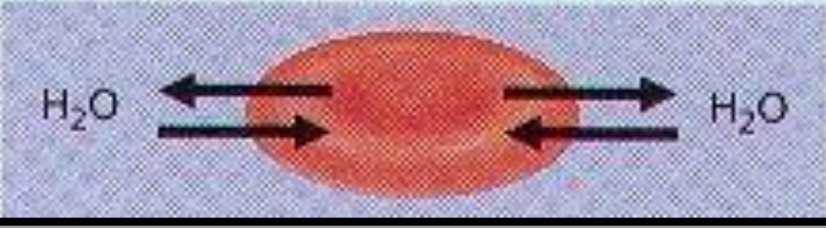
**MOSAIC-** because of the pattern produced by the scattered protein molecules when the membrane is viewed from above.

# Functions of Plasma Membrane

- ✓ **Protective barrier**
- ✓ **Regulate transport in & out of cell** (selectively permeable)
- ✓ **Allow cell recognition**
- ✓ **Provide anchoring sites for filaments** of cytoskeleton
- ✓ **Provide a binding site for enzymes**
- ✓ **Interlocking surfaces bind cells** together (junctions)
- ✓ **Contains the cytoplasm (fluid in cell)**

# Cells in Solutions

**TABLE 5-1** *Direction of Osmosis*

<b>Condition</b>	<b>Net movement of water</b>	
External solution is hypotonic to cytosol	into the cell	
External solution is hypertonic to cytosol	out of the cell	
External solution is isotonic to cytosol	none	

# Cellular Transport

- Passive Transport does **NOT** require cellular energy (ATP)

Examples:

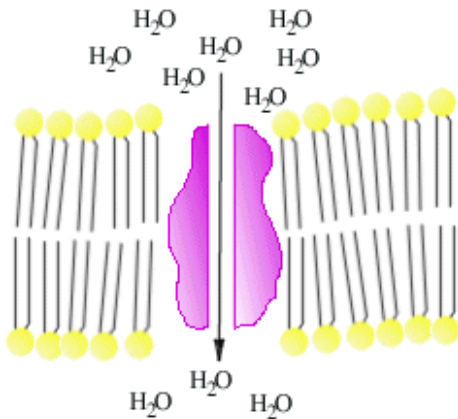
- Diffusion
- Facilitated Diffusion
- Osmosis

- Active Transport **DOES** require ATP

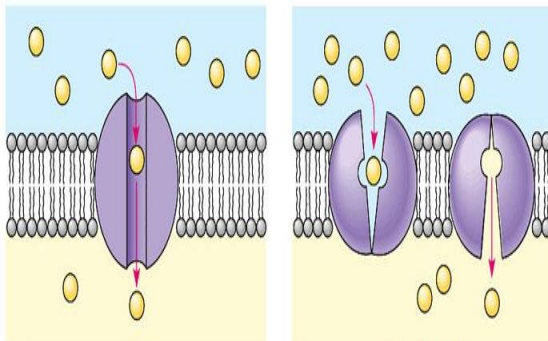
Examples:

- Phagocytosis
- Pinocytosis
- Protein Pumps , Use of membrane proteins (carrier proteins, etc)
- Moving molecules from low to high concentration

# Membrane Proteins



Diffusion through a protein channel



(a)

pore

(b)

carrier protein

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**Channel Proteins:** These proteins reach through the membrane to both sides. It allows specific molecules to pass from one side of the membrane to the other.

**Transport Proteins:** Proteins that physically move molecules across the membrane. There are a variety of types!

[YouTube - Cell membrane animation](#)

# External structures

## **Glycocalyx**

sticky coating produced by many bacteria covering the surface of cell.

- The glycocalyx is composed of polysaccharides (sugars) and proteins.

- The bacterial glycocalyx has 2 forms

- a highly rigid structure **capsule**

- a disorganised loose **slime layer**

- Capsules are found on many **pathogenic bacteria**

- The glycocalyx has several functions including :

protection, attachment to surfaces and formation of biofilms.

- The glycocalyx helps protect the bacterial cell by preventing immune cells from attaching to it and destroying it through phagocytosis.

# External structures

## **Capsules and Slime Layers**

- Polysaccharide layers
- May be thick or thin, rigid or flexible
- Assist in attachment to surfaces
- Protect against phagocytosis
- Resist desiccation

## **Fimbriae**

- Filamentous protein structures
- Enable organisms to stick to surfaces or form pellicles

## **Pili**

- Filamentous protein structures
- Typically longer than fimbriae
- Assist in surface attachment
- Facilitate genetic exchange between cells (conjugation)
- Type IV pili involved in twitching motility



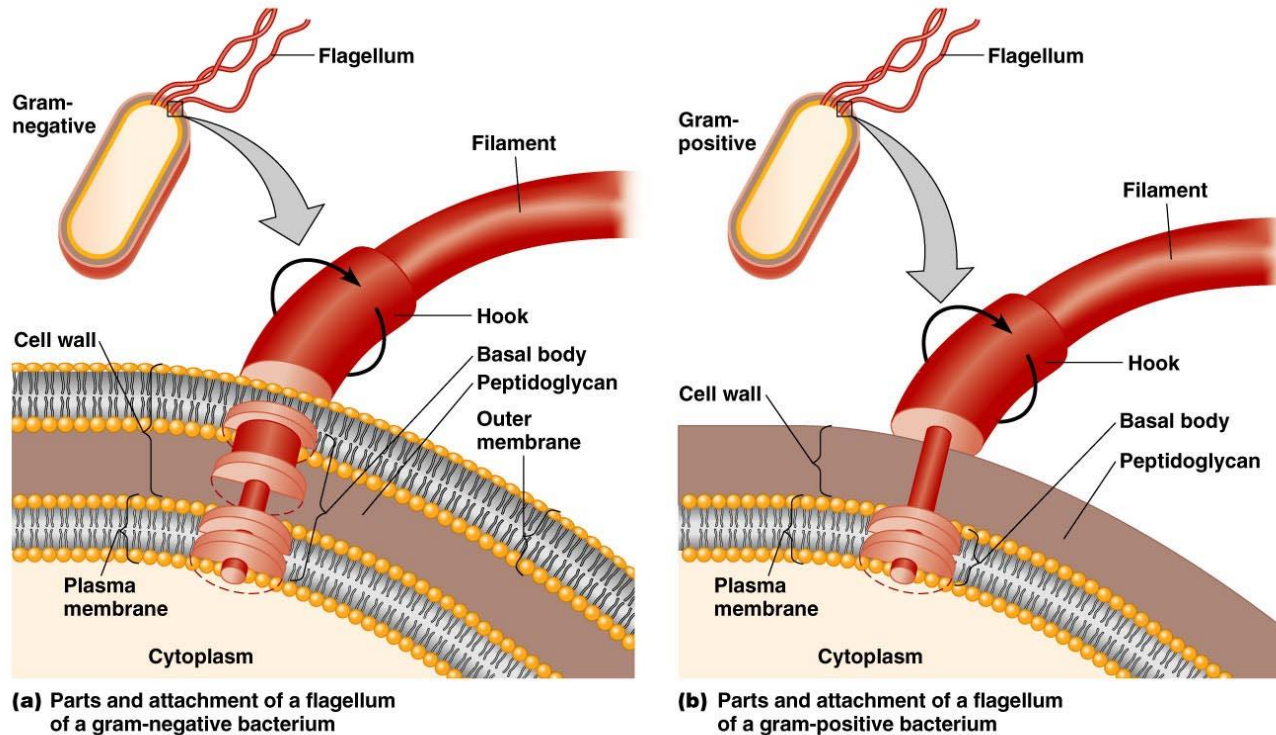
## **FLAGELLA**

- Locomotory organelles
- embedded in cell membrane
- project as strand
- Flagellin (protein) subunits
- move cell by propeller like action
- Some bacteria are motile
- Taste environment
- Respond to food/poison
- chemotaxis

## **Axial filaments**

- spirochetes
- similar function to flagella
- run lengthwise along cell
- snake-like movement

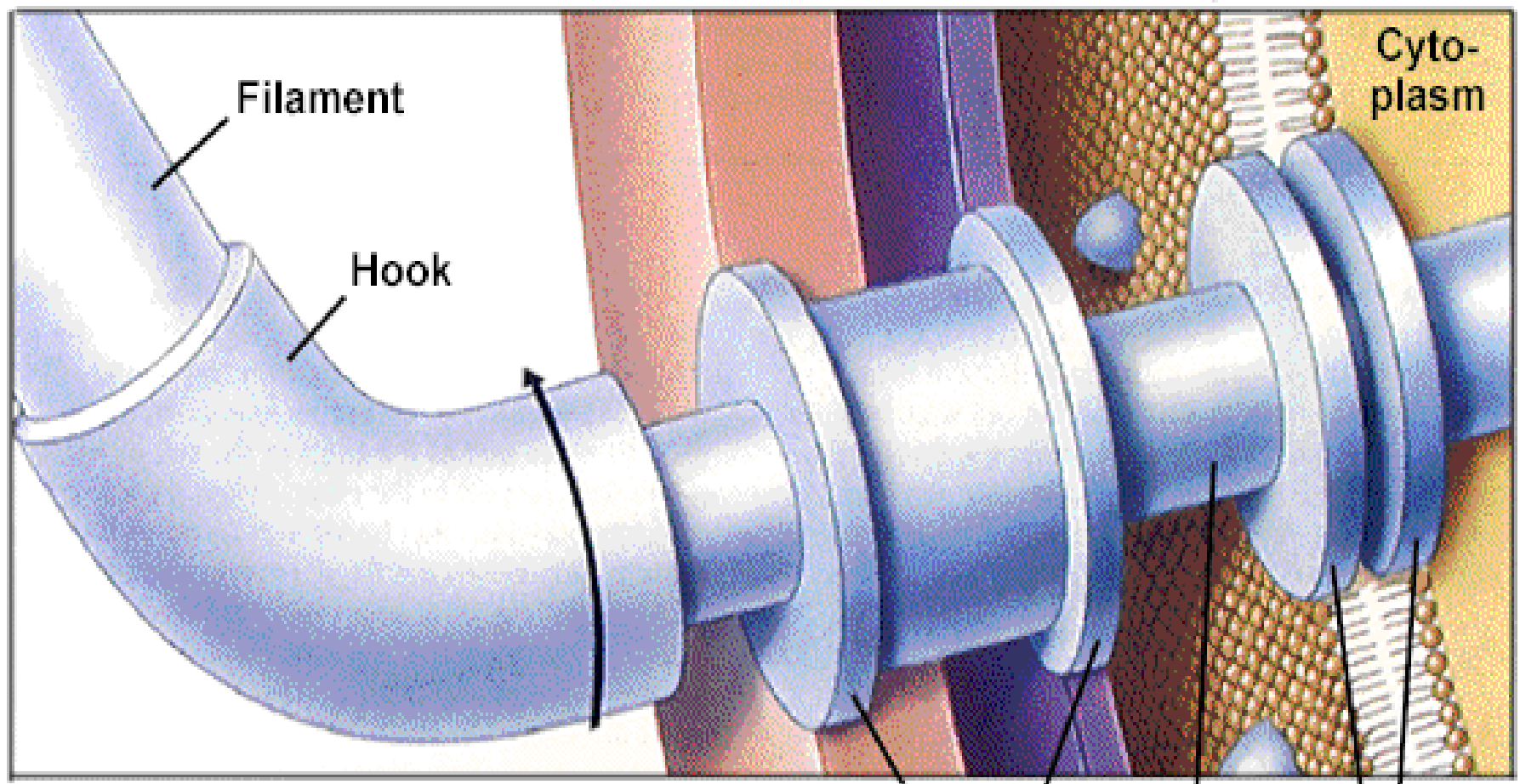
# Bacterial flagella



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- Composed of: 1) basal body, 2) filament, 3) hook
- Basal body connects to cell wall and to cell membrane
- Uses ATP to spin

Cell wall  
Outer membrane Peptidoglycan  
Cell membrane



Cytoplasm

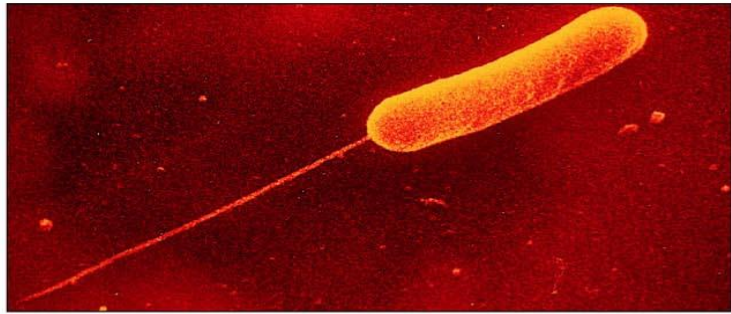
Filament

Hook

Outer rings Rod Inner rings

Basal body

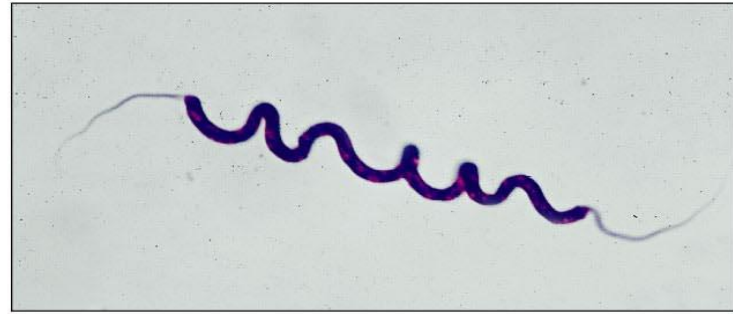
# Arrangements of flagella



(a) Monotrichous

SEM

1  $\mu\text{m}$



(b) Amphitrichous

SEM

10  $\mu\text{m}$



(c) Lophotrichous

SEM

1  $\mu\text{m}$



(d) Peritrichous

SEM

1  $\mu\text{m}$

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- Arrangement basis for classification
  - Monotrichous; 1 flagella
  - Lophotrichous; tuft at one end
  - Amphitrichous; both ends
  - Peritrichous; all around bacteria

# Intracellular structures

- Cytoplasm
- Chromosome( Nucleoid)
- Plasmid
- Ribosomes
- Endosomes
- Inclusion bodies

**Cytoplasm:** Gel-like matrix composed of mostly water(80% Water )& 20% Salts-Proteins . enzymes, nutrients, wastes, and gases .

**Nucleoid:** Unlike the eukaryotic (true) cells, bacteria do not have a membrane enclosed nucleus.

- The nucleoid is a region of cytoplasm where the chromosomal DNA is located.
- It is not a membrane bound nucleus, but simply an area of the cytoplasm where the strands of DNA are found.

**Plasmids** • small extra-chromosomal DNA • contain genes for antibiotic resistance or virulence. • Structure Similar to most bacterial chromosomes, but considerably smaller. • plasmids are covalently closed circular DNA • In a few species linear plasmids have been found. The function of plasmids is not always known, but they are not normally essential for survival of host, although their presence generally gives the host some advantage.

# **Ribosomes-** protein synthesis machinery

Consists of RNA and protein

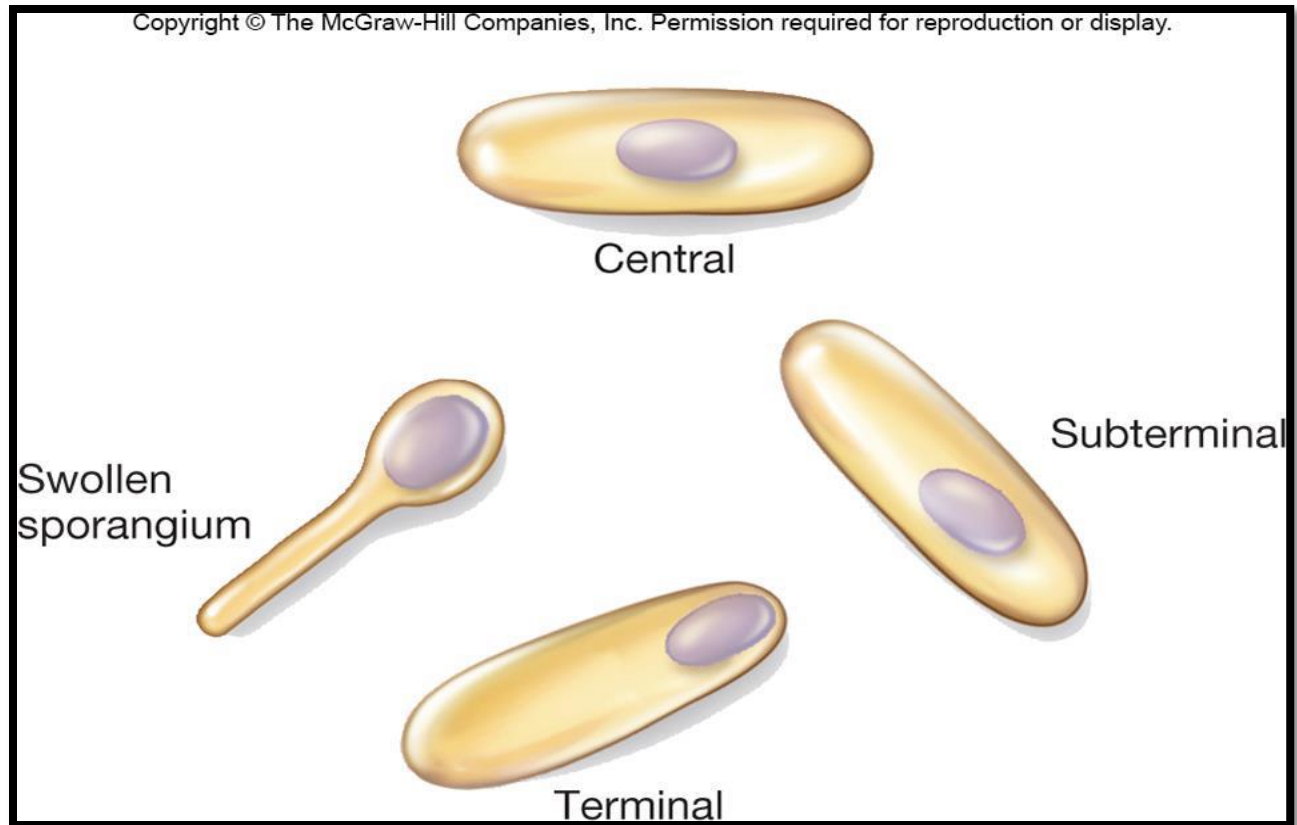
- Abundant in cytoplasm
- give the cytoplasm of bacteria a granular appearance in EM.
- smaller than the ribosomes in eukaryotic cells-but have a similar function
- Bacterial ribosomes have sedimentation rate of 70S; their subunits have rates of 30S and 50S.

The unit used to measure sedimentation velocity is Svedberg.

Ribosome Function in protein synthesis. Amino acids are assembled into proteins according to the genetic code on the surfaces of ribosomes during the process of translation.

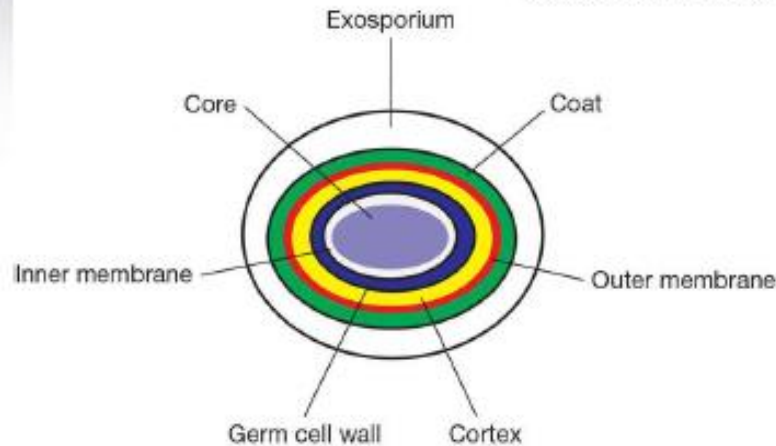
# The Bacterial Endospore

- Complex, dormant structure formed by some bacteria
- Various locations within the cell
- Resistant to numerous environmental conditions
- heat
- radiation
- chemicals
- desiccation

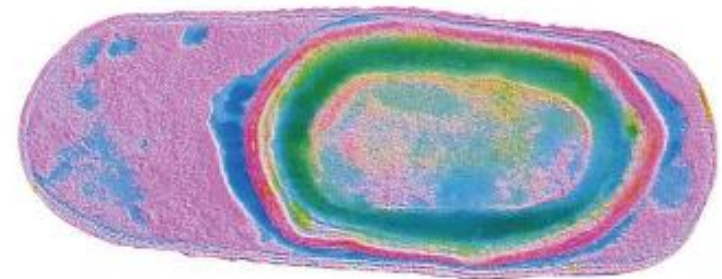


# Endospore Structure

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(a)



(b)

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- Spore surrounded by thin covering called exosporium
- Thick layers of protein form the spore coat
- Cortex, beneath the coat, thick peptidoglycan
- Core has nucleoid and ribosomes



