Basrah University
Al-Qurna Education College
Biology Department: 4th Stage

1st Course , Lecture #.3

Bacterial Cell ;Structure & Function

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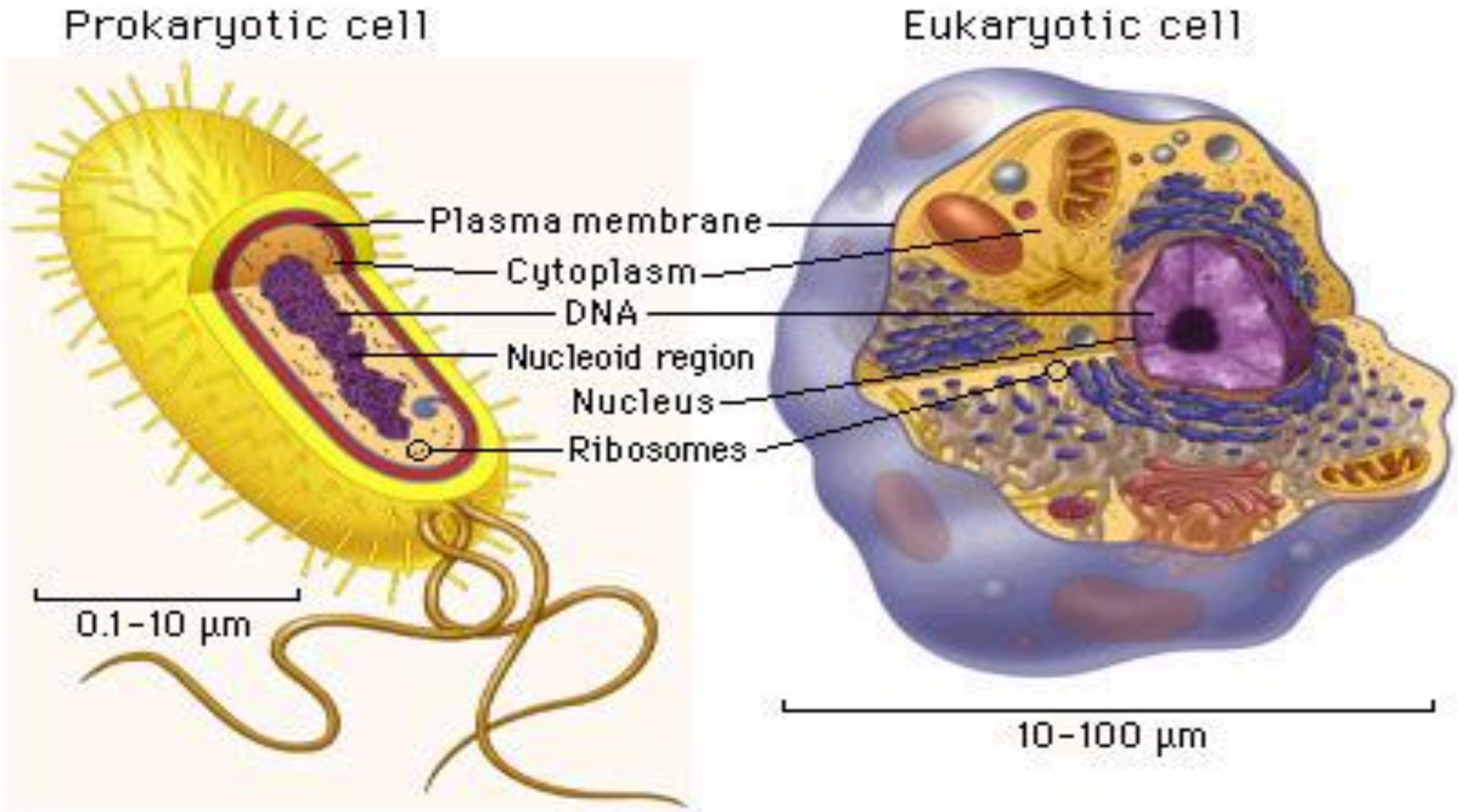
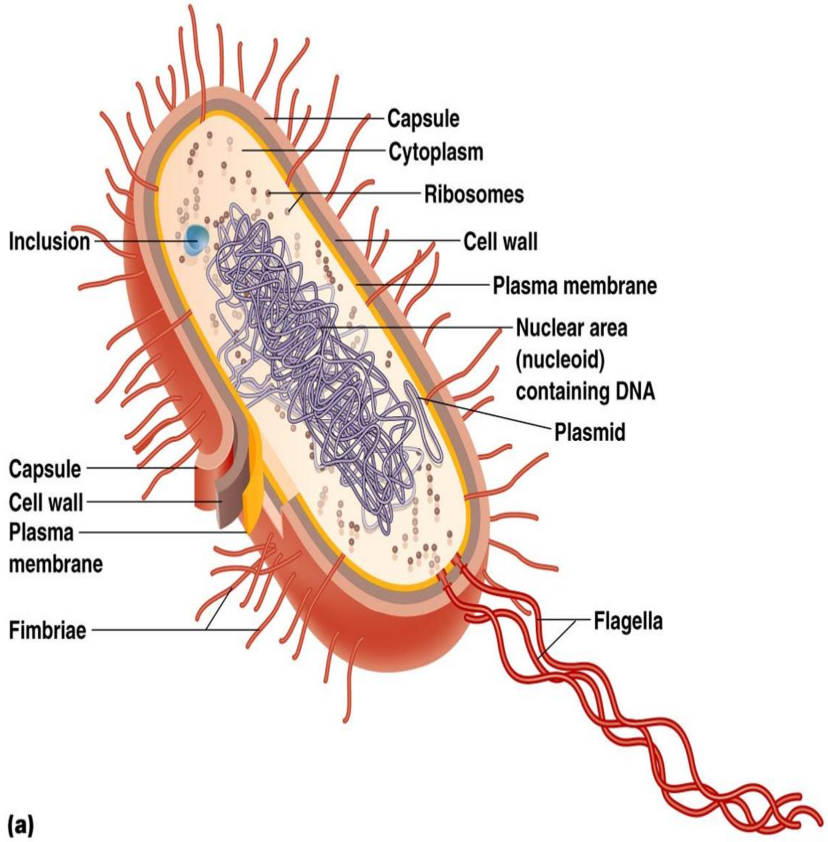
Two Basic Types of Cells



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 = Streptoccus

   Cluster = Staphylococcus

2. Bacillus

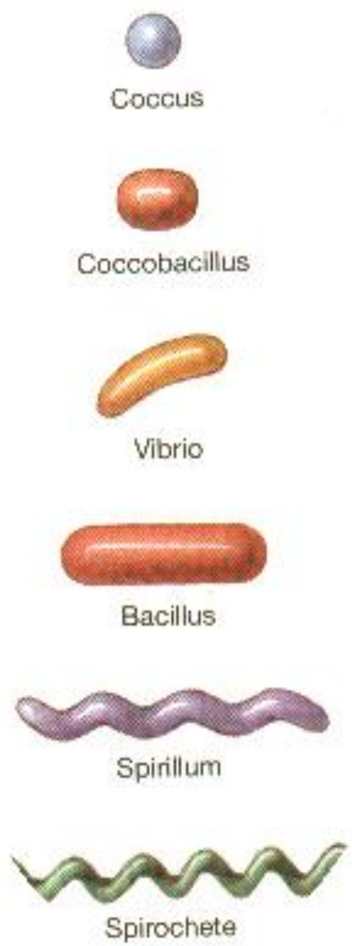
   Chain = Streptobacillus

   Coccobacillus

3. Vibrio = curved

   Spirillum

   Spirochete

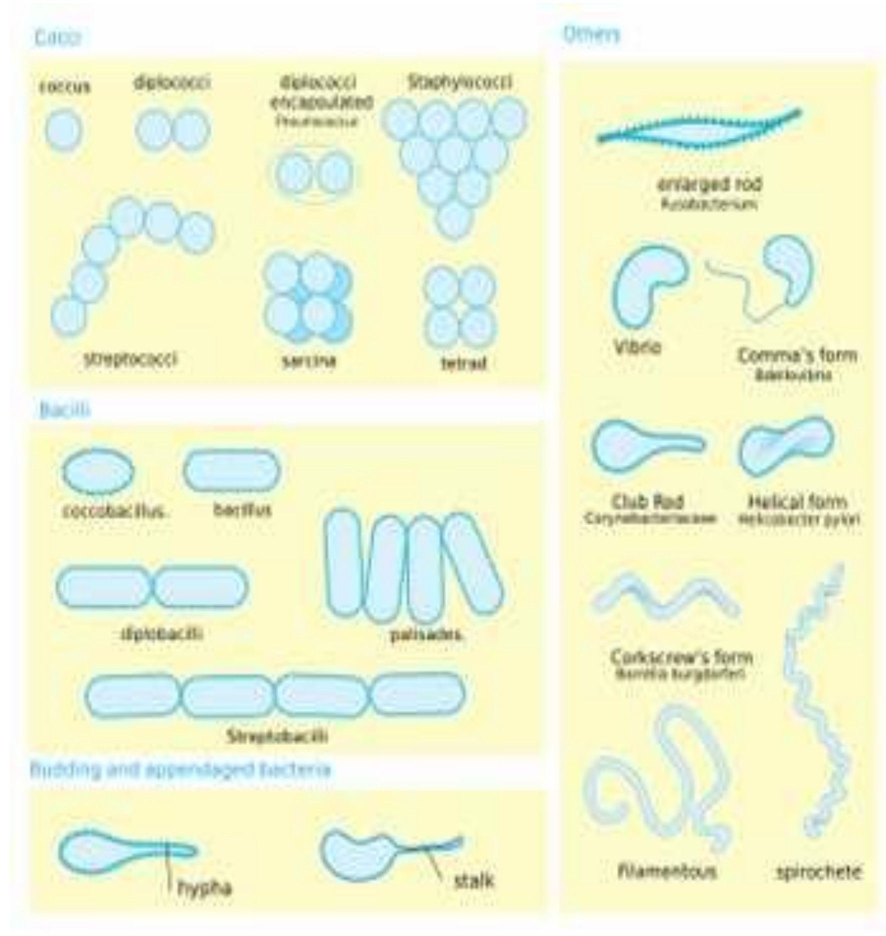


Prokaryotes – Arrangements of Cells

- Bacteria sometimes occur in groups, rather than singly.

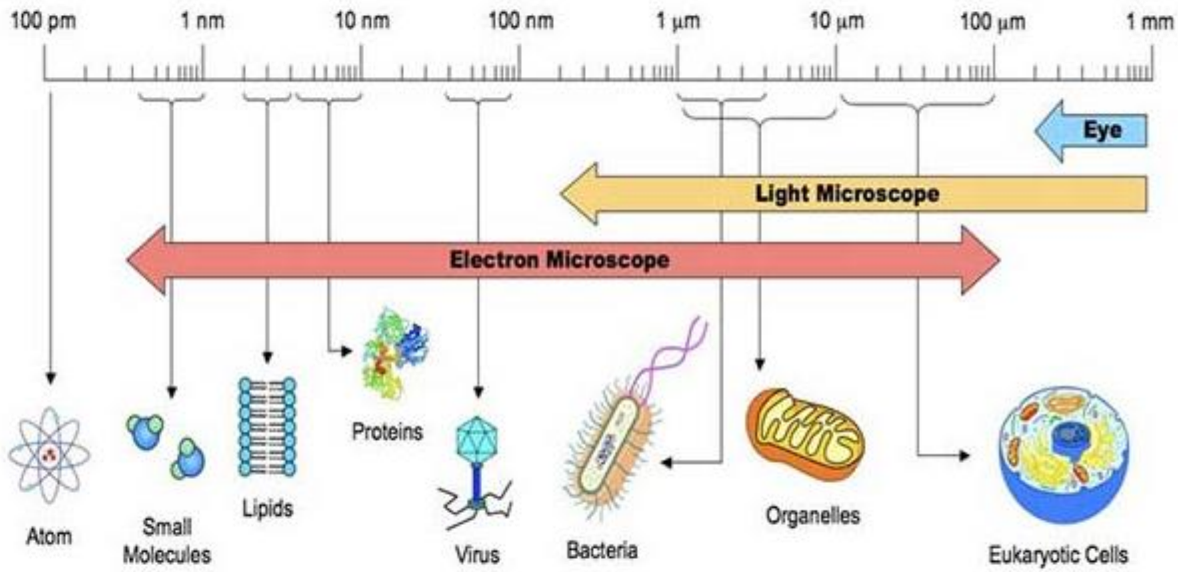
  - pairs (diplococci)
  - chains (streptococci)
  - packets (sarcinae)
  - clusters (staphylococci).

- Size, shape and arrangement of cells often first guide in identification of a bacterium.



Size of Different organisms

Size of Bacterial Cell



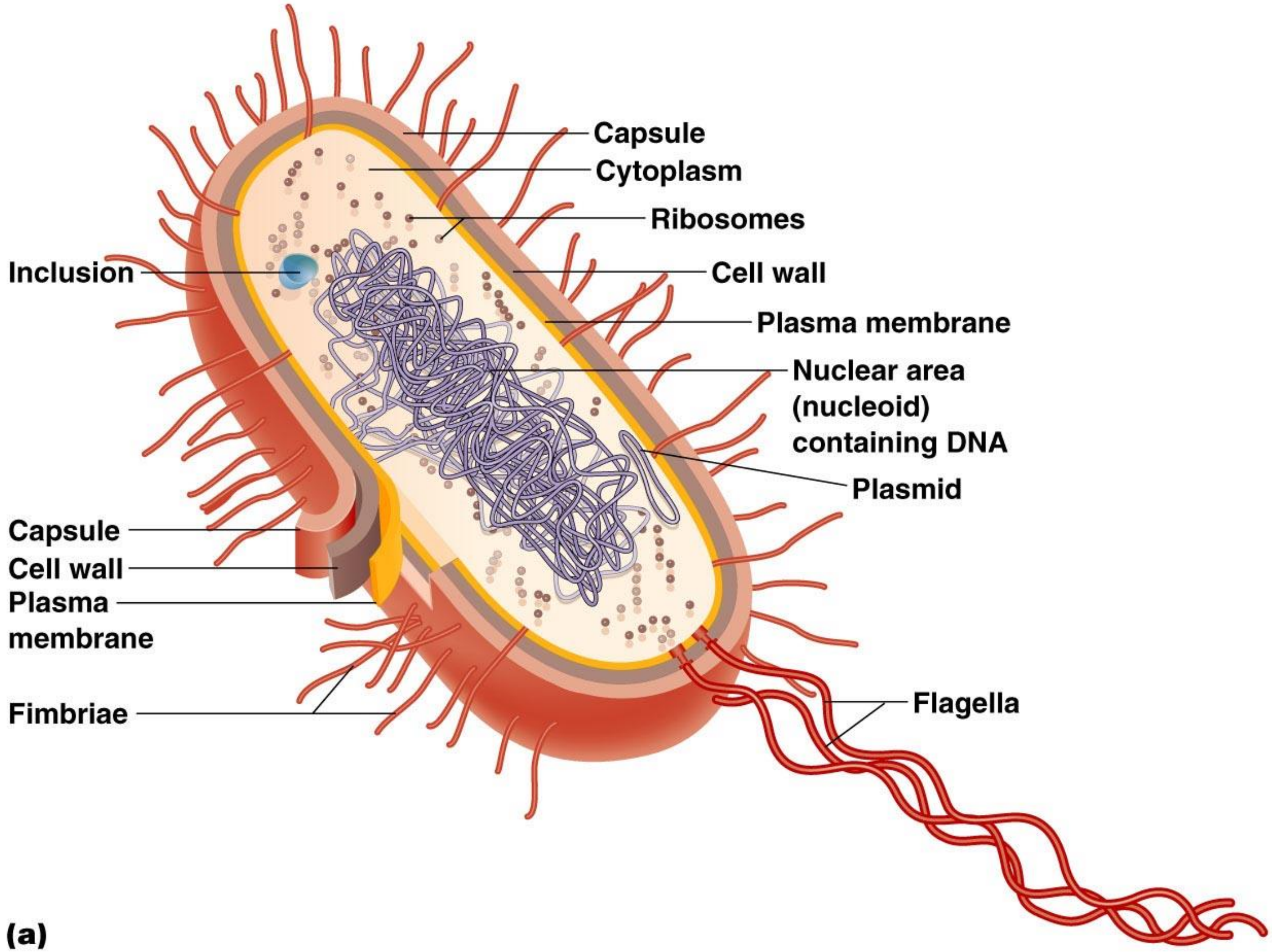
The average diameter of spherical bacteria is 0.5-2.0 µm. For rod-shaped or filamentous bacteria, length is 1-10 µm and diameter is 0.25-1 .0 µm.

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.

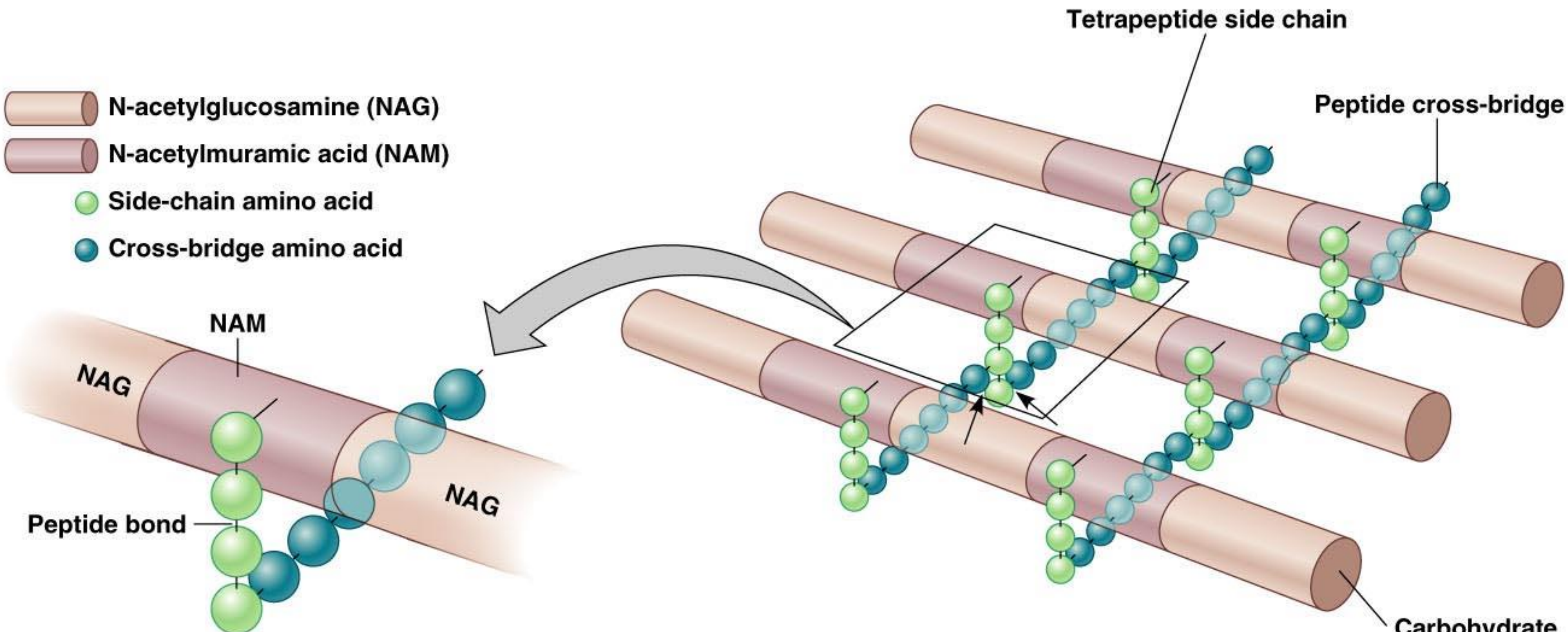
3.Maintains the osmotic integrity of the cell.

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 β-(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



(a) Structure of peptidoglycan in gram-positive bacteria

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

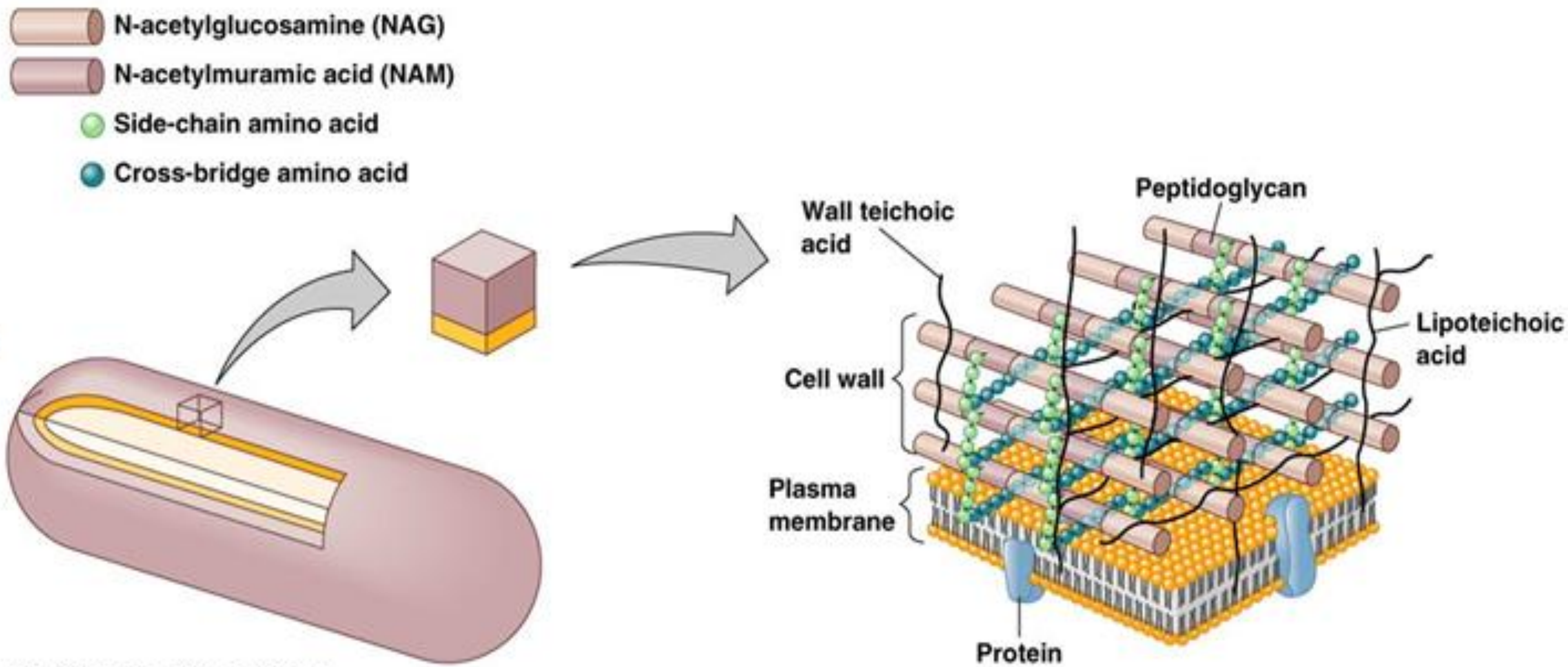
Gram Stain

Gram Positive

Gram Negative

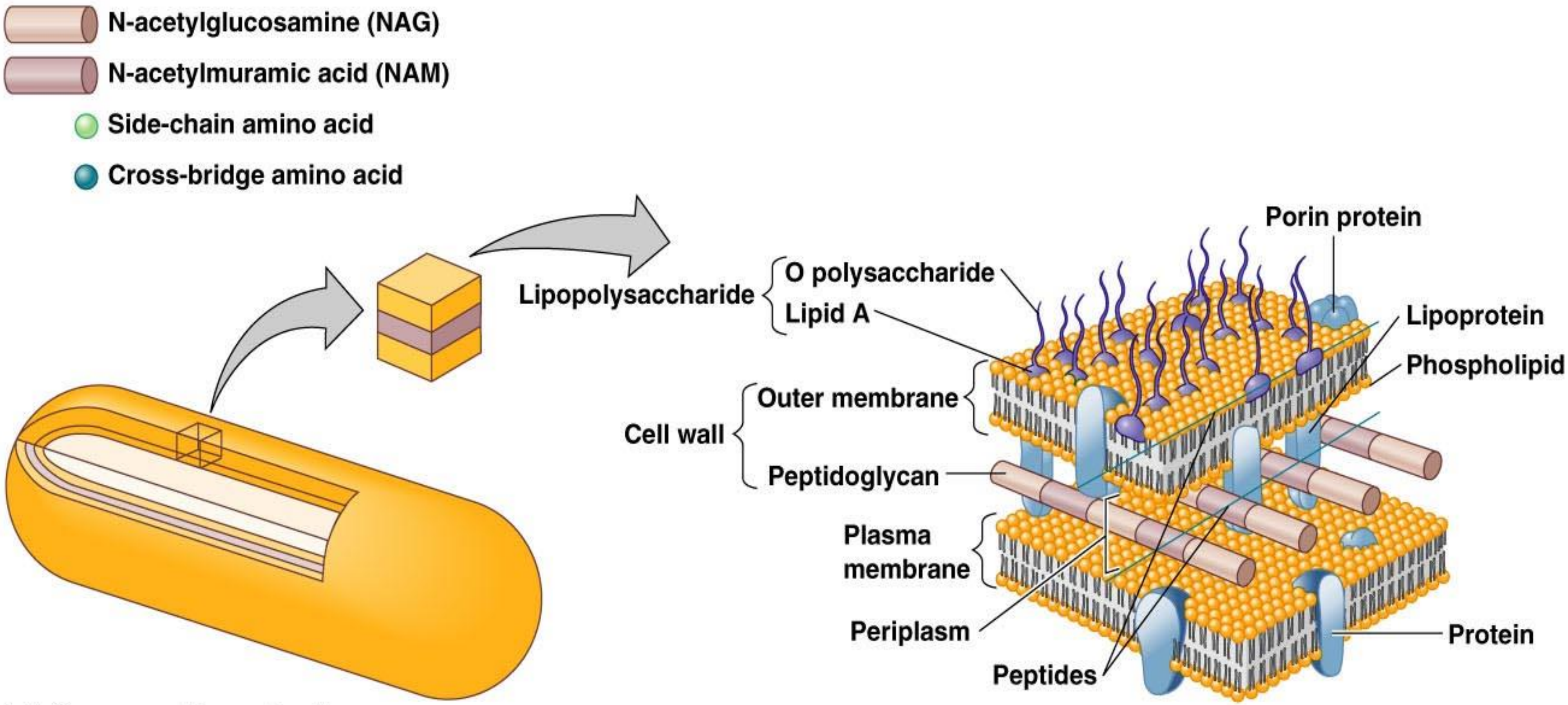
- Gram-positive cell wall is thick homogeneous monolayer
- Gram-negative cell wall is thin heterogeneous multilayer

Gram positive cell wall structure



(b) Gram-positive cell wall

Gram negative cell wall structure



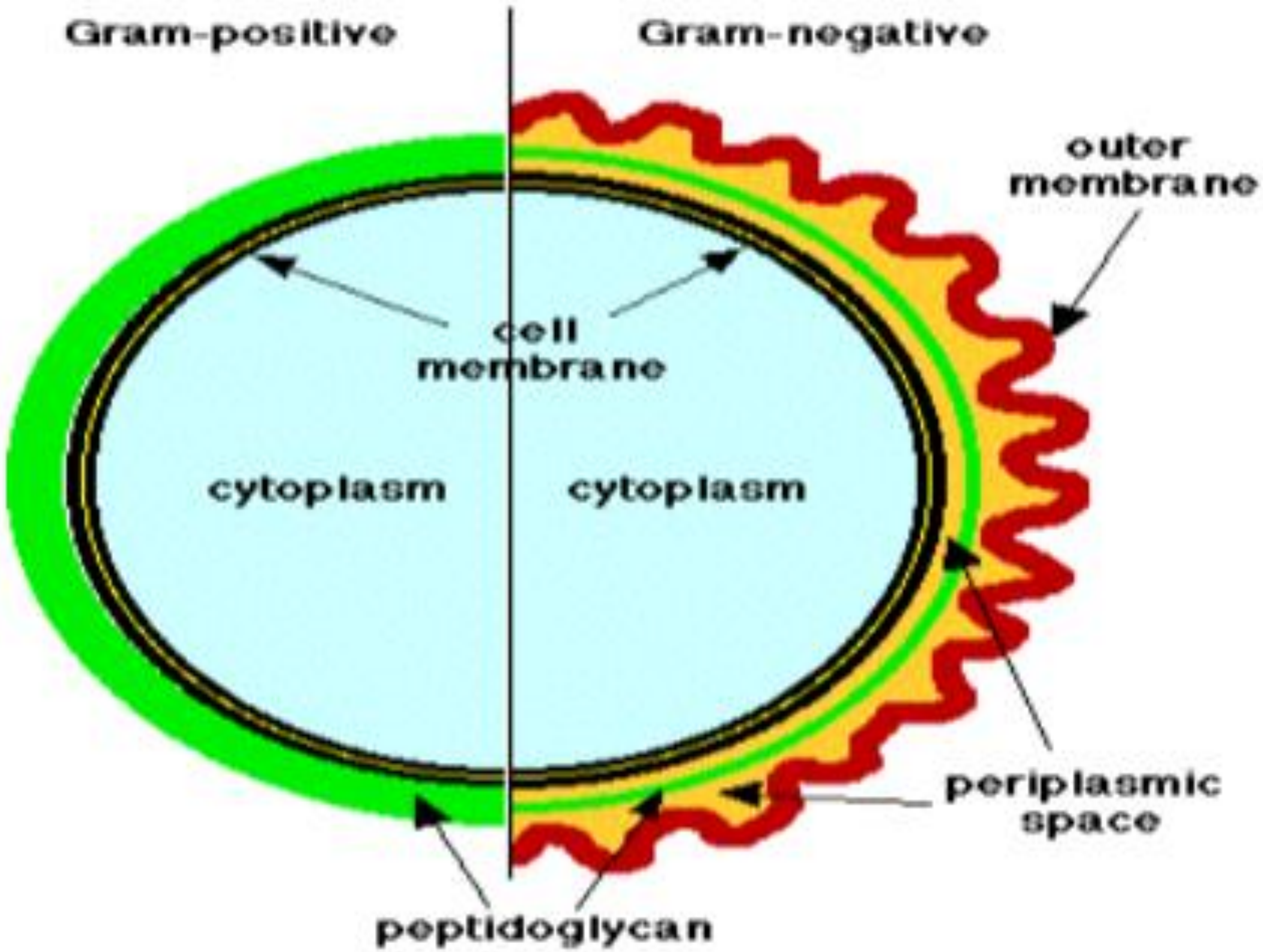
(c) Gram-negative cell wall

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.


Gram-positive
Gram-negative
outer membrane
cell membrane
cytoplasm
cytoplasm
periplasmic space
peptidoglycan

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.

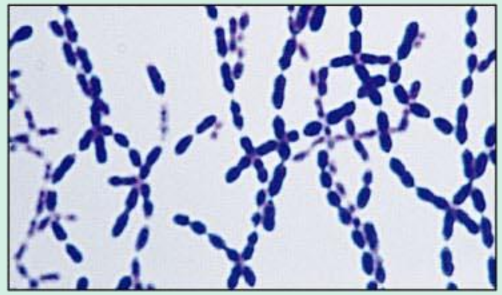
• Periplasm is filled with the proteins that are involved in various cellular activities, including nutrient degradation and transport.

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

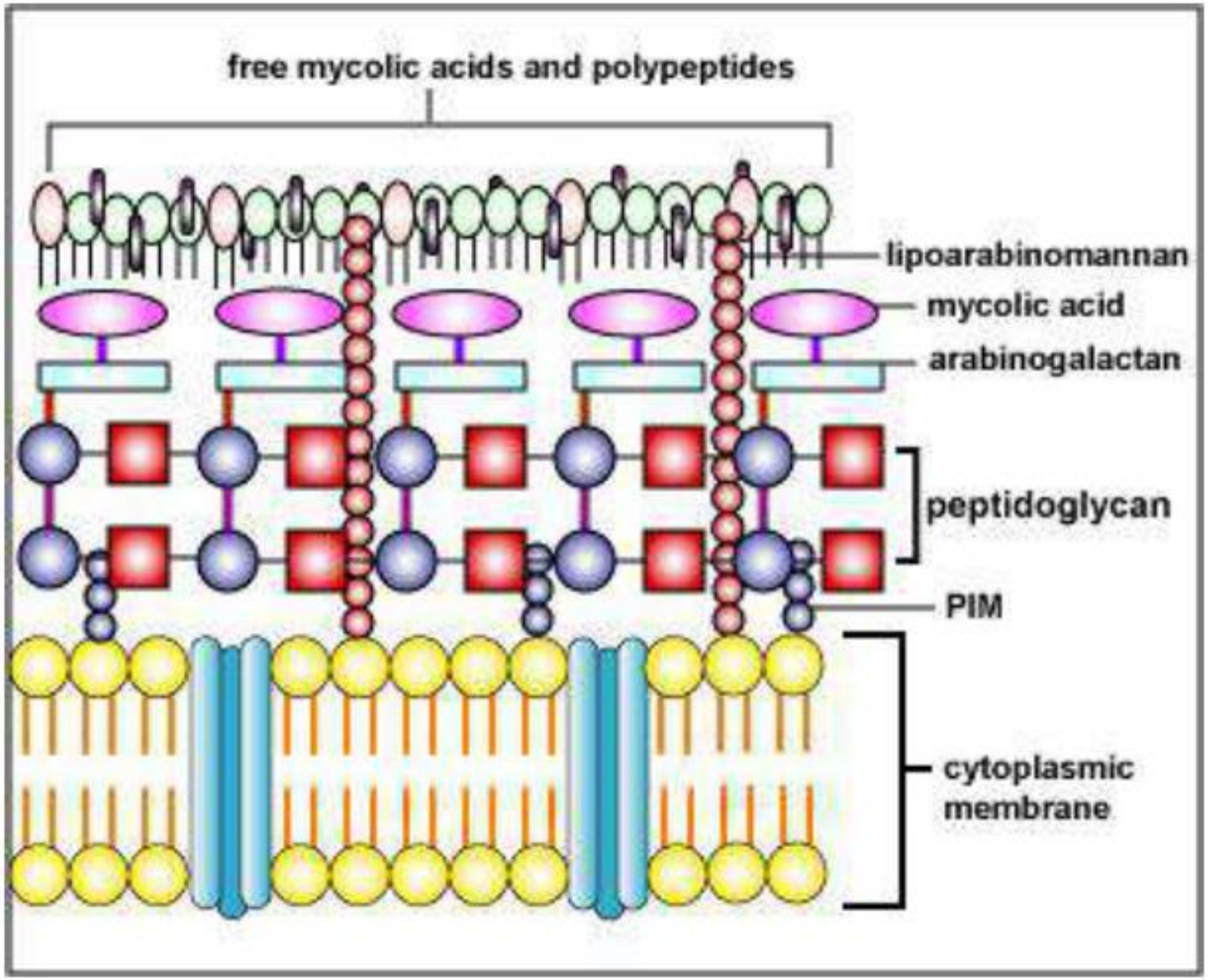
Acid fast and related bacteria
(*Mycobacteria*, *Nocardia* and *Corynebacteria*)

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 phosphatidyinositol 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

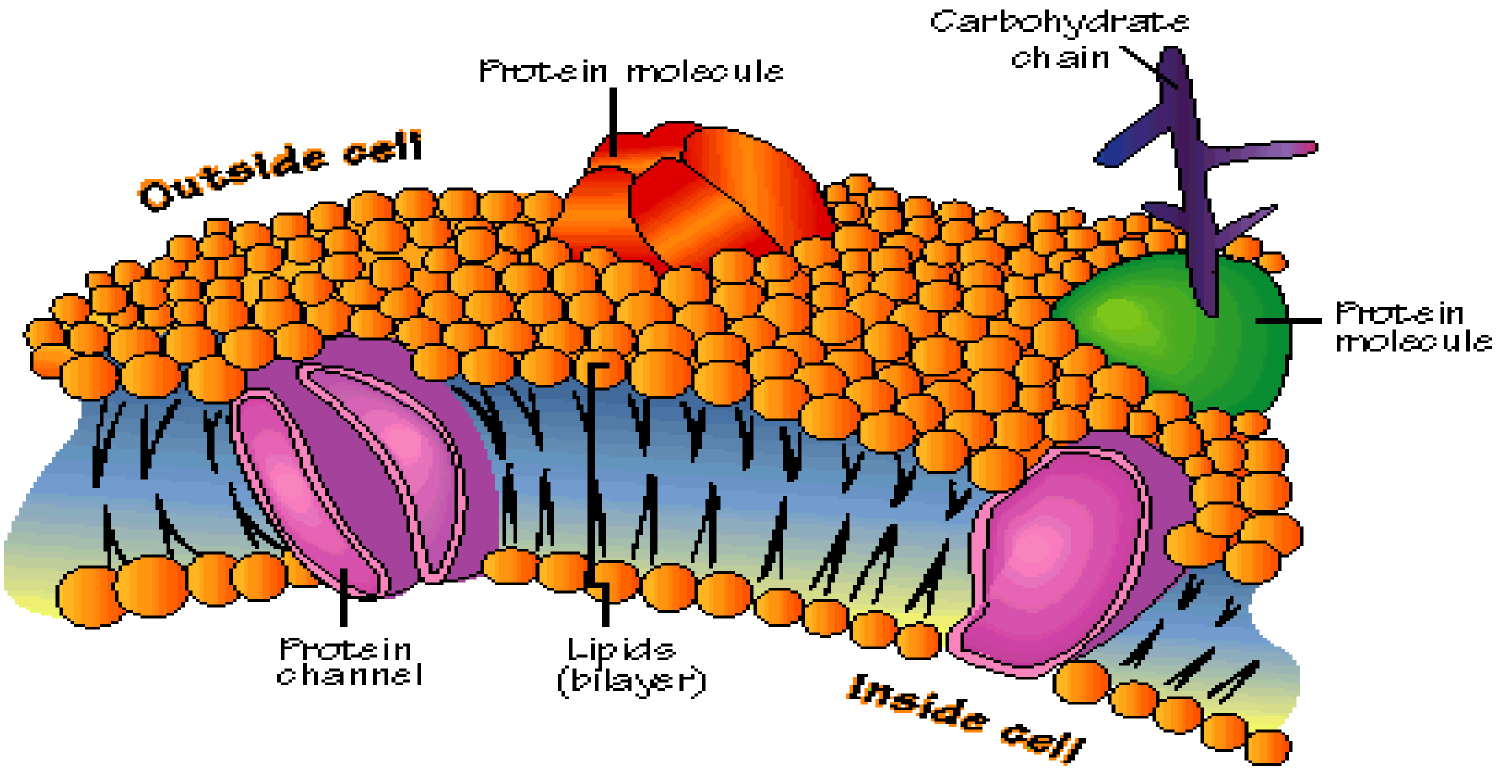
Wall-less bacteria that replicate : L-forms

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

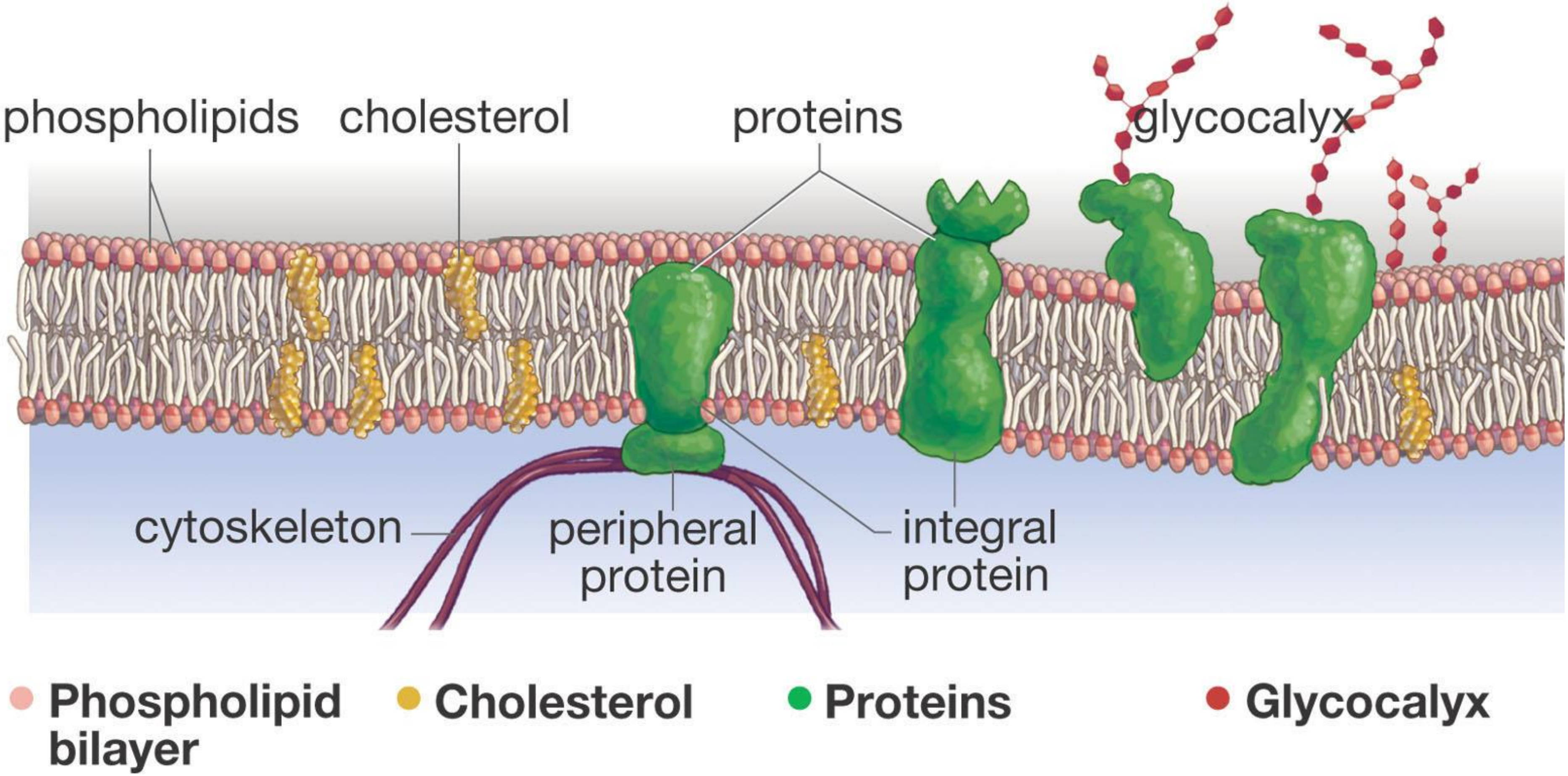
Plasma Membrane

- 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.

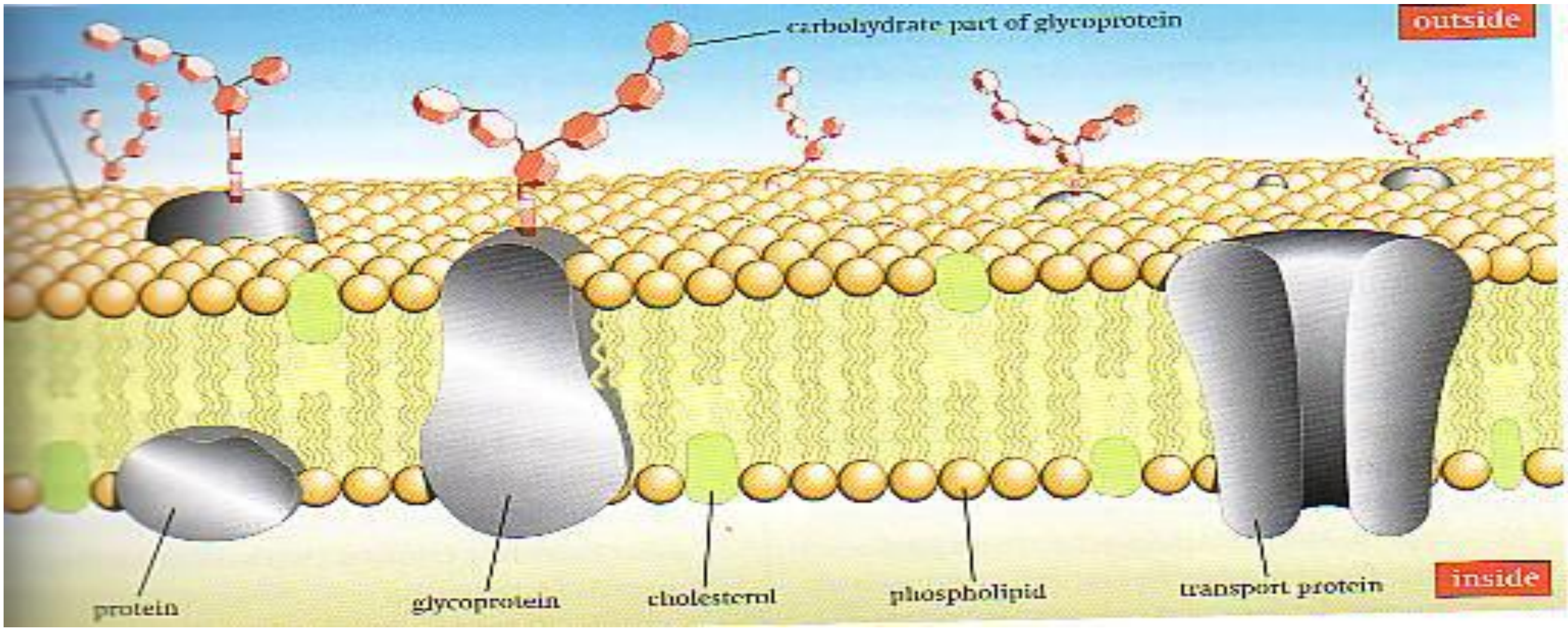
Structure of the Cell Membrane



Membrane Components



FLUID MOSAIC MODEL



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

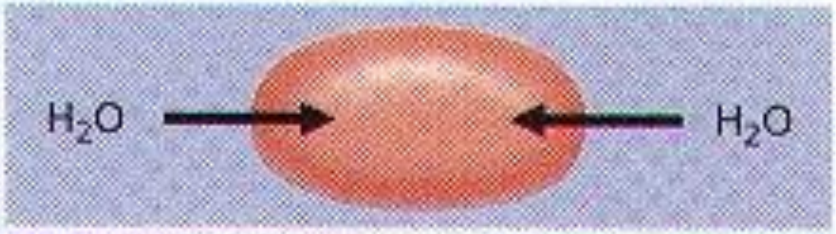
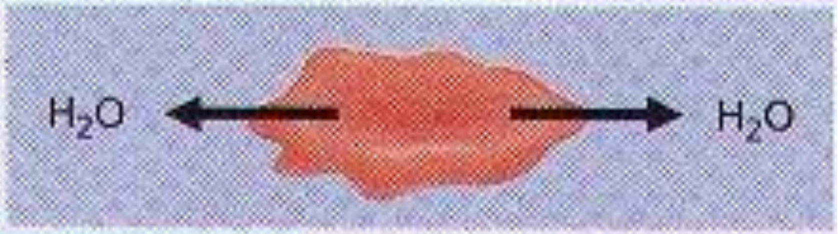
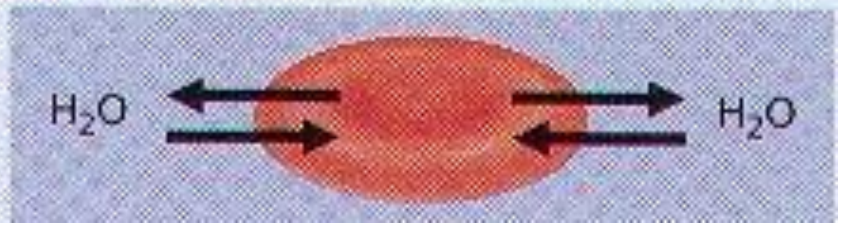
MOSAIC- because of the pattern produced by the scattered protein molecules when the membrane is viewed from above.

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***

Condition	Net movement of water	
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:

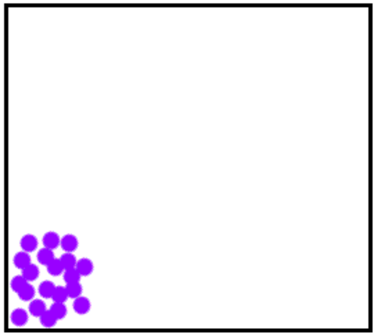
- Phagocytosis
- Pinocytosis
- Protein Pumps , Use of membrane proteins (carrier proteins, etc)
- Moving molecules from low to high concentration

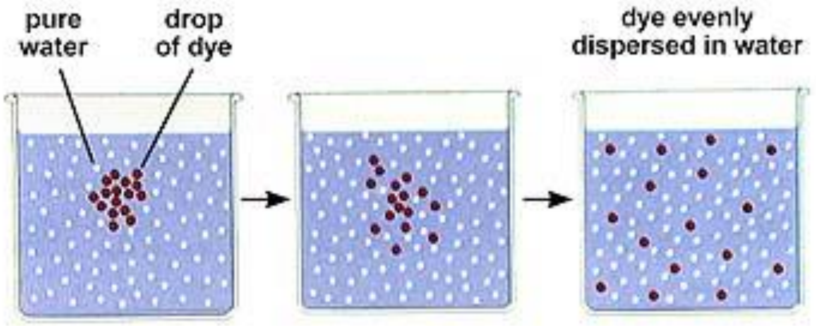
Diffusion

The movement of molecules from an area of HIGH concentration to an area of LOW concentration.

The direction of diffusion is called the *concentration gradient*.

This is a form of passive transport.



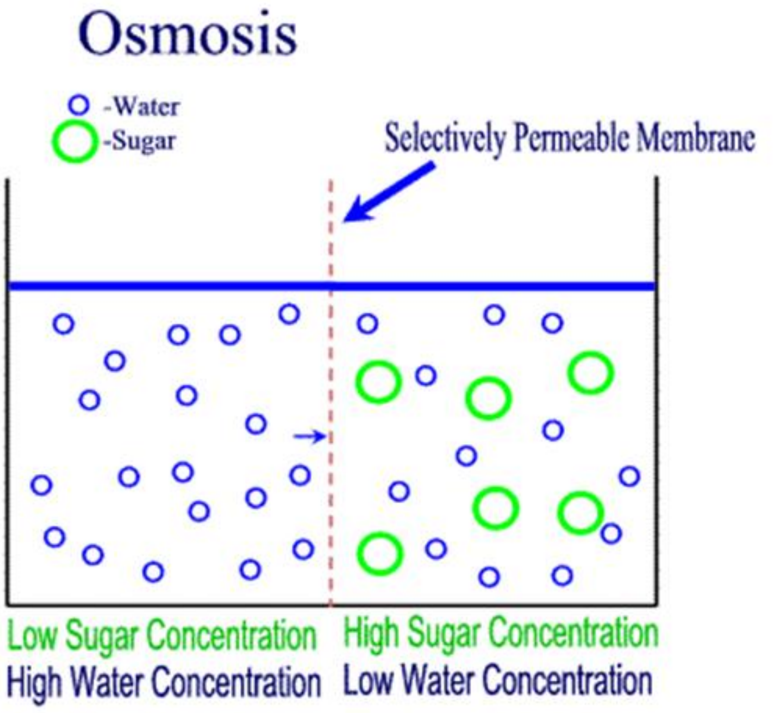


_LARGE__ molecules CANNOT diffuse, regardless of concentration gradient!

Osmosis

Osmosis is a special name for the diffusion of __WATER__ across a semi-permeable membrane.

Because this requires NO ATP, it is called __Passive transport__.



Active Transport

- The passing of molecules across a membrane against the concentration gradient
- Requires energy
- Small molecules are transported by pumps (molecular transport)
- Larger molecules are transported by
- endocytosis and exocytosis.

Endocytosis

- Process of taking material into the cell by means of forming a vesicle or pockets of the cell membrane
- This takes material into the cell and it forms a vacuole in the cell
- Large molecules of food and whole cells can be taken this way

Two Types of Endocytosis

Phagocytosis

- Means “cell eating”
- An extension of cytoplasm surrounds a particle and package it into a food vacuole
- requires an enormous amount of energy

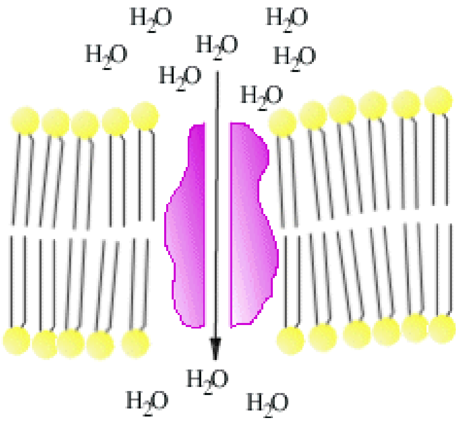
Pinocytosis

- Means” cell drinking”
- Tiny pockets form along the cell membrane fill with liquid and form vacuoles with in the cell
- Requires enormous amounts of energy

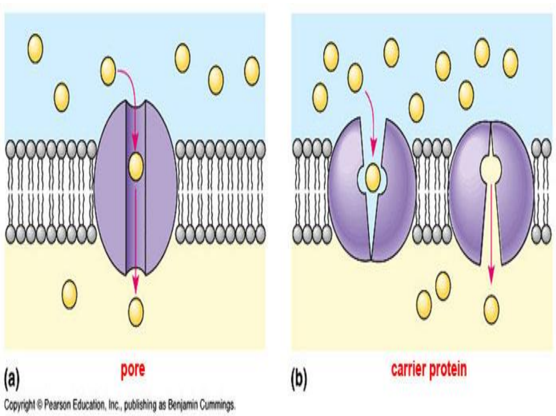
Exocytosis

- The process where cells release large amount of materials
- Vacuole surrounding material fuses with the cell membrane, forcing the contents out of the cell
- Also requires energy

Membrane Proteins



Diffusion through a protein channel



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

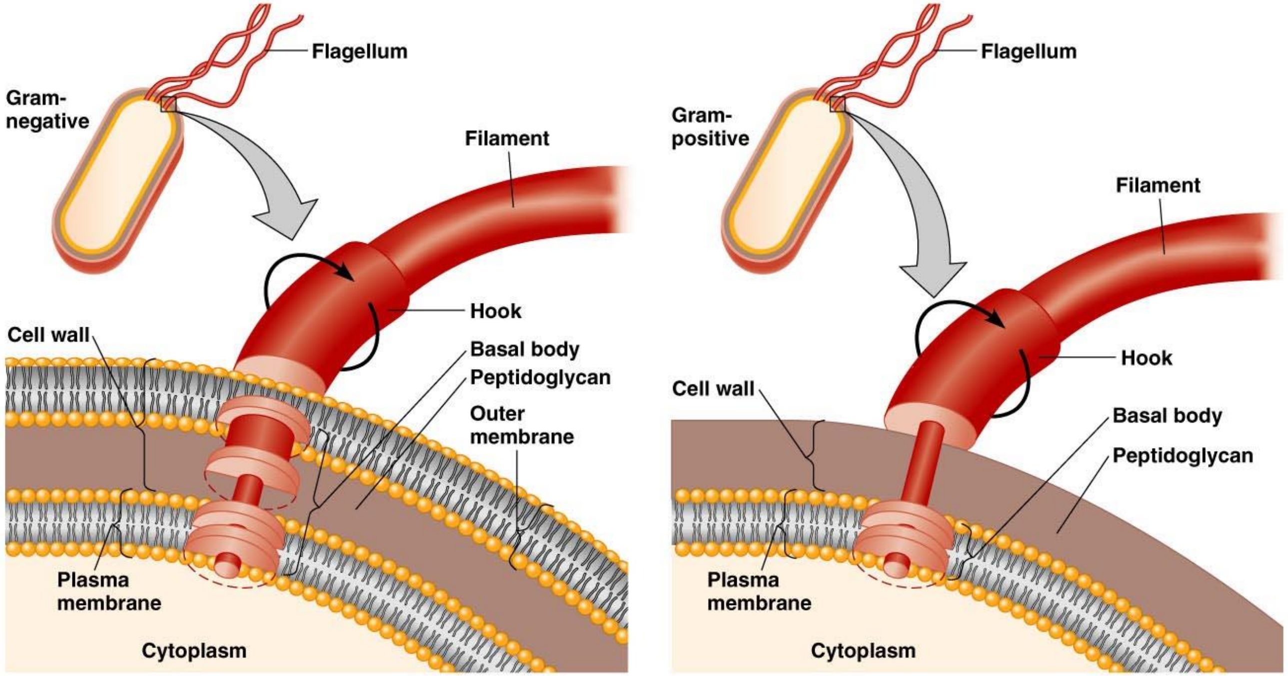
FLAGELLA

- 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

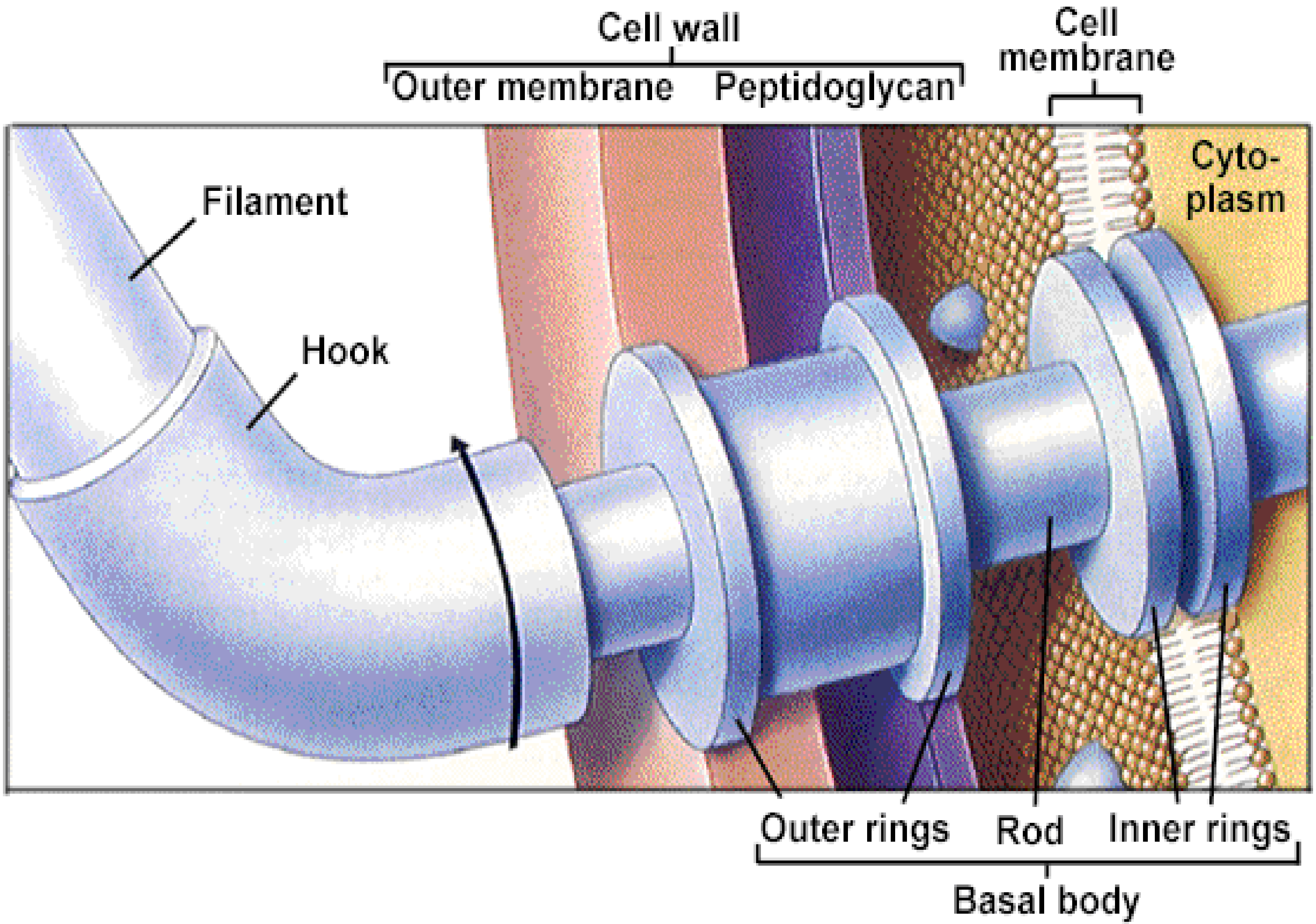
Bacterial flagella



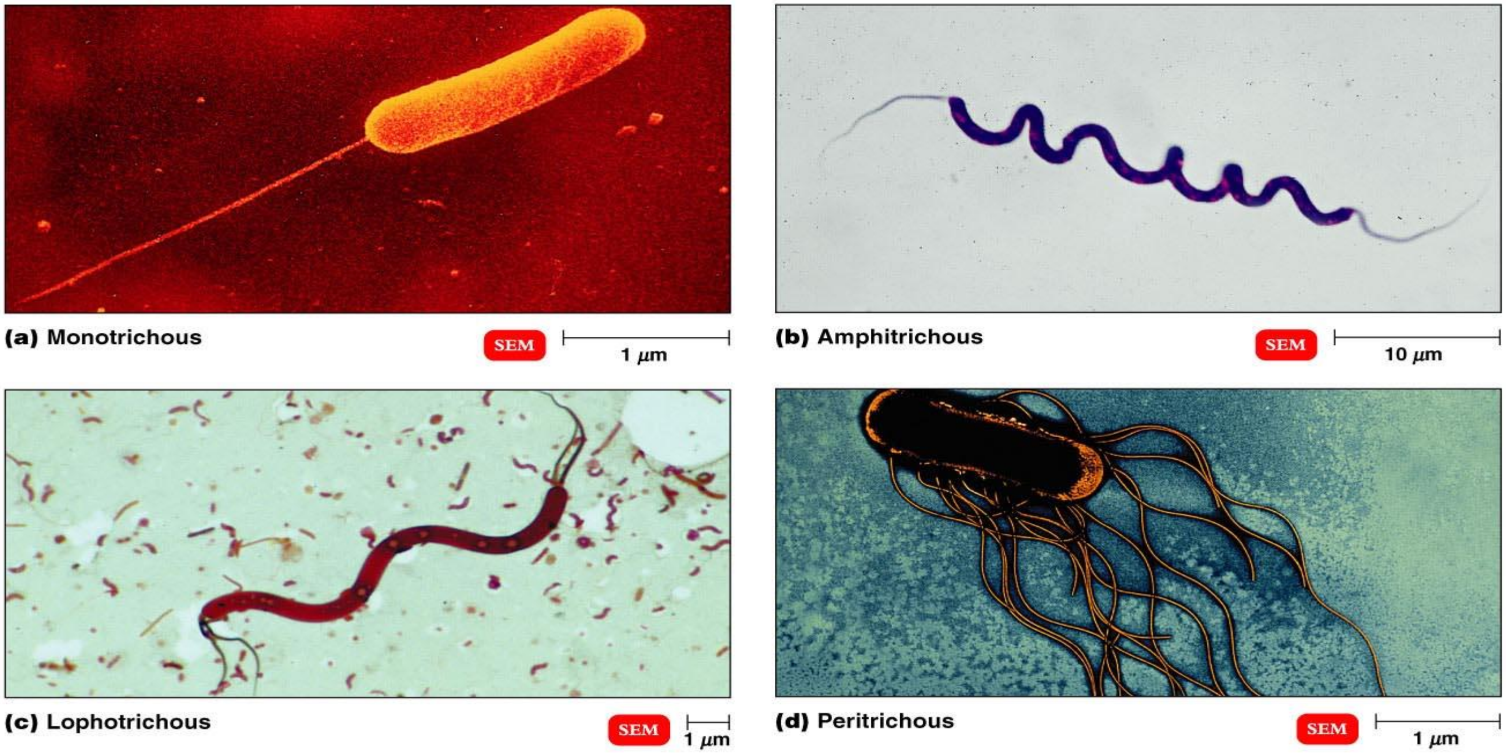
(a) Parts and attachment of a flagellum of a gram-negative bacterium

(b) Parts and attachment of a flagellum of a gram-positive bacterium

- 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
Cyto-
plasm
Filament
Hook
Outer rings
Rod
Inner rings
Basal body

Arrangements of flagella



- 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
- Endosores
- 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

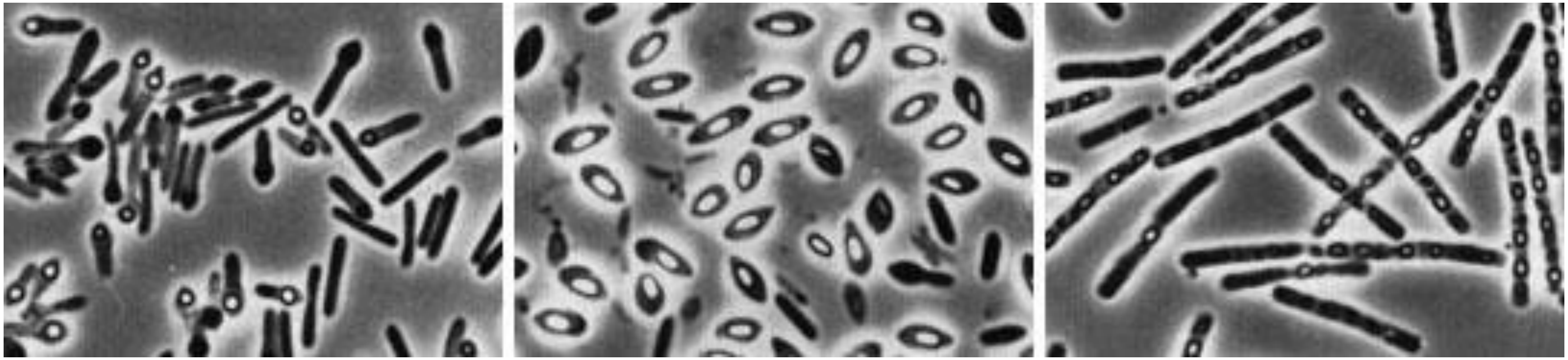
Consists of RNA and protein

- 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.

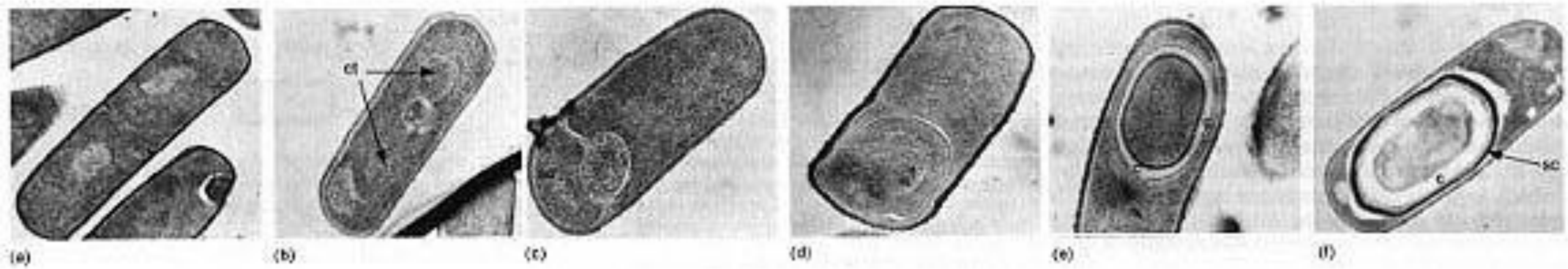
Ribosome Function in protein synthesis. Amino acids are assembled into proteins according to the genetic code on the surfaces of ribosomes during the process of translation.

Endospores are produced as intracellular structures within the cytoplasm of certain bacteria, most notably *Bacillus* and *Clostridium* species.

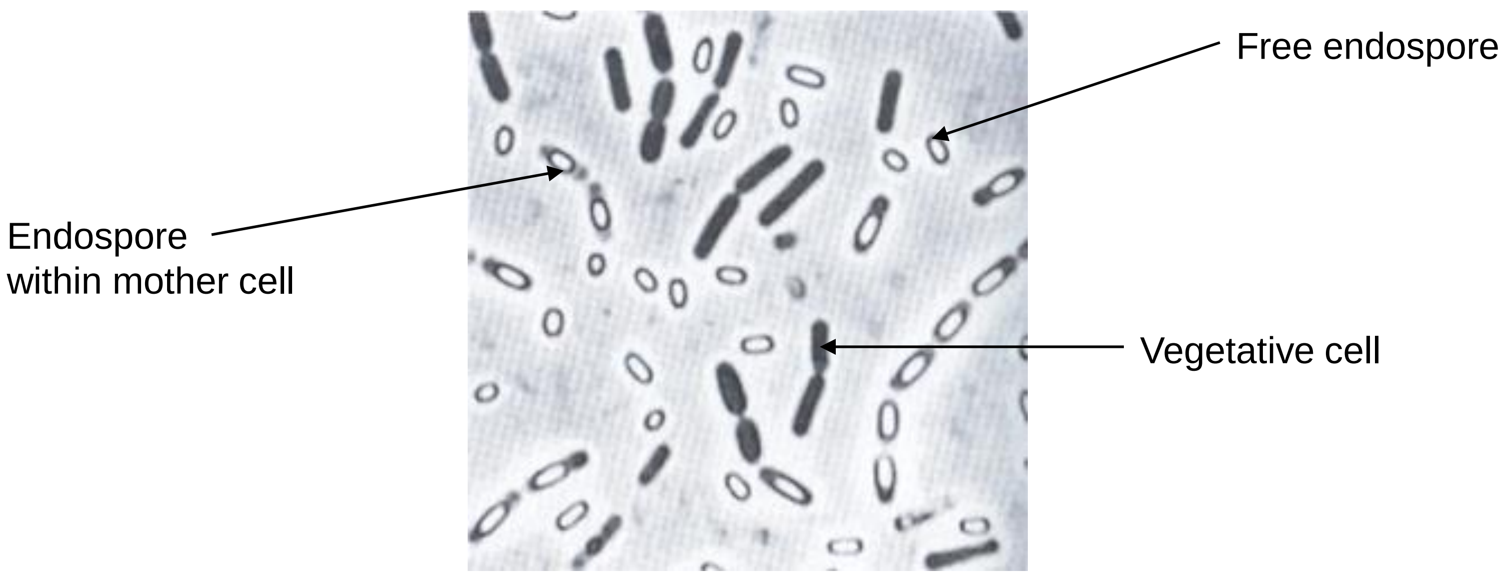


Endospore forming bacteria left to right: *Clostridium botulinum, Bacillus brevis, Bacillus thuringiensis*

Endospore formation is NOT a mechanism of reproduction. Rather it is a mechanism for survival in deleterious environments. During the process of spore formation, one vegetative cell develops into one endospore.



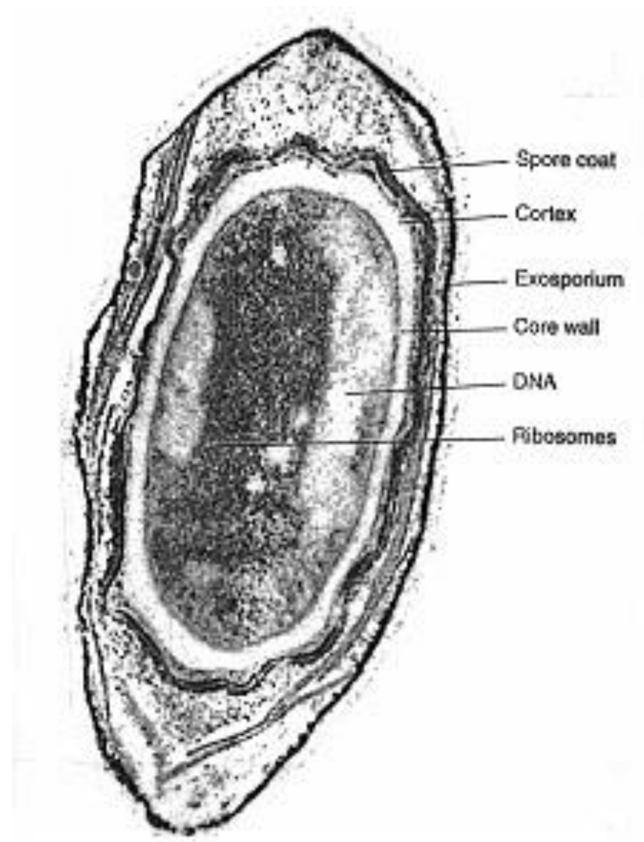
The sequential steps of endospore formation in a Bacillus species. The process of endospore formation takes about six hours. Eventually the mature endospore is released from its “mother cell” as a free spore



Under favorable nutritional and environmental conditions, an endospore germinates into a vegetative cell.

Properties of Endospores

- Resting (dormant) cells - “cryptobiotic” i.e., show no signs of life…..primarily due to lack of water in the spore .
- Several unique surface layers not found in vegetative cells: exosporium, spore coat, cortex, and core wall



Endospores

- Dormant cell, Resistant structure;;Produced when starved
- Resistant to adverse conditions
  - high temperatures, irradiation, cold, organic solvents
  - Boiling >1 hr still viable

- contain calcium dipicolinate
- *Bacillus* and *Clostridium sp.*

- Location important in classification
  - Central, Sub terminal, Terminal

- Bacillus stearothermophilus -spores
  - Used for quality control of heat sterilization equipment