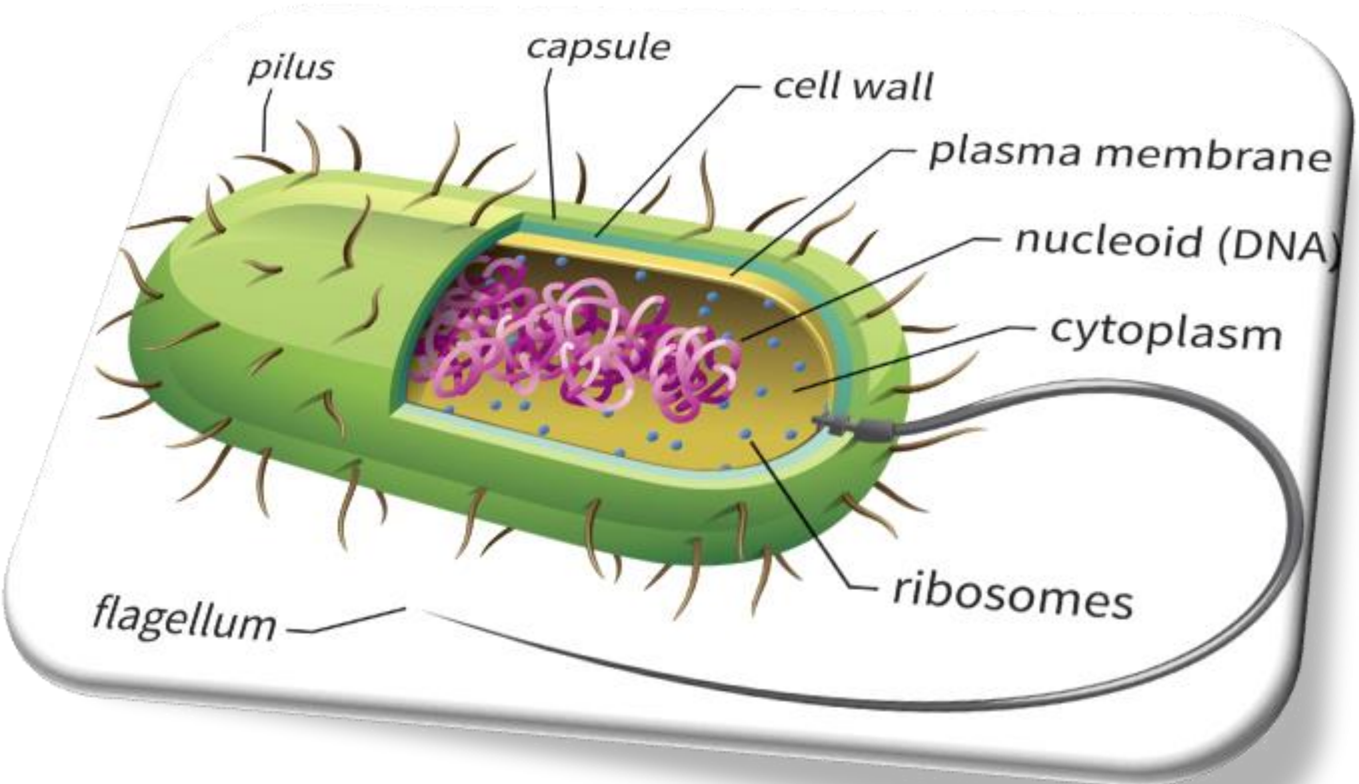


PROKARYOTIC CELL STRUCTURE

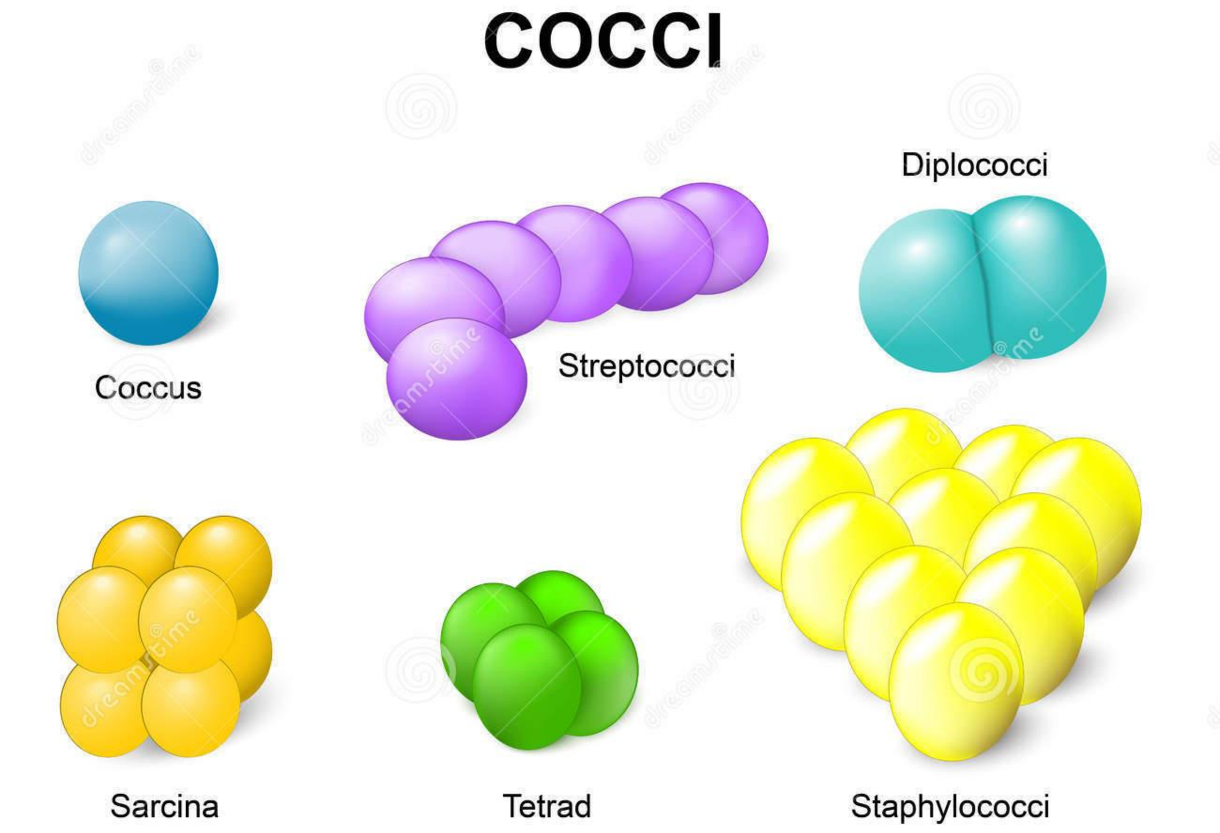
Dr. Bincy Joseph
Assistant Professor
PGIVER, Jaipur

Bacterial cell shape arrangement and morphology

- **Cocci (s. coccus)** are roughly spherical cells.
- **Diplococci (s., diplococcus)** arise when cocci divide and remain together to form pairs
- Long chains of cocci (Streptococci) result when cells adhere after repeated divisions in one plane

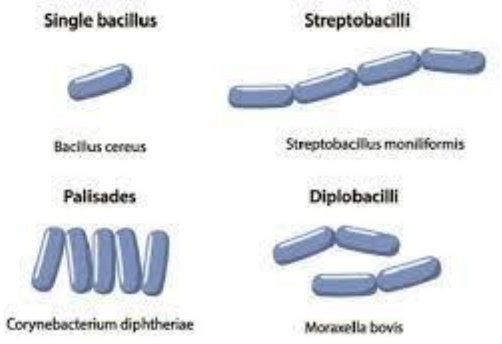
  Eg. Streptococcus, Enterococcus, and Lactococcus
- *Staphylococcus divides in random planes to generate irregular* grapelike clumps
- Divisions in two or three planes can produce symmetrical clusters of cocci.
- *In Micrococcus cocci divide in two planes to form square groups of* four cells called tetrads
- In the genus *Sarcina, cocci divide in* three planes producing cubical packets of eight cells.

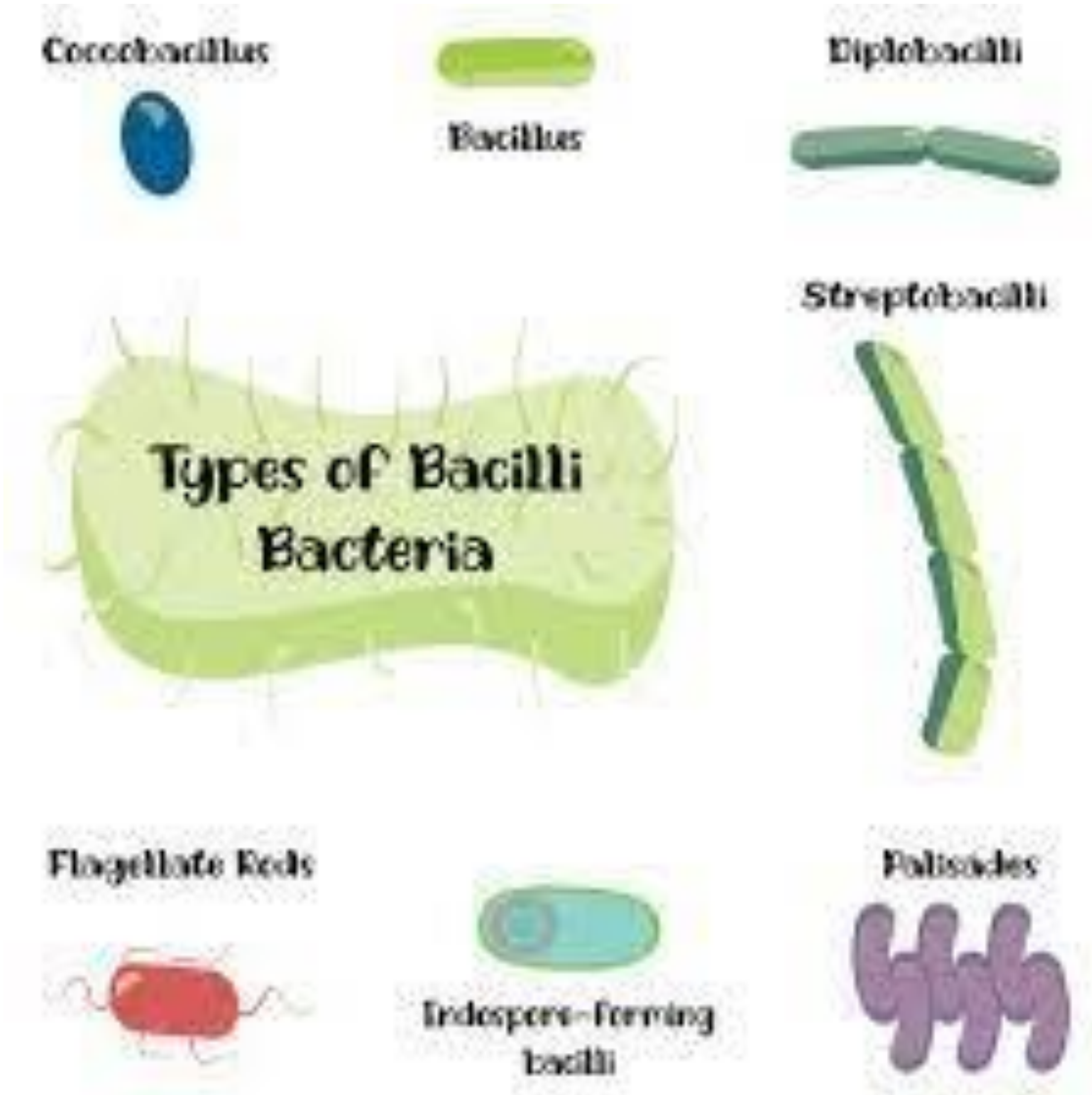
DIFFERENT TYPES OF COCCI



- **Rod shaped bacteria are called a bacillus (pl., bacilli).**
- ***Bacillus megaterium is a typical example***

  of a bacterium with a rod shape
- Coccobacilli being so short and wide that they resemble cocci.
- Rods can occur singly, in pairs or in chains
- Vibrio: comma shaped bacteria

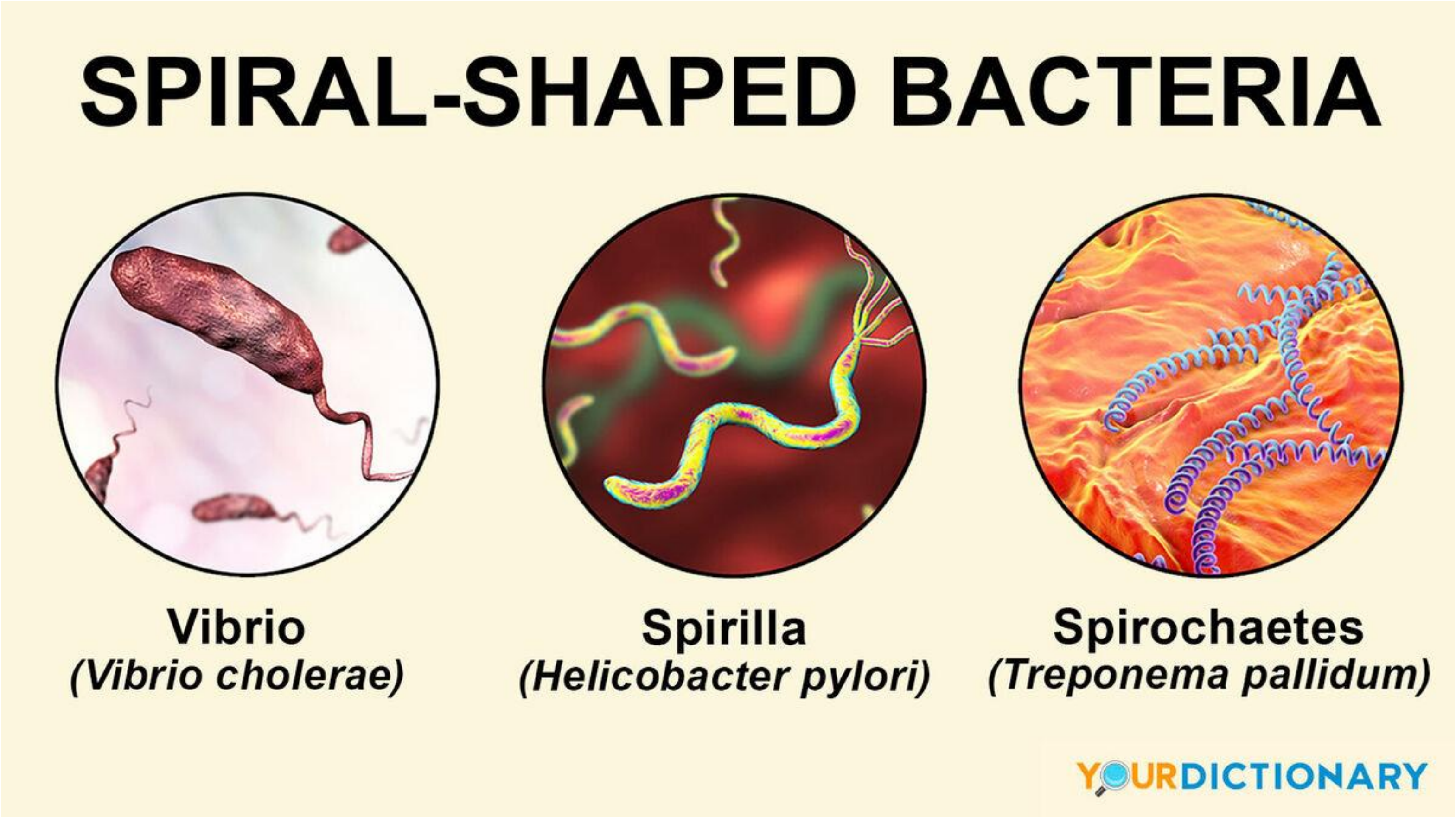




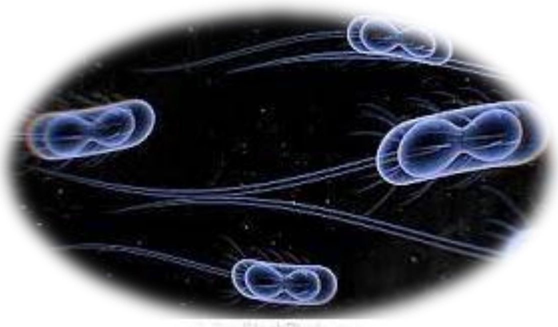
Coccobacillus
Bacillus
Diplobacilli
Streptobacilli
Types of Bacilli Bacteria
Flagellate Rods
Endospore-forming bacilli
Palisades

Contd..

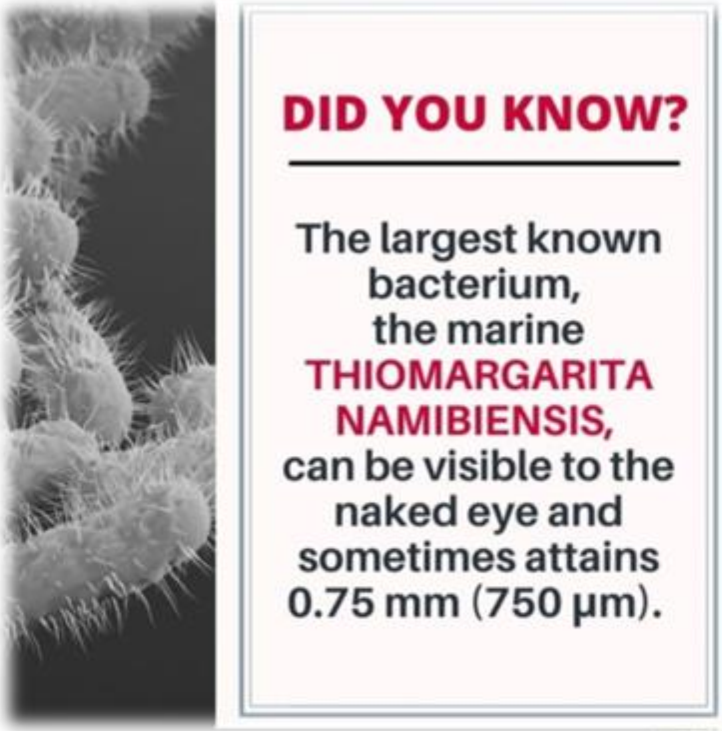
- Spiral-shaped procaryotes can be either classified as **spirilla, which** usually have tufts of flagella at one or both ends of the cell *or spirochetes*.
- ***Spirochetes are more flexible and*** have a unique, internal flagellar arrangement.
- Actinomycetes typically form long filaments called hyphae that may branch to produce a network called a **mycelium**
- some procaryotes are variable in shape and lack a single, characteristic form
- *These are called* ***pleomorphic*** even though they may, like *Corynebacterium,*


SPIRAL-SHAPED BACTERIA
Vibrio
(Vibrio cholerae)
Spirilla
(Helicobacter pylori)
Spirochaetes
(Treponema pallidum)
YOURDICTIONARY

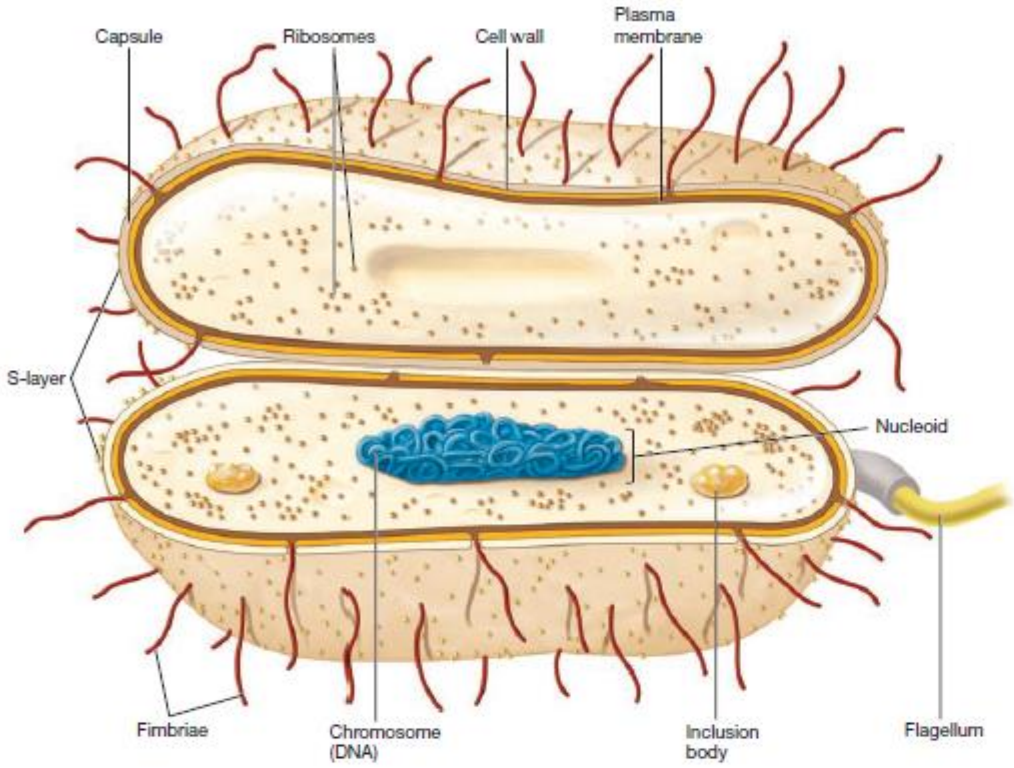
- The smallest bacteria is Nanobaceria of about 0.05-0.2um in size
- The largest bacteria : Thiomargarita namibiensis



Nanobacteria



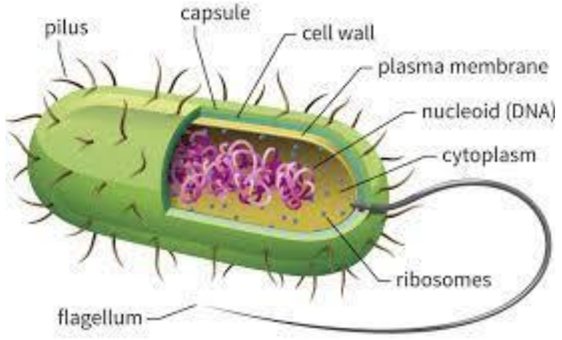
Prokaryotic cell structure



3.4 Morphology of a Procaryotic Cell.

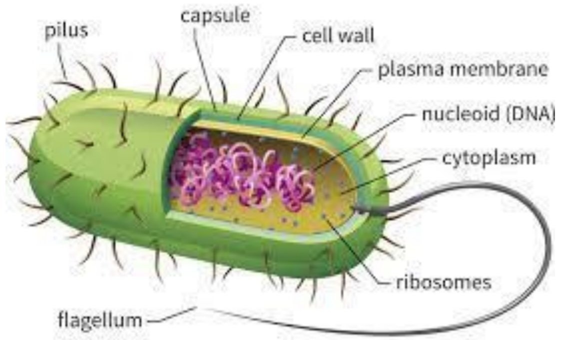
PROKARYOTIC CELL STRUCTURE

- Procaryotic cells almost always are bounded by a chemically complex cell wall.
- Interior to this wall lies the plasma membrane.
- This membrane can be invaginated to form simple internal membranous structures of bacteria
- The procaryotic cell does not contain internal membrane-bound organelles,



Prokaryotic cell structure

- The genetic material is localized in a discrete region, the nucleoid, and usually is not separated from the surrounding cytoplasm by membranes.
- Ribosomes and larger masses called inclusion bodies are scattered about the cytoplasmic matrix.
- Many procaryotes use flagella for locomotion.
- In addition, many are surrounded by a capsule or slime layer external to the cell wall



FUNCTIONS OF PROKARYOTIC CELL STRUCTURE

Table 3.1	Functions of Procaryotic Structures
Plasma membrane	Selectively permeable barrier, mechanical boundary of cell, nutrient and waste transport, location of many metabolic processes (respiration, photosynthesis), detection of environmental cues for chemotaxis
Gas vacuole	Buoyancy for floating in aquatic environments
Ribosomes	Protein synthesis
Inclusion bodies	Storage of carbon, phosphate, and other substances
Nucleoid	Localization of genetic material (DNA)
Periplasmic space	Contains hydrolytic enzymes and binding proteins for nutrient processing and uptake
Cell wall	Gives procaryotes shape and protection from osmotic stress
Capsules and slime layers	Resistance to phagocytosis, adherence to surfaces
Fimbriae and pili	Attachment to surfaces, bacterial mating
Flagella	Movement
Endospore	Survival under harsh environmental conditions

Plasma membrane

- The **plasma membrane encompasses the cytoplasm of both** procaryotic and eucaryotic cells.
- It is the chief point of contact with the cell’s environment
- The plasma membrane also serves as a selectively permeable barrier:
- It allows particular ions and molecules to pass, either into or out of the cell, while preventing the movement of others.
- Thus the membrane prevents the loss of essential components through leakage while allowing the movement of other molecules.

- The procaryotic plasma membrane also is the location of a variety of crucial metabolic processes: respiration, photosynthesis, and the synthesis of lipids and cell wall constituents
- The membrane contains special receptor molecules that help procaryotes detect and respond to chemicals in their surroundings.

Fluid Mosaic model of PLASMA membrane

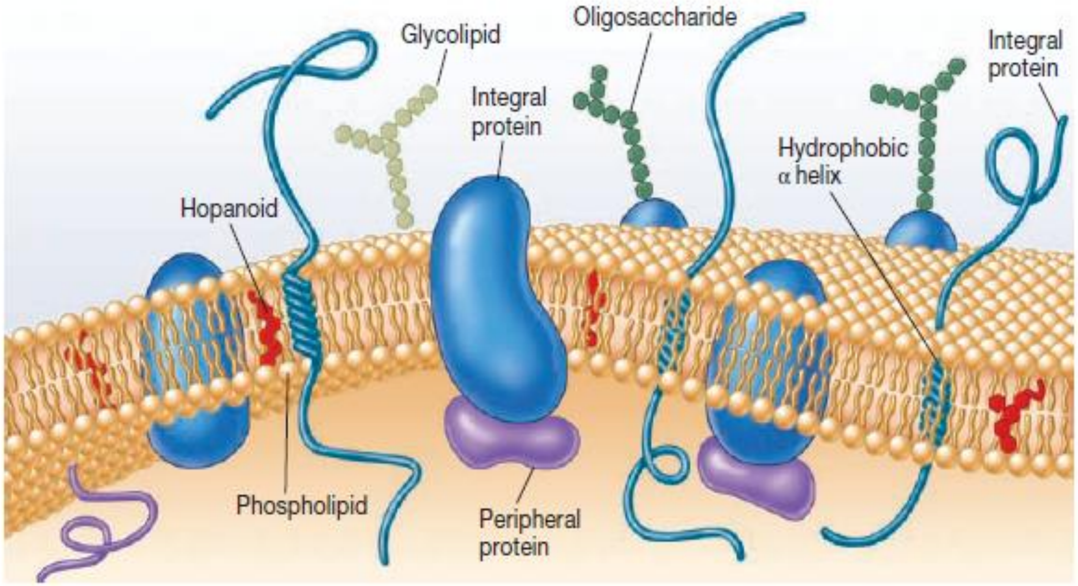


Figure 3.5 Bacterial Plasma Membrane Structure. This diagram of the fluid mosaic model of bacterial membrane structure shows the integral proteins (blue) floating in a lipid bilayer. Peripheral proteins (purple) are associated loosely with the inner membrane surface. Small spheres represent the hydrophilic ends of membrane phospholipids and wiggly tails, the hydrophobic fatty acid chains. Other membrane lipids such as hopanoids (red) may be present. For the sake of clarity, phospholipids are shown in proportionately much larger size than in real membranes.

- Bacterial membranes differ from eukaryotes in lacking sterols like cholesterols
- Many bacterial membranes have sterol like molecules called Hopanoids

BACTERIAL CELL WALL

- The cell wall is the layer, usually fairly rigid, that lies just outside the plasma membrane
- It is one of the most important procaryotic structures for several reasons:
- It helps determine the shape of the cell
- It helps protect the cell from osmotic lysis
- It can protect the cell from toxic substances
- In pathogens, it can contribute to pathogenicity.
- The procaryotic cell wall also is the site of action of several antibiotics.

Bacterial cell wall structure

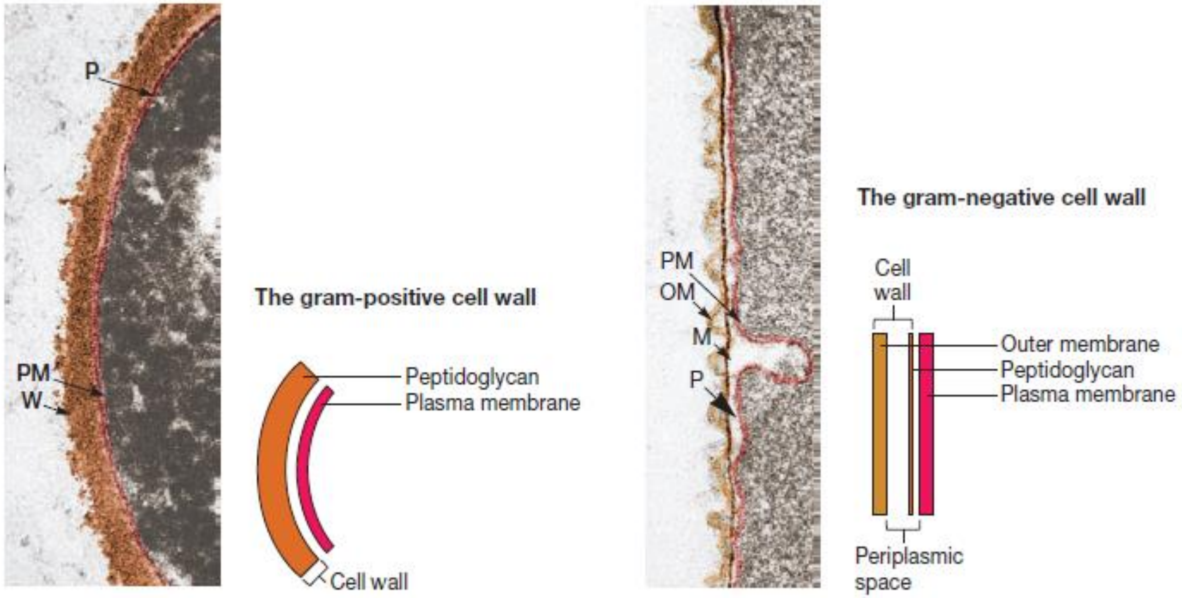


Figure 3.17 Gram-Positive and Gram-Negative Cell Walls. The gram-positive envelope is from *Bacillus licheniformis* (left), and the gram-negative micrograph is of *Aquaspirillum serpens* (right). M; peptidoglycan or murein layer; OM, outer membrane; PM, plasma membrane; P, periplasmic space; W, gram-positive peptidoglycan wall.

Bacterial cell wall

- After Christian Gram developed Gram staining 1884 bacteria are classified into two groups
- Gram-positive bacteria stained purple, whereas

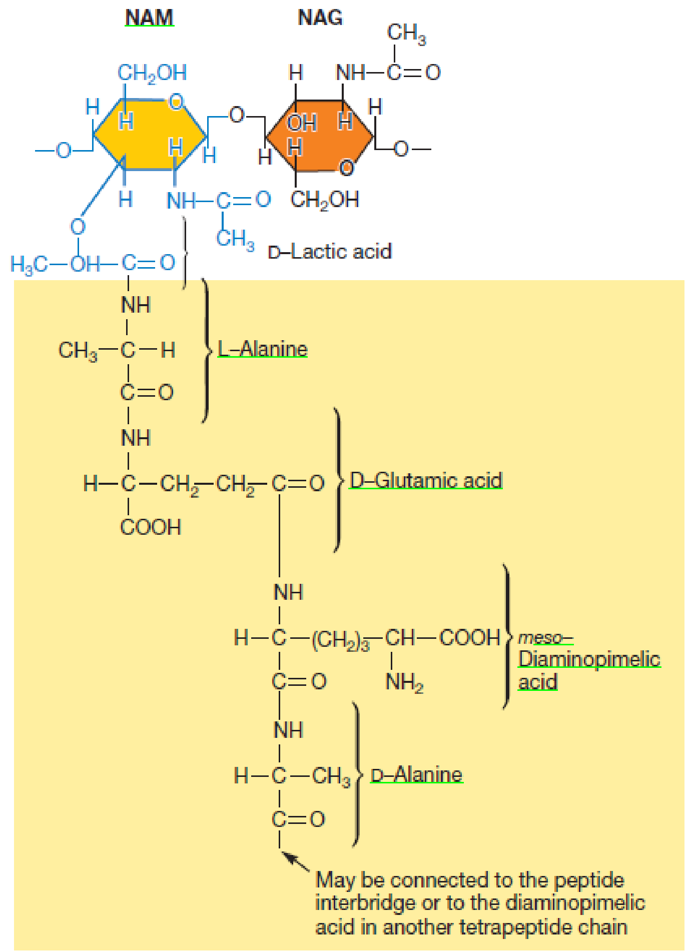
  gram-negative bacteria were colored pink or red by the technique
- The gram-positive cell wall consists of a single 20 to 80 nm thick homogeneous layer of p**eptidoglycan (murein) lying** outside the plasma membrane
- Gram-negative cell wall is quite complex as it has a 2 to 7 nm peptidoglycan layer covered by a 7 to 8 nm thick **outer membrane.**

- Because of the thicker peptidoglycan layer, the walls of Grampositive cells are more resistant to osmotic pressure than those of gram-negative bacteria
- All the structures from the plasma membrane outward the **cell envelope.**
- Therefore this includes the plasma membrane, cell wall, and structures like capsules

Peptidoglycan structure

- Peptidoglycan, or murein, is an enormous meshlike polymer composed of many identical subunits.
- The polymer contains two sugar derivatives, *N-acetylglucosamine and N-acetylmuramic*
- acid (the lactyl ether of *N-acetylglucosamine), and several* different amino acids.
- Three of these amino acids are notfound in proteins: D-glutamic acid, D-alanine, and *mesodiaminopimelic* acid.
- The presence of D-amino acids protects against degradation by most peptidases, which recognize only the L-isomers of amino acid residues.

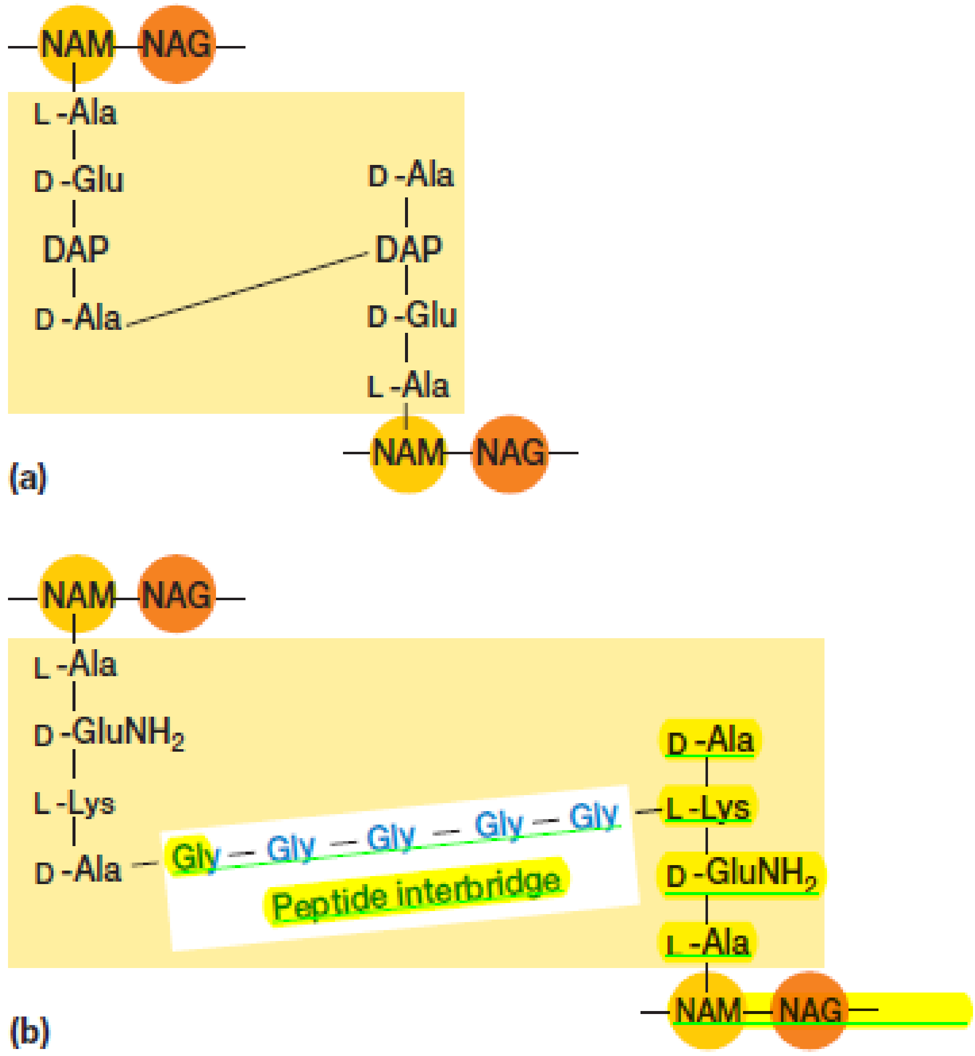
Peptidoglycan subunit



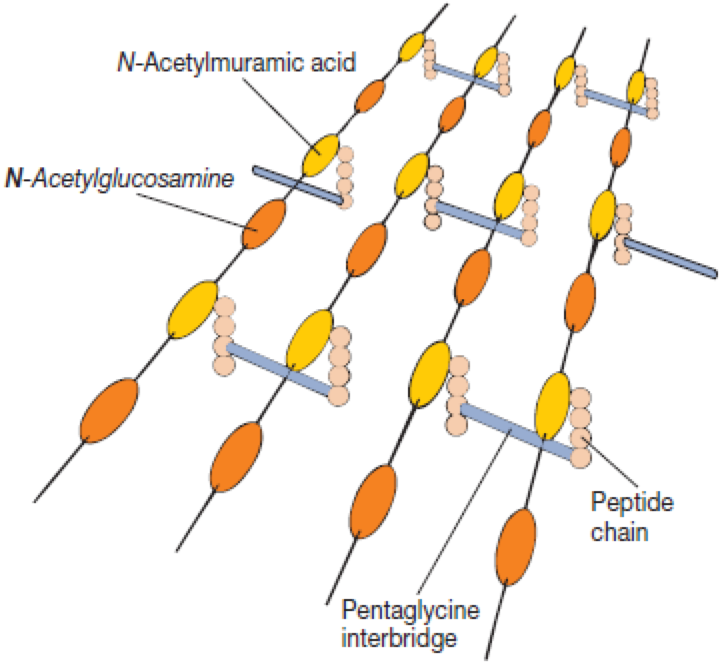
- Peptidoglycan is a polymer composed of alternating *N-acetylglucosamine and Nacetylmuramic* acid residues
- A peptide chain of four alternating D- and L-amino acids is connected to the carboxyl group of *Nacetylmuramic* acid
- Many bacteria replace *meso-diaminopimelic*

  acid with another diaminoacid, usually L-lysine

- In order to make a strong, meshlike polymer, chains of peptidoglycan subunits must be joined by cross-links between the peptides.
- Often the carboxyl group of the terminal D-alanine is connected directly to the amino group of diaminopimelic acid,but a **peptide interbridge may be used instead (penta glycine bridge)**
- Most gram-negative cell wall peptidoglycan lacks the peptide interbridge.

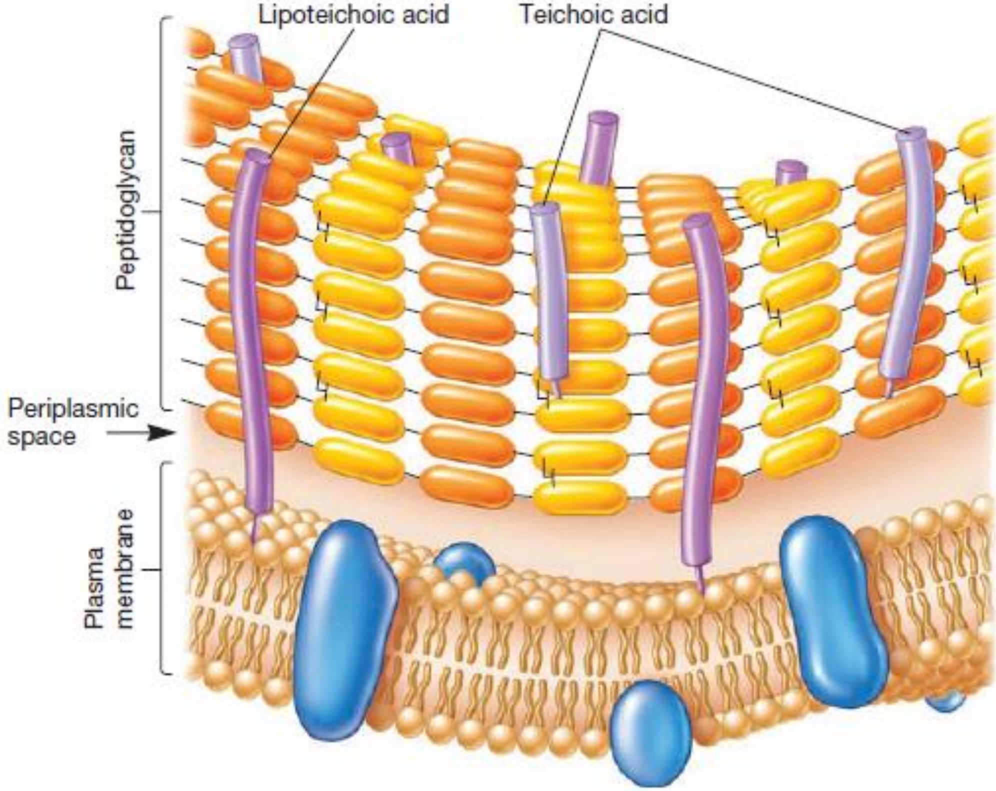


NAM
NAG
L -Ala
D -Glu
DAP
D -Ala
D -Ala
DAP
D -Glu
L -Ala
NAM
NAG
(a)
NAM
NAG
L -Ala
D -GluNH2
L -Lys
D -Ala
Gly — Gly — Gly — Gly — Gly
Peptide interbridge
D -Ala
L -Lys
D -GluNH2
L -Ala
NAM
NAG
(b)



N-Acetylmuramic acid
N-Acetylglucosamine
Peptide chain
Pentaglycine interbridge

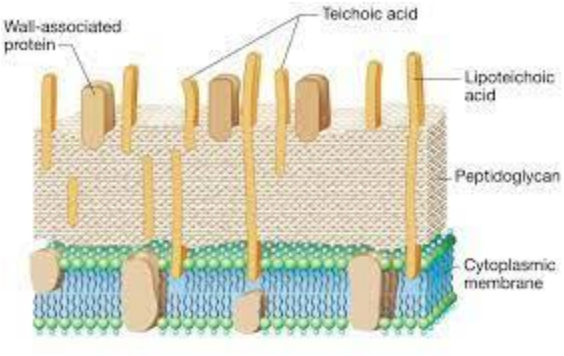
Gram positive cell wall



.23 The Gram-Positive Envelope.

- Gram-positive bacteria normally have cell walls that are thick and composed primarily of peptidoglycan
- Peptidoglycan in grampositive bacteria often contains a peptide interbridge
- **In addition, gram-positive cell walls usually contain** large amounts of **teichoic acids, polymers of glycerol or ribitol** joined by phosphate groups
- **Amino** acids such as D-alanine or sugars like glucose are attached to the glycerol and ribitol groups.

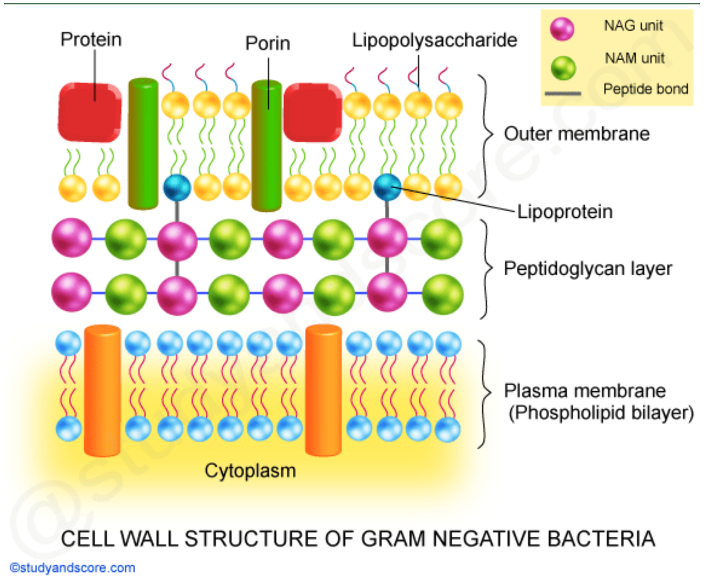
- The teichoic acids are covalently connected to either the peptidoglycan itself or to plasma membrane lipid , then they are called lipoteichoic acids.
- Teichoic acids appear to extend to the surface of the peptidoglycan, give the gram-positive cell wall its negative charge
- Teichoic acids are not present in gram-negative bacteria.



- The periplasmic space of gram-positive bacteria,
 lies between the plasma membrane and the cell wall and is smaller than that of gram-negative bacteria.
- An enzyme called sortase catalyzes the attachment of surface proteins to the gram-positive peptidoglycan

Gram negative cell wall

- Gram-negative cell walls are much more complex than gram-positive walls
- The thin peptidoglycan layer next to the plasma membrane and bounded on either side by the periplasmic space



- Peptidoglycan layer may constitute not more than 5 to 10% of the wall weight
- The periplasmic space of gram-negative bacteria ranges in size from 1 nm to as great as 71 nm.
- It may constitute about 20 to 40% of the total cell volume, and it is usually 30 to 70 nm wide

- The outer membrane lies outside the thin peptidoglycan layer **and is linked to the cell in two ways.**
- **The** first is by Braun's lipoprotein, the most abundant protein in the outer membrane.
- This small lipoprotein is covalently joined to

  the underlying peptidoglycan, and is embedded in the outer membrane by its hydrophobic end
- The second linking mechanism involves the many adhesion sites joining the outer membrane and the plasma membrane.
- In *E. coli, 20 to 100 nm areas of contact between the* two membranes can be seen.

Gram negative cell envelope

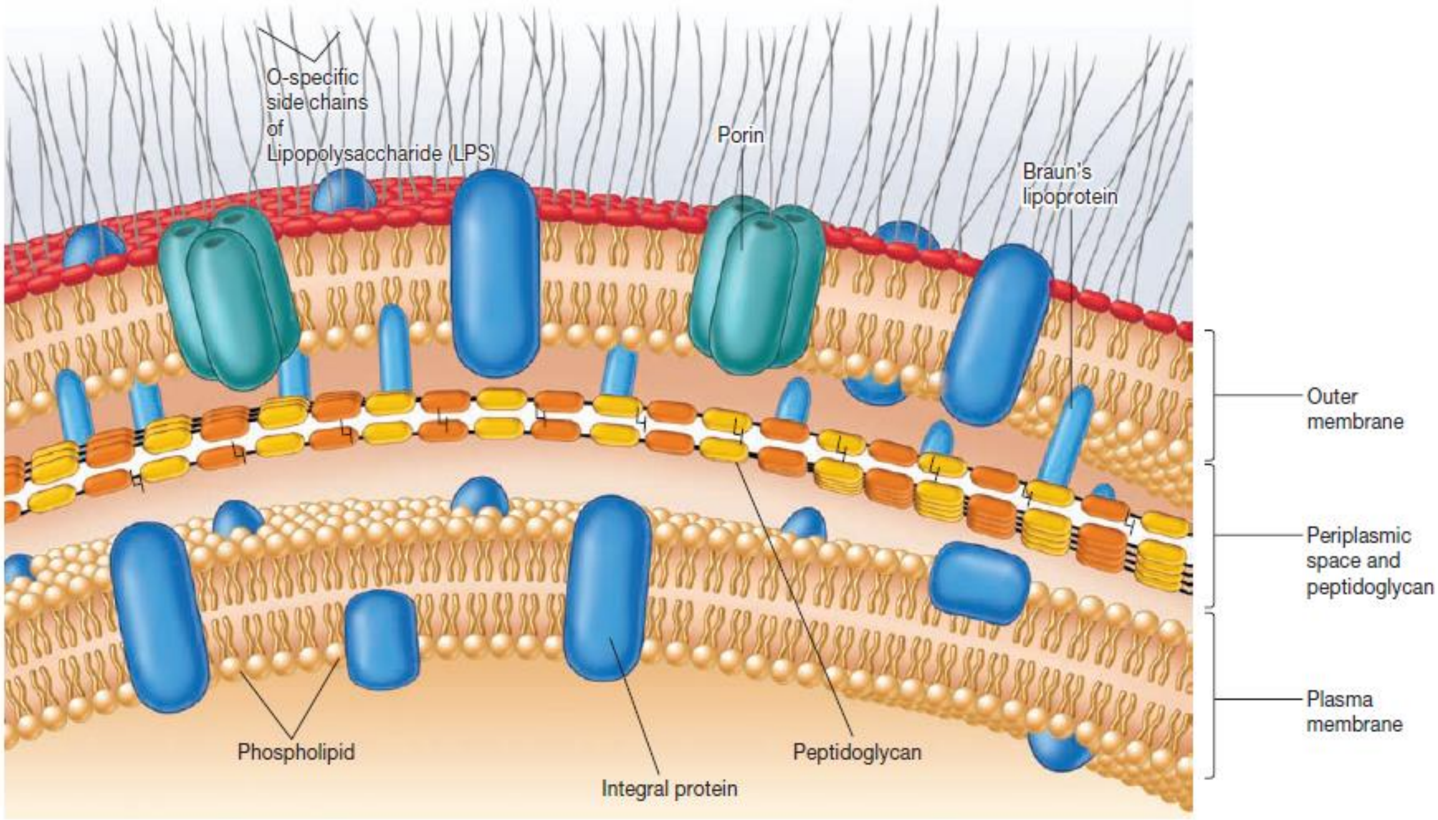
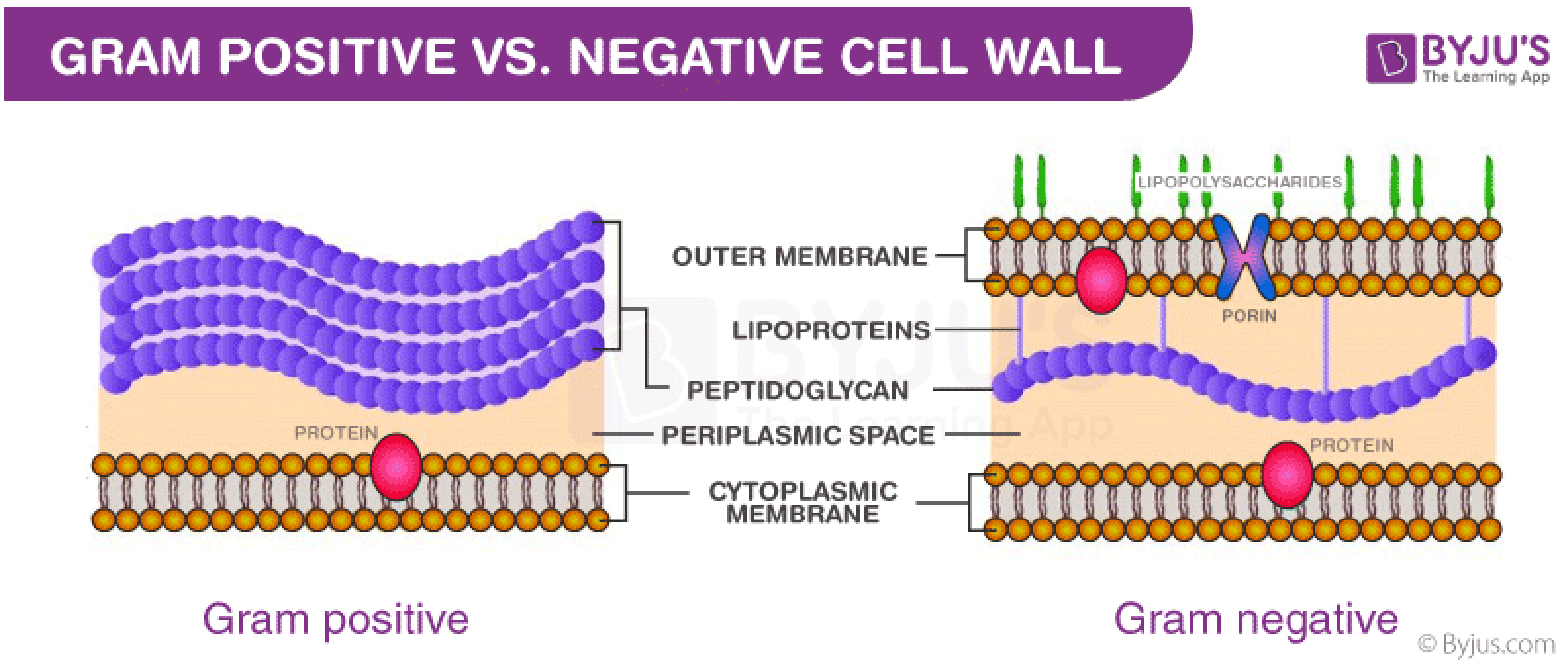


Figure 3.25 **The Gram-Negative Envelope.**


GRAM POSITIVE VS. NEGATIVE CELL WALL
BYJU'S
The Learning App
LIPOPOLYSACCHARIDES
OUTER MEMBRANE
PORIN
LIPOPROTEINS
PEPTIDOGLYCAN
PROTEIN
PERIPLASMIC SPACE
PROTEIN
CYTOPLASMIC MEMBRANE
Gram positive
Gram negative
© Byjus.com

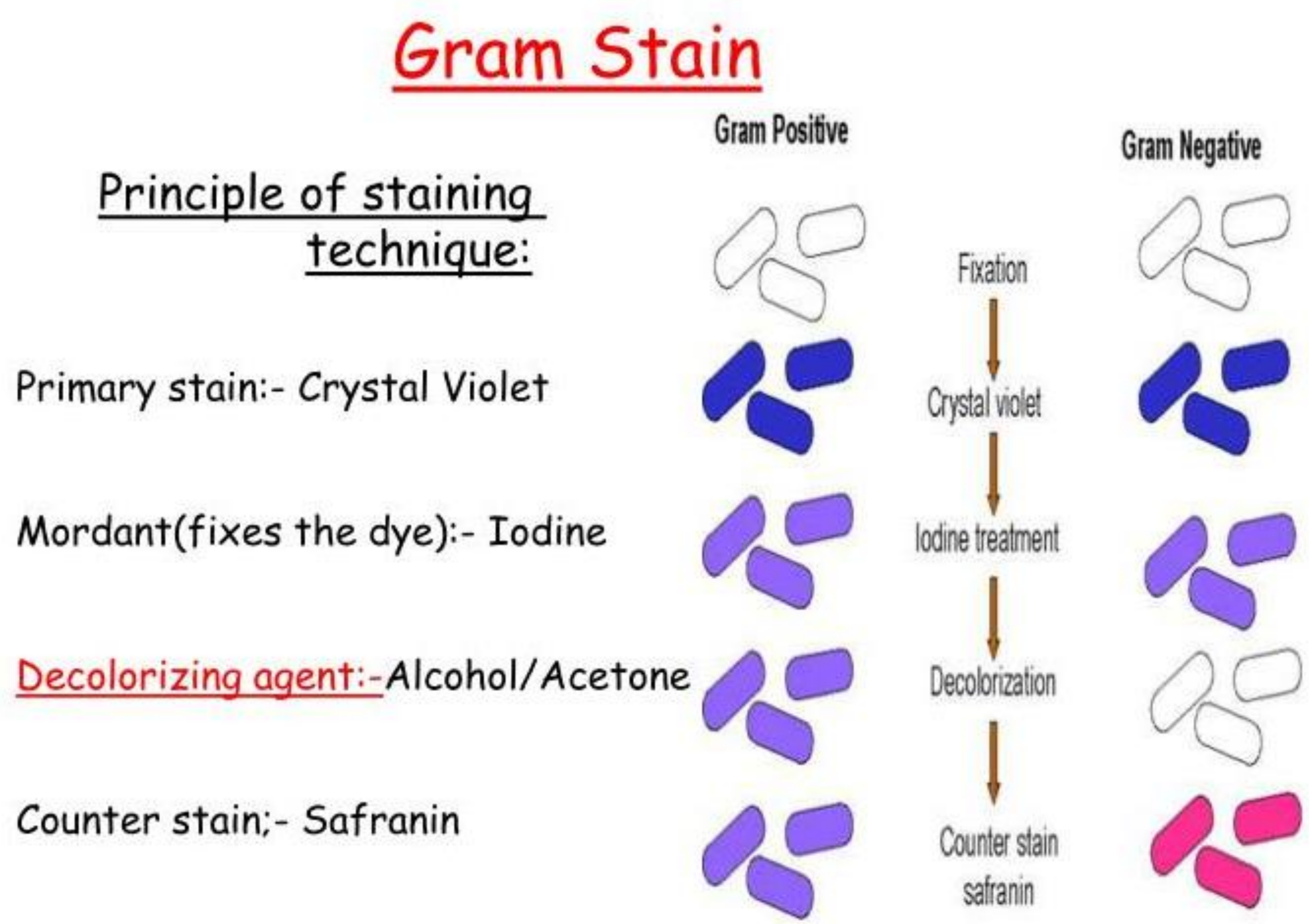
- Possibly the most unusual constituents of the outer membrane are its **lipopolysaccharides (LPSs).**
- **These large, complex molecules** contain both lipid and carbohydrate consist of three parts: (1) lipid A, (2) the core polysaccharide, and (3) the O side chain.

Functions of LPS

- LPS contributes to the negative charge on the bacterial surface.
- Lipid A also helps stabilize outer membrane structure.
- LPS may contribute to bacterial attachment to surfaces and biofilm formation.
- A major function of LPS is that it aids in creating a permeability barrier., restrict the entry of bile salts, antibiotics, and other toxic substances that might kill or injure the bacterium.

- LPS also plays a role in protecting pathogenic gram-negative bacteria from host defenses
- The O side chain of LPS is also called the O antigen because it elicits an immune response.
- Importantly, the lipid A portion of LPS often is toxic; as a result, the LPS can act as an endotoxin
- If the bacterium enters the bloodstream, LPS endotoxin can cause a form of septic shock
- The outer membrane also have transport proteins called Porin channels

Mechanism of gram staining



Mechanism of Gram staining

- The difference between gram-positive and gram-negative bacteria is due to the physical nature of their cell walls.
- The peptidoglycan act as a permeability barrier preventing loss of crystal violet.
- During the procedure the bacteria are first stained with crystal violet and next treated with iodine to promote dye retention
- When gram-positive bacteria are then treated with ethanol, the alcohol shrink the pores of the thick peptidoglycan.

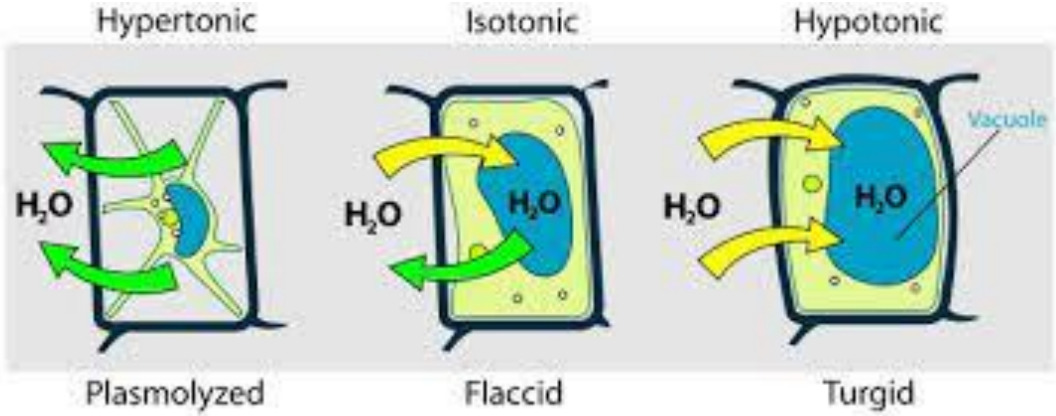
- Thus the dye-iodine complex is retained during this short decolorization step and the bacteria remain purple
- In contrast, recall that gram negative peptidoglycan is very thin, not as highly cross-linked, and has larger pores
- Alcohol treatment also may extract enough

  lipid from the gram-negative outer membrane to increase its porosity further
- Also the Gram positive cells have more acidic cytoplasm which have more affinity to the basic dye crystal violet

- For these reasons, alcohol more readily removes the purple crystal violet-iodine complex from gram-negative bacteria.
- Thus gram-negative bacteria are then easily stained red or pink by the counterstain safranin

Cell wall and osmotic protection

- When cells are in hypotonic solutions water moves into the cell, causing it to swell and the cell would burst—a process called **lysis.**
- In hypertonic solutions, water flows out and the cytoplasm shrivels up—a process called **plasmolysis.**



SPHROPLAST AND PROTOPLAST

- The cell wall peptidoglycan layer can be removed by treatment with either lysozyme or penicillin
- The enzyme **lysozyme attacks peptidoglycan by hydrolyzing the** bond that connects *N-acetylmuramic acid with N-acetylglucosamine*
- **Penicillin** inhibits peptidoglycan synthesis.
- In gram positive bacteria treatment with lysozyme or penicillin results in the complete loss of the cell wall, and the cell becomes a protoplast

- When gram-negative bacteria are exposed to lysozyme or penicillin, the peptidoglycan layer is lost, but the outer membrane remains. These cells are called **spheroplasts.**
- Because they lack a complete cell wall, both protoplasts and spheroplasts are osmotically sensitive and can grow only in isotonic solutions

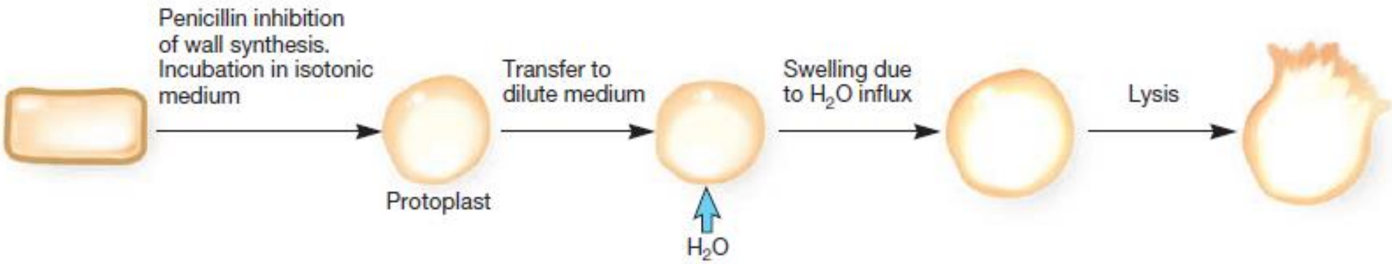


Figure 3.29 Protoplast Formation and Lysis. Protoplast formation induced by incubation with penicillin in an isotonic medium. Transfer to dilute medium will result in lysis.

Bacterial cell structure
Cell wall – Peptidoglycan

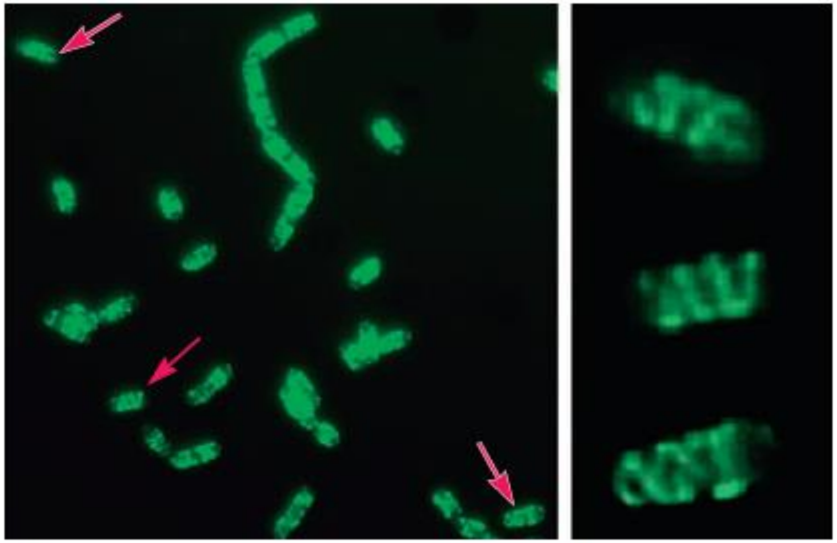
- **Isotonic media:**
  - **Gram-positive bacteria** → Lysozyme → **Protoplasts**
  - **Gram-negative bacteria** → EDTA-lysozyme → **Spheroplasts**
  - If protoplasts/spheroplasts are able to grow and divide, they are called **L-forms**.

Cytoplasmic matrix

- About 70% of bacterial mass is water
- The plasma membrane and everything within is called the **protoplast**

Prokaryotic cytoskeleton

- Homologs of all three eucaryotic cytoskeletal elements (microfilaments, intermediate filaments, and microtubules) have been identified in bacteria, and one has been identified in archaea
- **The cytoskeletal filaments of** procaryotes are structurally similar to their eucaryotic counterparts and carry out similar functions
- They participate in cell division, localize proteins to certain sites in the cell, and determine cell shape



(a) (b)

Table 3.2	Procaryotic Cytoskeletal Proteins	
Procaryotic Protein (Eucaryotic Counterpart)	**Function**	**Comments**
FtsZ (tubulin)	Cell division	Widely observed in *Bacteria* and *Archaea*
MreB (actin)	Cell shape	Observed in many rod-shaped bacteria; in *Bacillus subtilis* is called Mbl
Crescentin (intermediate filament proteins)	Cell shape	Discovered in *Caulobacter crescentus*

Inclusion bodies

- **Inclusion bodies, granules of organic or inorganic material that** often are clearly visible in a light microscope, are present in the cytoplasmic matrix.
- These bodies usually are used for storage (e.g., carbon compounds, inorganic substances, and energy), and also reduce osmotic pressure by tying up molecules in particulate form.
- Some inclusion bodies lies free in the cytoplasm

  Eg: polyphosphate granules, cyanophycin granules, and some glycogen granules


gettyimages
KATERYNA KON/SCIENCE PHOTO
LIBRARY
685024943

- Inclusion bodies enclosed by a shell

  about 2.0 to 4.0 nm thick are called enclosed inclusion bodies
- Examples of enclosed inclusion bodies are

  poly--hydroxybutyrate granules, some glycogen and sulfur granules, carboxysomes, and gas vacuoles.
- Many inclusion bodies are used for storage; their quantity will vary with the nutritional status of the cell.
- For example, polyphosphate granules will be depleted in freshwater habitats that are phosphate limited

- Organic inclusion bodies usually contain either glycogen or poly—hydroxyalkanoates
- Cyanobacteria, a group of photosynthetic bacteria, have two distinctive organic inclusion bodies. **Cyanophycin granules** *and* **Carboxysomes**
- **Carboxysomes** are present in many cyanobacteria and other CO2-fixing bacteria.
- They contain the enzyme ribulose-1, 5-bisphosphate carboxylase, called Rubisco.
- Rubisco is the critical enzyme for CO2 fixation,.

- A most remarkable organic inclusion body is the **gas vacuole,** a structure that provides buoyancy to some aquatic procaryotes

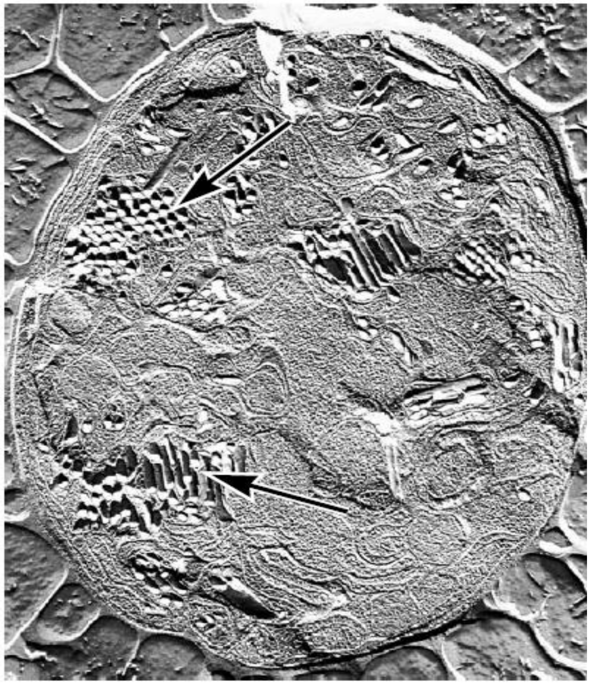


Figure 3.14 Gas Vesicles and Vacuoles. A freeze-fracture

- Two major types of inorganic inclusion bodies are seen in procaryotes:
- polyphosphate granules and sulfur granules.
- Many bacteria store phosphate as p**olyphosphate granules or volutin Granules**
- Thus volutin granules function as storage reservoirs for phosphate, an important component of cell constituents such as nucleic acids.

- These granules are sometimes called **metachromatic granules because they show the metachromatic** effect; that is, they appear red when stained with the blue dyes methylene blue or toluidine blue.
- Sulfur granules are used by some procaryotes to store sulfur temporarily

- Inorganic inclusion bodies can be used for purposes other than storage.
- An excellent example is the **magnetosome, which** is used by some bacteria to orient in the Earth's magnetic field.
- Many of these inclusion bodies contain iron in the form of magnetite
- Eg: Aquaspirillum magnetotactum

RIBOSOME

- Ribosomes are very complex structures made of both protein and ribonucleic acid (RNA)
- They are the site of protein synthesis
- Procaryotic ribosomes are called 70S ribosomes (as opposed to 80S in eucaryotes) and are
- constructed of a 50S and a 30S subunit
- **The S in 70S** stands for **Svedberg unit**
- **This is the unit of the** sedimentation coefficient, a measure of the sedimentation velocity in a centrifuge

Prokaryotic Ribosome

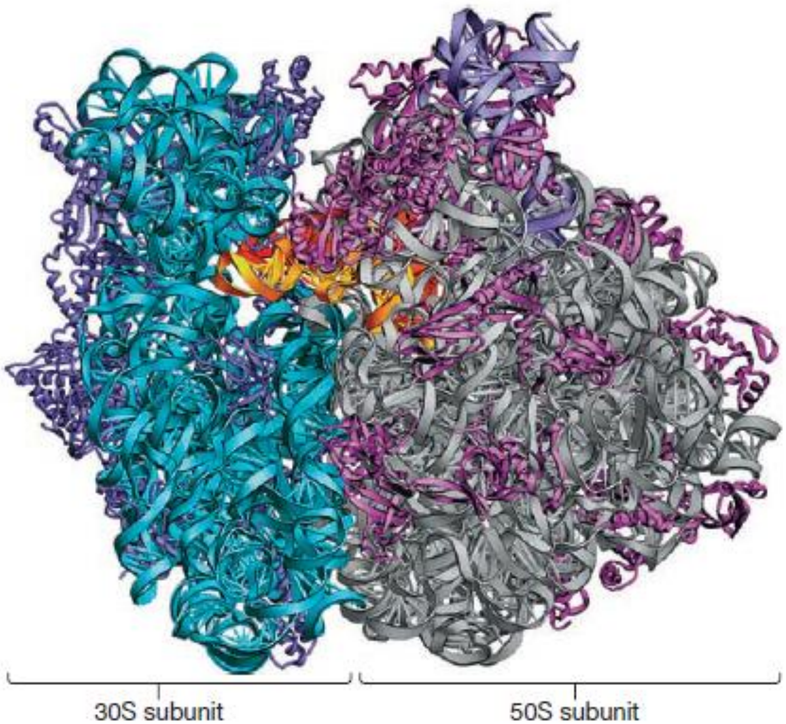
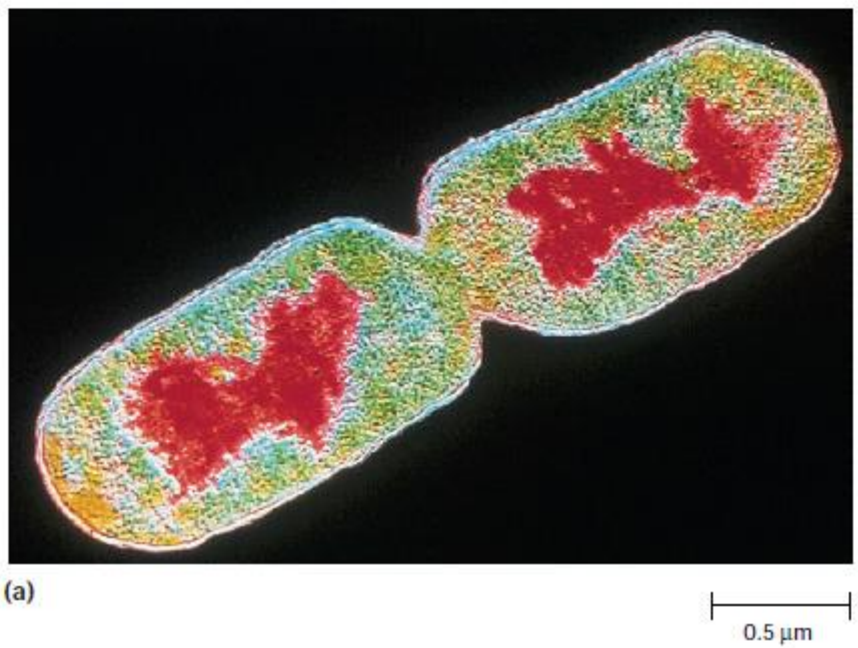


Figure 3.15 Procaryotic Ribosome. The two subunits of a bacterial ribosome are shown. The 50S subunit includes 23S rRNA (gray) and 5S rRNA (light blue), while 16S rRNA (cyan) is found in the 30S subunit. A molecule of tRNA (gold) is shown in the A site. To generate this ribbon diagram, crystals of purified bacterial ribosomes were grown, exposed to X rays, and the resulting diffraction pattern analyzed.

THE NUCLEOID

- Procaryotes lack a membrane-delimited nucleus
- The procaryotic chromosome is located in an irregularly shaped region called the **nucleoid or the nuclear body or chromatin** body or nuclear region
- **Usually procaryotes contain** a single circle of double-stranded **deoxyribonucleic acid (DNA),**
- but some have a linear DNA chromosome (*Borrelia burgdorferi*) and some, such as *Vibrio cholerae and Borrelia burgdorferi (the causative agents of* cholera and Lyme disease, respectively), have more than onechromosome.

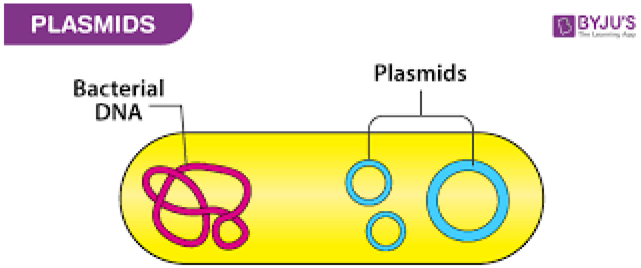
THE NUCLEOD



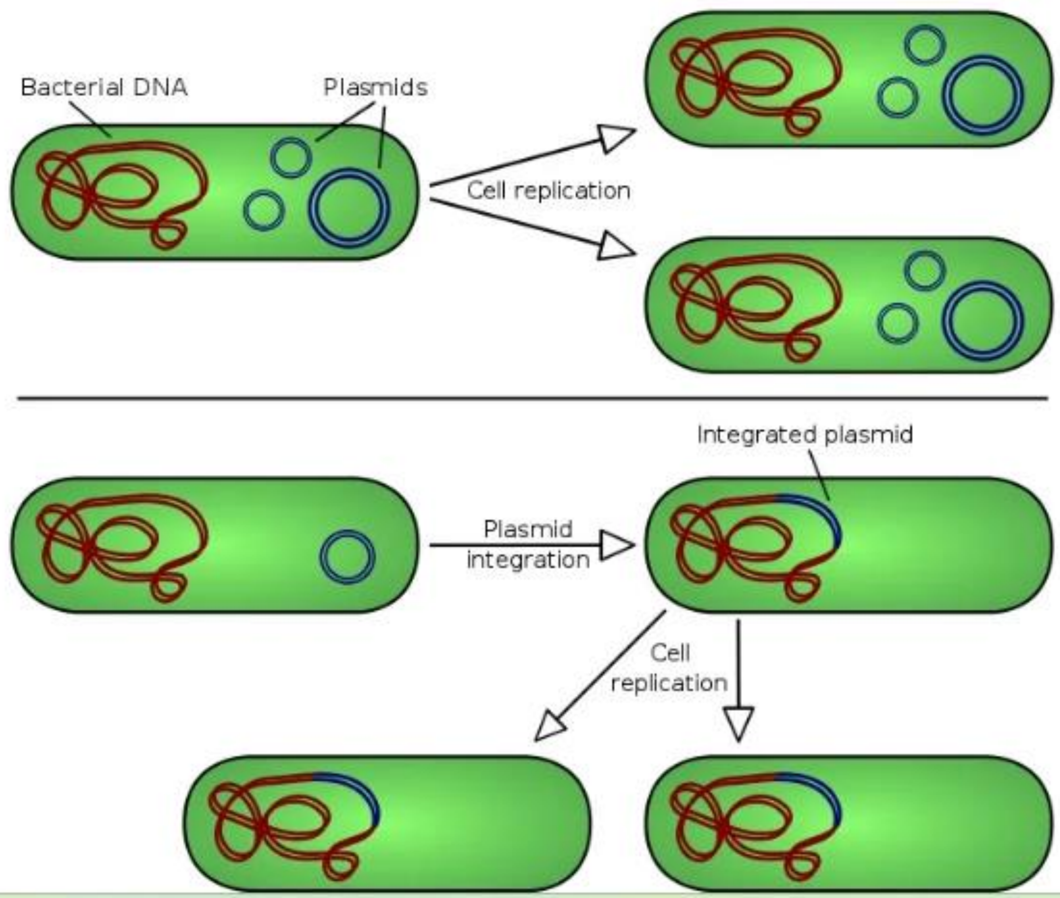
A color-enhanced transmission electron micrograph of a thin section of a dividing *E. coli cell. The red areas are* the nucleoids present in the two daughter cells

PLASMIDS

- Extrachromosomal DNA molecules called plasmids
- **Plasmids are small, double-stranded DNA molecules that can** exist independently of the chromosome
- Both circular and linear plasmids have been documented, but most known plasmids are circular
- *B. burgdorferi, carries* 12 linear and 9 circular plasmids.

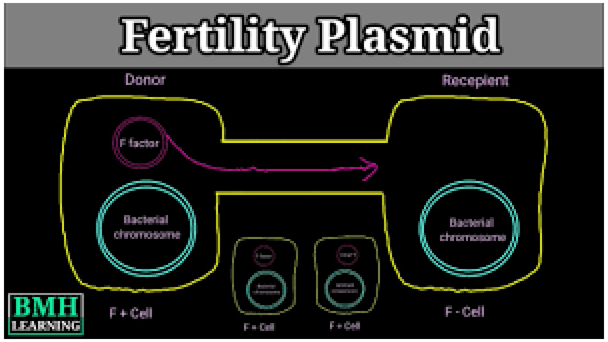


- Plasmids are able to replicate autonomously
- Single-copy plasmids produce only one copy per host cell
- Multicopy plasmids may be present at concentrations of 40 or more per cell
- Some plasmids are able to integrate into the chromosome and are thus replicated with the chromosome. Such plasmids are called **episomes**
- The loss of a plasmid is called **curing**
- Curing can be induced using acridine mutagens, UV and ionizing radiation, thymine starvation, antibiotics, and growth above optimal temperatures.


Bacterial DNA
Plasmids
Cell replication
Integrated plasmid
Plasmid integration
Cell replication

Classification of plasmid

- **Conjugative plasmids**
- **They have genes for the construction** of hairlike structures called pili and can transfer copies of themselves to other bacteria during conjugation
- Perhaps the best studied conjugative plasmid is the **F factor (fertility factor or F** plasmid)



- Resistance plasmids or R plasmids which confer antibiotic resistance on the cells that contain them
- Bacteriocin encoding plamids:**Bacteriocins are bacterial proteins** that destroy other bacteria. They usually act only against closely related strains
- **Col plasmids contain genes for the synthesis of bacteriocins** known as colicins, which are directed against *E. coli*
- Cloacins kill *Enterobacter species*

- **Virulence plasmids encode factors that make their hosts more** pathogenic
- For example, enterotoxigenic strains of *E. coli cause* traveler's diarrhea because they contain a plasmid that codes for an enterotoxin
- **Metabolic plasmids carry genes for enzymes that** degrade substances such as aromatic compounds (toluene), pesticides (2,4-dichlorophenoxyacetic acid), and sugars (lactose

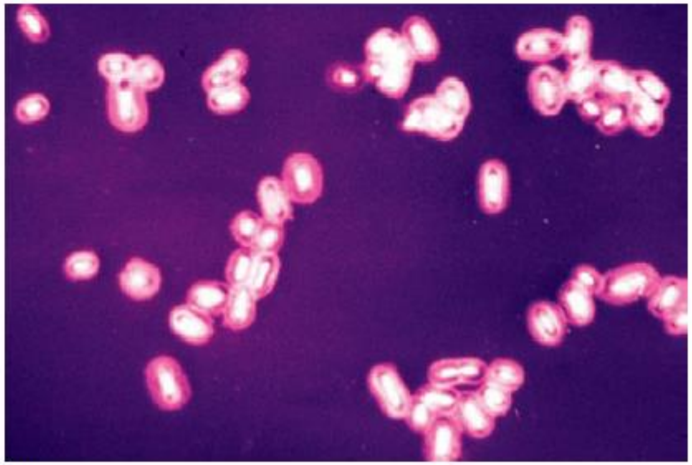
Components external to cell wall

Capsules, Slime Layers, and S-Layers

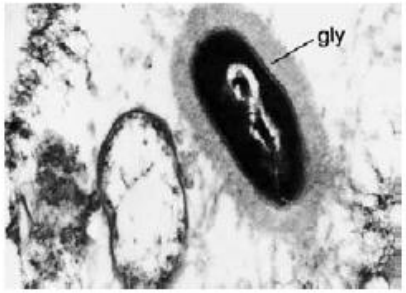
- When the layer is well organized and not easily washed off, it is called a **capsule**
- ***It is called a slime layer*** when it is a zone of diffuse, unorganized material that is removed easily.
- When the layer consists of a network of polysaccharides extending from the surface of the cell, it is referred to as the **glycocalyx**
- *The term Glycocalyx encompass both capsules*

  and slime layers because they usually are composed of polysaccharides.

- The capsule of Bacillus is made of polypeptide : Poly D glutamic acid



(a) *K. pneumoniae*



(b) *Bacteroides*

- Capsule help pathogenic bacteria resist phagocytosis by host phagocytes.
- Capsules contain a great deal of water and can protect against dessiccation
- They exclude viruses and most hydrophobic toxic materials such as detergents
- The glycocalyx also aids in attachment to solid surfaces, including tissue surfaces in plant and animal hosts
- **Gliding bacteria often** produce slime, which in some cases, has been shown to facilitate motility.

S LAYER

- Many procaryotes have a regularly structured layer called an **S layer** on their surface
- The S-layer has a pattern something like floor tiles and is composed of protein or glycoprotein
- In gram-negative bacteria the S-layer adheres directly to the outer membrane
- it is associated with the peptidoglycan surface in gram positive bacteria
- It may protect the cell against ion and pH fluctuations, osmotic stress, enzymes, or the predacious bacterium *Bdellovibrio*.

- *The S-layer also helps maintain the shape and envelope* rigidity of some cells
- It can promote cell adhesion to surfaces
- Finally, the S-layer seems to protect some bacterial pathogens against host defenses, thus contributing to their virulence

Pili and fimbriae

- Short, fine, hair like appendages that are thinner than flagella
- Helps in adhesion
- Sex pili play important role in conjugation
- Made of protein subunits called pilin

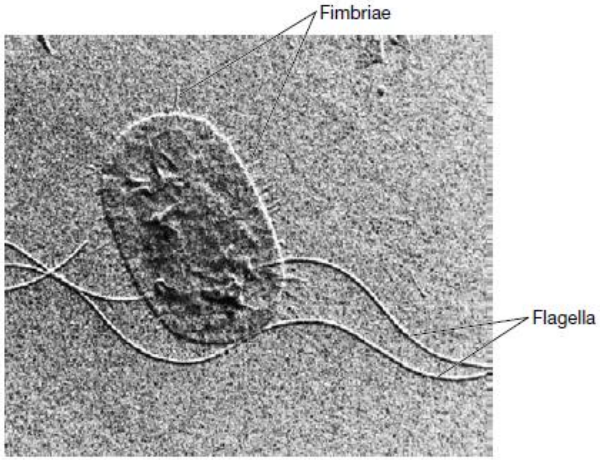
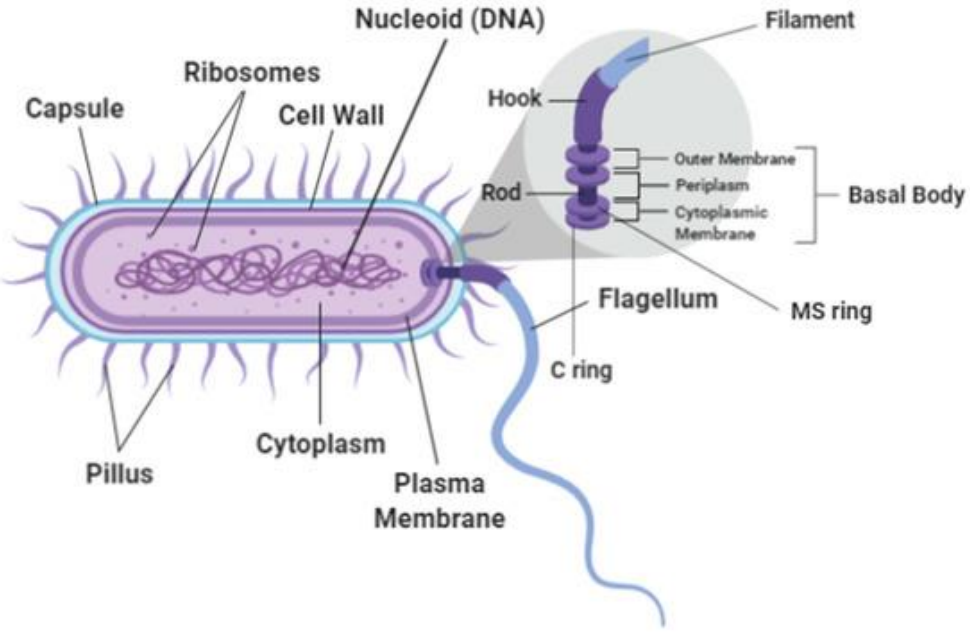


Figure 3.37 Flagella and Fimbriae. The long flagella and the numerous shorter fimbriae are very evident in this electron micrograph of the bacterium *Proteus vulgaris* (×39,000).

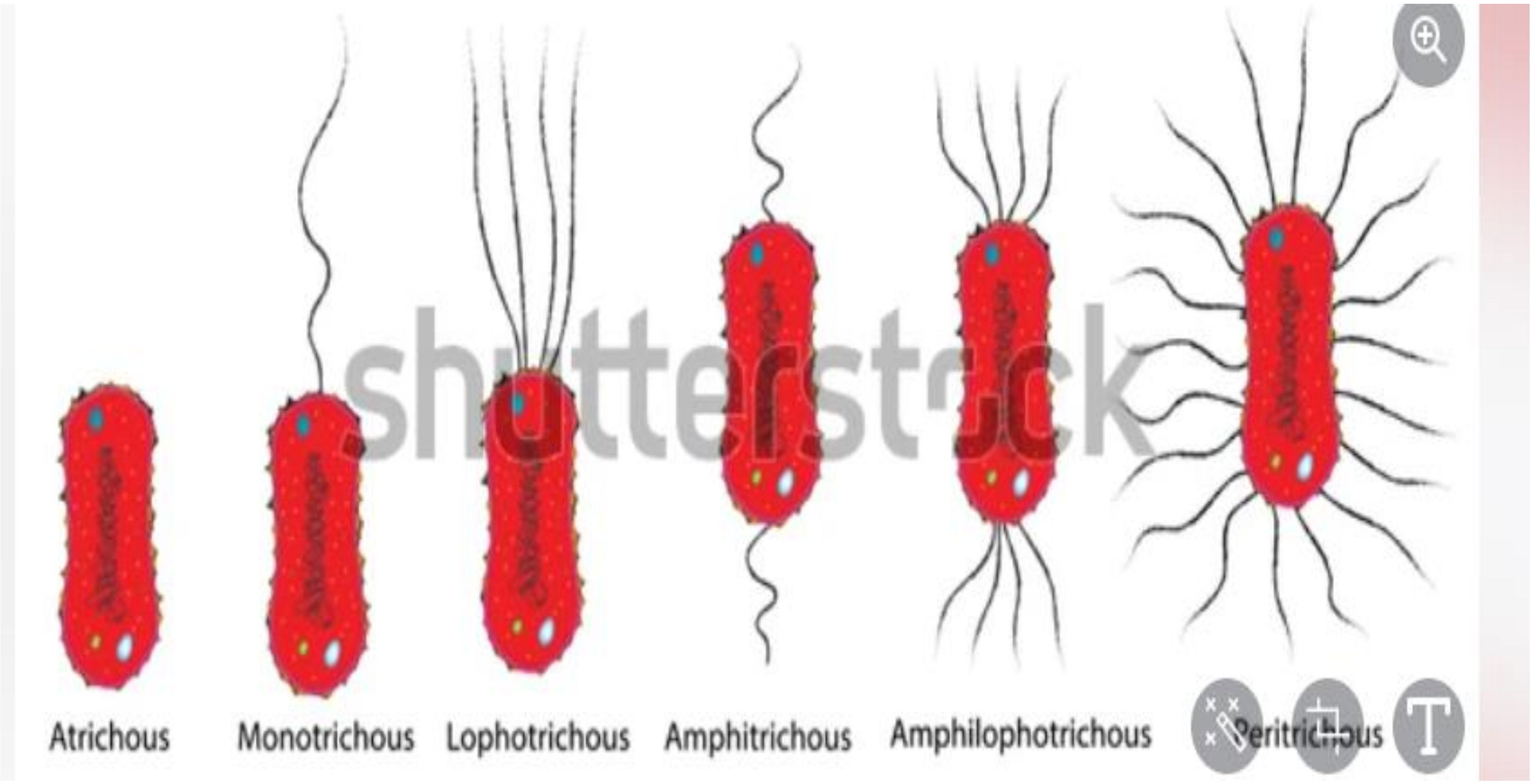
BACTERIAL FLAGELLA

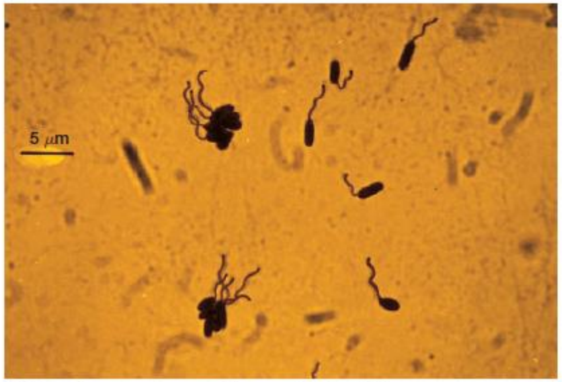
- It is the locomotory appendages of bacteria
- Bacterial flagella are slender, rigid structures, about 20 nm across and up to 15 or 20 µm long bacteria



CLASSIFICATION OF BACTERIA BASED ON FLAGELLAR ARRANGEMENT

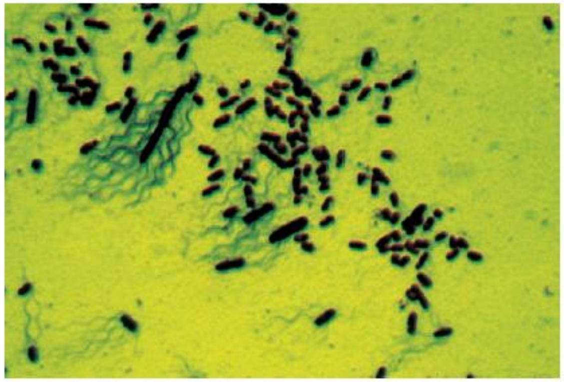
- **Monotrichous bacteria (*trichous means hair) have one*** flagellum; if it is located at an end, it is said to be a **polar flagellum**
- ***Amphitrichous bacteria (amphi means on*** both sides) have a single flagellum at each pole.
- **lophotrichous bacteria (*lopho means tuft) have a cluster of flagella*** at one or both ends
- *Flagella are spread fairly* evenly over the whole surface of **peritrichous (*peri means*** around) bacteria


Atrichous
Monotrichous
Lophotrichous
Amphitrichous
Amphilophotrichous
Peritrichous



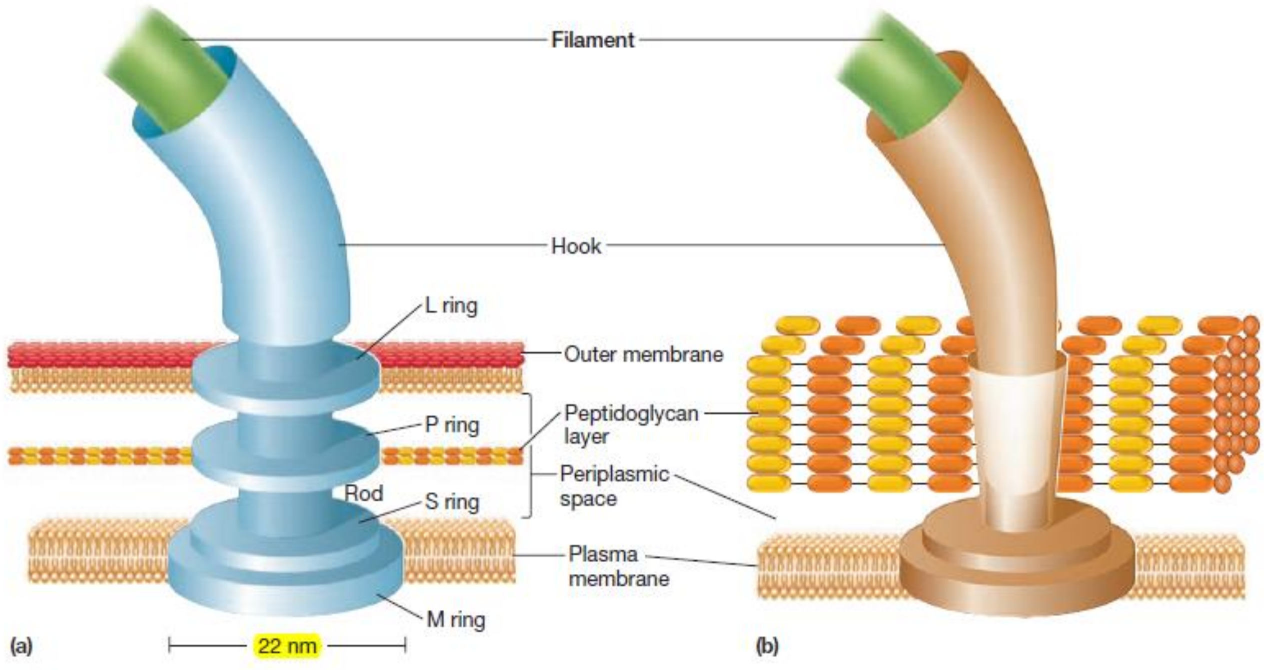
(a) *Pseudomonas*—monotrichous polar flagellation

(b) *Spirillum*—lophotrichous flagellation



(c) *P. vulgaris*—peritrichous flagellation

Flagellar structure



Gram Negative Bacteria

Gram Positive Bacteria

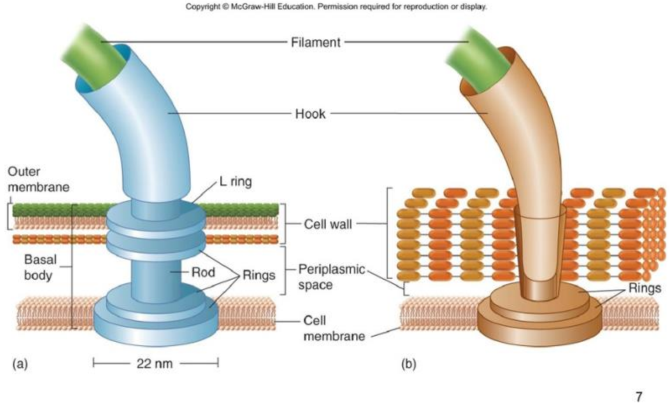
Flagellar structure

- Bacterial flagellum is composed of three parts
- The longest and most obvious portion is the **flagellar filament, which extends** from the cell surface to the tip
- A **basal body is embedded** in the cell
- A short, curved segment, the **flagellar hook, links the filament to its basal body and acts as a flexible** coupling
- The filament is a hollow, rigid cylinder constructed of subunits of the protein **flagellin and filaments ends with a** capping protein.

- The hook and basal body are quite different from the filament
- **Slightly wider than the filament, the hook is made of** different protein subunits
- The basal body is the most complex part of a flagellum
- In *E. coli and most gram-negative bacteria, the basal* body has four rings connected to a central rod
- *The* outer L and P rings associate with the lipopolysaccharide and peptidoglycan layers, respectively

- The inner M ring contacts the plasma membrane.
- Gram-positive bacteria have only two basal body rings—an inner ring connected to the plasma membrane and an outer one probably attached to the peptidoglycan

Gram-negative (a), and Gram-positive (b) Flagella



- Some bacteria have sheaths surrounding their flagella
- For example, *Bdellovibrio has a membranous structure surrounding the filament*.
- *Vibrio cholerae has a lipopolysaccharide sheath*