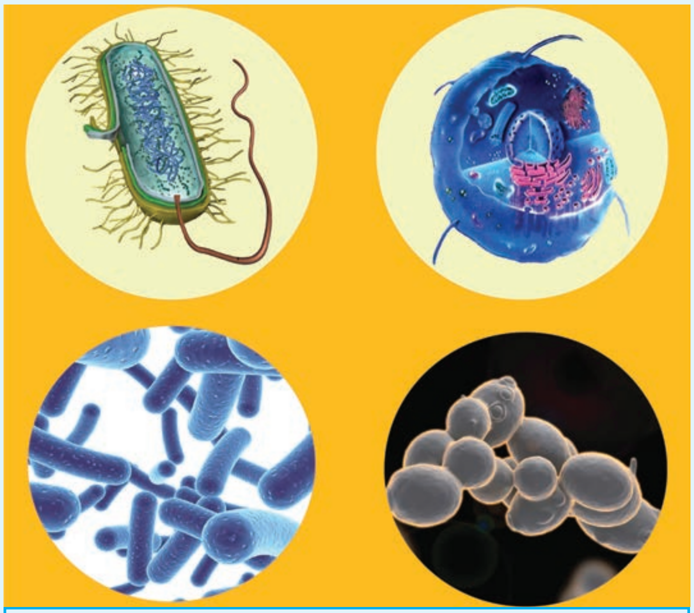
Chapter 7

Morphology of Bacteria

Chapter Outline

LYKE7



The distinction between **prokaryotes** and **eukaryotes** is considered to be the most important distinction among groups of organisms. Eukaryotic cells contain membrane bound organelles, such as mitochondria, while prokaryotic cells do not.

Learning Objectives

After studying this chapter the student will be able,

- *To know the size, shape and arrangement of bacteria.*
- *To list a few examples of bacteria with their shapes.*
- *To understand and describe the role of the structures external to the cell wall.*
- *To understand the structure, function and arrangement of bacterial flagella.*
- *To describe the role of capsule, slime layer, pili, flagella and fimbriae in a prokaryotic cell.*
- *To describe the structure and function of cell wall, outer membrane and cell membrane.*
- *To know the significance of Cell Envelope.*
- *To differentiate between Gram positive and Gram negative bacteria.*
- *To know the structures and functions internal to cell membrane.*
- *To differentiate between prokaryotic and eukaryotic cell structure.*

Living organisms are differentiated from non living matter by their (1) ability to reproduce (2) ability to ingest or assimilate food and metabolize them for energy and growth (3) ability to excrete waste products (4) ability to react to changes in their environment (irritability) and (5) susceptibility to mutation. The living organisms include a variety of micro and macro organisms of different size, shape, morphology and behaviour. They include tiny bacteria, protozoans, worms, plants and animals.

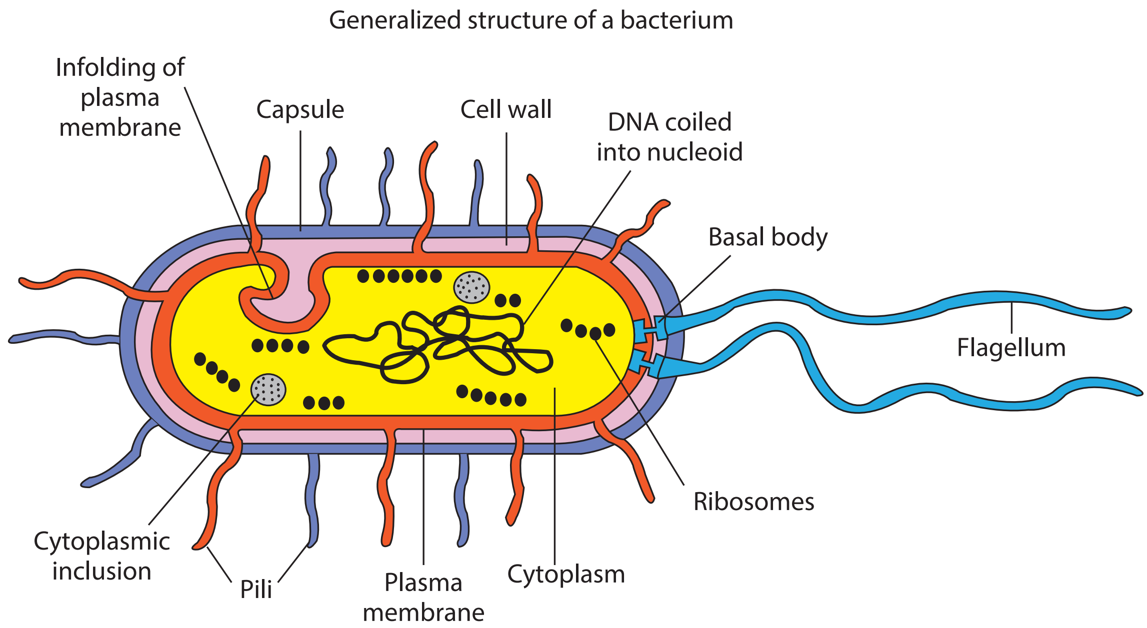


Figure 7.1: Generalized structure of a bacterium

Bacteria, cyanobacteria (blue green algae) microalgae, protozoa, yeasts and fungi represent the microorganisms. Prokaryotes are organisms with primitive type of nucleus lacking a well defined membrane (Figure 7.1). The nuclear material is a DNA molecule in prokaryotes compared to chromosomes of higher organisms. Eukaryotes are organisms with cells having true nuclei enclosed in a nuclear membrane and are structurally more complex than prokaryotes. There exists varying degree of localization of cellular functions in eukaryotes that occur in distinct membrane bound intracellular organelles like nuclei, mitochondria, chloroplasts. The cells of living organisms are either prokaryotic or eukaryotic in nature and there is not any intermediate condition. The size, shape, morphology and the internal cellular organizations are different in these two groups.

Satisfactory criteria to differentiate bacteria, fungi and algae could not be made until the development of electron microscope, which depicted the internal structure of these organisms. The absence of membrane bound internal structures in bacteria and their presence in fungi, algae, protozoa, plant and animal cells was taken as criterion to differentiate prokaryotes and eukaryotes.

7.1 Size, Shape and Arrangement of Bacteria

7.1.1 Size of Bacteria

Bacteria are minute living bodies and represent one of the lowest orders of living cells. The determination of size of the different forms is originally carried out by comparison with known RBC. A more accurate estimation is now obtained by the use of a special micrometer eye-piece, containing a graduated scale. The unit of measurement of bacteria is called micron (μ or μm). 1 micron is equal to 1 thousand of millimeter. Resolution of unaided eye is 200μm. The size of bacteria is constant but

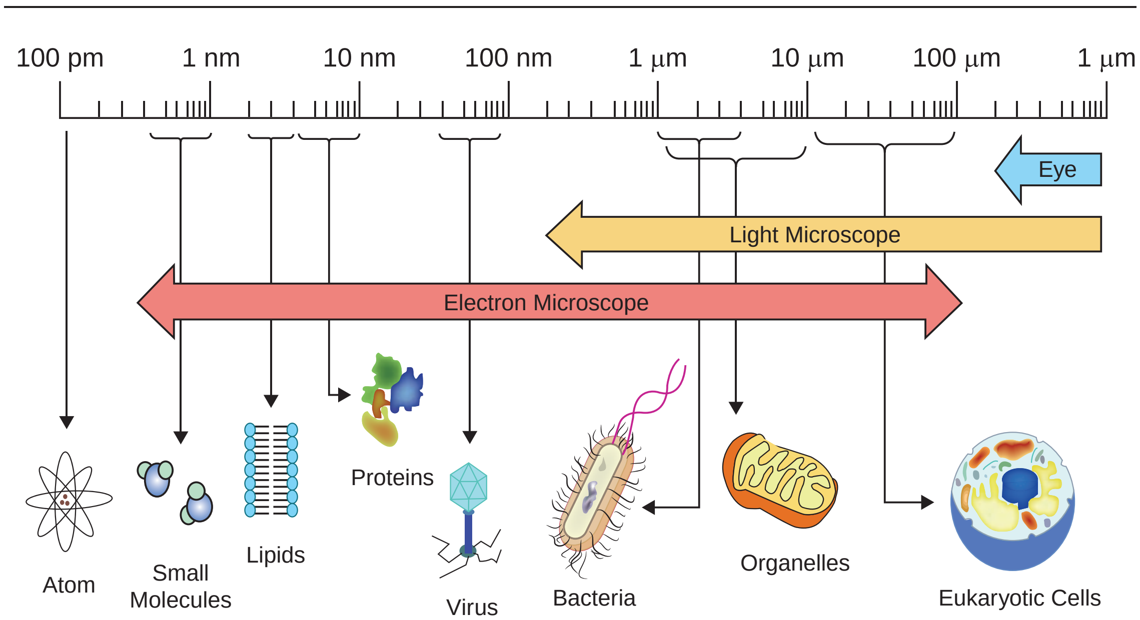


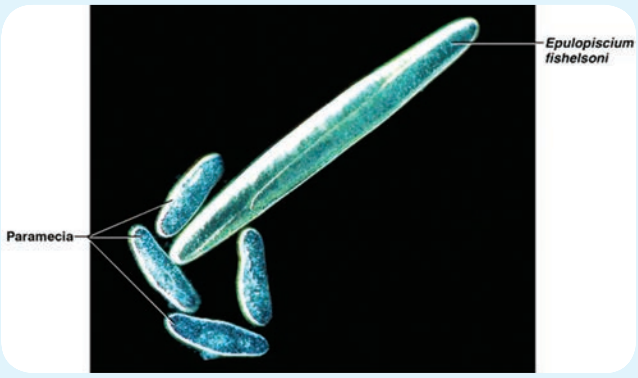
Figure 7.2: Metric unit of measurement

depends upon environmental and growth condition. Medically important bacteria ranges from 0.2 – 1.5 μm in diameter and 3-5μm in length (Figure 7.2).

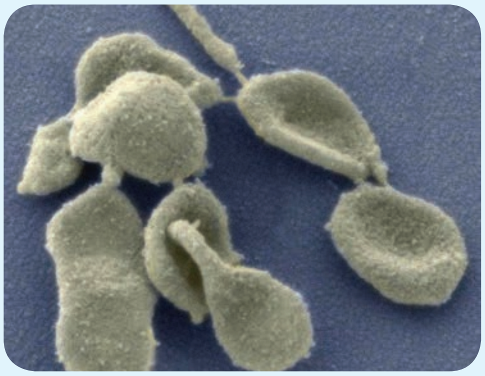
1 metre (m)	=	1000mm (millimeter)
1mm (10^{-3}m)	=	1000 μm (micrometer)
1 μm (10^{-6}m)	=	1000nm (nanometer)
1nm (10^{-9}m)	=	1000pm (picometer)
1A^0 (10^{-10}m) (angstrom)		

Infobits

The smallest bacteria is *Mycoplasma genitalium*, which has a diameter of 200-300nm. The largest and longest bacterium is *Thiomargarita namibiensis* (750μm) found in the ocean sediments in the continental shelf of Namibia. They are large enough to be visible to the naked eye. The previously known largest bacterial cell *Epulopiscium fishelsoni* is found only in the intestinal tract of certain topical fish over 500μm long. *Epulopiscium* means "guest at the table of fish".



Epulopiscium fishelsoni



Mycoplasma genitalium

7.1.2 Cell Shape and Arrangement of Bacteria

The shape of a bacterium is governed by its rigid cell wall. Typical bacterial cells are spherical (called cocci), straight rods (called bacilli) and helically curved rods (called spiral). These shapes are constant for the particular species or genus but there are bacterial cells that are pleomorphic in nature. They exhibit a variety of shapes.

- Cocci appear in several characteristic arrangements, depending on the plane of cellular division and whether daughter cells remain together with the parents even after cell division. The cells may occurs in pairs (diplococci), in groups of four (tetracocci), in clusters (*Staphylococcus*), in a bead like chain (*Streptococci*) or in cuboidal arrangement of cells (*Sarcinae*).
- Bacilli are rod shaped organism (Singular, bacillus = stick) usually ranging between 1 and 10 µm in length. Some bacilli are so short and stumpy that they appear ovoid and are referred to as coccobacilli. Bacilli are not arranged in patterns as complex as those of cocci and mostly occur as singles or in pairs (diplobacilli, Example: *Bacillus subtilis)* or in the form of chains (*Streptobacilli*). Some form trichomes, which are similar to chains. In other *Bacilli* such as *Corynebacterium diphtheria* the cells are lined side by side like matchsticks (pallisade arrangement). Some bacilli are curved into a form resembling a comma. These cells are called vibrios as in *Vibrio cholera*.
- Spiral bacteria: They are divided into two groups, spirilla (singular spirillum) and spirochetes (agent of syphilis). Although these two are similar in shape spirochetes are flexible in nature. Spiral bacteria are far too thin to be seen with the standard Brightfield microscope but are readily observed by Darkfield microscope (Figure 7.3).

Filamentous bacteria

Bacteria tend to form long strands composed of many cells. In these cases, an occasional single cell may be seen after it breaks away from a long filament. These organisms resemble the threadlike strands of fungi but their internal structure is typical of bacteria. Filamentous soil bacteria include *Streptomyces* species.

Pleomorphic bacteria

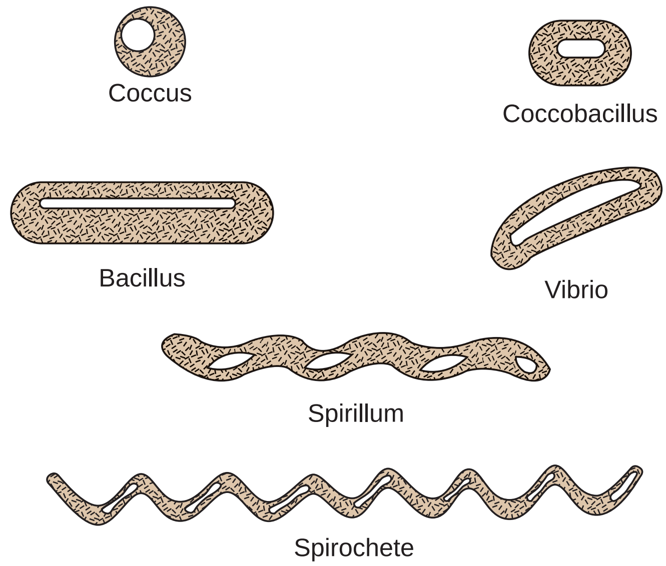
A few bacteria lack rigid cell walls, and their flexible plasma membrane allows them to change shape. These are called pleomorphic bacteria (pleo-more; morph-form). Example: *Mycoplasma*.

7.2 Structures External to Cell Wall of Bacetria

7.2.1 Appendages

Flagella

Flagella (singular flagellum) are threadlike, long, thin helical filaments measuring 0.01-0.02nm in diameter. These appendages extend outward from the plasma membrane and cell wall. Flagella are so thin that they cannot be observed directly with a bright field microscope, but must be stained with special techniques (example: Fontana's silver staining technique) that increase their thickness. The detailed structure of a flagellum can only be seen in the electron microscope.



Different Bacterial Shapes

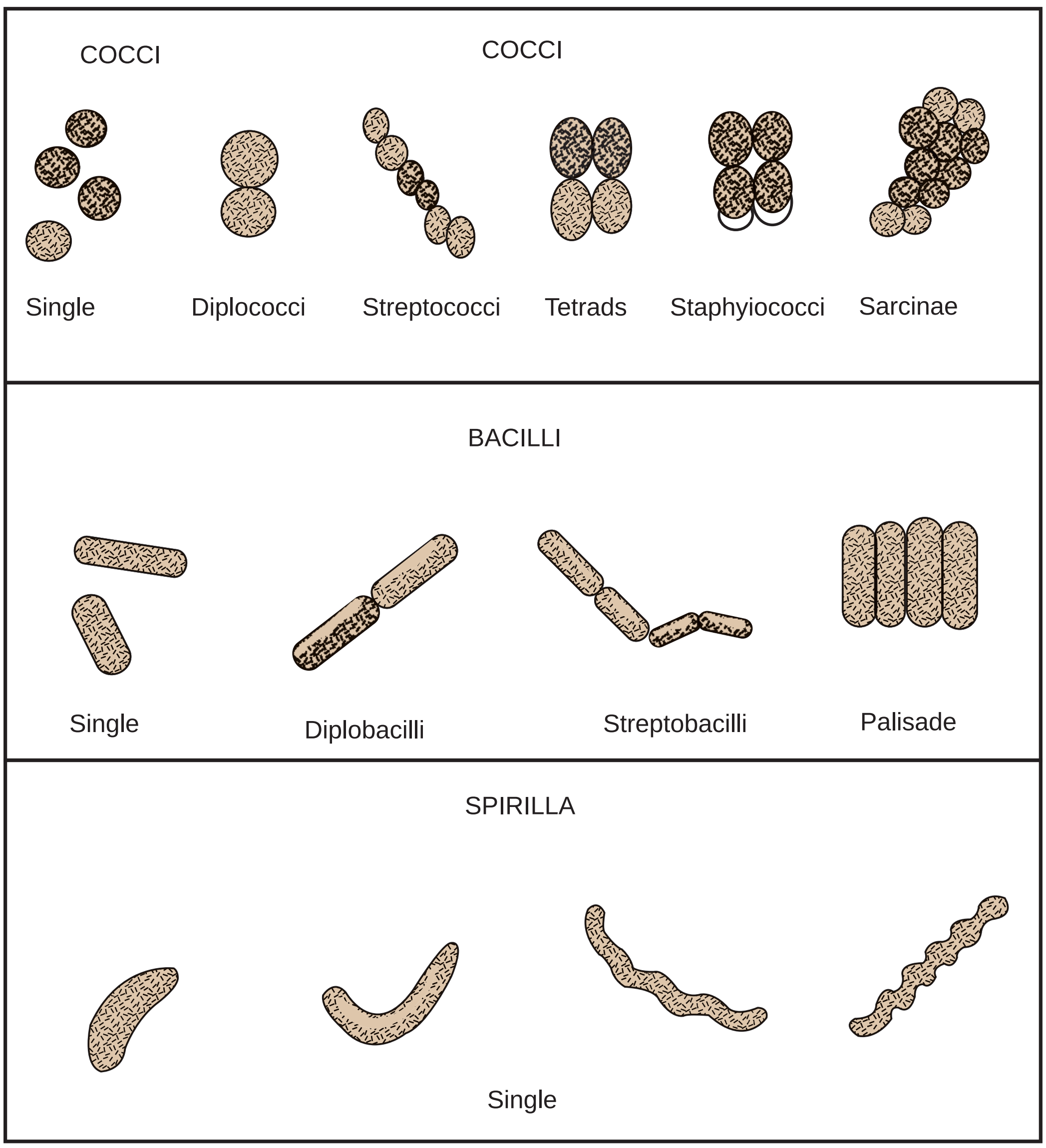


Figure 7.3: Shapes and arrangement of bacteria

The bacterial flagellum is composed of three parts: a basal body (associated with the cytoplasmic membrane and cell wall), a short hook and a helical filament (which is usually several times as long as the cell). Filament is external to cell wall and is connected to the hook at cell surface; the hook and basal body are embedded in the cell envelope (Figure 7.4). Hook and filament are composed of protein subunits called as flagellin.

One can generalize that all spirilla, about half of the bacilli and a small number of cocci are flagellated. Some bacteria do not have flagella. Flagella vary both in number and arrangement on the cell surface. Flagella are arranged generally in two patterns.

1. In polar arrangement, the flagella are attached at one or both ends of the cell. Bacteria with polar flagellar arrangement are further classified into monotrichous, lophotrichous, and amphitrichous.
2. In lateral arrangement, flagella are arranged randomly all over the surface of the cell. Bacteria with lateral flagellar arrangement are called peritrichous. (Table 7.1)

Various types of mobility are observed based on the arrangement of the flagella. Serpentine motility is seen with *Salmonella*, darting motility with *Vibrio* and tumbling motility with *Listeria monocytogenes*. Some bacteria like *Cytophaga* exhibit a gliding motility, which is slow sinuous flexing motion. This occurs when the cells come in contact with solid surface.

Some bacteria have the ability to move toward or away from chemical substance. This movement is called chemotaxis. Positive chemotaxis is the movement of a cell in the direction of a favorable chemical stimulus (usually a nutrient). Negative chemotaxis is the movement away from a chemical substance (usually harmful compound). Some photosynthetic bacteria exhibit phototaxis, movement in response to light rather than chemicals.

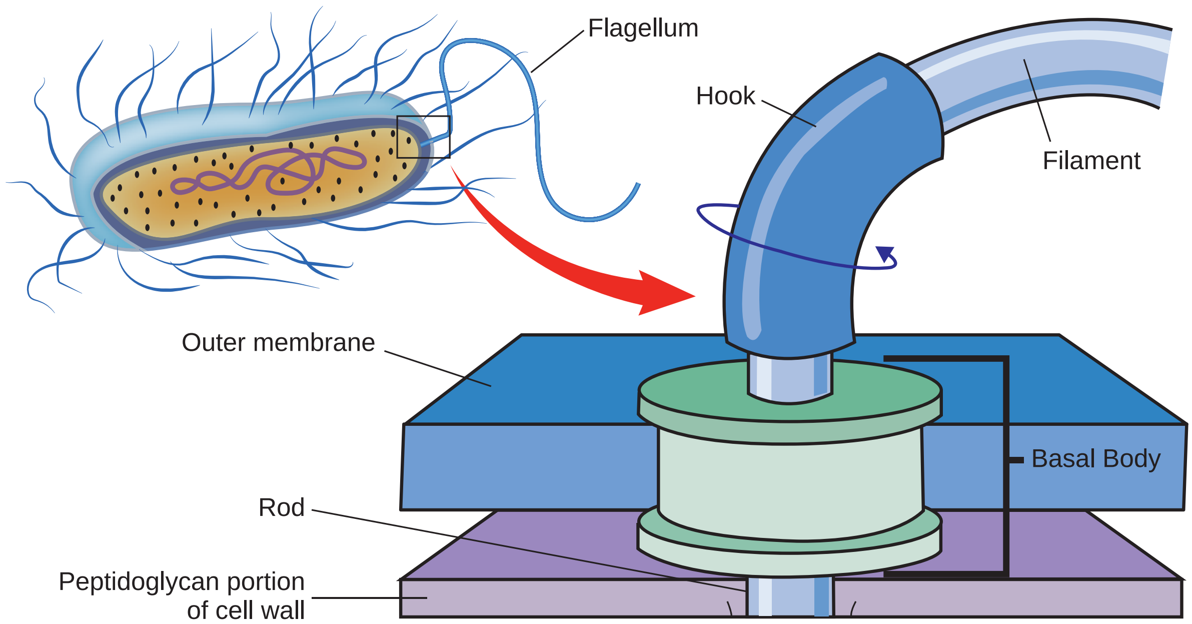
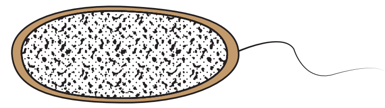
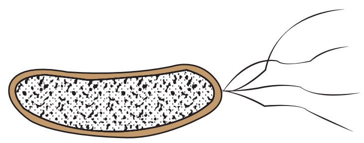
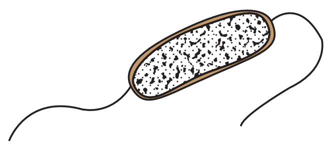
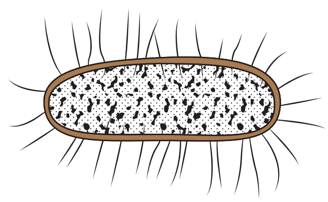


Figure 7.4: Structure of bacterial flagella

Table 7.1: Arrangement of bacterial flagella

Structure	Flagella type	Example
	Monotrichous(single flagella on one side)	*Vibrio cholera*
	Lophotrichous(tuft of flagella on one end)	*Pseudomonas fluorescens*
	Amphitrichous(single or tuft on both ends)	*Aquaspirillum serpens*
	Peritrichous(flagella throughout the cells)	*Salmonella typhi*

HOTS

A. If a bacterium loses its flagella, does it survive?

B. If you remove the cell wall from a flagellated bacterium, the organism loses the ability to move. Explain.

The presence of motility is one piece of information used to identify a pathogen in the laboratory. One way to detect motility is to stab a tiny mass of cells into soft (semi solid) medium in a test tube. Growth spreading rapidly through the entire medium is indicative of motility. Alternatively, cells can be observed microscopically by a hanging drop method.

Pili

Pili (singular pilus) are straight, short and thin and more numerous than flagella around the cell. They can be observed only by electron microscopy. They are found only in certain species of Gram negative bacteria. Pili play no role in motility. Pili originate from the plasma membrane and are made up of a special protein called pilin (Figure 7.5).

Pili play a major role in human infection by allowing pathogenic bacteria to attach to epithelial cells lining the respiratory, intestinal or genitourinary tracts. This attachment prevents the bacteria being washed away by body fluids, thus helps in establishment of infection. One specialized type of pilus (sex pilus) helps in the transfer of genetic material between the bacterial cells. This process is called conjugation.

Fimbriae

Fimbriae (singular: fimbria) is another term used for short pili that occur in great number around the cell. They enable bacteria to attach to surfaces and to each other, so that the bacteria form clumps or films called pellicles on the surface of liquid in which they are growing. Fimbriae are found in Gram positive as well as in Gram negative bacteria.

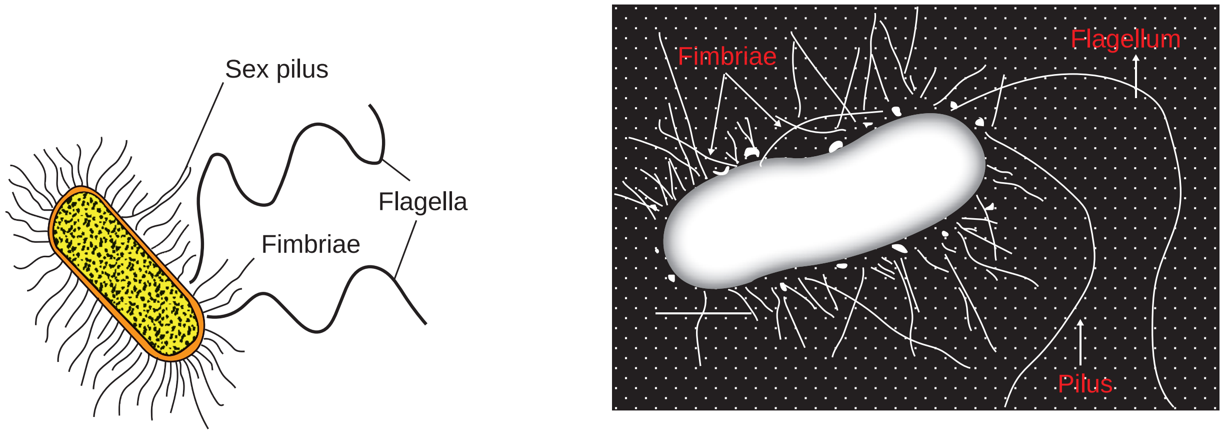


Figure 7.5: Structures of pili and fimbriae

Table 7.2 compares the pili and fimbriae.

7.2.2 Extracellular Polymeric Substance (EPS)

Many bacteria secrete high molecular weight polymers that adhere to the exterior of the cell wall to form a capsule or slime layer. Glycocalyx is often used to refer to any polysaccharide material outside the cell wall. Capsules and slime layer are considered to be glycocalyxes (Table 7.3).

Capsules

Some bacterial cells are surrounded by a viscous substance forming a covering layer or envelope around the cell wall called capsule (Figure 7.6). Capsule is usually made up of polysaccharide. It may be homopolysaccharide (made up of a single kind of sugar) or heteropolysaccharide (made up of several kinds of sugars). These are synthesized from sugars within the cell, transported and polymerized outside the cell. The capsule of some bacteria is made of polypeptides. The capsule of *Bacillus anthracis* has polymer of D-glutamic acid. Capsules are highly impermeable. Capsules can be demonstrated using special staining technique utilizing Indian ink or with Nigrosin stain. The presence of capsule in fresh isolates gives a moist and shiny appearance to the bacterial colonies on an agar medium. Capsular material is antigenic and may be demonstrated by serological methods.

Table 7.2: Comparison of pili and fimbriae

Characteristics	Pili	Fimbriae
Appearance	Hair like, straight appendages.	Tiny bristle like fibers arising from the surface of bacterial cell.
Length	Longer than fimbriae	Shorter than pili
Numbers per cell	1-10/cell	200-400/cell
Presence	Present only in Gram negative bacteria	Present in both Gram positive and Gram negative bacteria
Made -up of	Pilin protein	Fimbrillin protein

Table 7.3: Difference between Capsule and Slime layer

Capsule	Slime layer
Capsule is a glycocalyx layer, consisting of firmly associated polysaccharide molecules with the cell wall.	Slime layer is a glycocalyx layer that consists of loosely associated glycoprotein molecules.
It is a well-organized layer, difficult to be washed off.	It is an unorganized layer and can be easily washed off.
It is tightly bound to the cell wall.	It is loosely bound to the cell wall.
It is thicker than slime layer.	It is a thin glycocalyx layer.
It acts as a virulence factor that helps to escape phagocytosis.	It mainly helps in adherence. It protects the cell from dehydration and nutrient loss.

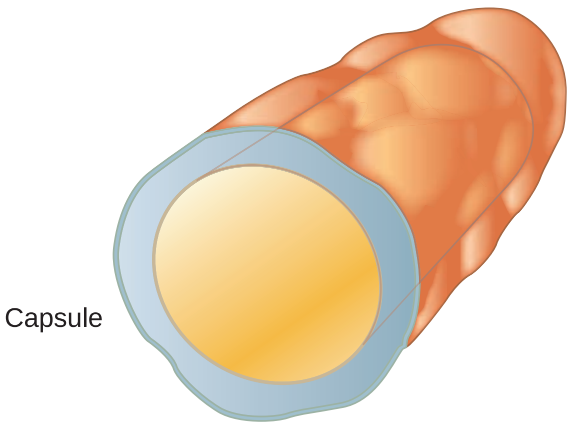


Figure 7.6: Structure of capsule

The role of the capsule varies depending on the bacterium.

- A thick capsule protects cells from dehydration.
- Capsules protect the pathogenic bacteria from being engulfed and destroyed by white blood cells (phagocytes).
- Capsules are virulence factors of many pathogenic bacteria, such as *Streptococcus pneumoniae*, *Haemophilus influenzae* and *Bacillus anthracis*. Encapsulated bacterial cells generally have greater virulence.

Slime layer

Some bacteria are covered with a surface layer that is loosely distributed around the cell and diffuses into the medium, this surface layer is referred to as slime layer. (Figure 7.7) The slime layer is a structure that is easily washed off. Slime layer protects bacteria from loss of water and nutrients. Slime has little affinity for basic dyes and is ivisible in Gram stained smears.

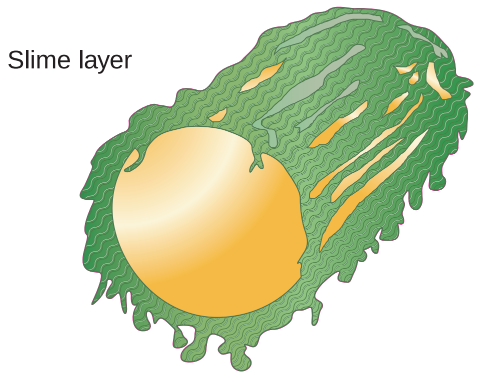


Figure 7.7: Structure of slime layer

7.2.3 Other Appendages

Sheath

Sheathed bacteria are bacteria that grow as long filaments in the form of chain or trichome. These bacteria are enclosed by a hollow tube like structure known as sheath

(Figure 7.8). Within the shealth, the bacteria are capable of growth and division. Aquatic bacteria mostly form sheath. Examples of sheathed bacteria include *Leptothrix discophora* (also known as iron bacteria), *Sphaerotilus* and *Clonothrix*.

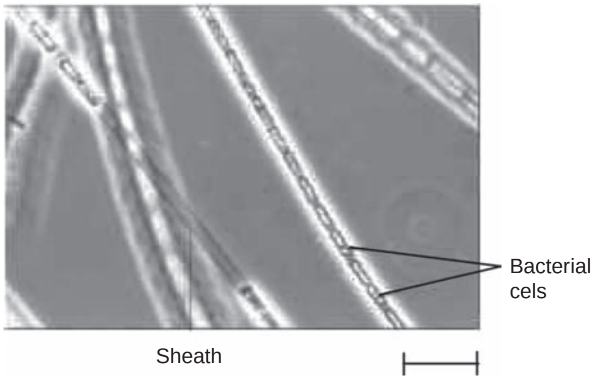


Figure 7.8: Sheathed bacterium

Function:

- It provides mechanical support.
- In a few bacteria, shealth is strengthened by the deposition of ferric and manganese hydroxides.

Prosthecae

They are semi rigid extensions of cell wall and cell membrane. Some bacteria may contain more than one prosthecae (Figure 7.9). Aerobic bacteria in fresh water and marine environment possess prosthecae. Some of the prosthecate bacteria are *Caulobacter, Stellar, Prosthecobacter and Hyphomicrobium*.

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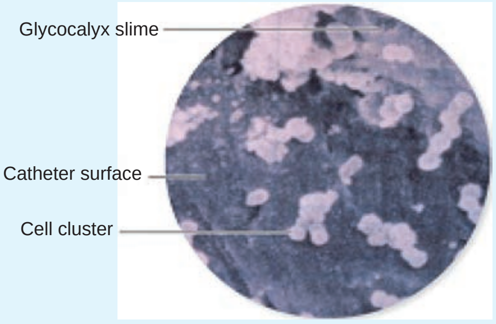
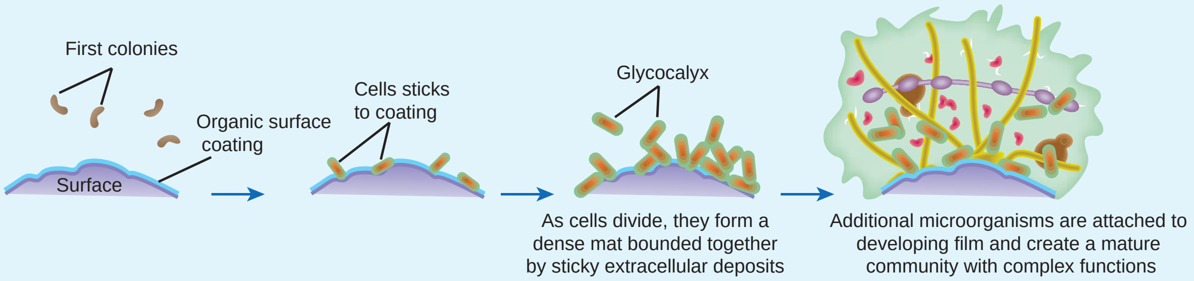
Biofilms:



Microbial adhesion to animate or inanimate surfaces can be mediated by polysaccharides capsules or slime. These adherence polymers are collectively called as adhesions. Microorganism tend to adhere to any surface and the layer they produce is called Biofilm. Biofilm can be harmful or beneficial to humans. Biofilm formation is a critical issue for almost all surfaces in health care and food preparation settings. Biofilms may form on a wide variety of surfaces, including living tissues, medical devices, industrial or portable water piping system, etc., Biofilm formation is a multi-step process starting with attachment to a surface, then formation of three dimensional structure and finally ending with maturation and detachment. During biofilm formation many species of bacteria are able to communicate with one another through specific mechanism called quorum sensing.



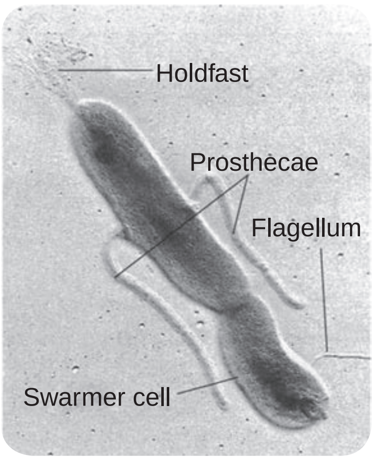


Figure 7.9: Prosthecate bacteria

Function:

- Prosthecae increase surface area for absorption of nutrients from the dilute aquatic environment.
- Helps in adhesion.
- Some prosthecae develop bud at the tip and helps in asexual reproduction.

Stalk

It is a nonliving ribbon like tubular structure. It is formed by excretory product of bacteria. Some of the stalked bacteria are *Gallionella, Planctomyces* (Figure 7.10).

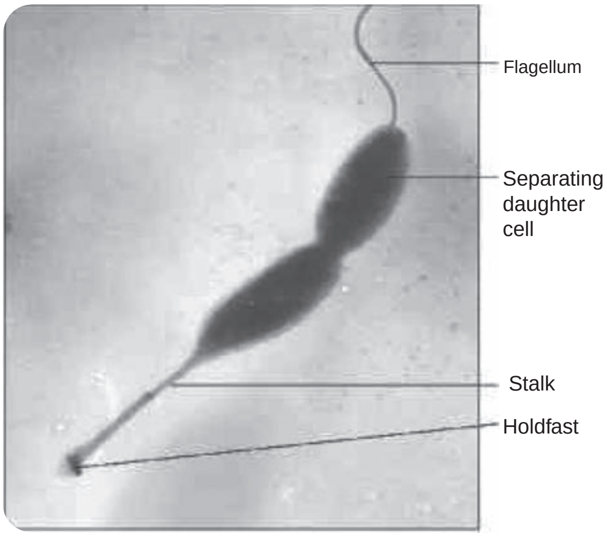


Figure 7.10: Stalked bacteria

Function:

- Stalk helps in attachment of cells to solid surface.

7.3 Cell Envelope of Bacteria

Cell envelope is an external covering that lies outside the cytoplasm. It is composed of two or three basic layers: the cell wall, the cell membrane and in some bacteria the outer membrane.

7.3.1 Structure of Prokaryotic Cell Wall

Prokaryotic cells almost always are bounded by a chemically complex cell wall. Cell wall lies beneath the external structures (capsules, sheaths and flagella). Cell wall lies external to the plasma membrane (cell membrane). Cell wall of eubacteria is made up of **peptidoglycan** or **murein**, whereas that of Archaeobacteria is composed of proteins, glycoproteins or polysaccharides. A few genera such as *Methanobacterium*, have cell walls composed of **pseudomurein**, a polymer whose structure superficially resemble eubacteria peptidoglycan of eubacteria but differs markedly in chemical composition.(Note: Ordinary or typical bacteria are sometimes called eubacteria to distinguish them from the phylogenetically distinct group known as archaeobacteria). Peptidoglycan is a cross linked polymer of enormous strength and rigidity. It is a polymer composed of many identical subunits (Figure 7.11). Peptidoglycan differs somewhat in composition and structure from one species to another, but it is basically a polymer of N-acetylglucosamine(NAG), N-acetylmuramic acid(NAM), L-alanine, D-alanine, D-glutamate, and a diamino acid (LL- or meso-diaminopimelic acid, L-lysine, L-ornithine, or L- diaminobutyric acid).

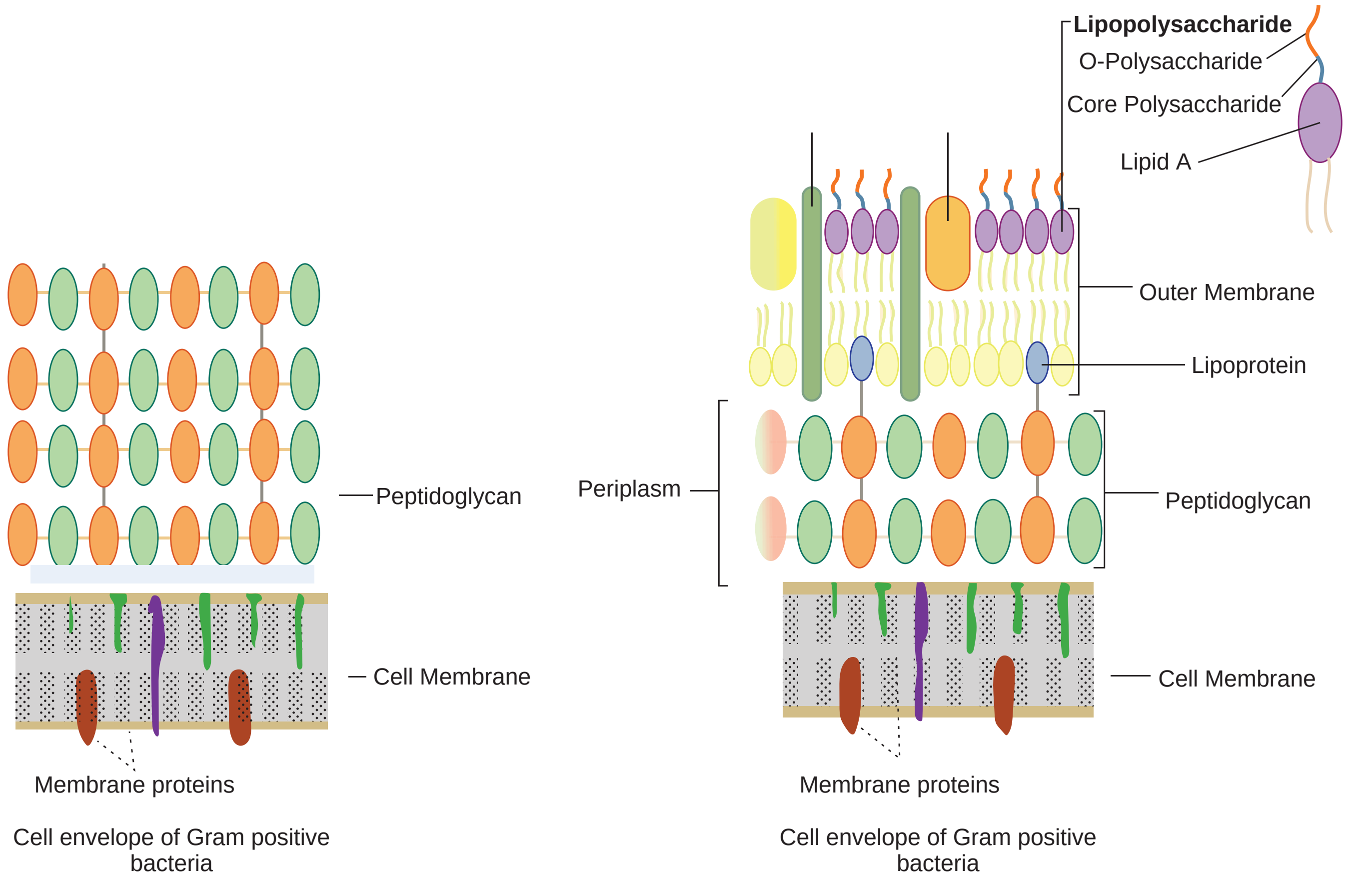


Figure 7.11: Cell envelope of Gram positive and Gram negative bacteria

Cell wall may contain other substances in addition to peptidoglycan. For instance, *Staphylococcus aureus* and *Streptococcus fecalis* contain **teichoic acids** (polymer of acidic polysaccharides) covalently linked to peptidoglycan. Cell wall of Gram positive bacteria contain very little lipid but *Mycobacterium* and *Corynebacterium* cell walls are rich in **mycolic acid** (or Cord factor) which make them acid fast. When stained, the cells cannot be decolorized easily despite treatment with dilute acids. *Mycoplasma* lack cell wall.

Protoplast is a bacterial cell consisting of cell material bound by a cytoplasmic membrane.

Spheroplast is a bacterial cell with two membranes namely the cytoplasmic membrane and the outer membrane but no cell wall.

Functions of cell wall

- It gives shape to bacteria like a bicycle tyre that maintains the necessary shape and prevents the more delicate inner tube (the cytoplasmic membrane) from bursting when it is expanded.
- It protects bacteria from osmotic lysis in dilute solutions (hypotonic environment).
- It protects cell from toxic substances.

HOTS

How do bacteria maintain their shape?

7.3.2 Structure of Outer Membrane

Eubacteria and Archaeobacteria (Gram positive and Gram negative) differ with respect to their cell walls. Gram negative cell walls are more complex. An outer membrane surrounds a thin underlying layer of peptidoglycan (Table 7.4). Outer membrane is bilayered, consisting mainly of phospholipids, proteins and lipopolysaccharide (LPS).

LPS is composed of three parts which are covalently linked to each other. They are

1. **Lipid A** which is firmly embedded in the membrane,
2. **Core polysaccharide** that is located at the membrane surface and
3. **Polysaccharide O antigens** that extend like whiskers from the membrane surface into the surrounding medium

Special protein channels called porins span the membrane. The points of contact between outermembrane and cytoplasmic membrane are known as adhesions. Outer membrane is anchored to peptidoglycan layer by means of **Braun's** lipoprotein. Periplasmic space between the cell membrane and the outer membrane.

Functions of outer membrane

- It serves as an impermeable barrier to prevent the escape of important enzymes (such as those involved in cell wall growth) from the periplasmic space.
- It serves as a barrier to various external chemicals and enzymes that could damage the cell. For example, the walls of many Gram positive bacteria can be easily destroyed by treatment with an enzyme called lysozyme, which selectively

Table 7.4: Difference between Gram positive and Gram negative bacteria

	Gram positive bacteria	**Gram negative bacteria**
Gram reaction	The bacteria that retain the colour of the primary stain (crystal violet) are Gram positive	The bacteria that cannot retain the primary stain but takes on the colour of the counterstain safranin are called Gram negative
Cell wall	The cell wall is thick (20-30nm thick)	The cell wall is thin (8-12nm thick)
Peptidoglycan layer	Thick (multilayered)	Thin (single layered)
LPS content Lipopolysaccharide	None	High
Periplasmic space	Absent	Present
Outer membrane	Absent	Present
Lipid and lipoprotein content	Low (acid fast bacteria have lipids linked to peptidoglycan)	High due to the presence of outer membrane
Teichoic acids	Present in many	Absent
Example:	*Streptococcus, Staphylococcus, Corynebacterium, Bacillus, Clostridium*	*Escherichia coli, Pseudomonas, Haemophilus, Salmonella, Shigella.*

dissolves peptidoglycan. However, Gram negative bacteria are refractory to this enzyme because large protein molecules of enzyme cannot penetrate the outer membrane. Only when outer membrane is damaged the enzyme can penetrate.

- Porins allow the smaller molecules, such as amino acids, monosaccharides to pass across.
- Adhesions are export sites for newly synthesised LPS and porins, and are sites at which pili and flagella are made.

7.3.3 Structure of Cytoplasmic Membrane

Immediately beneath the cell wall is the cytoplasmic membrane also known as plasma membrane or cell membrane. It is composed of phospholipids and proteins. The phospholipids form a bilayer. Integral proteins are embedded within this bilayer. Surface proteins or peripheral proteins are loosely attached to the bilayer. The lipid matrix of the membrane has fluidity, allowing the components to move around laterally. In eubacteria, the phospholipids are phosphoglycerides, in which straight chain fatty acids are ester linked to glycerol. In archaeobacteria, the lipids are polyisoprenoid branched-chain lipids, in which long-chain branched alcohols (phytanols) are ether linked to glycerol.

Functions of the cell membrane

- Prokaryotes do not have intracellular membrane bound organelles as present in eukaryotic organelles. Thus cell membrane provides a site for functions such as energy reactions, nutrient processing and synthesis.
- It regulates transport, the passage of nutrients into the cell and the discharge of wastes. It is a selectively permeable membrane.
- It is also involved in secretion or discharge of a metabolic product into extracellular environment.
- Cell membrane is an important site for a number of metabolic activities. Most enzymes of respiration and ATP synthesis reside in the cell membrane since prokaryotes lack mitochondria.

Significance of cell envelope

- It has toxic properties (Example: LPS)
- It stimulates antibody production by immune system
- The cell walls of many pathogens have components that contribute to their pathogenicity. Example mycolic acids of *Mycobacterium tuberculosis*
- Cell wall is a site of action of several antibiotics.
- Many of the serological properties of Gram negative bacteria are attributable to O antigens; they can also serve as receptors for bacteriophage attachment.

7.4 Structures Internal to Cell Membrane of Bacteria

Cytoplasm is called as the internal matrix of the cell inside the cell membrane. Its major component is water (70-80%). It also contains proteins carbohydrates, lipids, inorganic ions, and certain low molecular weight compounds. Inorganic ions are present in much higher concentrations in cytoplasm than in most media.

Cytoplasm is thick, aqueous, semi-transparent and elastic. The major structures in the cytoplasm of prokaryotes are nucleoid (containing DNA), ribosomes and reserve deposits called inclusions. Prokaryotic cytoplasm lacks certain features of eukaryotic cytoplasm such as a cytoskeleton and cytoplasmic streaming.

Ribosomes

All living cells contain ribosomes. They are the sites of protein synthesis. High number of ribosomes represents the high rate of protein synthesis. Prokaryotic ribosomes are freely found in the cytoplasm, whereas eukaryotic ribosomes are attached to the cell membrane. Prokaryotic ribosomes consists of protein and a type of RNA called ribosomal RNA. They are smaller and less dense than the eukaryotic ribosomes. The ribosomes of prokaryotes are 70S where as that of eukaryote are 80S (Figure 7.12).

Nucleus

The nuclear area has the hereditary material of most bacteria. It contains a single, circular, long, continuous, thread like double stranded DNA called the bacterial chromosome. Some bacteria with linear chromosome also exist. It carries the information required for the cells structure and function. They are not surrounded by a nuclear envelope and are devoid of highly conserved histone proteins. The nuclear area can be spherical, elongated or dumbbell shaped. In actively growing bacteria, as much as 20% of the cell volume is occupied by DNA, because such cells presynthesize nuclear material for future cells. The chromosome is attached to the cell membrane. Proteins in the plasma membrane are believed to be responsible for the replication of the DNA and segregation of the new chromosomes to daughter cells in cell division.

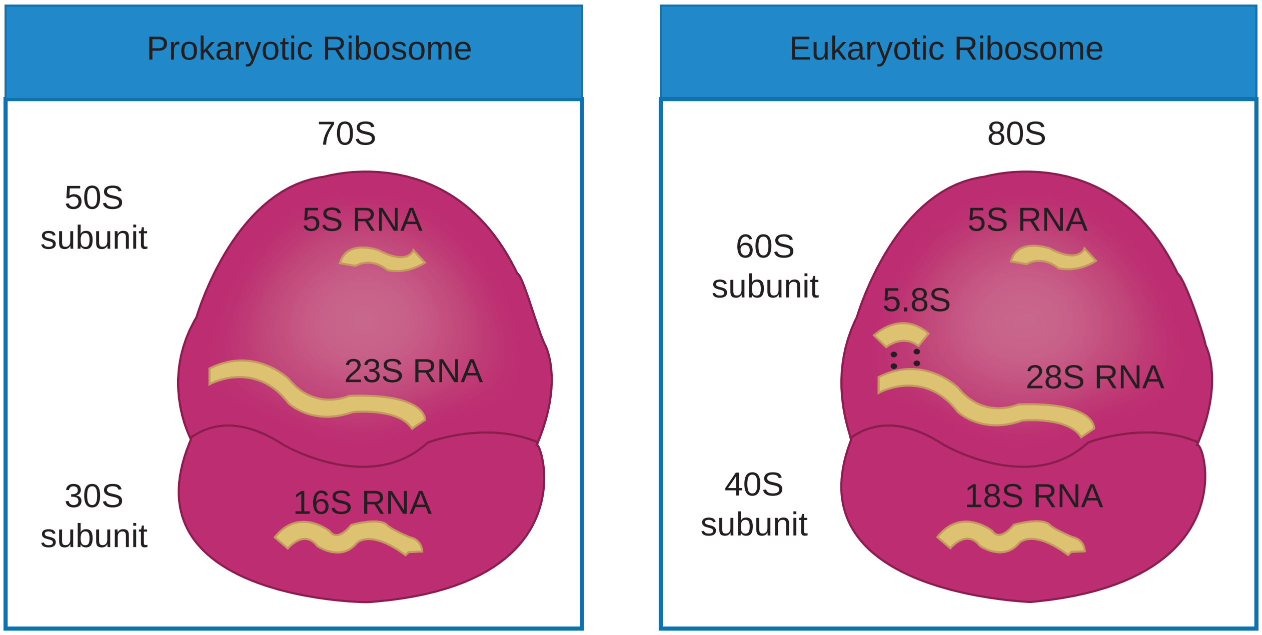


Figure 7.12: Prokaryotic and Eukaryotic Ribosomes

Plasmids

Apart from the bacterial chromosome, bacteria also contain small circular, double stranded DNA molecules called plasmids (Figure 7.13). Plasmids are self replicating extra chromosomal genetic elements. Plasmids may carry genes for activities such as antibiotic resistance and tolerance to toxic metals. Examples: Fertility plasmid (F plasmid), Resistance plasmid (R plasmid) and colicin plasmid (Col plasmid).

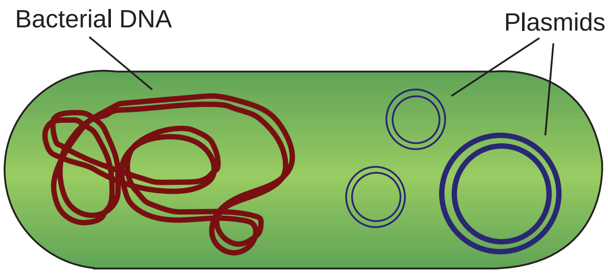


Figure 7.13: Plasmids in Prokaryotes

Molecular Chaperones

They are the helper proteins which recognize the newly formed polypeptides and fold them into their proper shape of secondary and tertiary structure. Many chaperones are involved in proper folding of bacteria. They were first identified in *Escherichia coli* mutant. Example: Heat shock proteins are produced in *Escherichia coli* cells subjected to live at high temperatures, or in any other stressful unfavorable conditions.

Inclusions

The cytoplasm of prokaryotic cells has several kinds of reserve deposits known as inclusions. Cells may accumulate certain nutrients when they are plentiful and use them when they are deficient. Some inclusions are common to a wide variety of bacteria whereas others are limited to certain species (Table 7.5).

Endospores:

Some species of bacteria produce metabolically dormant structures called spores. They are highly durable and dehydrated resting bodies produced inside the cells. They are formed by bacteria only when there is lack of water or depletion of essential nutrients in the environment. Endospores are coated with a specific chemical compound diaminopimelic acid. It binds with the Calcium and forms Calcium dipicolinate which removes the water from it and makes the spore resistant to extreme conditions Example: *Bacillus anthracis* and *Clostridium tetani* possess endospores.

Mesosomes

Generally prokaryotes do not have cytoplasmic organelles like mitochondria and chloroplast. It contains mesosome as their organelle. They are the invaginations of the cell membrane and they are in the form of tubules, vesicles or lamellae. They are seen in both Gram positive and Gram negative bacteria, generally more in Gram positive bacteria. They are located next to the septa or cross walls in dividing bacteria (Figure 7.14). They may be involved in cell wall formation during division or play a role in chromosome replication and distribution to daughter cells. If they are located near to the surface they are called peripheral mesosomes and if they are located deep into the cytoplasm they are called central mesosomes.

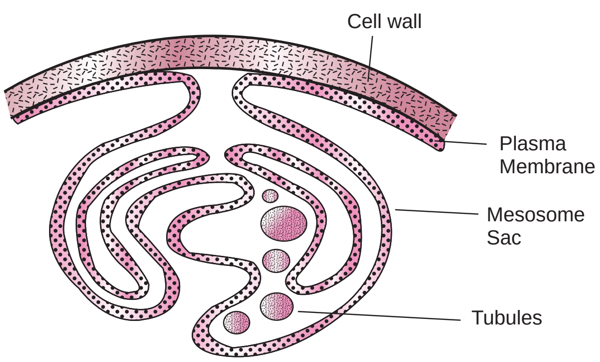


Figure 7.14: Bacterial Mesosome

Table 7.5: Different types of inclusion bodies in bacteria

Type of inclusion bodies	Example of organisms possessing	Significance
Polyhydroxybutyrate (PHB)	*Bacillus megaterium*	Reserve of Carbon and energy sources. Sudan dye is used to observe lipid inclusions
Polyphosphate (volutin granules) or metachromatic granules	*Corynebacterium diphtheriae*	Reserve of phosphate
Sulphur globules	Phototrophic bacteria Like purple and green Sulphur bacteria Example: *Thiobacillus*	Elemental sulphur, reserve of electrons in phototrophs. Reserve of energy source in lithotrophs
Gas vesicles	Aquatic bacteria, *Cyanobacterium*	They are protein shells filled with gases. They provide buoyancy and keep the cells floating in vertical water column
Parasporal crystals	Genus *Bacillus*	It is a proteinaceous compound, It is toxic to certain insects
Magnetosomes	*Aquaspirillum magnetotacticum*	They are like intracellular chains of magnetite particles. They help the bacteria to swim to nutrient rich sediments. It protects the cell against H_2O_2 accumulation
Carboxysomes	Photosynthetic Bacteria, cyanobacteria Autotrophic bacteria	They contain the enzyme Ribulose 1-5 bisphosphate carboxylase which is involved in Carbon dioxide fixation during photosynthesis
Phycobilisomes or cyanophycin Granules	Cyanobacteria	They have a long polypeptide with equal proportion of Arginine and Aspartic acid. They store Nitrogen
Chlorosomes	Green bacteria	They contain bacteriocholorophyll pigments which are involved in bacterial photosynthesis

HOTS

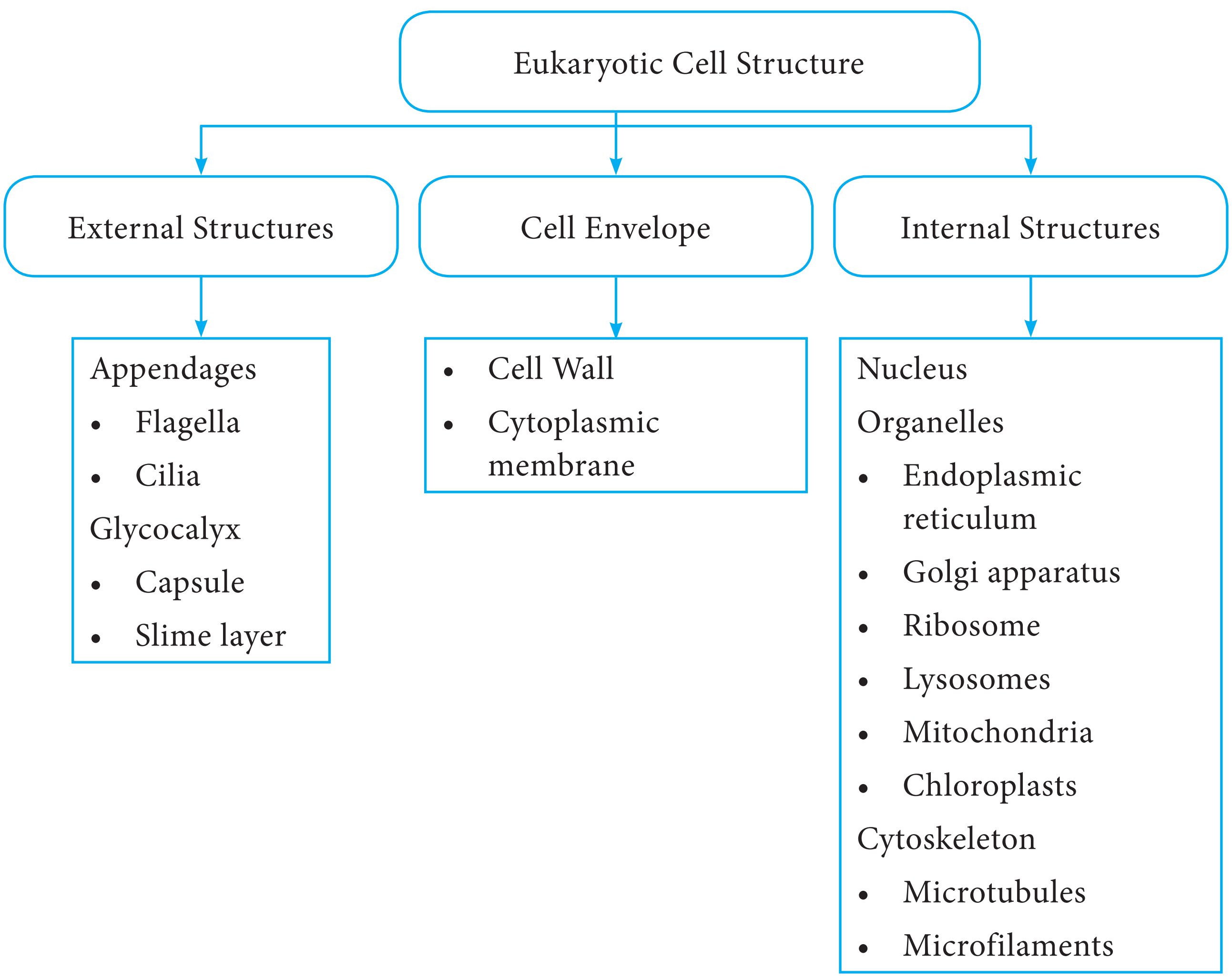
Why are endospores so difficult to destory?

7.5 Eukaryotic Cell Structure

As mentioned earlier, eukaryotic organisms include algae, protozoa, fungi, higher plants and animals. The eukaryotic cell is typically larger and structurally more complex than the prokaryotic cell (Flowchart 7.1).

Prokaryotes and Eukaryotes are chemically similar, in the sense that they both contain nucleic acids, proteins, lipids, and carbohydrates (Figure 7.15). They use the same kinds of chemical reactions to metabolize food, build proteins, and store energy. It is primarily the structure of cell walls and membranes, and the absence of organelles (specialized cellular structures that have specific functions), that distinguish prokaryotes from eukaryotes (Table 7.6).

The general, eukaryotic microbial cells have a cytoplasmic membrane, nucleus, mitochondria, endoplasmic reticulum, Golgi apparatus, vacuoles, cytoskeleton, and glycocalyx. A cell wall, locomotor appendages and chloroplasts are found only in some groups. The structure and functions of the eukaryotic cells are discussed in (Table 7.7).



Flowchart 7.1: Eukaryotic Cell Structure

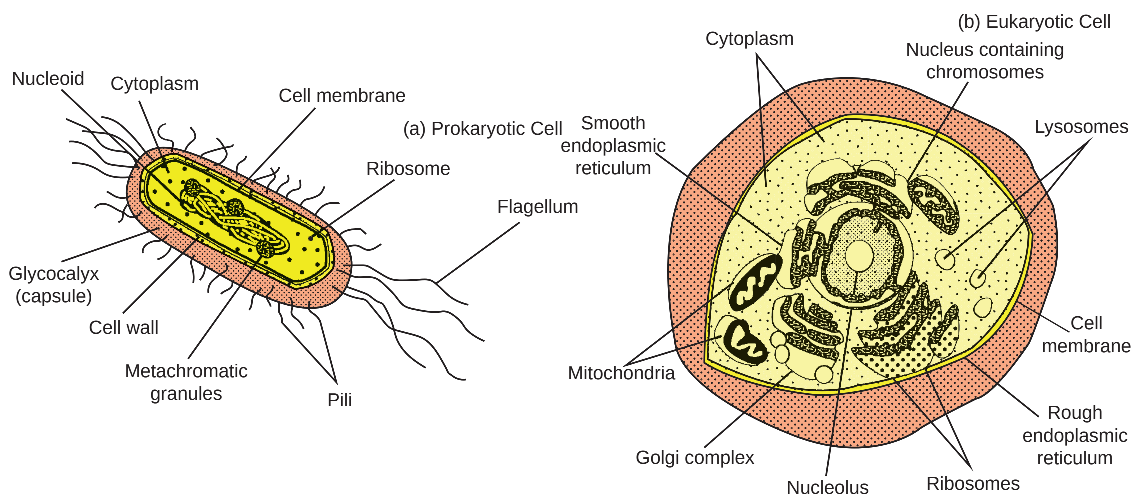


Figure 7.15: Structure of prokaryotic and eukaryotic cell

Table 7.6: Differences between prokaryotic and eukaryotic cell

S. No	Characteristic	Prokaryotic	Eukaryotic
1	Size of cell	Typically 0.2-2.0nm in diameter	Typically 10-100 nm diameters
2	Nucleus	No nuclear membrane or nucleoli	True nucleus, consisting of nuclear membrane and nucleoli
3	Membrane enclosed organelles	Absent	Present. Example: lysosomes, Golgi complex, endoplasmic reticulum, mitochondria and chloroplasts
4	Flagella	Consist of two protein building blocks	Complex, consist of multiple micro tubules
5	Glycocalyx	Present as a capsule or slime layer	Present in some cells that lack cell wall
6	Cell wall	Usually present and is chemically complex (typical bacterial cell wall includes peptidoglycan)	When present, chemically simple
7	Plasma membrane	No carbohydrates and generally lacks sterols	Sterols and carbohydrates that serve as receptors are present
8	Cytoplasm	No cytoskeleton or cytoplasmic streaming	Has cytoskeleton and shows cytoplasmic streaming
9	Ribosomes	70S	80S (70S in organelles)

(Continued)

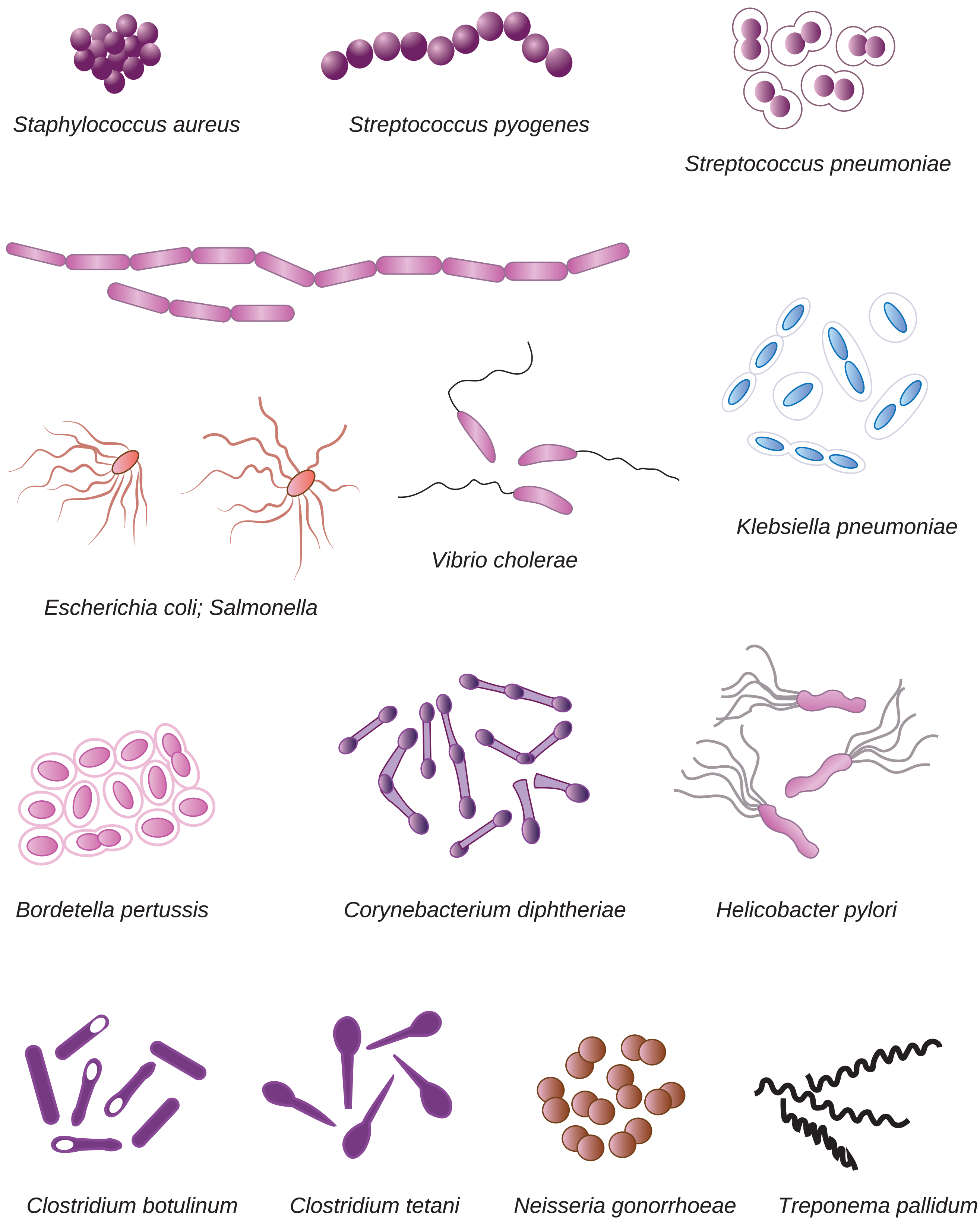
Table 7.6: Differences between prokaryotic and eukaryotic cell *(Continued)*

10	Chromosome (DNA)	Single circular chromosome, lacks histone	Multiple linear chromosomes with histone arrangement
11	Cell division	Binary fission	Mitosis
12	Sexual recombination	No meiosis (transfer of DNA fragments only)	Involves meiosis

Table 7.7: Functions of Eukaryotic organelles

Eukaryotic organelles	**Functions**
Plasma membrane	Mechanical cell boundary, selectively permeable barrier with transport systems, mediates cell to cell interactions and adhesion to surfaces, secretion
Cytoplasmic matrix	Environment for other organelles, location of many metabolic processes
Microfilaments, intermediate filaments, and Microtubules.	Cell structure and movements from the cytoskeleton
Endoplasmic reticulum	Transport of materials, protein and lipid synthesis
Ribosome	Proteins synthesis
Golgi apparatus	Packaging and secretion of materials for various purposes, lysosome formation
Lysosomes	Intracelluar digestion
Mitochondria	Energy production through use of the tricarboxylic acid cycle, electron transport, oxidative hosphorylation, and other path ways
Chloroplasts	Photosynthesis, trapping light energy and formation of carbohydrate from CO_2 and water
Nucleus	Repository for genetic information, control center for cell
Cell wall and pellicle	Strengthen and give shape to the cell
Cilia and flagella	Cell attachment and Cell movement
Vacuole	Temporary storage and transport, digestion (food vacuoles), water balance(contractile vacuole)

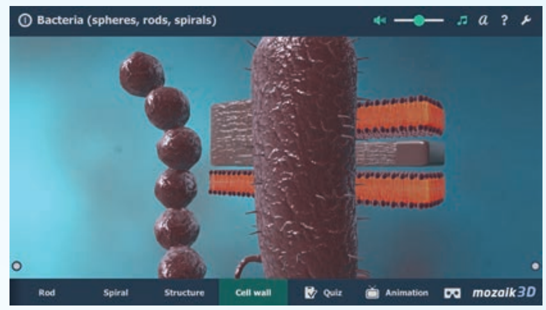
Different Shapes of Bacteria



ICT CORNER

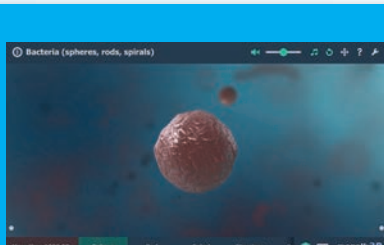
Bacteria

Know the various shapes of Bacteria

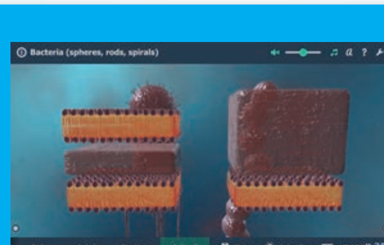


STEPS:

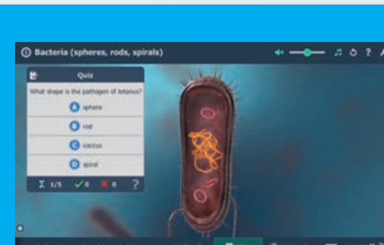
- Use the URL or scan the QR code to download the Bacteria interactive educational VR 3D app.
- Select sphere, rod and spiral to observe the structure of bacteria shapes.
- Select 'structure' tab and note the internal structure of bacteria.
- Click cell wall and note the difference between different shapes.



Step1



Step2



Step3

URL:

https://play.google.com/store/apps/details?id=com.rendernet.bacteria&hl=en

Q5SWE

Summary

Most prokaryotes have one of three general shapes coccus (round), bacillus (rod), or spiral, based on the configuration of the cell wall. Two types of spiral cells are spirochetes and spirlla. Shape and arrangement of cells are key factors for describing prokaryotes. Arrangements of cells are based on the number of planes in which a given species divides.

Cocci can divide in many planes to form pairs, chains, packets, or clusters. Bacilli divide only in the transverse plane. If they remain attached, they form chains or palisades.

Some bacterial cell walls are covered by capsules or slime which protect the cell from phagocytosis, drying and nutrient loss. Fimbriae and Pili are involved in attachment and in transfer of genetic information between bacterial cells. Flagella are involved in cell motility.

The cell envelope is the complex boundary structure surrounding a bacterial cell. In Gram negative bacteria, the envelope consists of outer membrane, the cell wall, and the cell membrane. Gram positive bacteria have only cell wall and cell membrane. Gram positive bacteria have thick murein and teichoic acid. The cell walls of Gram negative bacteria are thinner and have wide periplasmic space. The outer membrane of Gram negative cells contains LPS toxic to mammalian hosts. The cell membrane is typically composed of phospholipids and proteins, and it performs many metabolic functions as well as transport activities.

The cytoplasm of bacterial cell serve as a solvent for material used in all functions. The genetic material of bacteria is DNA and the genes are arranged on larger, circular chromosomes. Additional genes are carried on plasmid. Bacterial ribosomes are dispersed is the cytoplasm in chains and are also embedded in the cell membrane.

Bacteria may store nutrients in their cytoplasm, in form of inclusions. Inclusion vary in structure and the materials that are stored. A few bacteria produce dormant bodies called endospores, which are the hardiest of all life forms, survival for hundreds or thousands of years. The genus *Bacillus* and *Clostridium* are spore forming deadly pathogens.

Eukaryotes are cells with nucleus and membrane bound organelles. Cell structures common to most eukaryotes are the cell membrane, nucleus, vacuoles, mitochondria, endoplasmic reticulum, golgi apparatus and a cytoskeleton. Cell wall, chloroplast and locomotory organelles are present in some eukaryote groups.

Evaluation

Multiple choice questions

1. The arrangement of flagella on cell surface can sometimes help in the identification of an organism for example, *Escherichia coli* to has flagella throughout the cell surface that is referred to as.
   a. Lophotrichous
   b. Monotrichous
   c. Peritrichous
   d. None of the above

2. The movement of an organism toward or away from a chemical substance in its environmentis called.
   a. Tracking
   b. Chemotaxis
   c. Tumbling
   d. Tumbling of none of the above.
3. Bacterial cell wall is composed of
   a. Lipid
   b. Murein
   c. Cellulose
   d. Chitin
4. Cell wall shows
   a. Semipermeability
   b. Complete permeability
   c. Differential permeability
   d. Impermeability
5. Gram positive differ from Gram negative in having
   a. Thick wall
   b. Absence of wall lipids
   c. Complete wall
   d. Simple wall
6. Lipopolysaccharide is found in cell wall of
   a. Gram positive bacteria
   b. Gram negative bacteria
   c. Both Gram positive and Gram negative
   d. Algae
7. Cell wall of archaeobateria contain
   a. Peptidoglycan
   b. Murein
   c. Pseudomurein
   d. All the above
8. Endotoxin present in
   a. Outer membrane
   b. Plasma membrane
   c. Murein
   d. All the above.
9. ______________________ has fluidity
   a. Cell wall
   b. Cell membrane
   c. Outer membrane
   d. All the above
10. The organelle of prokaryote involved in active cell division.
    a. Mesosomes
    b. Mitochondria
    c. Ribosomes
    d. Endoplasmic reticulum
11. The metachromaticgranules are seen in the bacteria
    a. *Escherichia coli*
    b. *Corynebacterium diptheriae*
    c. *Pseudomonas aeroginosa*
    d. *Bacillus antharcis*
12. The extra chromosomal DNA is called
    a. Plasmid
    b. Episome
    c. Nucleus
    d. Nucleoid
13. The siderophores has high affinity towards.
    a. Iron
    b. Magnesium
    c. Chloride
    d. Copper
14. The molecular chaperones are involved in
    a. Folding of proteins
    b. Folding of carbohydrates
    c. Folding of lipids
    d. Folding of fatty aids

Answer the following

1. What is Glycocalyx?
2. What is a capsule? What are its functions?
3. What is a pilus, what is its function?
4. What is chemotaxis?
5. Explain the arrangement of flagella in bacteria with example.
6. Define carboxysomes
7. State volutin granules
8. What is called magnetosomes?
9. What is the role of ribosomes involved in protein synthesis?
10. Define periplasmic space.
11. What is LPS composed of?
12. List functions of cell wall
    a. Cell membrane
    b. Outer membrane
13. Discuss why a cell lyses without cell wall
14. Give the significance of cell envelope.
15. What is the role of siderophores?
16. Differentiate between capsule and slime/pili and fimbriae.
17. Diagrammatically explain structure of cell wall.
18. Differentiate Gram positive and Gram negative bacteria.
19. Explain any five cytoplasmic inclusions
20. Differentiate between Prokaryotes and Eukaryotes.

Student Activity

1. Students will prepare clay model of bacteria.
2. Students will collect the pictures of different Eukaryotic microorganisms.