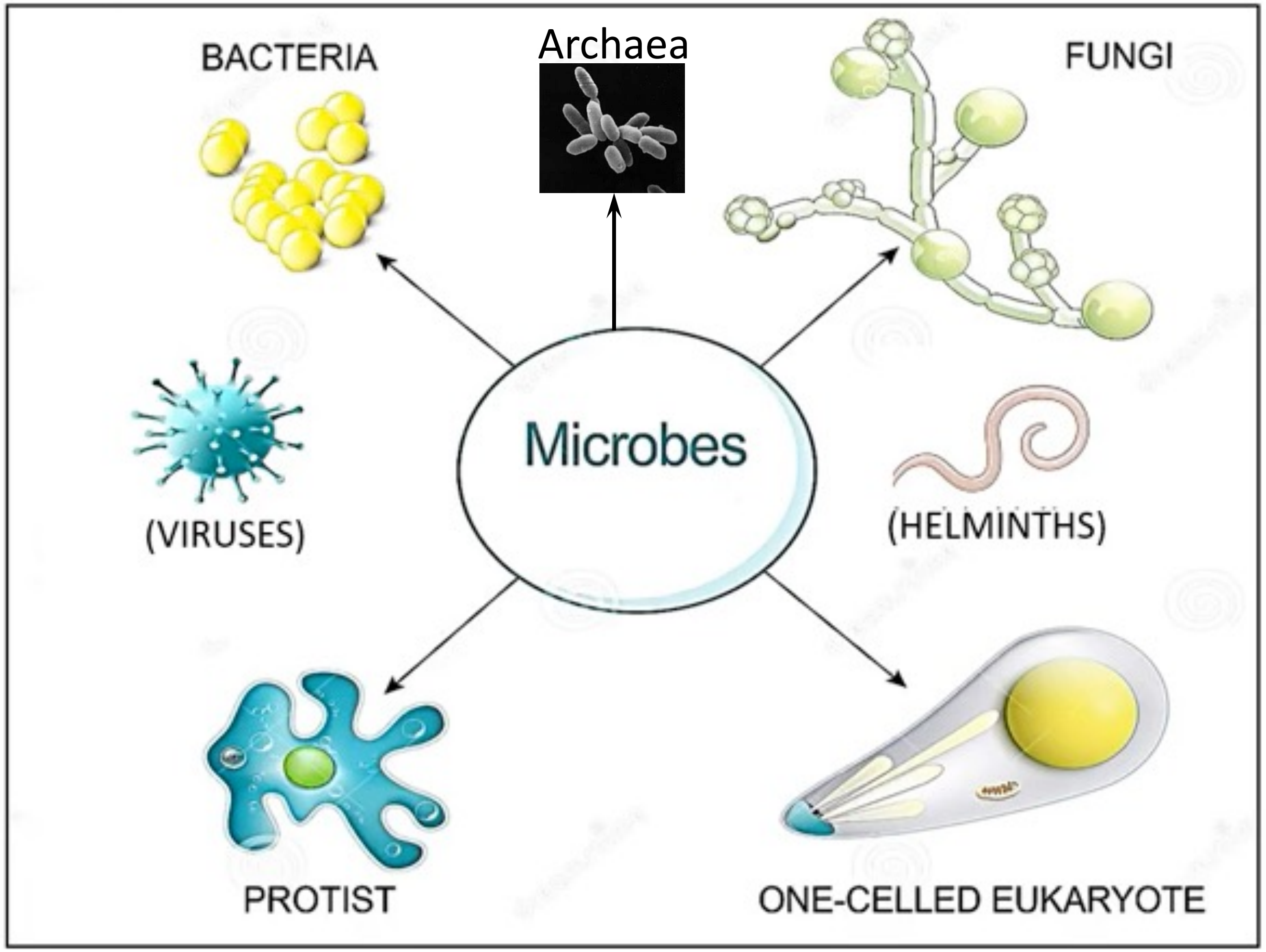
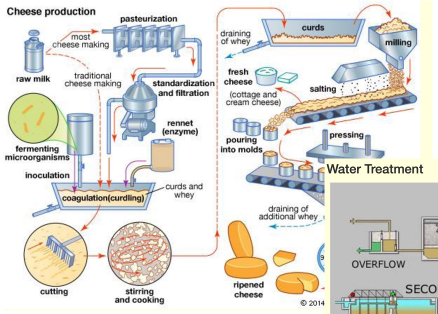
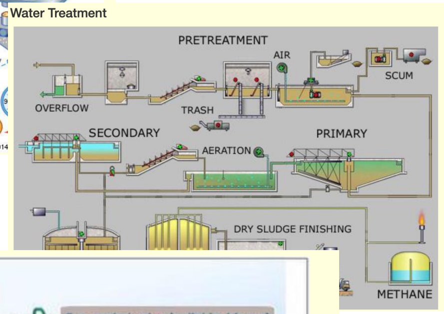
Introduction to Microbiology

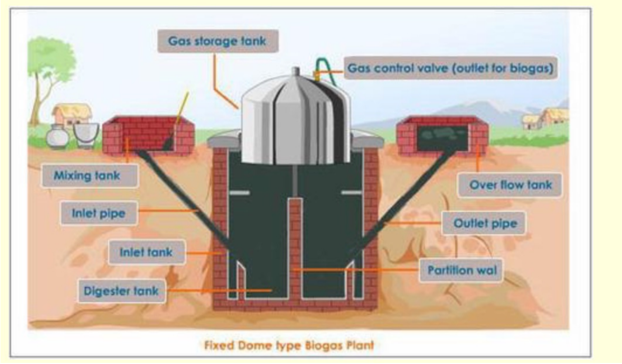
- Microbiology is study of microorganisms, or microbes, a huge diverse group of generally minute (too small to be seen by naked eye) simple life-forms includes; bacteria, archaea, fungi, algae, protozoa, and viruses.



- The field is concerned with the structure, function, and classification of such organisms and with ways of both exploiting and controlling their activities.
- This field study includes basic microbial research, research on infectious diseases, study of prevention and treatment of disease, environmental functions of microorganisms, and industrial use of microorganisms for commercial, agricultural, and medical purposes.

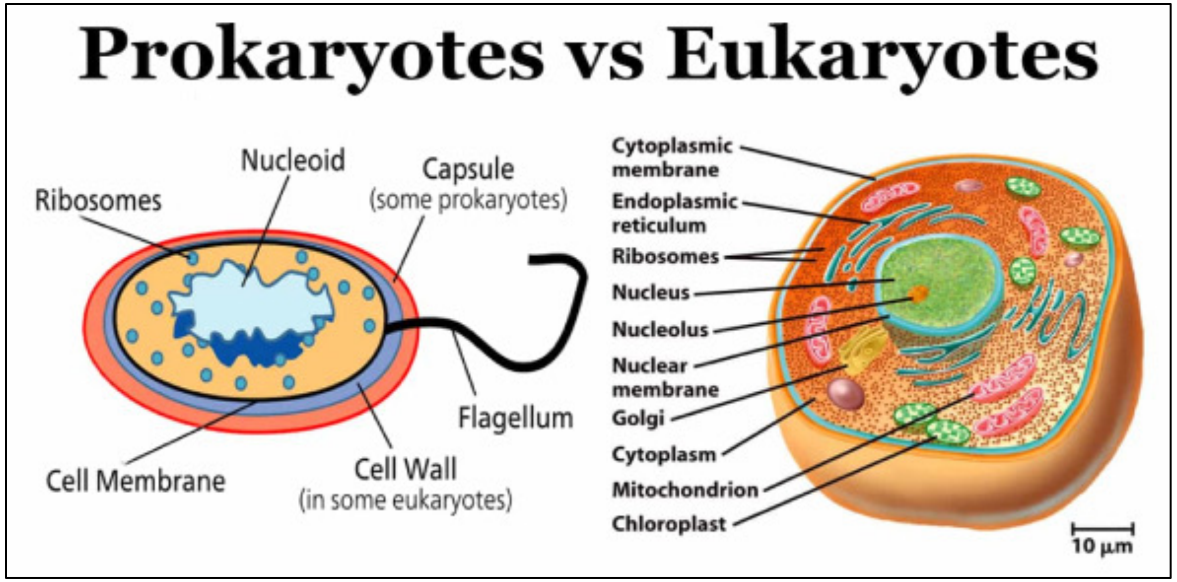




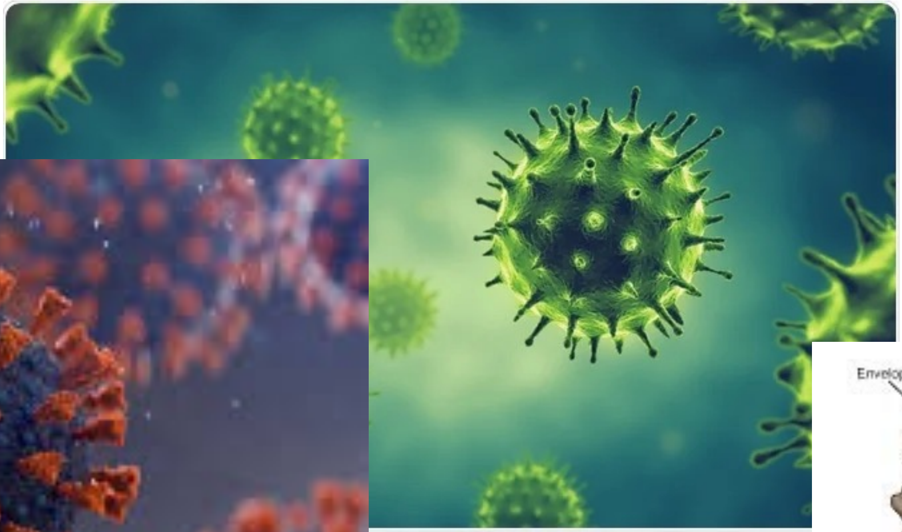


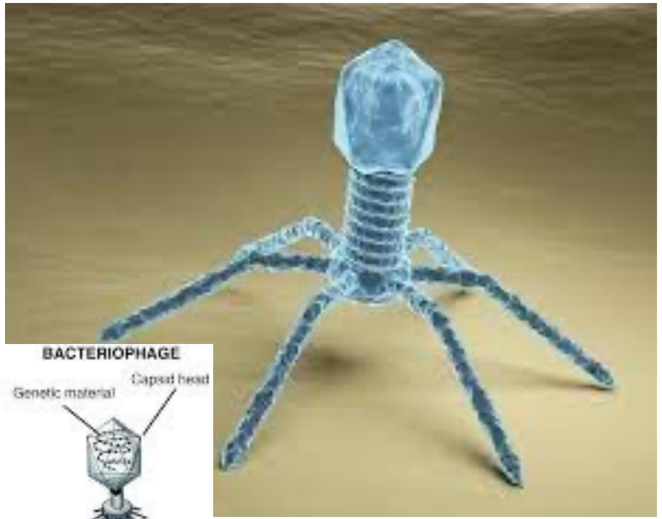
Microorganisms are either unicellular, multicellular or acellular living organisms. And are either **Eukaryotes** or **Prokaryotes**.

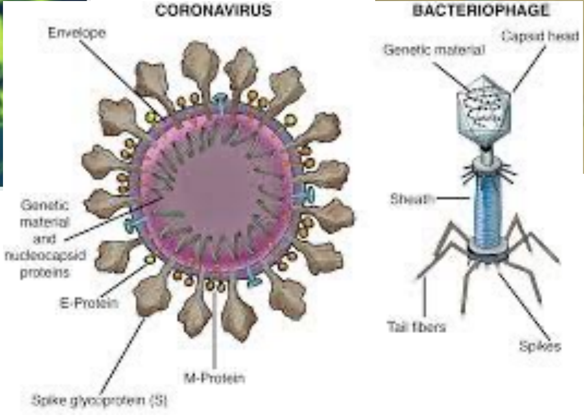
- **-Eukaryotes**; whose cells have a nucleus and organelles (e.g. mitochondria) enclosed within membranes, may also be multicellular and include organisms consisting of many cell type forming different kinds of tissue.
- **-Prokaryotes** is a unicellular that lacks nucleus, mitochondria , or any other organelle. All the intracellular components (proteins, DNA and metabolites) are located together in the cytoplasm enclosed by the cell membrane, rather than in separate cellular compartments.



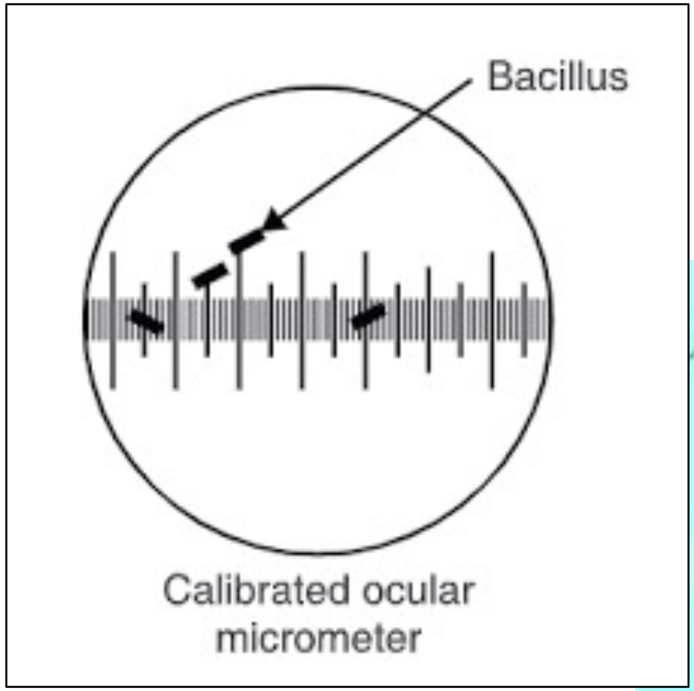
- **Viruses** are acellular microorganisms metabolically inert and therefor replicate only within living cells. They are included in microbiology because of their small size, their close relationship with cells, and their involvement in numerous infectious diseases.

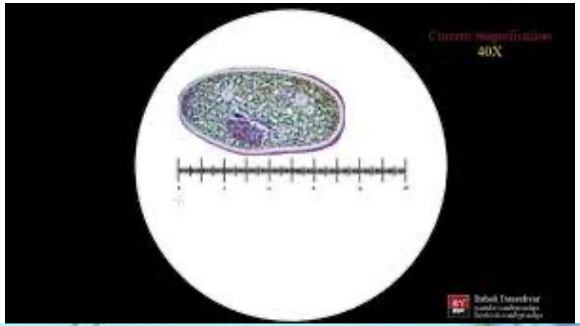


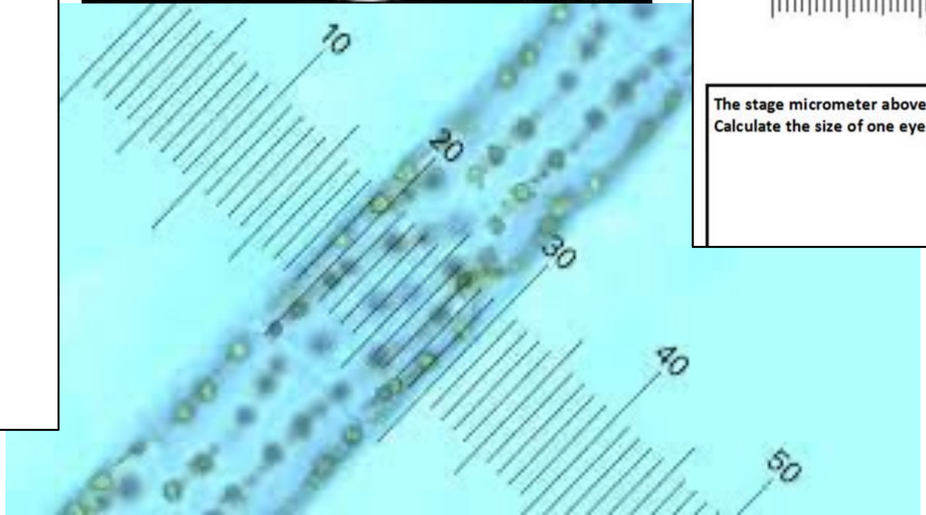


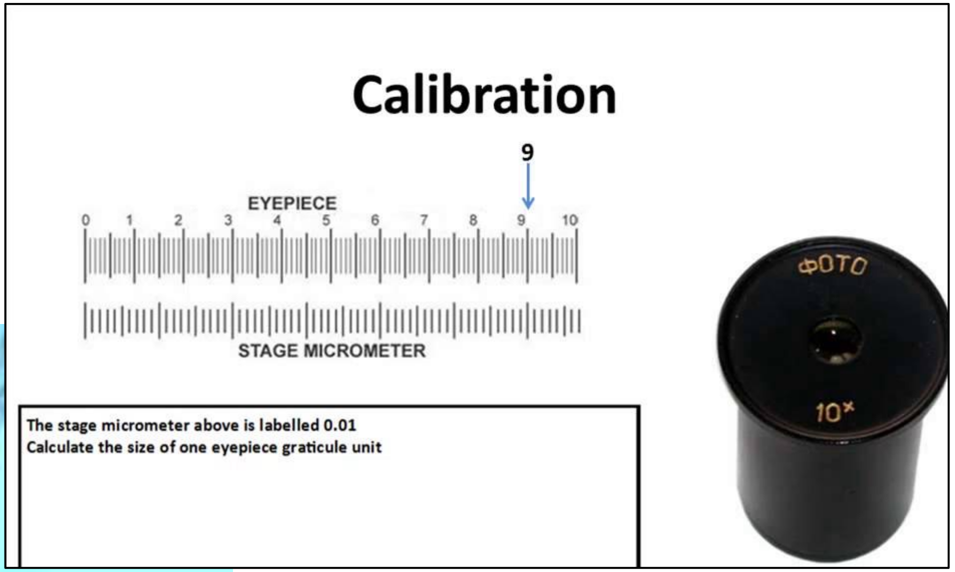


- Most microorganisms are measured in micrometres, with two exceptions.
- The **helminths** are measured in millimetres, and
- the **viruses** are measured in nanometres.

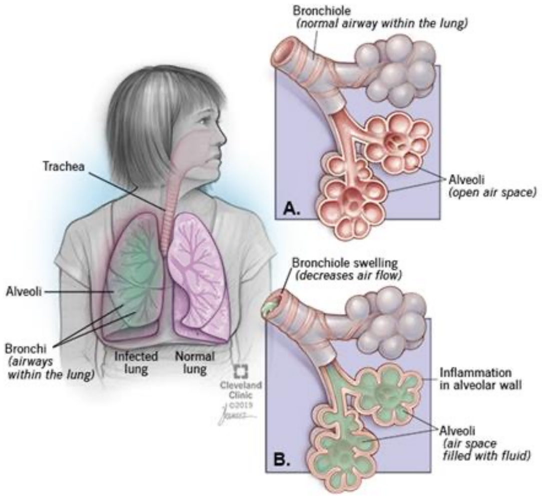








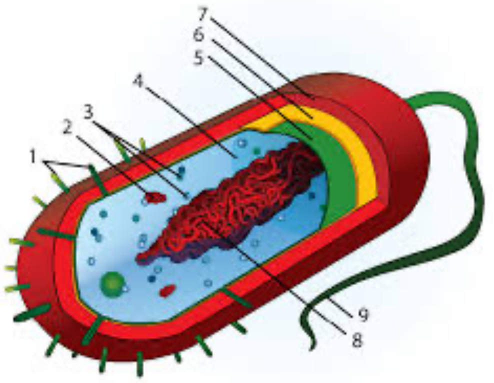
- Microbes have identified as causative agents for over 2,000 infectious diseases. Some infectious diseases are currently emerging and re-emerging. These are on the rise because of rapid travel, the opening up of undeveloped geographic areas, questionable agricultural practices and food handling, drug resistance, and increases in people with chronic medical conditions.

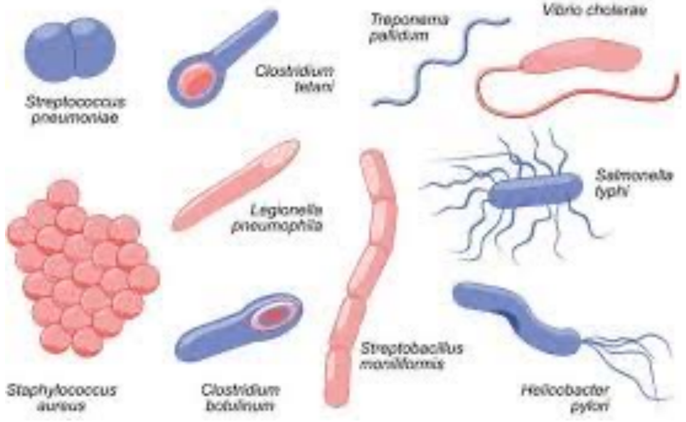


(a) (b)

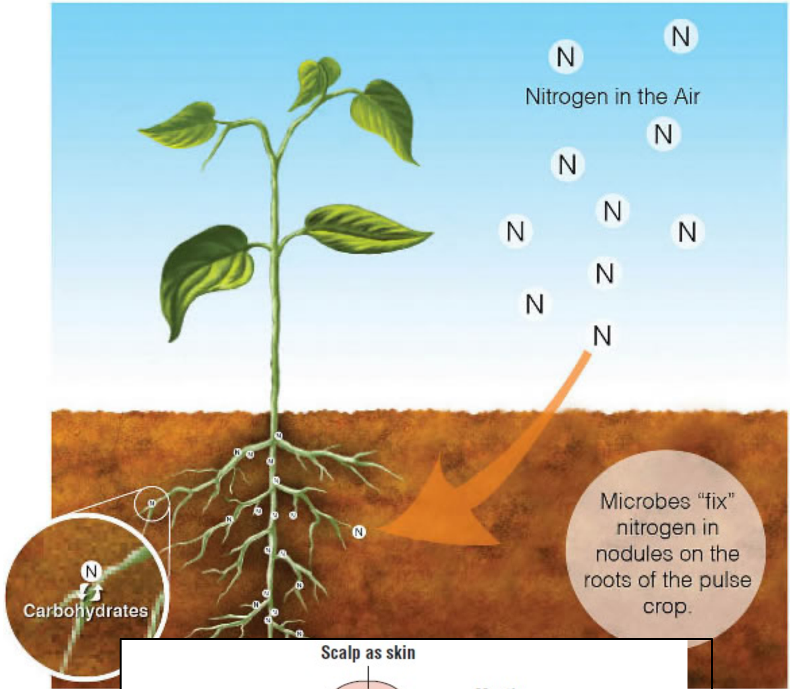
BACTERIA (bacterium)

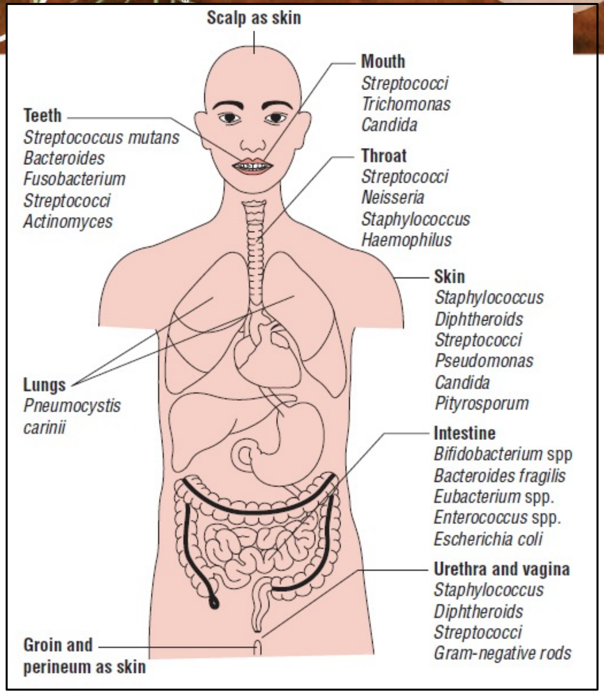
- Bacteria are microscopic single-celled prokaryotic microorganisms that thrive in diverse environments. Typically a few micrometres in length, bacteria have a number of shapes , ranging from spheres to rods and spirals. Bacteria inhabit soil, water, acidic hot springs, radioactive waste, and the deep portions of Earth's crust. Bacteria also live in symbiotic and parasitic relationships with plants and animals.
- There are typically 40 million bacterial cells in a gram of soil and a million bacterial cells in a millilitre of fresh water.



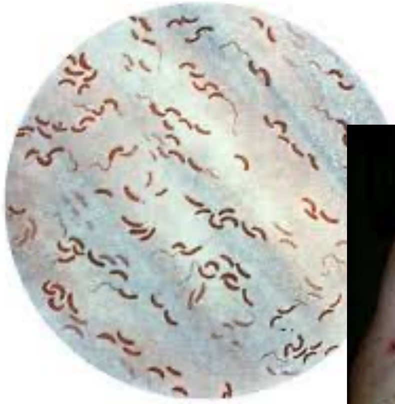


- Bacteria are vital in recycling nutrients, with many of the stages in nutrient cycles such as the fixation of nitrogen from the atmosphere and putrefaction.
- There are approximately ten times as many bacterial cells in the human flora as there are human cells in the body, with the largest number of the human flora being in the gut flora, and a large number on the skin. The vast majority of the bacteria in the body are rendered harmless by the protective effects of the immune system, and some are beneficial.



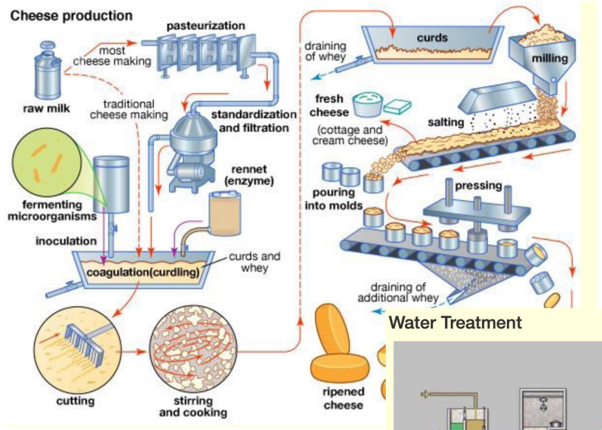


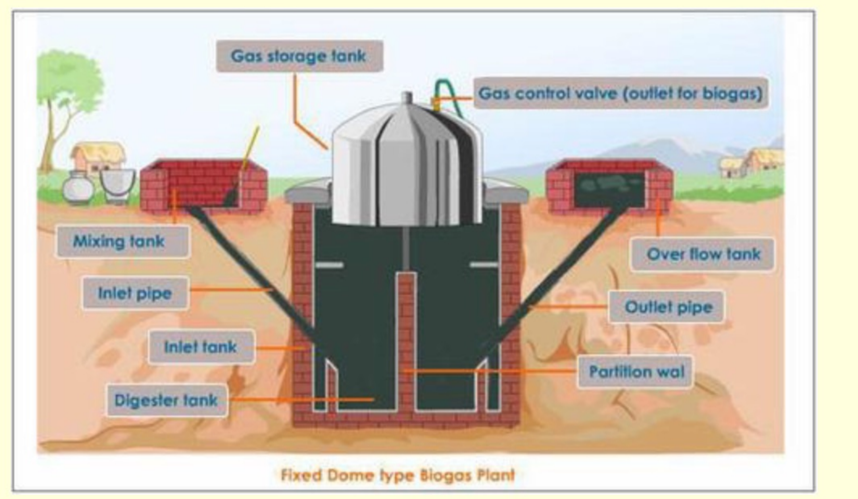
- However, several species of bacteria are pathogenic and cause infectious diseases, like
- **cholera** (*Vibrio cholera*e),
- **syphilis**(*Treponema pallidum*),
- **anthrax**(*Bacillus anthra*cis)
- **leprosy** (*Mycobacterium leprae*)
- and **plague**(*Yersinia pestis*) ,
- The most common fatal bacterial diseases are respiratory infections, with tuberculosis (*Mycobacterium tuberculosis*) alone killing about 2 million people a year ,mostly in Africa.





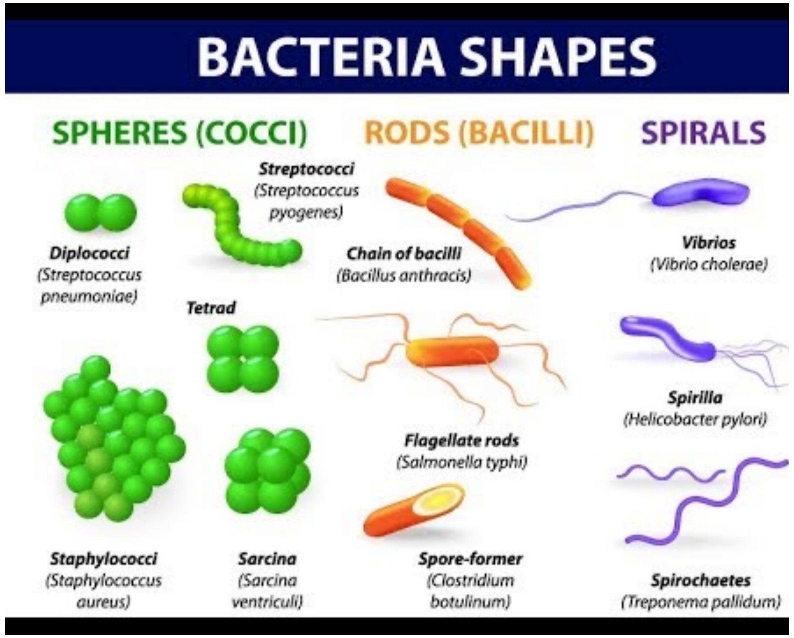
- In developed countries, antibiotic care used to treat bacterial infections. However wrong use of antibiotic might leads to antibiotic resistance, a growing problem. In industry, bacteria are important in sewage treatment and the breakdown of oil spills, the production of cheese and yogurt through fermentation, and the recovery of gold, copper and other metals in the mining sector, as well as in biotechnology, and the manufacture of antibiotics and other chemicals.



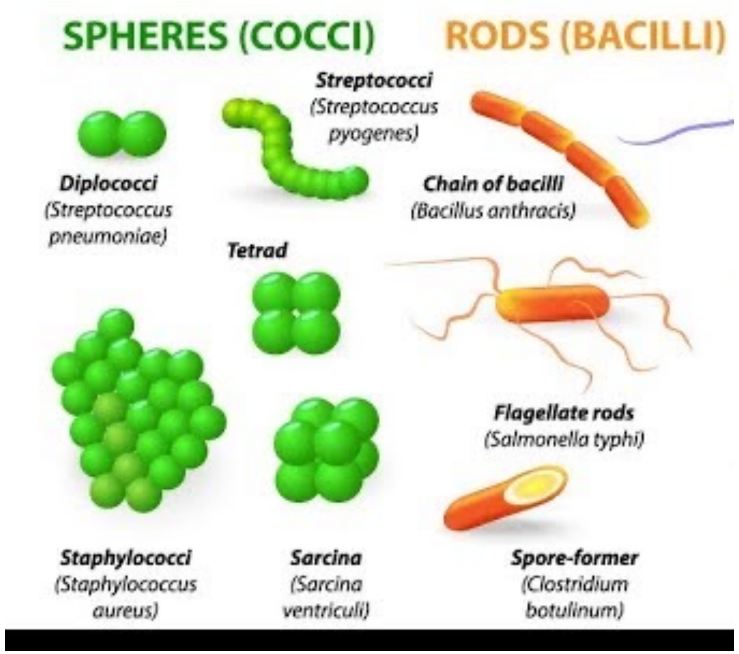


Bacterial Morphology

- Bacteria display a wide diversity of shapes and sizes. Bacterial cells are about tenth-one the size of eukaryotic cells and are typically 0.5– 5.0 micrometres in length.
- Bacteria can be classified by direct examination with the light microscope according to their morphology and arrangement.
- Most bacterial shaped (Fig.1) are either:
- 1-Spherical (coccus), (e.g. *Staphylococcus aureus*).
- 2-Rod shaped with round-ended cylinders (bacillus)
- 3- Slightly curved rods or comma-shaped (vibrio) (e.g. *Bacillus anthracis*).
- 4- Spiral-shaped, called **spirilla** (e.g. *Helicobacter pylori*)
- *5*-Tightly coiled, called **spirochetes** (e.g. *Treponema pallidum*) .

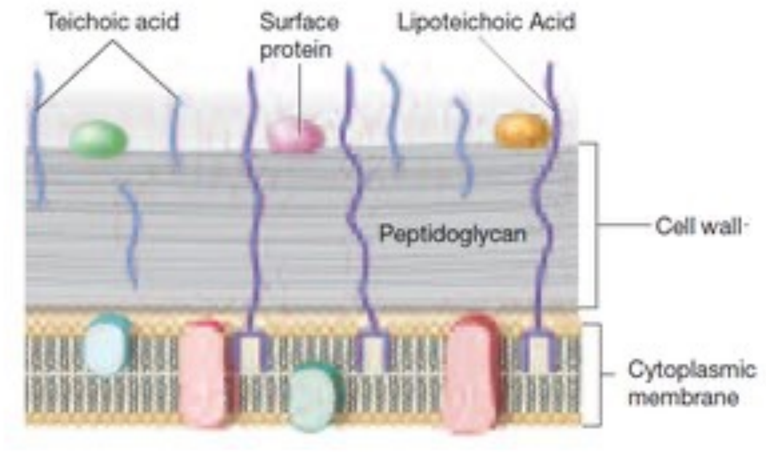


- This wide variety of shapes is determined by the **bacterial cell wall** and **cytoskeleton,** and is important because it can influence the ability of bacteria to acquire nutrients, attach to surfaces, swim through liquids and escape predators.
- Arrangements of cells are based on the number of planes in which a given cell divides. Cocci can divide in many planes to form pairs (diplococci) (*Streptococcus pneumonia*) , chains (streptococci), packets or clusters (micrococci or staphylococci). Bacilli divide only in the transverse plan. If they remain attached, they form pairs, chains, or palisades arrangements.

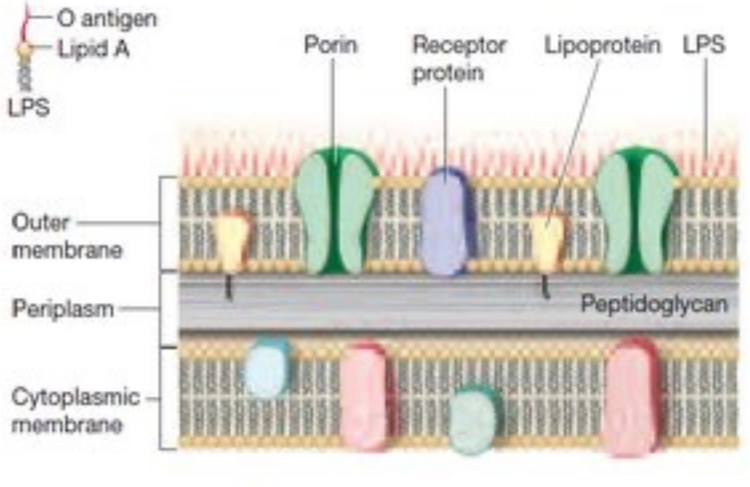


Bacterial Cell Wall

- Bacterial cell wall provides structural safety to the cell. In prokaryotes, the primary function of the cell wall is to protect the cell from internal pressure caused by the much higher concentrations of proteins and other molecules inside the cell compared to its external environment.
- The bacterial cell wall differs from that of all other organisms by the presence of peptidoglycan which is located immediately outside of the cytoplasmic membrane.

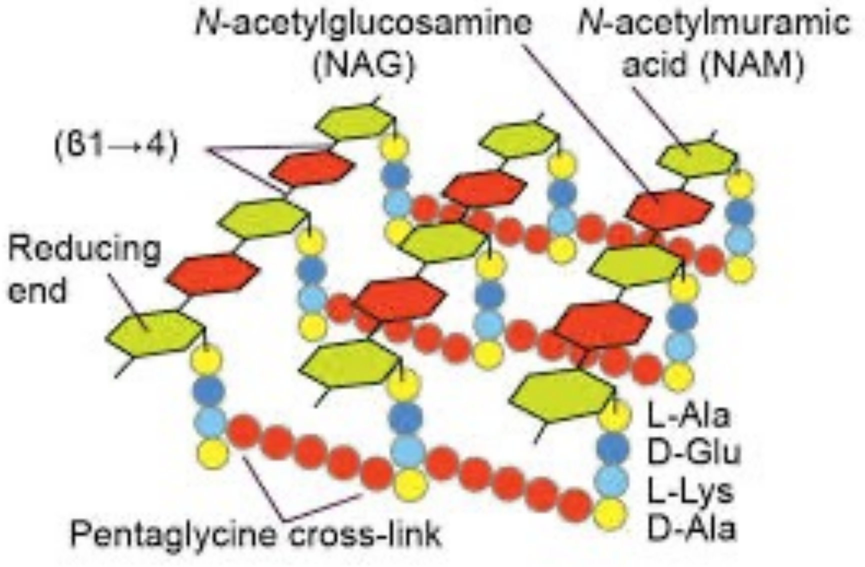


Cell Wall of Gram Positive Organism

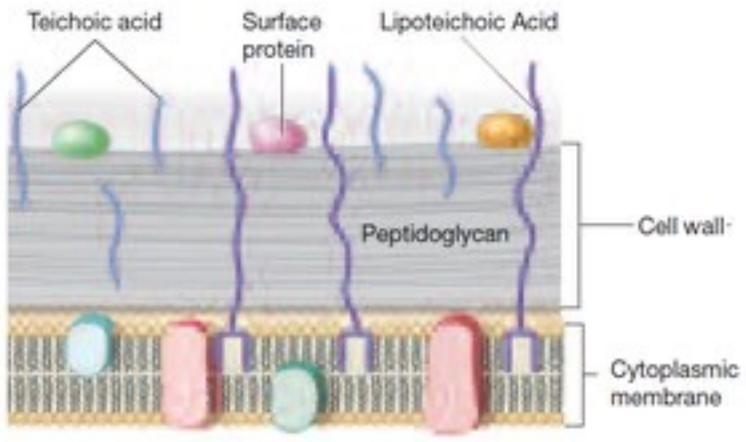


Cell Wall of Gram Negative Organism

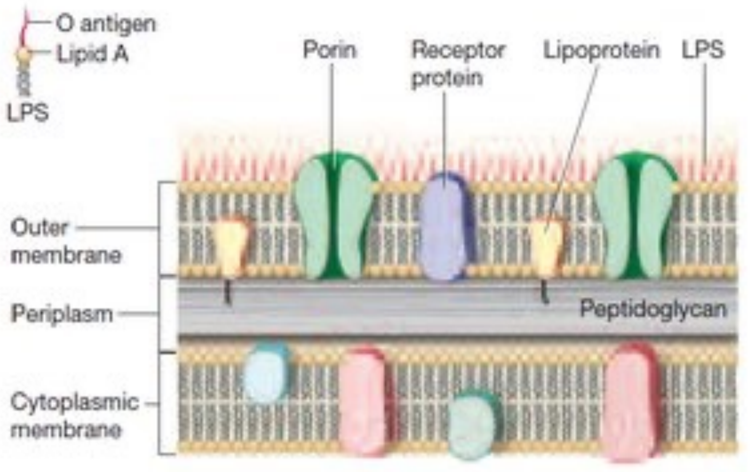
- Peptidoglycan is made up of a polysaccharide backbone consisting of alternating N-Acetylmuramic acid (NAM) and N-acetylglucosamine (NAG) residues in equal amounts. Peptidoglycan is responsible for the rigidity of the bacterial cell wall and for the determination of cell shape. It is relatively porous and is not considered to be a permeability barrier for small substrates.



- While most of bacterial cell walls contain peptidoglycan, not all cell walls have the same overall structures. There are two main types of bacterial cell walls, those of gram-positive bacteria and those of gram-negative bacteria, which are differentiated by their Gram staining characteristics.



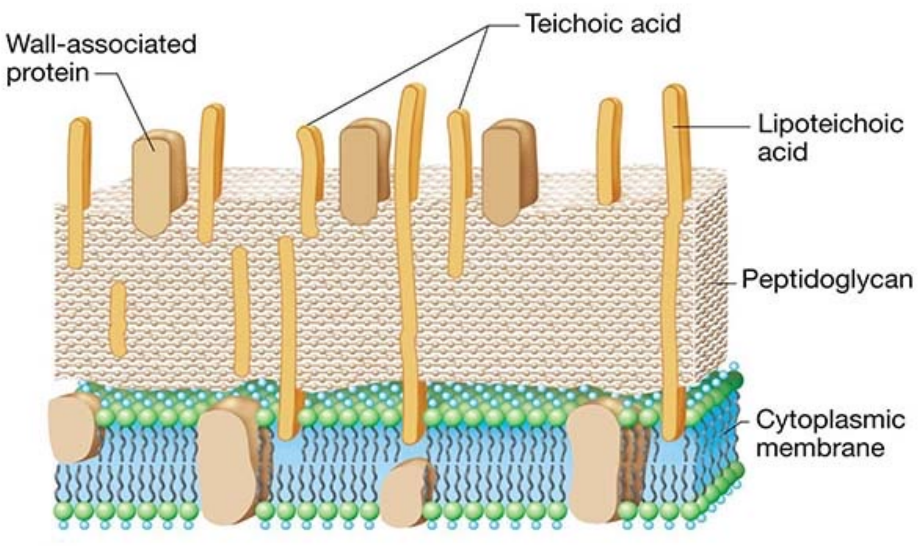
Cell Wall of Gram Positive Organism



Cell Wall of Gram Negative Organism

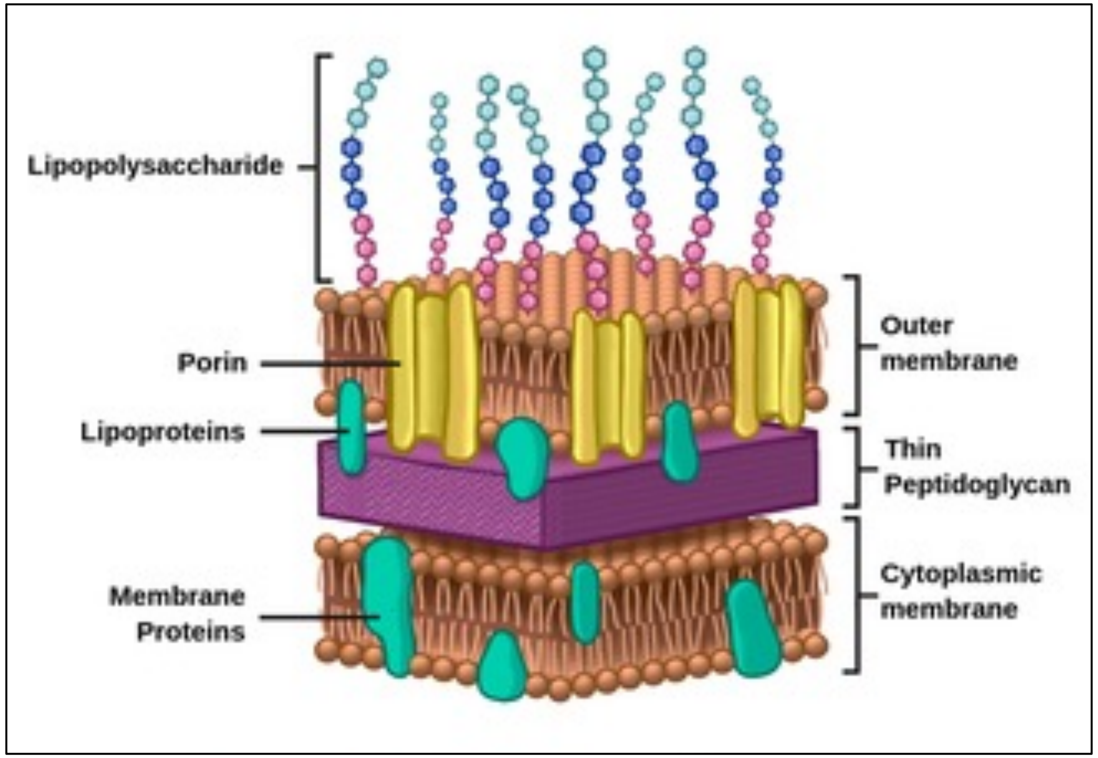
The gram-positive cell wall

- Gram-positive cell wall (Its bacteria stained as purple colour by Gram stain) has a thick <u>peptidoglycan</u> layer and it constitutes almost 95% of the cell wall in some gram-positive bacteria. It also contains teichoic acid and lipoteichoic acid directly attached to the peptidoglycan.
- There are two main types of teichoic acid: ribitol teichoic acids and glycerol teichoic <u>acids</u>. The latter one is more widespread. These acids are polymers of <u>ribitol</u> phosphate and <u>glycerol phosphate</u>, respectively, and only located on the surface of many gram-positive bacteria.

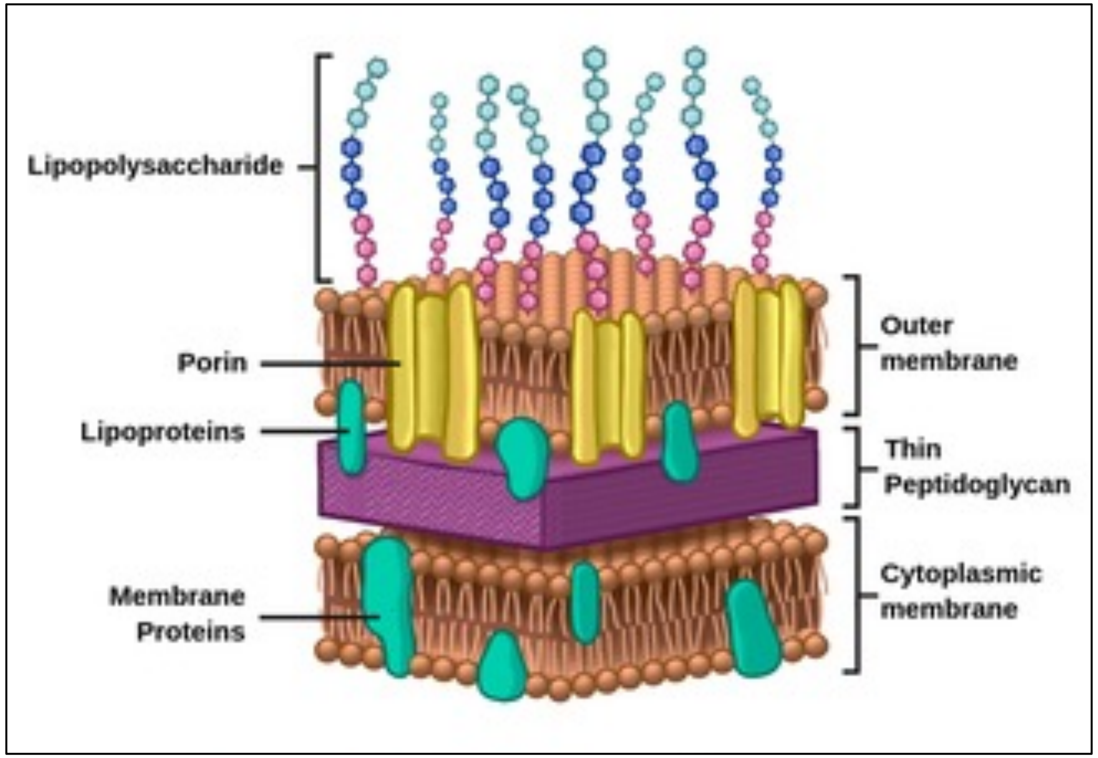


The Gram-negative cell wall

- Gram-negative cell walls are unlike the gram-positive cell walls, they composed of an outer membrane (OM) and a thinner shell of peptidoglycan layer adjacent to the cytoplasmic membrane. Gram-negative bacteria are stained as pink colour by gram stain. The outer membrane contains a unique component, lipopolysaccharide (LPS) in addition to proteins and phospholipids.

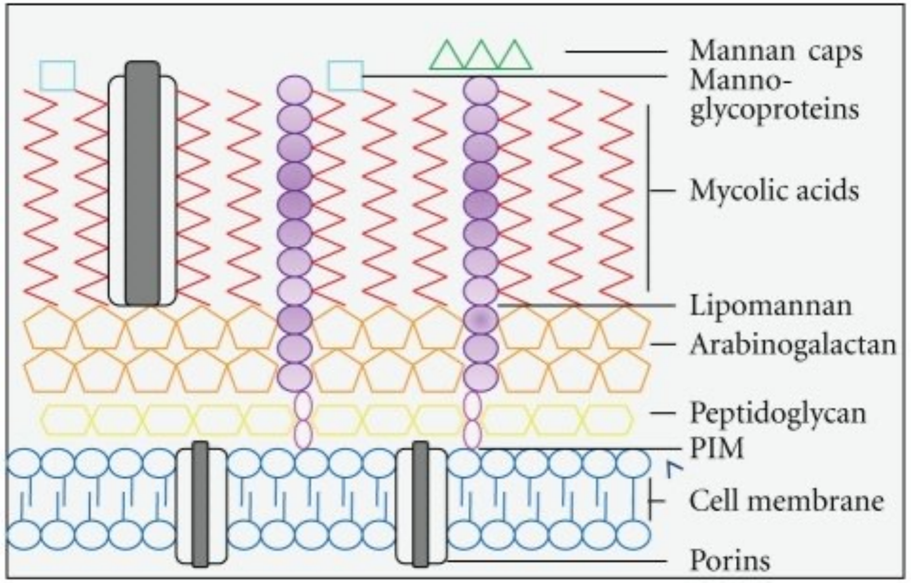


- The chemical structure of lipopolysaccharides is often unique to specific bacterial sub-species and is responsible for many of antigenic properties of these strains.
- Lipopolysaccharides, also called (endotoxins), are composed of polysaccharides and lipid A which are responsible for much of the toxicity of Gram-negative bacteria.



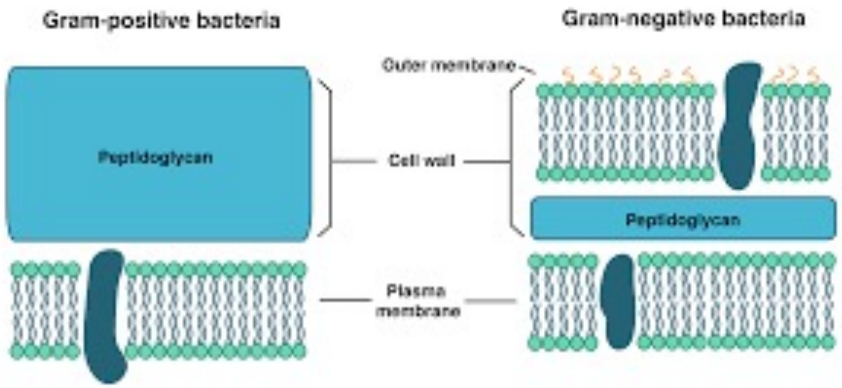
Non typical cell wall

- **Mycobacterium and Nocardia** contain peptidoglycan and stain gram positive, but their cell wall is composed of unique types of lipids.
- **Mycoplasmas** are bacteria that naturally lack a cell wall. Its cell membrane contains sterols that make it resistant to lysis.



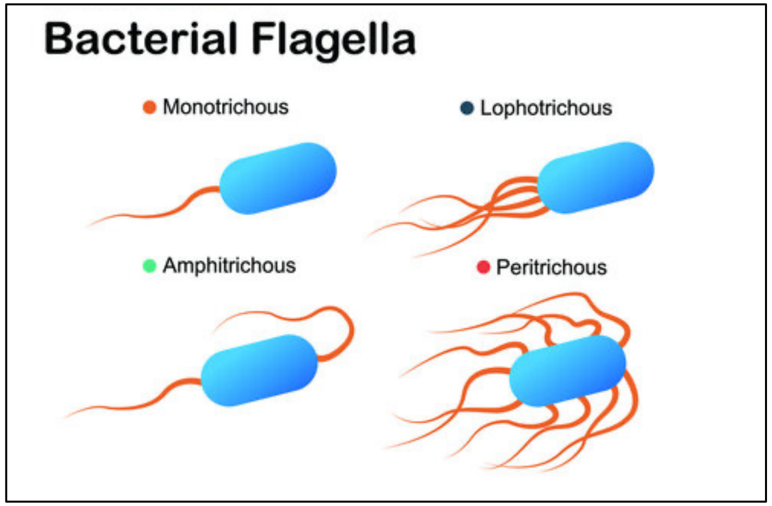
Plasma membrane

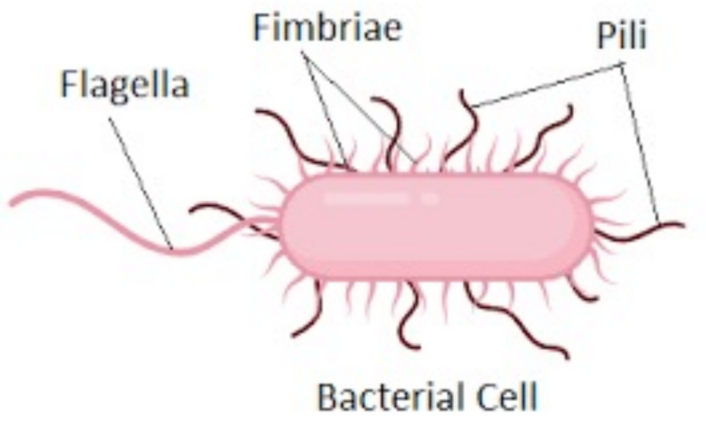
- The plasma membrane or bacterial cytoplasmic membrane is composed of a phospholipid bilayer.
- The General functions of a cell membrane are **acting as a permeability barrier** for most molecules and serving as the location for the **transport of molecules** into the cell and **energy conservation**.
- The region between the cytoplasm membrane and the outer membrane is called a periplasm. There are channels called porins present in the outer membrane that allow for passive transport of many ions, sugars and amino acids across the outer membrane to the periplasm and than be transported into the cell by The plasma membrane.



Cell Extensions and Surface Structures

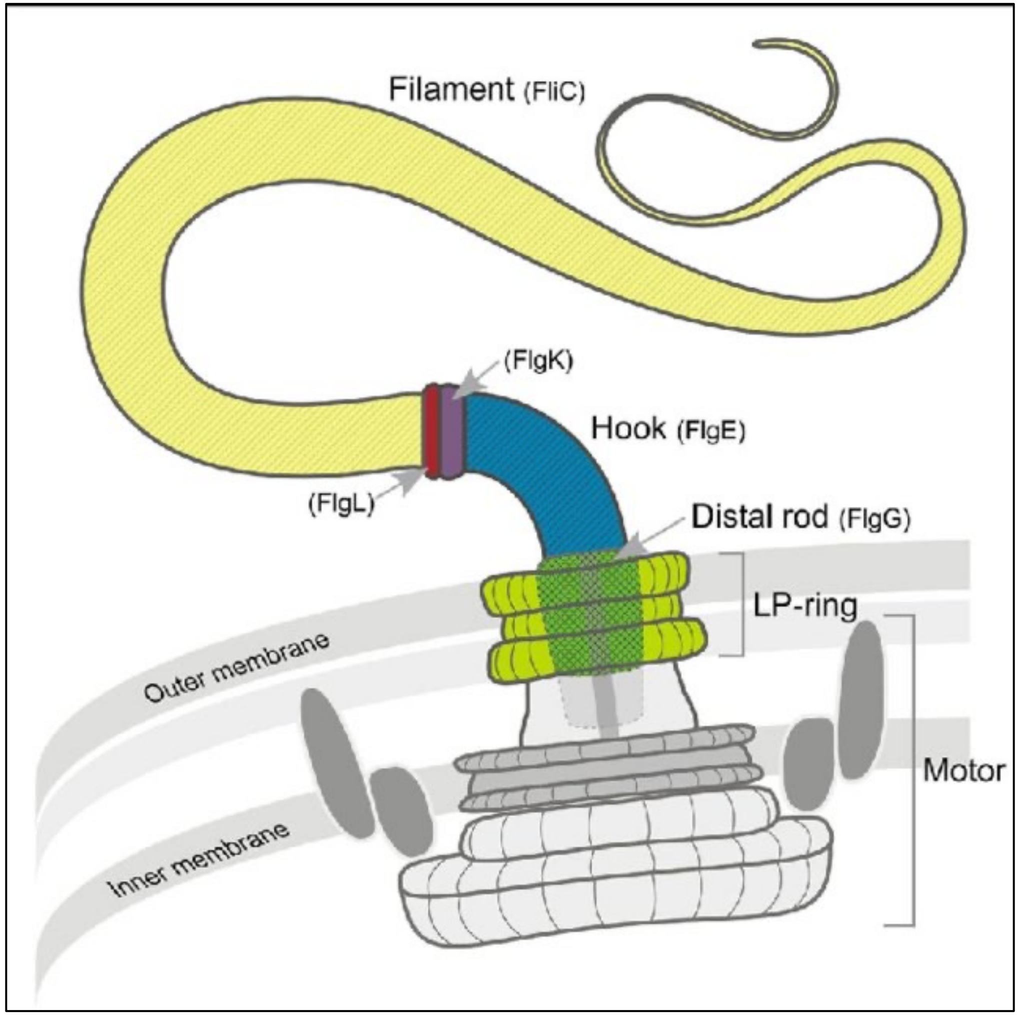
- Bacteria often have accessory **appendages** sprouting from their surfaces. Appendages can be divided into two major groups:
- those that provide motility (flagella and axial filaments) and
- those that provide attachments or channels (fimbriae and pili).





Flagella—Bacterial Propellers

- The prokaryotic **flagellum** is provide the power of motility. This allows a cell to swim freely through an aqueous habitat.
- The bacterial flagellum when viewed under high magnification displays three distinct parts: the filament, the hook (sheath), and the basal body.



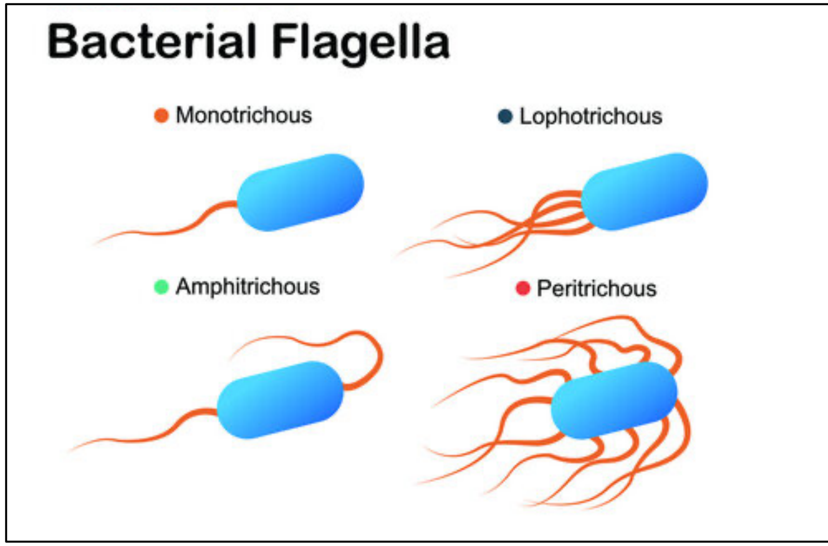
Flagella vary both in number and arrangement according to two general patterns

(A) In a **polar** arrangement, the flagella are attached at one or both ends of the cell.

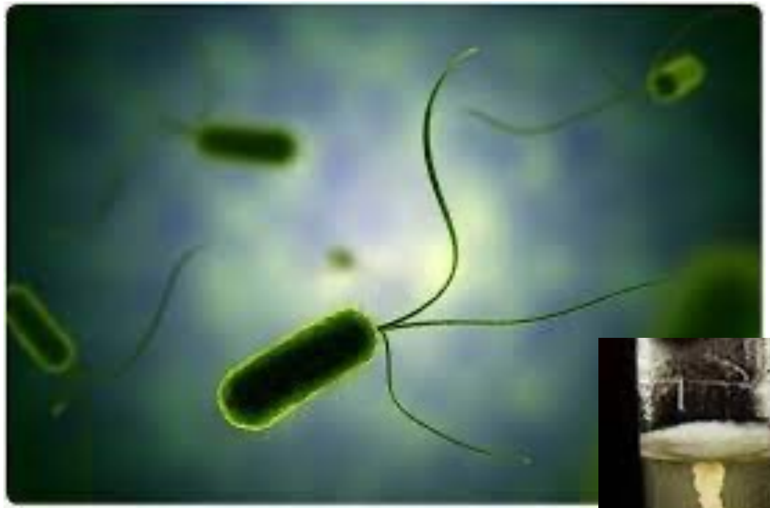
Three subtypes of this pattern are:

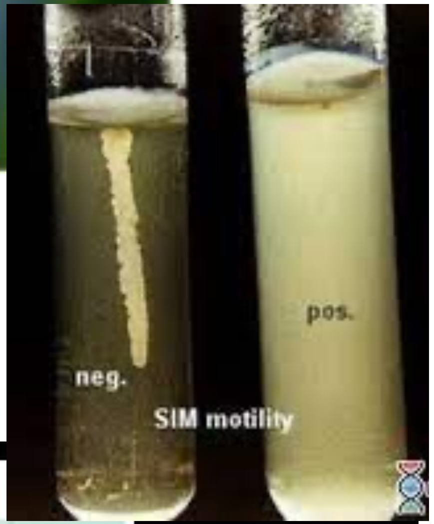
- **1-monotrichous *** with a single flagellum.
- 2- **amphitrichous *** with one flagellum in each side.
- 3- **lophotrichous *** with small bunches of flagella emerging from the same one site.

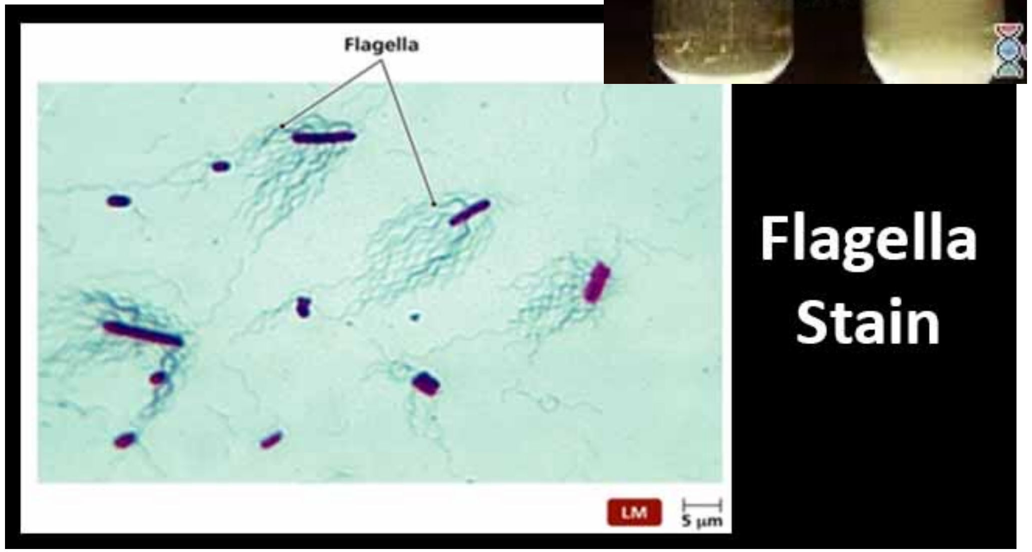
(B) In a **peritrichous *** arrangement, flagella are dispersed randomly over the surface of the cell.



- The presence of motility is used in the laboratory identification of various groups of bacteria.
- Special stains or electron microscope preparations must be used to see arrangement, because flagella are too minute to be seen in live preparations with a light microscope.

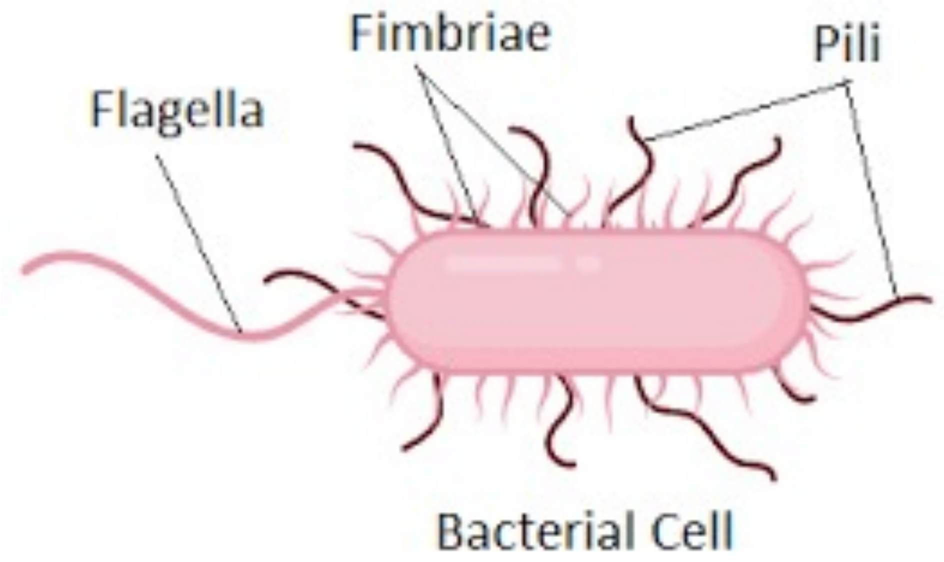




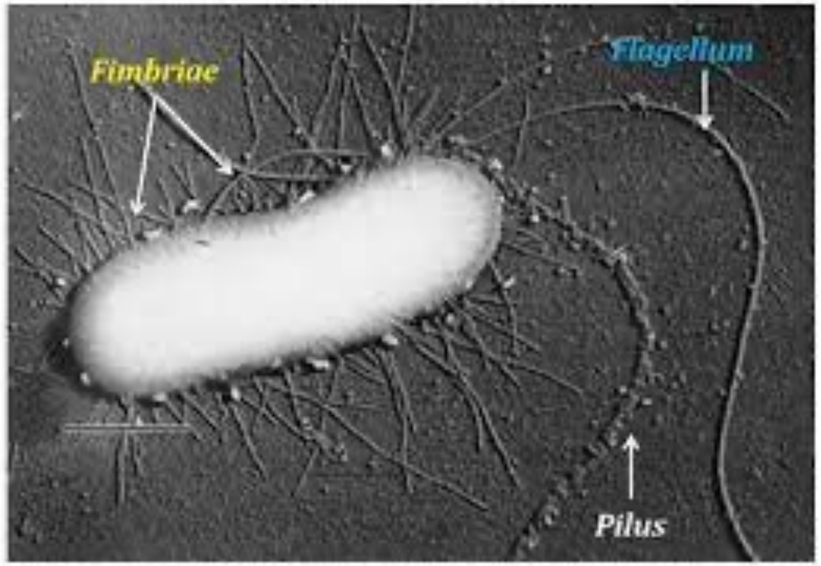


Fimbriae and Pili

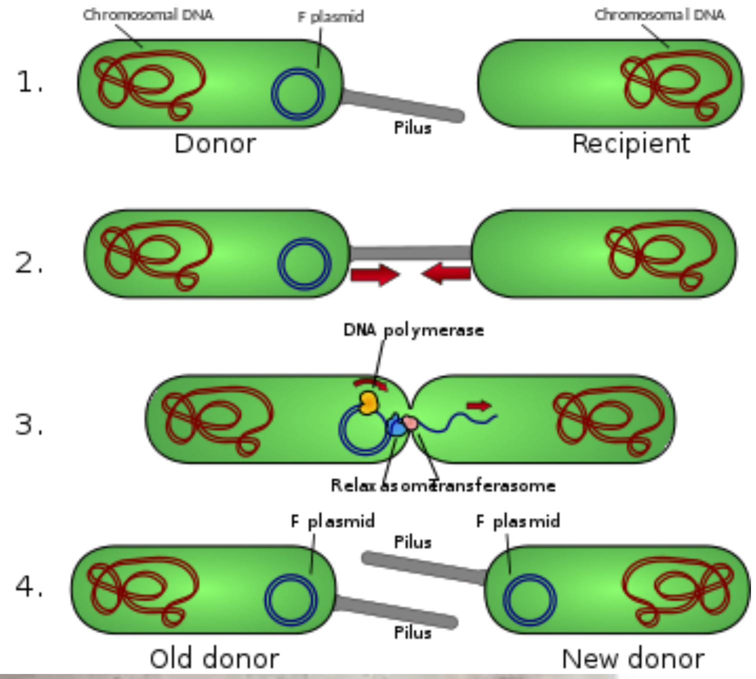
- The structures termed **fimbria** and **pilus** both refer to bacterial surface appendages that are involved in interactions with other cells but do not provide locomotion.



- **Fimbriae** are small, bristle like fibers emerging from the surface of many bacterial cells **.**
- Compose of protein. Fimbriae have an **inherent tendency** to stick to each other and to surfaces.
- They may be responsible for the mutual clinging of cells that leads to **biofilm formation** and other thick aggregates of cells on the surface of liquids and for the microbial colonization of solid surfaces such as, teeth, rocks and glass.
- Some pathogens can colonize and infect host tissues because of a tight adhesion between their fimbriae and epithelial cells **.** For example, the gonococcus (agent of gonorrhoea) colonizes the genitourinary tract, and *Escherichia coli* colonizes the intestine by this means.



- **Pilus** (also called a *sex pilus*) is an elongate, rigid tubular structure made of a special protein, *pilin* .
- So far, true pili have been found only on gram-negative bacteria, where they are utilized primarily in conjugation which involves a transfer of DNA from one cell to another.



Other Bacterial Surface Structures

- Glycocalyx (slime layer)

The glycocalyx is a loose shield of polysaccharide coating that covers the outer surface of many bacteria, protects them from dehydration and loss of nutrients and allows bacteria to adhere firmly to the various structures, e.g. oral mucosa, teeth, heart, and catheters, and contribute to the formation of biofilms.

Slime Layer

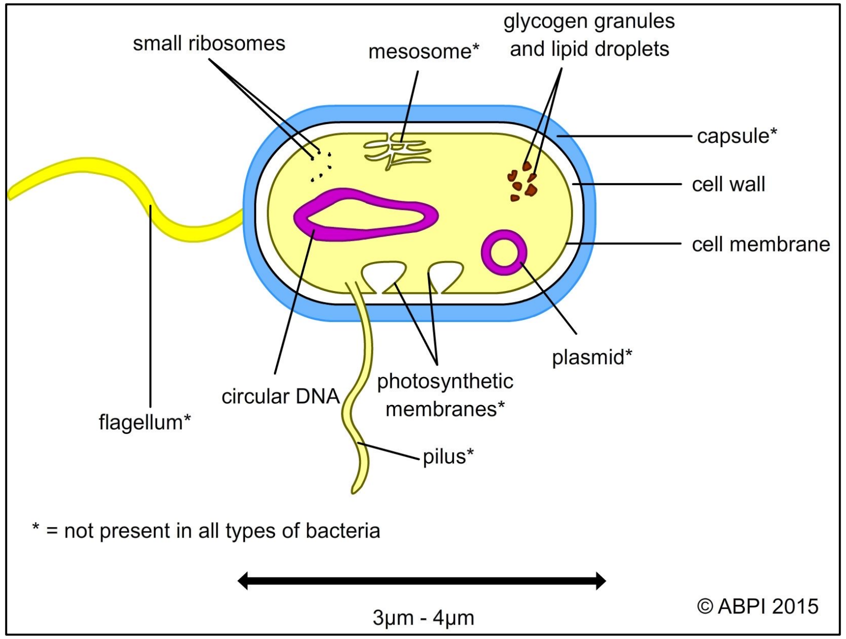
- **Capsule**

An amorphous, gelatinous layer (usually more substantial than the glycocalyx) surrounds the entire bacterium.

It composed of polysaccharides and sometimes proteins. The sugar components of the polysaccharides vary in different bacterial and frequently determine the serological type within a species.

Contents of the Cell Cytoplasm

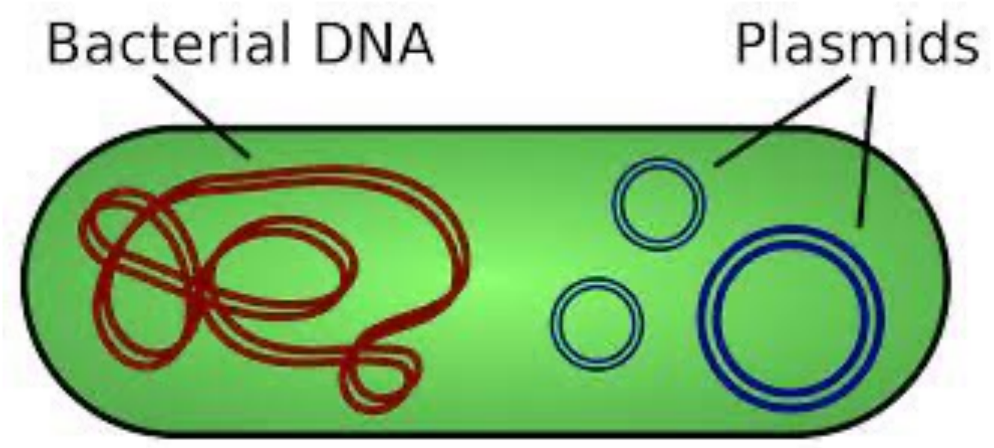
- ***Bacterial Chromosomes and Plasmids:***
- The hereditary material of most bacteria exists in the form of a single chromosome consisting of a circular, **double stranded** DNA molecule**.** By definition, bacteria do not have a true nucleus. Their DNA is not enclosed by a nuclear membrane but instead is aggregated in a central area of the cell called the **nucleoid.** The chromosome is actually an extremely long molecule of DNA that is tightly coiledto fit inside the cell compartment.



- Arranged along its length are genetic units (about 2000 genes) that carry information required for bacterial maintenance and growth. many bacteria contain other, nonessential pieces of DNA called plasmids.

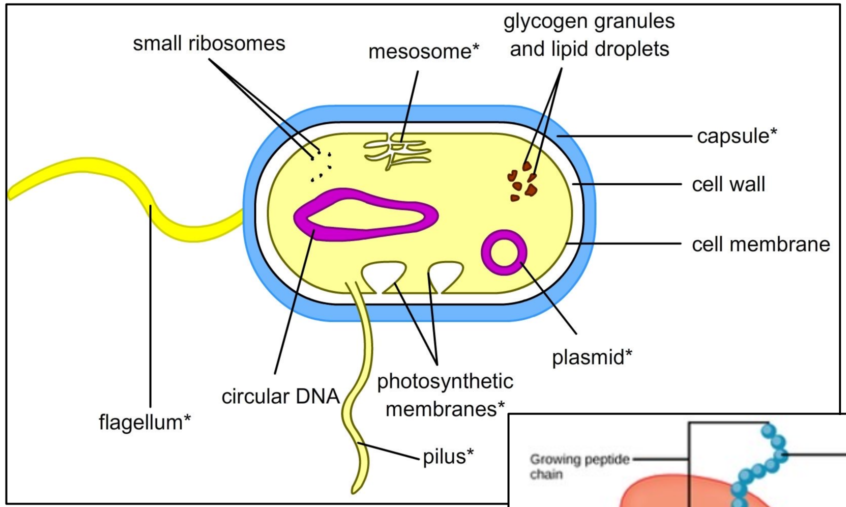
Plasmids

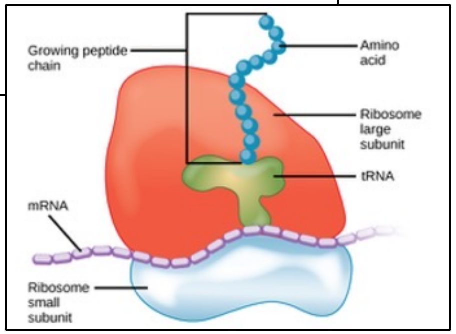
- A **plasmid** is a small DNA molecule within a cell that is physically separated from a chromosomal DNA and can replicate independently. They are most commonly found as small circular, double-stranded DNA molecules in bacteria; however, plasmids are sometimes present in archaea and eukaryotic organisms. In nature, plasmids often carry genes that may benefit the survival of the organism, for example antibiotic resistance.

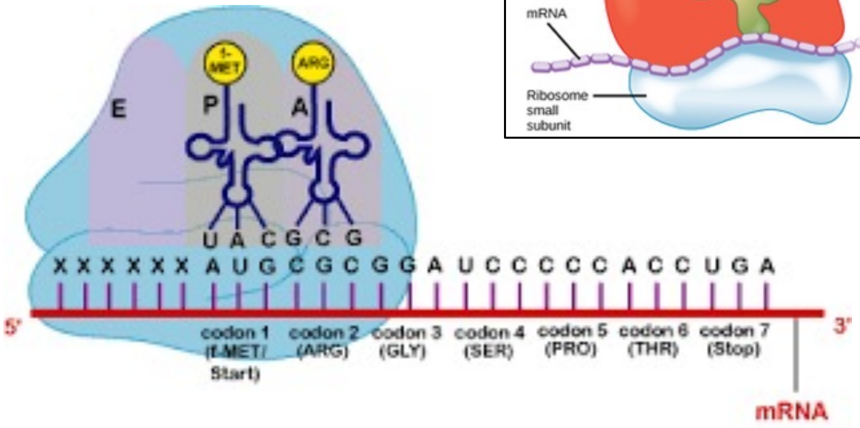


Ribosomes: Sites of Protein Synthesis

- A bacterial cell contains thousands of **ribosomes,** which are made of RNA and protein., ribosomes show up as fine, spherical specks dispersed throughout the cytoplasm that often occur in chains (polysomes). Many are also attached to the cell membrane. Chemically, a ribosome is a combination of a special type of RNA called ribosomal RNA, or rRNA (about 60%), and protein (40%). They fit together to form factory where protein synthesis occurs.







Inclusions, or Granules: Storage Bodies

- **Inclusion bodies**, sometimes called **elementary bodies**, are nuclear or cytoplasmic aggregates of stable substances, usually proteins.
- Some inclusion bodies contain condensed, energy-rich organic substances, such as glycogen and poly b-hydroxybutyrate (PHB), within special single-layered membranes.
- **Granules,** contain crystals of inorganic compounds and are not enclosed by membranes.

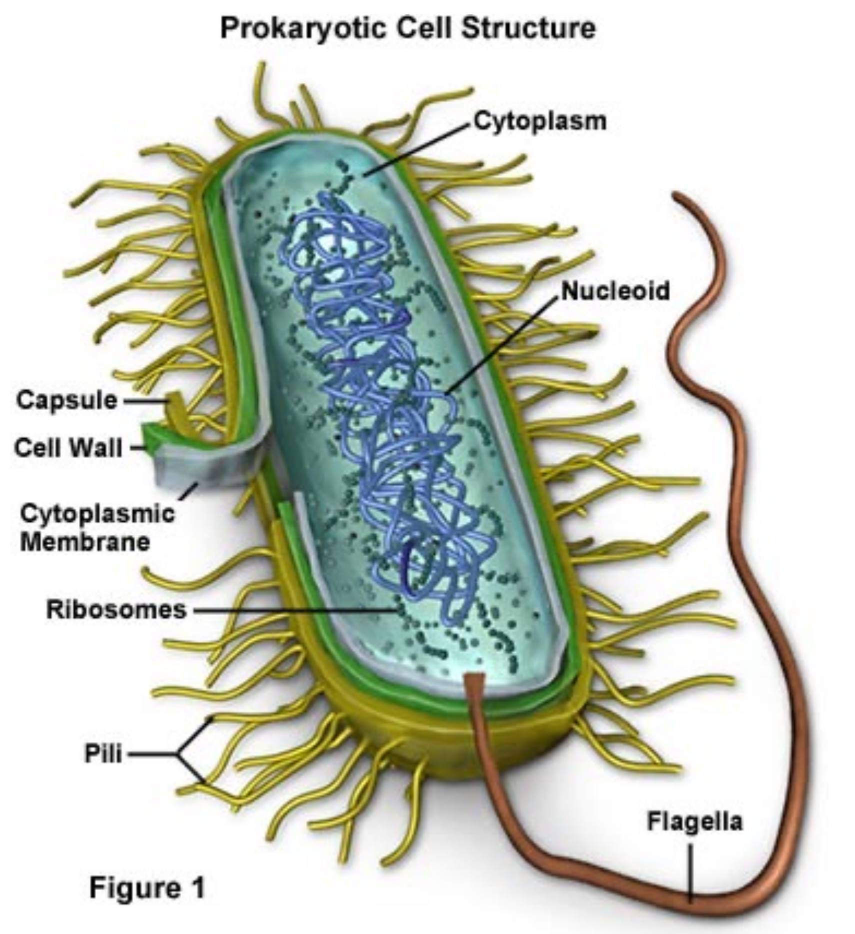


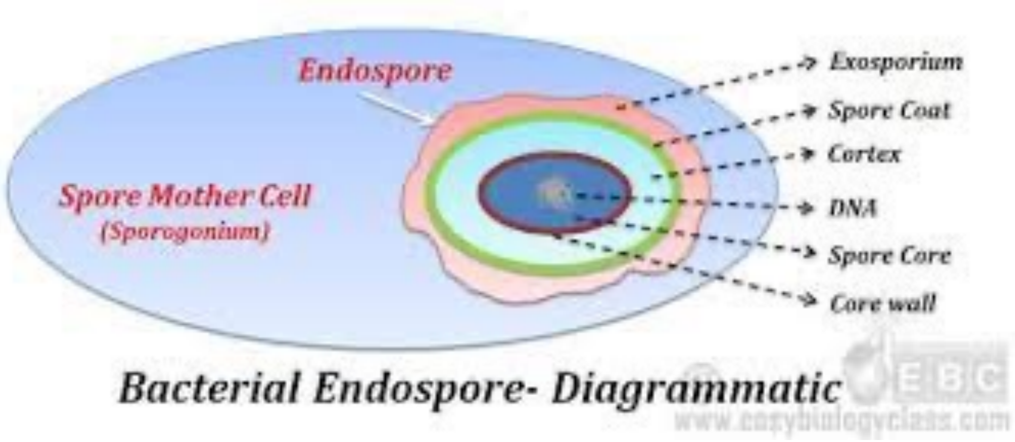
Figure 1

Bacterial Endospores:

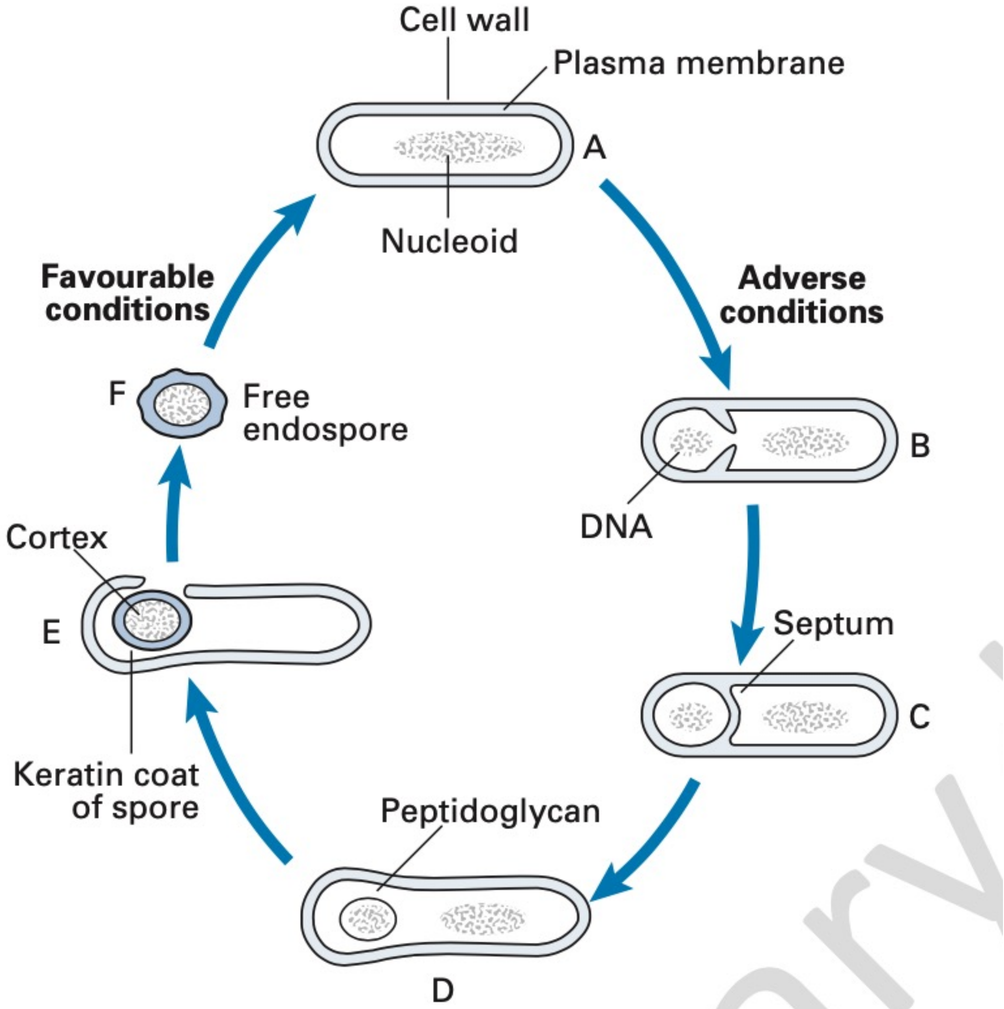
An **endospore** is a dormant, tough, and non-reproductive structure produced by certain bacteria for withstanding hostile conditions and facilitating survival. (e.g. endospores produced by *Bacillus, Clostridium)*.

These bacteria have a two-phase life cycle that shifts between a **vegetative cell** and an **endospore.** The vegetative cell is the metabolically active and growing phase. When exposed to certain environmental signals, it forms an endospore by a process termed **sporulation.** The spore exists in an inert, resting condition that is capable of high resistance and very long-term survival.

- The spore contains bacterial DNA, a small amount cytoplasm, cell membrane, peptidoglycan, very little water and a thick keratin like coat. This coat is remarkably resistant to heat, dehydration, radiation and chemicals. Once formed, the spore is metabolically inert, and can remain dormant for many years. Bacterial endospores can be called either terminal or subterminal spores depending on their position inside the bacterial cell. When appropriate conditions supervene (e.g. water, nutrients), there is enzymatic degradation of the coat, and the spore transforms into a metabolizing, reproducing bacterial cell once again



Bacterial Endospores Formation



The cycle of sporulation. (**A**) Vegetative cell; (**B**) ingrowth of cytoplasmic membrane; (**C**) developing forespore; (**D**) forespore completely cut off from the cell cytoplasm; (**E**) development of cortex and keratin spore coat; (**F**) liberation of spore and conversion to vegetative state under favourable conditions.