Morphology of Bacteria and Virus

(EXTERNAL CAPSULE AND GLYCOCALYX, PLASMIDS AND EPISOMES. NUCLEAR MATERIAL, BACTERIAL CHROMOSOME)

BY

SUMAN KALYAN KHANRA

SACT

DEPARTMENT OF PHYSIOLOGY

NARAJOLE RAJ COLLEGE

Narajole; Paschim Medinipur

EXTERNAL CAPSULE

Capsule (also known as K antigen) is a major virulence factor of bacteria, e.g. all of the principal pathogens which cause pneumonia and meningitis, including *Streptococcus pneumoniae*, *Haemophilus influenzae*, *Neisseria meningitidis*, *Klebsiella pneumoniae*, *Escherichia coli*, and group B *streptococci* have polysaccharide capsules on their surface. Nonencapsulated mutants of these organisms are avirulent.

Capsule is a ....

- Gelatinous layer covering the entire bacterium
- Composed of polysaccharide (i.e. poly: many, saccharide: sugar). These polymers are composed of repeating oligosaccharide units of two to four monosaccharides.
- Capsule is located immediately exterior to the murein (peptidoglycan) layer of gram-positive bacteria and the outer membrane (Lipopolysaccharide layer) of gram-negative bacteria.

Importance of Bacterial Capsule

1. **Virulence determinants:** Capsules are anti-phagocytic. They limit the ability of phagocytes to engulf the bacteria. The smooth nature and negative charge of the capsule prevents the phagocyte from adhering to and engulfing the bacterial cell. If a pathogenic bacteria lose capsule (by mutation), they wont be able to cause disease (i.e. loses disease causing capacity).
2. **Saving engulfed bacteria from the action of neutrophil:** Bacterial capsule prevents the direct access of lysosome contents with the bacterial cell, preventing their killing.
3. Prevention of complement-mediated bacterial cell lysis.
4. Protection of anaerobes from oxygen toxicity.
5. **Identification of bacteria:** Anti-phagocytic nature of Bacterial capsule
6. Using specific antiserum against capsular polysaccharide. E.g. Quellung reaction
7. **Development of Vaccines:** Capsular polysaccharides are used as the antigens in certain vaccines. For examples:

- Polyvalent (23 serotypes) polysaccharide vaccine of *Streptococcus pneumoniae* capsule.
- Polyvalent (4 serotypes) vaccine of *Neisseria meningitidis* capsule.
- A monovalent vaccine made up of capsular material from *Haemophilus influenzae*.

8. **Initiation of infection**: Capsules helps the organism to adhere to host cells.The capsule also facilitates and maintains bacterial colonization of biologic (e.g. teeth) and inanimate (e.g. prosthetic heart valves) surfaces through formation of **biofilms**.
9. Receptors for Bacteriophages.

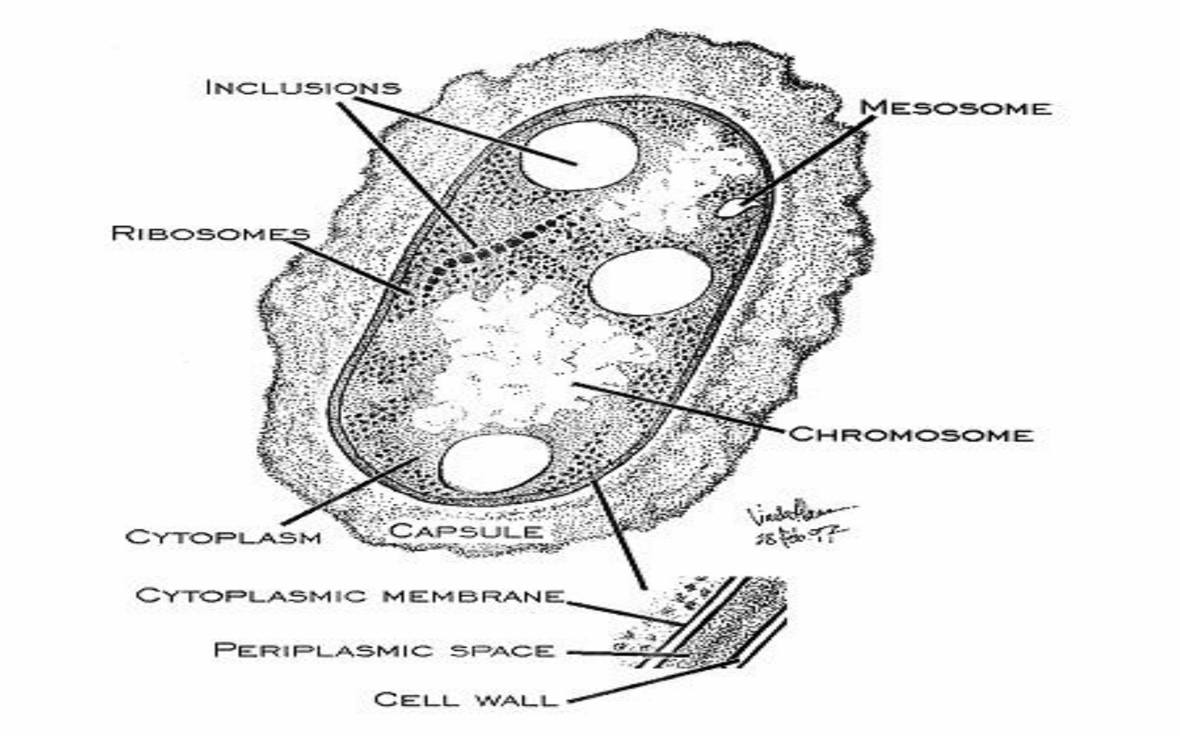
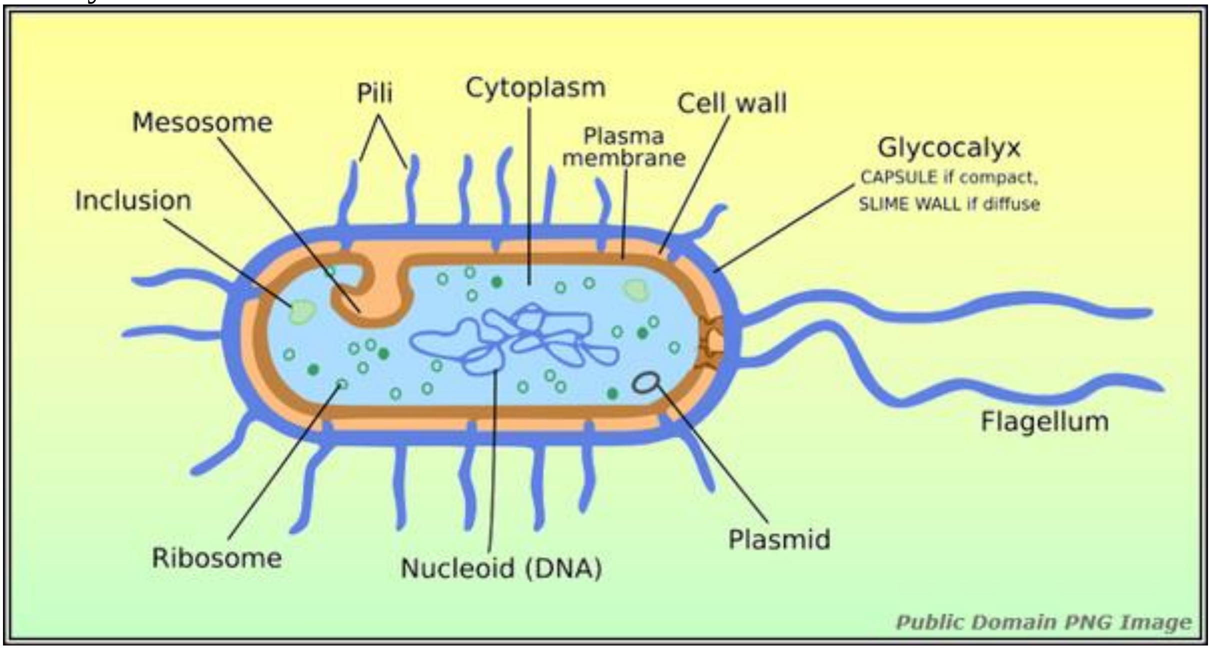


Fig: Structure of capsule

- **GLYCOCALIX :**

The glycocalyx is a carbohydrate-enriched coating that covers the outside of many eukaryotic cells and prokaryotic cells, particularly bacteria . When on eukaryotic cells the glycocalyx can be a factor used for the recognition of the cell. On bacterial cells, the glycocalyx provides a protective coat from host factors. The possession of a glycocalyx on bacteria is associated with the ability of the bacteria to establish an infection.

The glycocalyx of bacteria can assume several forms. If in a condensed form that is relatively tightly associated with the underlying cell wall, the glycocalyx is referred to as a capsule. A more loosely attached glycocalyx that can be removed from the cell more easily is referred to as a slime layer.



- **SLIME LAYER:**

A slime layer in bacteria is an easily removable, unorganized layer of extracellular material that surrounds bacteria cells. Specifically, this consists mostly of exopolysaccharides, glycoproteins, and glycolipids. Therefore, the slime layer is considered as a subset of glycocalyx.

The bacterial glycocalyx can vary in structure from bacteria to bacteria. Even particular bacteria can be capable of producing a glycocalyx of varying structure, depending upon the growth conditions and nutrients available. Generally, the glycocalyx is constructed of one or more sugars that are called saccharides. If more than one saccharide is present, the glycocalyx is described as being made of polysaccharide. In some glycocalyces, protein can also be present.

Function

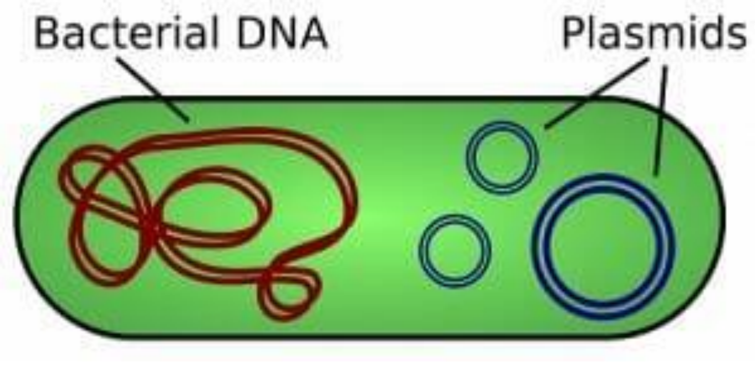
There are two prominent functions of the glycocalyx. The first function is to enable bacteria to become harder for the immune cells called phagocytes so surround and engulf. This is because the presence of a glycocalyx increases the effective diameter of a bacterium and also covers up components of the bacterium that the immune system would detect and be stimulated by. Thus, in a sense, a bacterium with a glycocalyx becomes more invisible to the immune system of a host.

Infectious strains of bacteria such as Staphylococcus, Streptococcus, and Pseudomonas tend to elaborate more glycocalyx than their corresponding non-infectious counterparts.

The second function of a bacterial glycocalyx is to promote the adhesion of the bacteria to living and inert surfaces and the subsequent formation of adherent, glycocalyx-enclosed populations that are called biofilms . Biofilm bacteria can become very hard to kill, party due to the presence of the glycocalyx material. Many persistent infections in the body are caused by bacterial biofilms. One example is the dental plaque formed by glycocalyx-producing Streptococcus mutans, which can become a focus for tooth enamel-digesting acid formed by the bacteria. Another example is the chronic lung infections formed in those afflicted with certain forms of cystic fibrosis by glycocalyx-producing Pseudomonas aeruginosa. The latter infections can cause sufficient lung damage to prove lethal.

Plasmid

A plasmid is a small, circular piece of DNA that is different than the chromosomal DNA, which is all the genetic material found in an organism's chromosomes. It replicates independently of chromosomal DNA. Plasmids are mainly found in bacteria, but they can also be found in archaea and multicellular organisms. Plasmids usually carry at least one gene, and many of the genes that plasmids carry are beneficial to their host organisms. Although they have separate genes from their hosts, they are not considered to be independent life.



This simplified figure depicts a bacterium's chromosomal DNA in red and plasmids in blue.

Functions of Plasmids:

Plasmids have many different functions. They may contain genes that enhance the survival of an organism, either by killing other organisms or by defending the host cell by producing toxins. Some plasmids facilitate the process of replication in bacteria. Since plasmids are so small, they usually only contain a few genes with a specific function (as opposed to a large amount of noncoding DNA). Multiple plasmids can coexist in the same cell, each with different functions. The functions are further detailed in the section "Specific Types of Plasmids" below.

General Types of Plasmids

Conjugative and Non-Conjugative

There are many ways to classify plasmids from general to specific. One way is by grouping them as either conjugative or non-conjugative. Bacteria reproduce by sexual conjugation, which is the transfer of genetic material from one bacterial cell to another, either through direct contact or a bridge between the two cells. Some plasmids contain genes called transfer genes that facilitate the beginning of conjugation. Non-conjugative plasmids cannot start the conjugation process, and they can only be transferred through sexual conjugation with the help of conjugative plasmids.

Incompatibility

Another plasmid classification is by incompatibility group. In a bacterium, different plasmids can only co-occur if they are compatible with each other. An incompatible plasmid will be expelled from the bacterial cell. Plasmids are incompatible if they have the same reproduction strategy in the cell; this allows the plasmids to inhabit a certain territory within it without other plasmids interfering.

Specific Types of Plasmids

There are five main types of plasmids: fertility F-plasmids, resistance plasmids, virulence plasmids, degradative plasmids, and Col plasmids.

Fertility F-plasmids

Fertility plasmids, also known as F-plasmids, contain transfer genes that allow genes to be transferred from one bacteria to another through conjugation. These make up the broad category of conjugative plasmids. F-plasmids are episomes, which are plasmids that can be inserted into chromosomal DNA. Bacteria that have the F-plasmid are known as F positive (F+), and bacteria without it are F negative (F–). When an F+ bacterium conjugates with an F– bacterium, two F+ bacterium result. There can only be one F-plasmid in each bacterium.

Resistance Plasmids

Resistance or R plasmids contain genes that help a bacterial cell defend against environmental factors such as poisons or antibiotics. Some resistance plasmids can transfer themselves through conjugation. When this happens, a strain of bacteria can become resistant to antibiotics. Recently, the type bacterium that causes the sexually transmitted infection gonorrhea has become so resistant to a class of antibiotics called quinolones that a new class of antibiotics, called cephalosporins, has started to be recommended by the World Health Organization instead. The bacteria may even become resistant to these antibiotics within five years. According to NPR, overuse of antibiotics to treat other infections, like urinary tract infections, may lead to the proliferation of drug-resistant strains.

Virulence Plasmids

When a virulence plasmid is inside a bacterium, it turns that bacterium into a pathogen, which is an agent of disease. Bacteria that cause disease can be easily spread and replicated among affected individuals. The bacterium *Escherichia coli (E. coli)* has several virulence plasmids. *E. coli* is found naturally in the human gut and in other animals, but certain strains of *E. coli* can cause severe diarrhea and vomiting. *Salmonella enterica* is another bacterium that contains virulence plasmids.

Degradative Plasmids

Degradative plasmids help the host bacterium to digest compounds that are not commonly found in nature, such as camphor, xylene, toluene, and salicylic acid. These plasmids contain genes for special enzymes that break down specific compounds. Degradative plasmids are conjugative.

Col Plasmids

Col plasmids contain genes that make bacteriocins (also known as colicins), which are proteins that kill other bacteria and thus defend the host bacterium. Bacteriocins are found in many types of bacteria including *E. coli*, which gets them from the plasmid ColE1.

Applications of Plasmids

Humans have developed many uses for plasmids and have created software to record the DNA sequences of plasmids for use in many different techniques. Plasmids are used in genetic engineering to amplify, or produce many copies of, certain genes. In molecular cloning, a plasmid is a type of vector. A vector is a DNA sequence that can transport foreign genetic material from one cell to another cell, where the genes can be further expressed and replicated. Plasmids are useful in cloning short segments of DNA. Also, plasmids can be used to replicate proteins, such as the protein that codes for insulin, in large amounts. Additionally, plasmids are being investigated as a way to transfer genes into human cells as part of gene therapy. Cells may lack a specific protein if the patient has a hereditary disorder involving a gene mutation. Inserting a plasmid into DNA would allow cells to express a protein that they are lacking.

RELATED BIOLOGY TERMS:

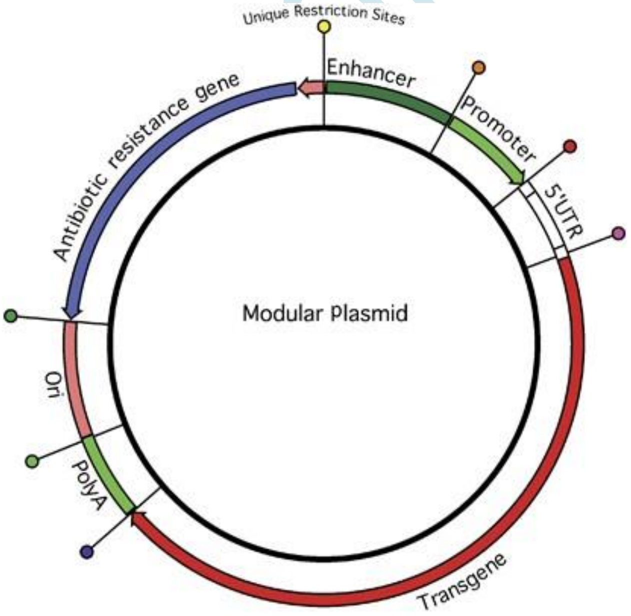
Bacteria – Single-celled microbes that were one of the first types of lifeforms to evolve on Earth; they can exist independently or inside other organisms.

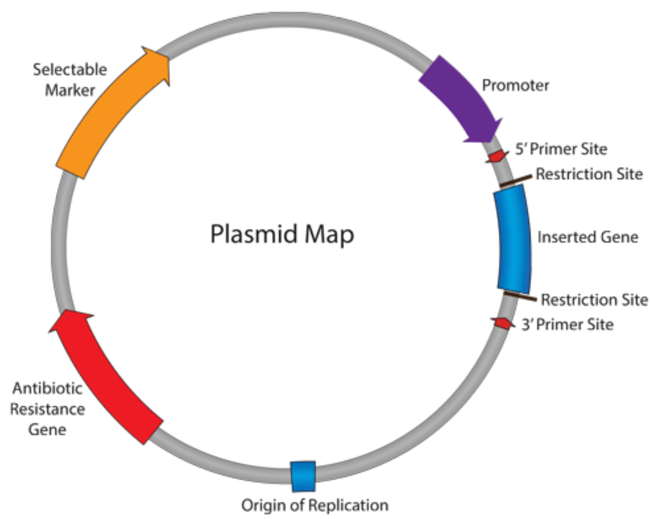
Episome – In bacteria, a plasmid that can be inserted into the chromosome. In eukaryotes, plasmid refers to non-chromosomal DNA that can be replicated in the nucleus, such as a virus.

Conjugative – A category of plasmids that start the process of sexual conjugation in bacteria.

Bacteriocin – a protein produced by a plasmid in a bacterium that kills other bacteria of a closely related strain.

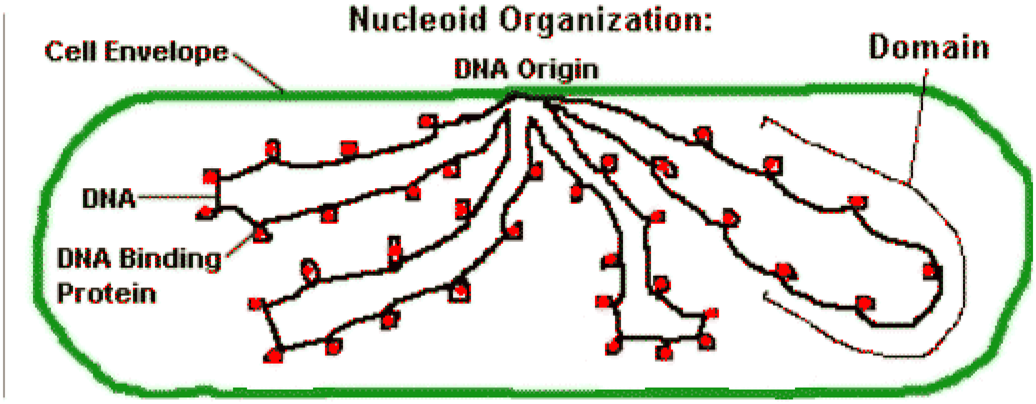
Episome, in bacteria, one of a group of extrachromosomal genetic elements called plasmids, consisting of deoxyribonucleic acid (DNA) and capable of conferring a selective advantage upon the bacteria in which they occur. Episomes may be attached to the bacterial cell membrane (such a cell is designated F+) or become integrated into the chromosome (such a cell is designated Hfr). F+ and Hfr cells act as donors during conjugation, a mating process in certain bacteria (*e.g., Escherichia, Salmonella, Serratia, Pseudomonas*). During conjugation, cells lacking the episome (called F- cells) may receive either the episome (from an F+ cell) or the episome plus the chromosomal genes to which it is attached (from an Hfr cell).



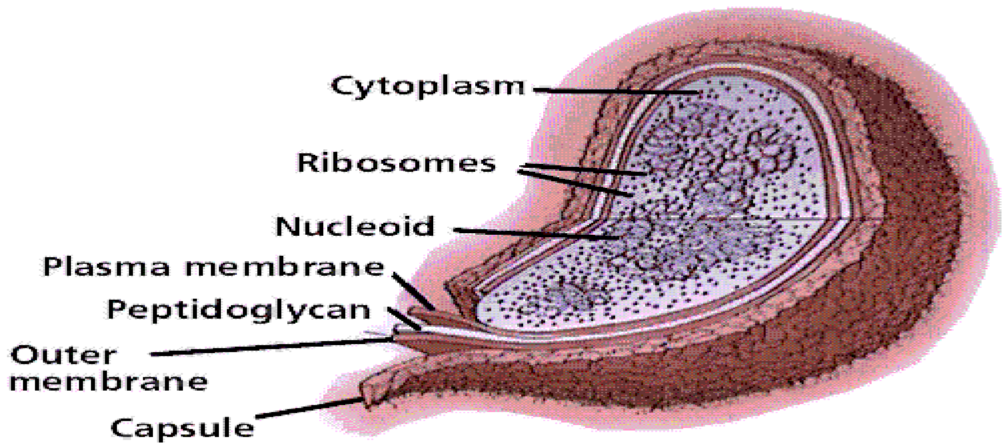


Bacterial Chromosome Structure

Prokaryotic cells (bacteria) contain their chromosome as circular DNA. Usually the entire genome is a single circle, but often there are extra circles called plasmids. The DNA is packaged by DNA-binding proteins.



The bacterial DNA is packaged in loops back and forth. The bundled DNA is called the nucleoid or Genophore. It concentrates the DNA in part of the cell, but it is not separated by a nuclear membrane (as in eukaryotes.) The DNA does form loops back and forth to a protein core, attached to the cell wall.



The DNA is accessible to enzymes that make RNA and protein. In the bacterial cell, the DNA gets transcribed to RNA, and the RNA gets translated to protein before it is even completed.