B. SC. SEMESTER – I

BOTANY PAPER – I

VIRUSES, PROKARYOTES, ALGAE & BIOFERTILIZERS

Unit I (Viruses and Prokaryotes):

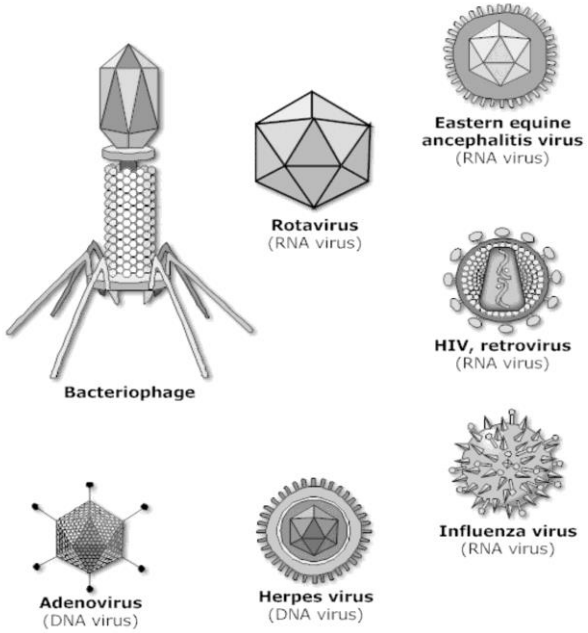
Virus: nature of Viruses (Living and Non-living Characteristics), Ultra structure of TMV, Structure and Multiplication of T4 - Bacteriophage. Economic importance of Viruses.

Mycoplasma : Properties, Structure and Reproduction.

Bacteria: General Characteristics, Ultrastructure of Bacterial cell, Reproduction (Binary Fission and Conjugation), Economic importance of Bacteria (with reference to their role in Agricultural Industry)

General Characteristics of Viruses

•They are extremely small in size and simpler than bacteria.
•They are ultra-microscopic, which are visible only with an electron microscope.
•They are considered to be the organisms that live at the edge of living and non-living things.
•They are dependent parasites that cannot survive on their own.
•They require a living organism to multiply as they cannot live on their own.
•Viruses consist of genetic materials (DNA or RNA) which are surrounded by a protein coat (capsid).
•Viruses are responsible for causing severe fatal diseases in humans, plants, animals, etc.

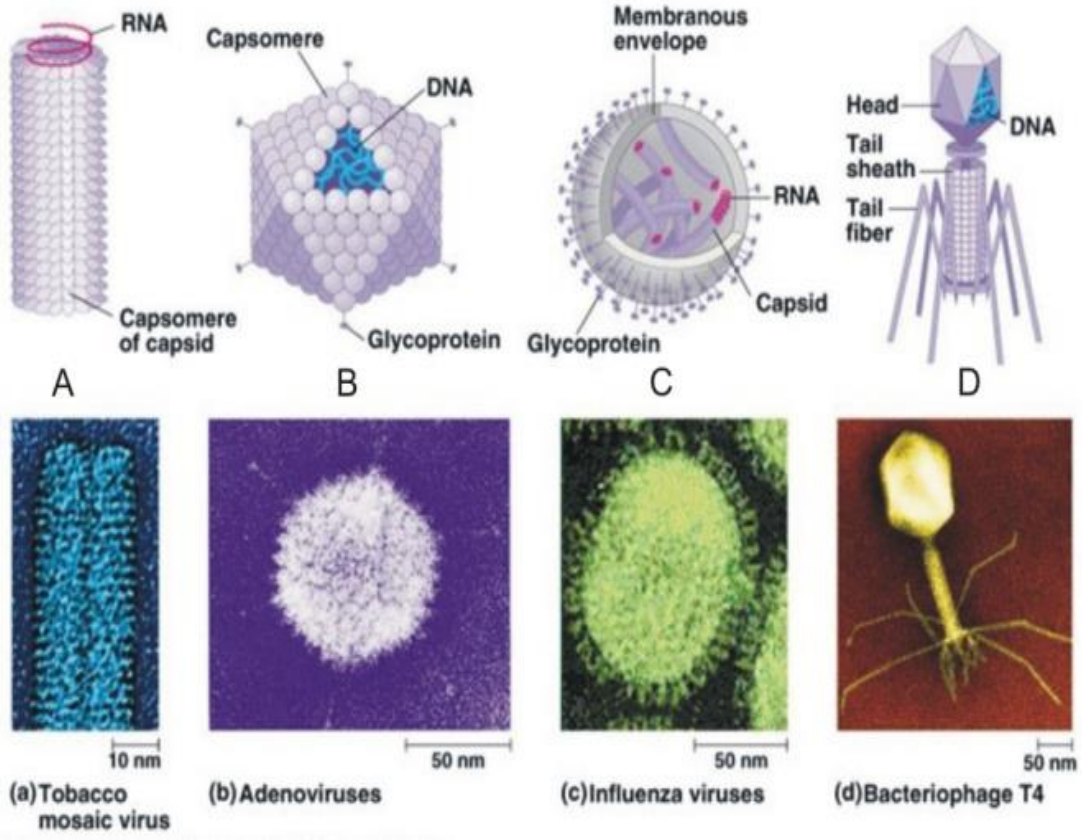


1. Size:

Virus	Size (nm)
Turnip yellow mosaic virus	28
ØX-174 virus	22
Tomato bushy stunt virus	30
Polio virus	27-30
Alpha virus	35-80
Adeno virus	60-90
Influenza virus	80-120
Herpes virus	180-200
Tobacco mosaic virus	17.5 X 300
Beet yellow virus	10 X 1250

2. Shape

i. Helical viruses
ii. Polyhedral viruses
iii. Enveloped viruses
iv. Complex viruses



3. Nucleic acid

(i) all plant viruses have single stranded RNA,

(ii) animal viruses have either single or (rarely) double-stranded RNA or double-stranded DNA,

(iii) bacterial viruses contain mostly double-stranded DNA but can also have single-stranded DNA or RNA and

(iv) most of the insect viruses contain RNA and only a few have DNA. The DNA of some bacterial and animal viruses is circular, but in others it is like RNA. Viruses contain only single molecule of nucleic acid.

3. Nucleic acid

Virus	Nucleic acid	Size (in bp)
Polyoma	ds DNA	4,500
Adenovirus	ds DNA	35,000
Coliphage T_4	ds DNA	200,000
Coliphage T_2	ds DNA	60,000
Tobacco mosaic virus	ss RNA	7,500
Tobacco necrosis virus	ss RNA	1,500
Beab mosaic virus	ss RNA	3,000
Polio virus	ss RNA	6,000s

4. Protein Coat

- **The nucleic acid core of the virus is protected by a protein coat called capsid.**
- **Each capsid consists of several identical protein subunits, known as capsomeres.**
- **In some viruses the proteins composing the capsomeres are of a single type, while in others several types of proteins may be present.**
- **These subunits are usually arranged in the helical or polyhedral geometric forms.**

NATURE OF VIRUSES:

Living Nature of Viruses:

i. That they can live only in a living cell.

ii. They can infect healthy plants just like bacteria and fungi.

iii. They multiply in number and grow in size, as the living organisms reproduce and grow.

iv. They have physiologic specialization in relation to the insect vectors and the plants.

v. They respond to stimuli, such as acids, alkalies, light and temperature.

NATURE OF VIRUSES:

Non- Living Nature of Viruses:

i. They are too small to be observed under visible light.

ii. They retain infectivity even in very low concentrations.

iii. They can be crystallized like a chemical substance.

iv. They can be sediment like proteins.

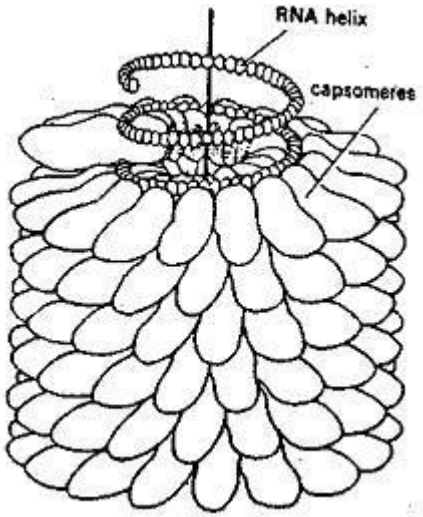
v. They can be precipitated by a number of chemical substances.

Ultra Structure of TMV:

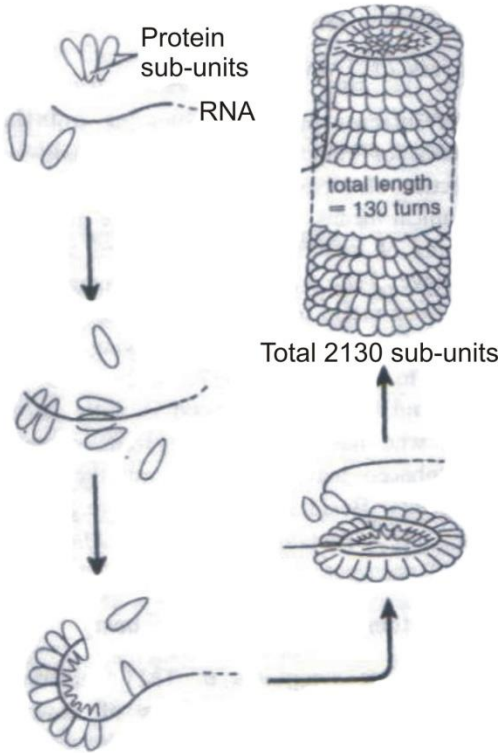
More than 100 types of plant viruses are known which cause various diseases in plants. Of these, tobacco mosaic virus (TMV) has been studied most extensively, both in the field as well as in the laboratory. This virus was discovered by D. Iwanowski in 1892, but its isolation from infected plant and crystallization was done by W. M. Stanley in 1935.

Structure

TMV particles appear as bundle of rods or needles under electron microscope. Each rod is approximately 300 λ in length and 170 λ in diameter and has a molecular weight of approximately 4,00,000. The electron microscope and X-ray crystallographic investigations have revealed that these particles have two constituents, a protein and nucleic acid. (**Fig. 1.3**).

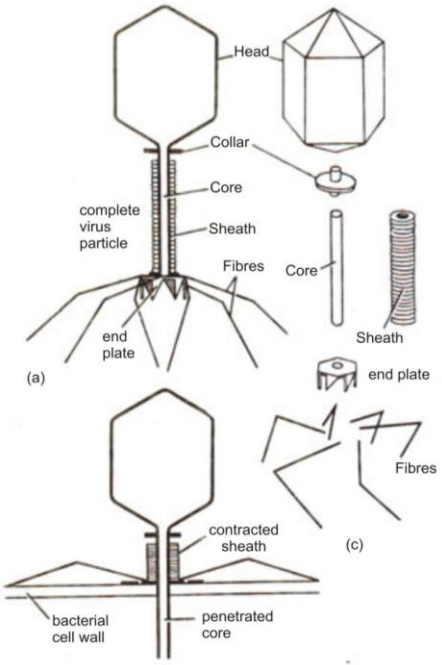


The protein coat (capsid) is made up of approximately 2130 identical protein subunits called capsomeres. Each capsomere consists of a long chain of 158 amino acids and its molecular weight is 18,000. The capsomeres are helically arranged around a central single stranded RNA molecule (**Fig. 1.4**). The RNA consists of some 6,000 nucleotide pairs. The protein and nucleic acid ration in these is 94.4:5.6.



The total length of each rod has about 130 helicals and in each helix there are approximately 16.5 protein subunits. In each helix of RNA there are 49 nucleotides and the helix has a pitch of 23 λ. The genetic information necessary for the formation of a complete TMV particle is contained in its RNA. This information determines the replication of RNA and sequence of amino acids in the protein subunits of the capsid. As all subunits are identical, only one coded gene is required for the formation of all capsomeres. It is possible to remocre the protein coat form RNA. The naked RNA is capable of infecting tobacco plant; once inside the host cell, the virus RNA directs the protein synthesizing apparatus of the host cell to synthesize its own proteins. Thus RNA has two functions: (i) self replication and (ii) synthesis of virus specific proteins for which it takes the raw material from the host cell.

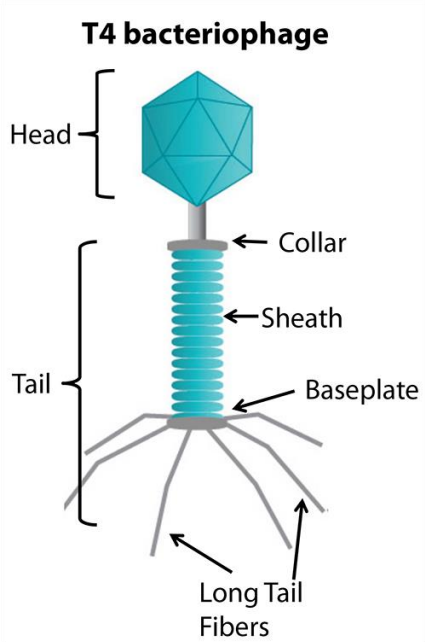
Structure of T_4 bacteriophage



The bacteriophage particle resembles a tiny sperm. It has a head and a tail. In addition there is some sort of attachment region to stick to the surface of the host cell.

The virus particle of is about 200 to 280 mμ in length. The virus particle is thus too small to be seen with the best of light microscopes. Nevertheless pictures of virus particles are obtained by the use of electron microscope.

The head of T_4 bacteriophage is hexagonal in outline and bears numerous facets. It consists of protein coat surrounding a core of genetic material which in this case is linear double stranded DNA molecule.



The coiled coil of a single thread-like double-stranded macro-molecule of DNA is packed tightly in the head. It is about 50 microns long. The phage DNA is said to lack the base cytosine. Instead it has another base ***hydroxylmethylcytosine*** (HMC). The protein coat is built of globular proteins.

The cylindrical tail entirely consists of a protein sheath surrounding an empty core. The tail sheath can contract longitudinally. The attachment appraratus of the phage consists of six long, slender protein fibres known as the tail or caudal fibres. They arise from a hexagonal plate at the basal end of the tail. The tail fibres normally remain twined inside the core of the tail. Extended they help to attach the phage particle to the ***E. coli*** cells. The head is attached to the tail by mean of narrow neck which is encircled a circular collar, both made up of proteins.

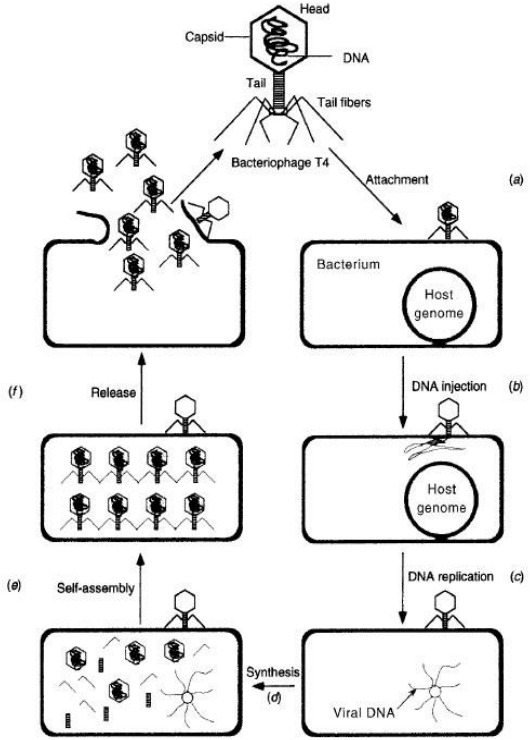
Multiplication of T_4 bacteriophages

Nucleic acid in a virus does not contain all the genes needed for the synthesis of new viruses. Although genes governing the synthesis of viruses' structural components are present in its nucleic acid, the enzymes needed for protein synthesis, ribosomes, tRNA and energy production are supplied by the host cell. These are used for synthesizing viral proteins including viral enzymes. Thus for a virus to multiply, it must be invade a host cell. Once inside the host cell, even a single virus can give rise to thousand of viruses.

Although the basic mechanism of peretration and multiplication is similar in all the viruses, the process is best studied in bacteriophages. Phages can multiply by two alternate methods- (i) Lytic cycle: which ends with the death or lysis of the host cell where as in, (ii) Lysogenic cycle: host cell remains alive. The lytic cycle is as follows.

Lytic cycle

Multiplication of T_4 bacteriophages in their host cell is an example of the lytic cycle. The process of multiplication involves the following four steps.



i. **Infection**
ii. **Synthesis of phage components in the host cells**
iii. **Assembly of new phage particle**
iv. **Liberation of phage particles from the host cells**

Economic importance of viruses

The viruses are generally considered of great negative economic importance as they cause serious human and animal diseases and vastly destructive plant diseases. However, not all viruses cause disease resulting in death or malformations of the host. In some of them, for instance, those of the fig trees and many ornamental plants bring about only molting of leaves and have no harmful effect. In some cases the viruses attack may destroy some chlorophyll but what usually remains is more than enough for the leaves to carry on photosynthesis. The petals of flowers of tulips develop beautiful striations of various shades due to viral infection.

The viruses also interfere in the working of many industrial processes dependent on bacterial action. They attack the bacteria involved in the industrial process and cause loss in economy. The curative properties of waters of certain springs and Ganges at Haridwar are attributed to the presence in the water of viruses which attack and lyse the pathogenic bacteria (bacteriophages) and the bacteria of decay and decomposition. From the evolutionary point of view the viruses are important as they stand at the very threshold of life representing the starting point in the evolution of other organisms.

MYCOPLASMA

Mycoplasmas are the smallest known aerobic prokaryotes without a cell wall. These microorganisms were first discovered by Pasteur (1843) while studying the causative agent of pleuropneumonia in cattle. They were designated as PPLO (Pleuropneumonia-like organisms). How-ever, Pasteur could not isolate them in pure cultures on standard nutrient media or observe them under the light microscope. In 1898, two French microbiologist, Nocard and Roux, were successful in obtaining pure cultures of these microorganisms in media containing serum. They observed that these organisms could produce disease when inoculated in healthy cattle.

Mycoplasmas found in hot-water springs and other thermal environment. They occur in soil, sewage water, different substrates and in humans, animals and plants. Newak (1929) placed these organisms in class Mollicutes of the order Mycoplasmatales.

Morphology of Mycoplasma:

Since mycoplasmas pass through many filters and grow on media without living tissues, these are considered to be intermediate between bacteria and viruses.

1. Mycoplasma are very small unicellular, usually non-motile, procaryotic organisms.
2. They can grow in cell free media forming, typical “fried egg” shaped colony.
3. They are highly pleomorphic (variable in shape) showing small coccoid bodies, ring forms and five filamentous forms which may be branched.
4. Mycoplasma cells are bounded by triple layered unit membrane without a rigid cell wall. They lack ability to synthesize cell wall material.

Morphology of Mycoplasma:

5. They are filterable through bacterial filter.

6. They are highly resistant to pencillium but inhibited by tetracyclines.

7. They are inhibited by specific antibody.

8. They require sterols for growth.

9. Mycoplasma have no history of reversion to or derivation from a bacterial parent.

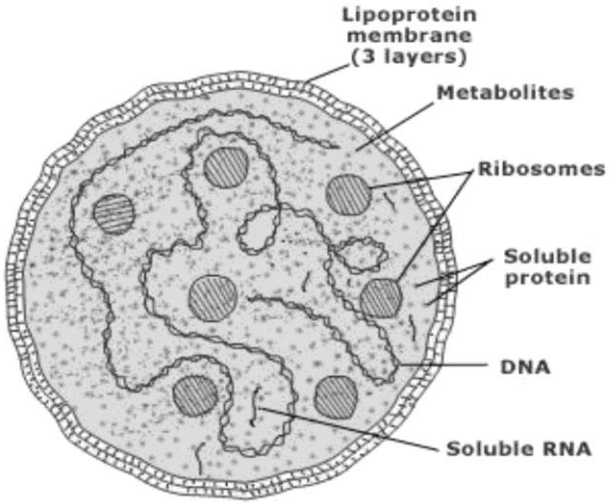
10. Mycoplasma cells contain both DNA & RNA.

11. Reproduction is controversial – perhaps develop within filaments tiny coccoid structures called elementary bodies, released by fragmentation of filaments or by binary fission or by budding.

Structure

The absence of true cell wall makes the organisms highly plastic and readily deformable, hence mycoplasmas are irregular and variable in shape. The cells may be coccoid, granular, pear-shaped, cluster-like or filamentous etc. The filaments may be branched or unbranched. There is so much variability in shape that no two forms are alike. The cells are small, ranging in diameter between 0.3 and 0.9 μm. Since mycoplasmas pass through many filters (due to their plastic nature) and grow on media which do not contain live tissue, they are considered to be intermediate between bacterial and viruses.

These organisms are covered with a unit lipoprotein cytoplasmic membrane, 7.5 -10 μm thick. The cytoplasm contains ribosomes and nucleoplasm-like structure



Though genetic material is composed of both DNA and RNA, it is less than half that usually occur in other prokaryotes, and is perhaps the lowest limit required for a cellular organism. The amount of DNA is up to 4 per cent and RNA about 8 per cent. The G + C content in DNA ranges between 23 and 40 per cent. Mycoplasmas may be the simplest form of life capable of independent growth and metabolism.

Properties

Mycoplasma are gram-negative and stain slowly on long exposure to dyes. They are usually non-motile; some forms however, show gliding movements. They reproduce by budding or binary fission.

They are sensitive to oxytetracycline, streptomycin, erythromycin and chloramphenicol.

Mycoplasmas can grow in a medium which contains no living tissues. They can also pass through many filters which cannot pass bacteria. Because of these two characteristics, mycoplasmas are considered to be intermediate between bacteria and viruses. Chemically, they are more close to bacteria than viruses.

Pathogenic mycoplasmas can be cultivated on medium containing proteins, sterols (cholesterol), phospholipids, mucins and nucleic acids (DNA and RNA). The growth of some obligate anaerobic mycoplasmas is stimulated by adding yeast extract and cholesterol to the medium. The optimal temperature for their growth is 36-37^{o}C. On a solid medium, the colonies of mycoplasmas have a characteristic round form with a thickened centre and delicate periphery, like a ‘fried egg’. Aerobic mycoplasmas grow on a medium supple-mented with 20 per cent horse serum.

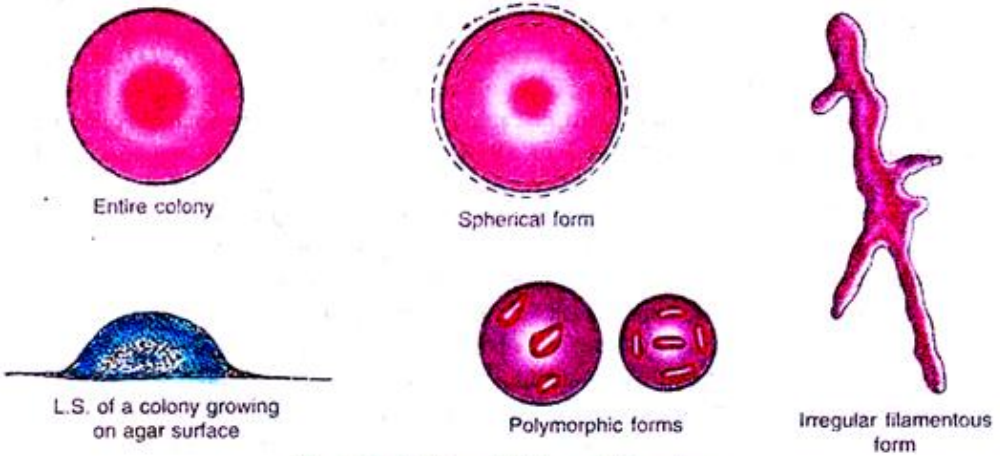


Fig. 19.10. *Different Cell Shapes of Mycoplasma*

Reproduction in Mycoplasma:

Mycoplasmas reproduce by budding and/or binary fission (Fig. 19.12). Cells of mycoplasma divide unevenly into very minute bodies called the elementary bodies or minimal reproductive units.

These are formed inside the large bodies or mature cells. Their size varies from 330 nm to 450 nm. These bodies are the smallest independent living entities so far known.

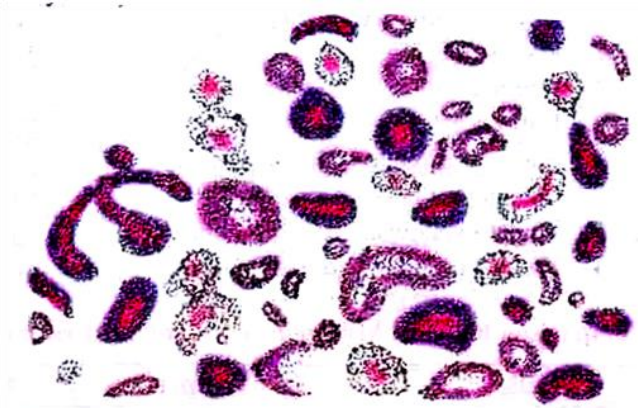


Fig. 19.12. *Several polymorphic mycoplasmas showing binary fission or budding.*

BACTERIA

Anton van Leeuwenhoek, a Dutch man, was the first to discover the bacteria on June 10, 1675, but he thought them to be animalcules. After two centuries, Louis Pasteur in 1864 and Koch in 1876 reported that these microorganisms could cause disease. But it was in 1890 that an earnest study of these primitive, mostly unicellular organisms began. During the last few decades much has been added to our knowledge of bacterial.

The bacterial constitute a highly specialized group of unicellular plants. There are about 2,000 known species. They occur in abundance in both fresh and salt water. The air we breathe is full of them. They are present in the food we eat and the objects we touch. They flourish in our mouth and intestines. They live in the bodies of other organisms and their dead remains. Some live in hot spring and others in ice. They are found in all soil and above the earth. In fact they live in all conditions not fatal to living matter.

Size

In fact they are the smallest of all known cellular organisms and are visible only with the aid of the microscope. The size of bacterial varies considerably ranging from about 0.2μ to 2.0 μ in width and less than 2-10 μ in length. The coccus forms vary from 0.5 to 2.5 μ in diameter. The variations in the *Bacillus* forms are still greater from 0.3 to 15 μ in length and from 0.2 to 2.0 μ in width. *E. coli* is 0.4 to 0.7 μ in diameter and 1.0 to 3.0 μ long. A single drop of liquid can contain about 50 milion bacteria. A few *Bacillus* and *Spirilla* forms are much larger.

Shape

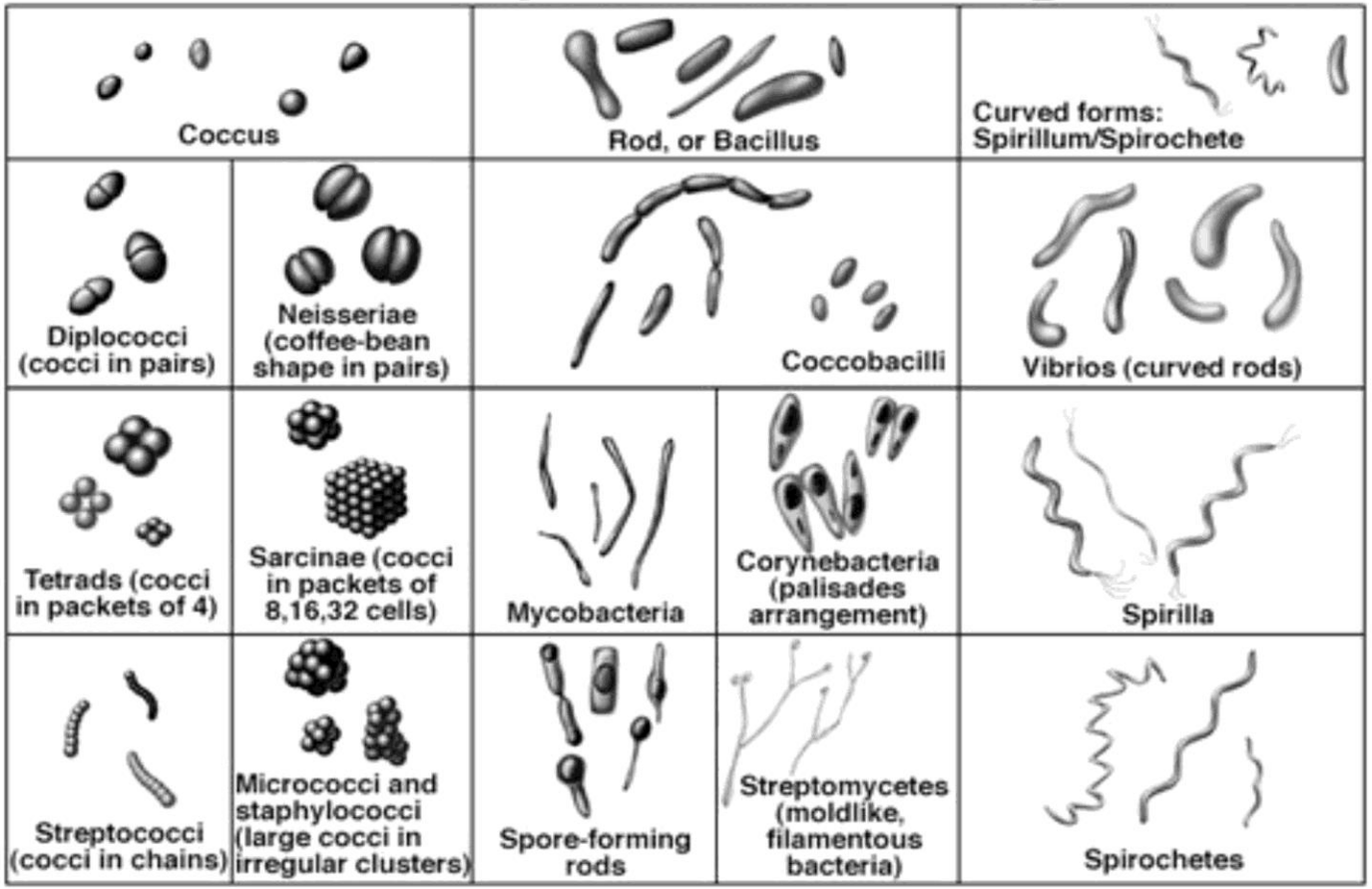
The shape of these tiny organisms is their only readily visible characteristic. Thus it is used as a basis for describing them. The bacterial vary in their shape which is usually constant for each species. The three funda-mental forms among the bacteria are rods, spheres and helices. Thus bacteria belong to one of these three types (**Fig. 2.1**).

Rod-Shaped Bacteria

The rod-shaped bacteria may be cylindrical and straight or slightly curved or wavy with rounded or blunt ends. These are known as ***bacilli*** (singular *bacillus*). The bacillary forms are commonest and range round 1.5 μ in diameter and 10 μ in length. Some bear flagella and other not. e.g. *Lactobacillus*.

Spherical Bacteria

The second largest group of bacteria have spherical or ellipsoidal cells varying 0.5 to 1.25 μ in diameter. These are called as ***cocci*** (sing. *coccus*). Almost all coccal forms lack flagella and are non-motile. The spherical cells may occur singly but often tend to stick together and various cell arrangements occur.


Coccus
Rod, or Bacillus
Curved forms:
Spirillum/Spirochete
Diplococci
(cocci in pairs)
Neisseriae
(coffee-bean
shape in pairs)
Coccobacilli
Vibrios (curved rods)
Tetrads (cocci
in packets of 4)
Sarcinae (cocci
in packets of
8,16,32 cells)
Mycobacteria
Corynebacteria
(palisades
arrangement)
Spirilla
Streptococci
(cocci in chains)
Micrococci and
staphylococci
(large cocci in
irregular clusters)
Spore-forming
rods
Streptomycetes
(moldlike,
filamentous
bacteria)
Spirochetes

Helical Bacteria

The helical forms are of two types, ***spirilla*** and ***vibrios***.

Spirilla having the body twisted spirally like a cork-screw through 1-5 complete turns. The *spirilla* are larger than the *cocci* and *bacilli* ranging from 10 μ to 50 μ in length though only 0.5 μ to 3.0 μ in diameter. The spirilla forms usually bear two or more flagella at one or both poles.

Vibrios forms of bacteria are short and look like a curved rod or twine of a spiral. In fact it is less than the full turn of a helix and shaped much like a slightly twisted comma. The vibrios have flagella at one pole only and seldom exceed 10 μ in length and 1.5 μ to 1.7 μ in diameter.

Filamentous

A fourth type of bacterial forms may occur in a few species. The number of filamentous forms, as compared with others, is very small.

Pleomorphic Bacteria

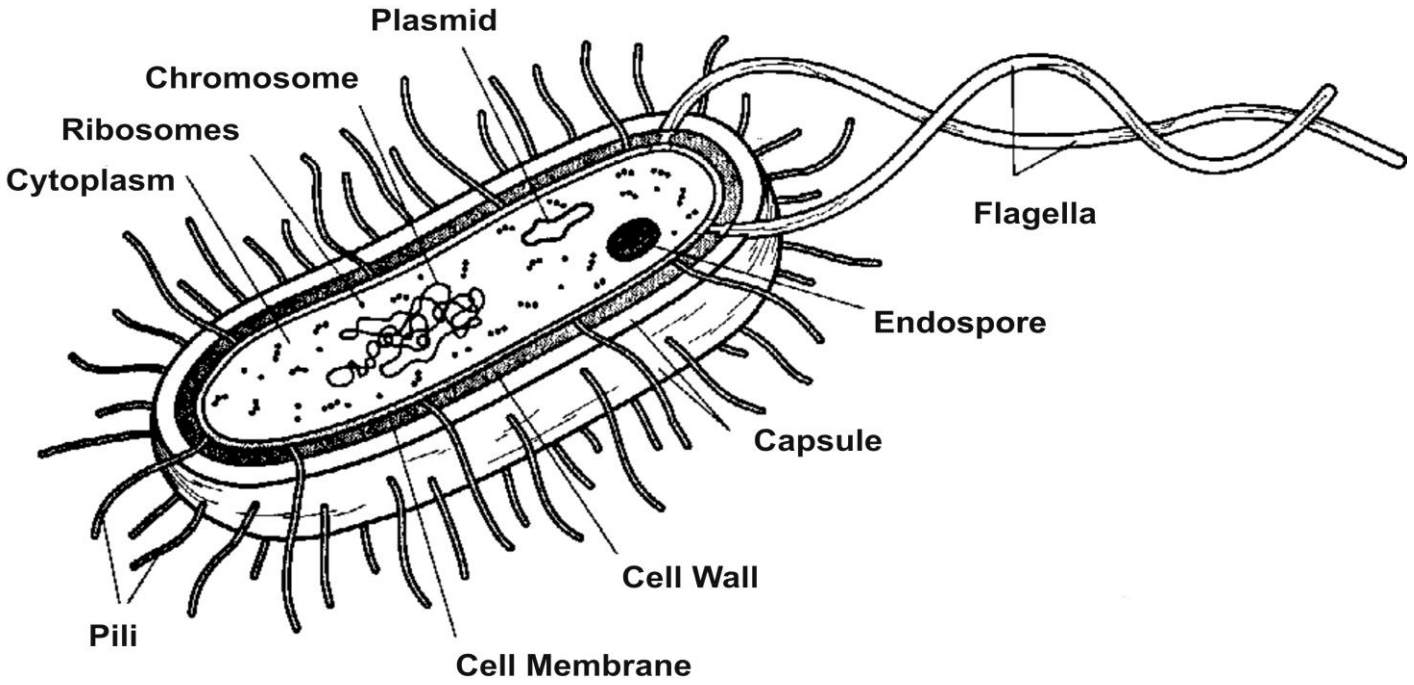
Some bacteria are able to change shape and size with changes in the environmental conditions. These changes are usually temporary. In a few species, however, several types of cell forms may occur in the life cycle. For example, *Acetobactor,* a group of vinegar bacteria occur as small rods, long rods, ellipsoids or a chain of small rods. Such bacteria are called pleomorphic.

Cell Structure

The bacterial cell shows a typical prokaryotic structure. Like other living plant cells, the bacterial cell comprises a cell wall and protoplast. External to the cell wall may be present a thin layer of slime

The Slime

It is viscous or gelatinous substance secreted by the cell protoplast. The slime diffuses through the cell wall and deposits in the form of a thin extracellular, viscous layer external to the cell wall. It is usually composed of polysaccharides or of polypeptides of one or two different amino acids. Under certain conditions of growth the slime accumulates to form a thick conspicuous layer around the cell wall. It is called the **sheath** or **capsule**. The sheath protects the enclosed organism against desiccation and antibodies. The bacterial cell with capsule normally does not bear flagella.


Plasmid
Chromosome
Ribosomes
Cytoplasm
Flagella
Endospore
Capsule
Cell Wall
Pili
Cell Membrane

The Cell Wall

In the electron micrograph the cell wall is seen as a thin, sharply defined envelope around the protoplast. It ranges in thickness around 0.02μ. The cell wall is tough though flexible. The inert and somewhat rigid bacterial cell wall limits the volume occupied by the protoplast and thus gives rigidity and shape to the bacterial cell. It shows granular structure and lacks microfibrils.

The cell wall proper is composed of 4 layers (Mazanec and Martinec). Of these two are of lower electron density. The other two layers are of higher electron density and thus darker. The outer darker layer (L_4) is wavy. Within it is the lighter layer of low electron density (L_3). Next comes the inner dense or darker layer (L_2) followed by the innermost layer of low electron density (L_1). The L_2 darker layer of higher electron density is considered to be mucopeptide.

Chemical composition differs in different species. Basically it is composed of acetyl-glucosamine and acetylmuramic acid. They are present in equal amount and form the main component of the bacterial cell wall. The other compounds included are polysaccharides, amino acids and in some species lipids.

The polysaccharides which form a major fraction of the bacterial cell wall, in many cases, consists of amino-sugars rather than simple sugars. Cellulose (rarely present) and chitin are absent. Recently microbiologists have reported that the bacterial cell wall contains an amino acid **diaminopimellic acid**. It commonly occurs in the bacterial cell walls and those of some blue green algae. It is a polypeptide attached to muramic acid, derivative of glucose.

The Protoplast

Within the cell wall is the living stuff of the bacterial cell. It is called the protoplast. The protoplast is a clear watery or slightly viscous substance. It is differentiated into the cell or cytoplasmic membrane, also called plasmalemma, cytoplasm and chromatin or nuclear body.

The Cytoplasmic Membrane

At the surface of the protoplast is differentiated a delicate, fine membrane known as the cell membrane or cytoplasmic membrane. It completely encloses the protoplast and lies close against the cell wall pressed by the turgor of the protoplast. Chemically it consists of phospholipids with proteins and some polysaccharides. It is a differentially permeable membrane which controls the passage of dissolved substances in and out of the cell when active metabolism is going on in the protoplasm. In addition, the cytoplasmic membrane serves as a matrix upon which many respiratory and other enzymes are organized. In some bacteria the cytoplasmic membrane, at certain places, is seen to form infoldings, which in some cases form complex structures within the cytoplasm. These are called as **mesosomes**. It has been suggested that the highly infolded membrane system of mesosomes perhaps serves to accommodate more centers of respiration.

The Cytoplasm

It is complex mixture of protein, carbohydrates, lipids, minerals, nucleic acids and water. The water forms as much as 90% of the cell. The non-living inclusions are the storage granules of volutin, glycogen, lipid globules or protein crystals. Sulphur and iron are also found in some bacteria. The cytoplasm shows no streaming movements and contains no obvious vacuoles. It apprears rather dense and highly refrigent under light microscope and is fairly homogeneous when free from inclusions. In electron micrographs the bacterial cytoplasm is granular and contains numerous minutes, nearly spherical, hollow bodies called the ribosomes. Ultrastructurally the ribosome consists of subunits which are nearly spherical but of unequal sizes. Each subunit is composed of roughly equal amounts of RNA and protein. The ribosomes lie free in the cytoplasm but sometimes they occur in small groups held by a strand of messenger RNA, called as polysomes or polyribosomes. The ribosomes are the sites of protein synthesis. Other cell organelles such as mitochondria, endoplasmic reticululm and dictyosomes have not been seen in the bacterial cytoplasm. The chloroplasts are absent and so is a definitely organized nucleus. The pigments in the photosynthetic bacteria have long been considered to be diffused throughout the cytoplasm. Recent investigations with the electron microscope have revealed the presence of numerous ultramicroscopic chromatophores in the cell of certain photosynthetic bacteria. In rare cases lamellar structure has been revealed.

The Nuclear Apparatus

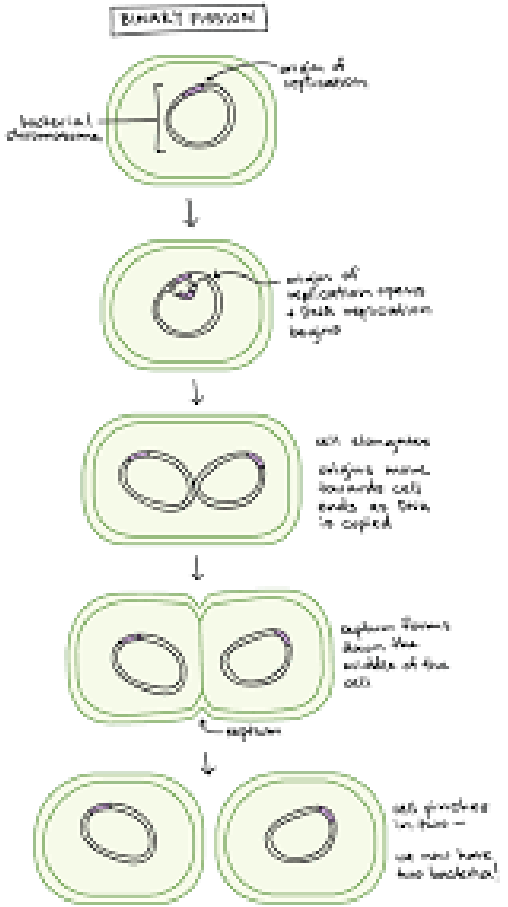
It is the area in which all the chromatin or genetic material (DNA) of the cell is concentrated. Usually it is centrally located in resting bacteria cells and is equivalent of the nucleus in other organisms. However, it lacks the nuclear membrane and nucleoli. It does not divide by mitosis. Nucleoid or gonophores is the term applied to the nuclear body of bacteria. Lacking the bounding nuclear membrane the shape of the nuclear body varies. Often it is irregular, sometimes spherical or oval but elongated (rod-shaped) or dumb-bell-shaped in the dividing cells. The cell in the phase of rapid growth may contain one to four nuclear bodies or nucleoids. In contrast to the granular cytoplasm the nucleoids appear as light on low density areas containing fine fibrils or DNA (genetic or chromatin material) variously interwoven. The DNA in the nucleoid of *Escherichia coli* occurs in the form of a single, double-stranded, thread-like molecule about 1000 μ (=1mm) long. It is ring-shaped (circular) and tightly packed. The DNA molecule contains all the genetic information of the cell. It is often but erroneously referred to as a chromosome.

Binary Fission

It is the simplest and most common method of multiplication in bacteria. Under favourable conditions the cell divides into two daughter cells by a transverse wall. During fission, the cell elongates and there is division of the nuclear material. In gram-negative bacteria it is followed by the development of a simple medium constriction that finally results in complete separation of two daughter cells (without cross wall formation). In gram-positive bacteria, however, first a transverse cell membrane is laid down between the two nucleoids of a dividing cell and then the centripetal growth of the cell wall forms a complete cross wall. The transverse wall between the daughter cells is very often incomplete and then the daughter cells remain connected at the transverse membrane. When the planes of the successive divisions are parallel, long chain may be formed and if perpendicular to one another sheets of packets of the cells are formed.

In binary fission, DNA replication preceeds septum formation the two resulting cells are mirror images of one another. Analyses of cell wall components of dividing cells indicate that the chemical constituents of the original ‘mother’ cell wall are equally shared in the cell walls of two resulting ‘daughter’ cells.

The process of binary fission is very rapid. Bacterial cells may undergo fission every 20-30 minutes, and under favourable conditions, within 6 hours, approximately 2,50,000 cells may be formed from a single bacterium. But in nature the essential nutrients are generally a limiting factor and moreover the accumulated waste products of bacteria also restrict their rapid growth. Normally, growth and multiplication is very fast in the early stages, reaching at the optimum and then declining rapidly. Fission is different from normal mitotic division as it does not involve spindle formation during the division of nuclear material. It is not definitely known whether in fission the genetic material is equally distributed between the daughter cells.



Conjugation

It is known to occur in several bacteria but has been studied in detail in *Escherichia coli* by Lederberg, Hayes and Woolman.

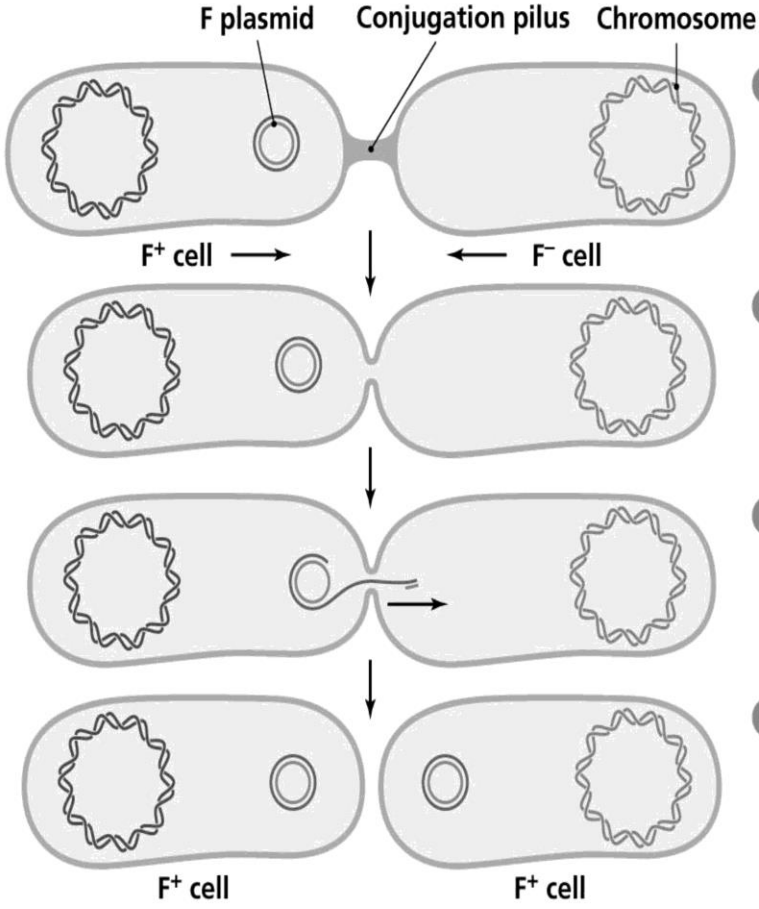
Conjugation is a mechanism of DNA exchange mediated by plasmids. A plasmid is a circular piece of DNA that replicates independently from the cell's chromosome. Bacterial cells often contain several different plasmids that carry genetic information for various nonessential cell functions. Some plasmids are self-transmissible; it means they can promote their own transfer as well as mediate the transfer of other plasmid and even portions of bacterial chromosomes. Bacteria that contain transmissible plasmids are called donor cells and those that receive plasmids are known as recipient cells. Transfer of a self-transmissible plasmid into a recipient converts that recipient to a donor, because by inheriting a self-transmissible plasmid, it acquires the ability to conjugate with other recipients. Not all plasmids are self-transmissible. Some plasmids lack the genes that encode the transfer function. Such plasmids can, however, be transferred if the other plasmids present in the cell carry genes necessary for transfer function.

For example, a plasmid lacking a certain transfer function, such as sex pili, can still transfer to a recipient cell, provided, the donor cell has another plasmid that encodes pili. This helper plasmid thus is capable of mobilizing another plasmid for transfer.

Analogous to sexual transfer in higher eukaryotes, **donor** bacteria are often called male cells, while **recipient** cells are called female. Most of the experimental work on conjugation has been done on the transfer of **F-factor** (fertility factor) plasmid in *Escherichia coli*. Cells in which F-factor is present, is represented by $\mathbf{F^+}$ (it functions as donor or **male cell**) and cell without F-factor are denoted by $\mathbf{F^-}$ (it functions as recipient or **female cell**). F-factor has genes that code for the components as well as protein involved in the biogenesis of sex pili.

The process of conjugation has two characteristics (i) it requires direct cell to cell contact, and (ii) the conjugation cell must be of opposite stains i.e., F^+ and F^-.

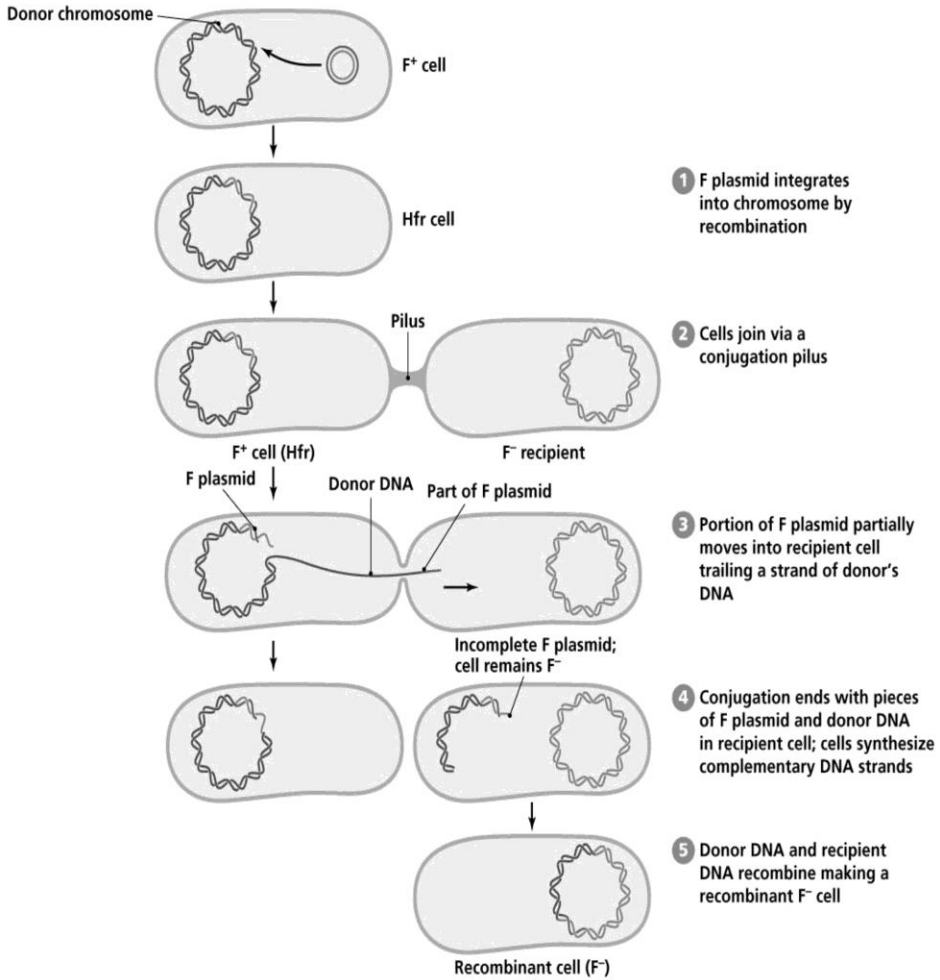
The first stem in the conjugation is the establishment of contact between cells of opposite stains. It may be either by cell to cell contact or mediated by sex pili. It results in the formation of a channel between the two mating cells. Now the plasmid DNA breaks at the specific site, called the origin of transfer, often abbreviated as ***ori T***. From this site 5'-region of the double stranded DNA is transferred to the recipient cell via a channel



1. Donor cell attaches to a recipient cell with its pilus. The pilus draws the cells together.
2. The cells contact one another.
3. One strand of plasmid DNA transfers to the recipient.
4. The recipient synthesizes a complementary strand to become an F^+ cell; the donor synthesizes a complementary strand, restoring its complete plasmid.

The transfer process is accompanied by immediate copying of the template strand in the donor cell in the 5’ to 3’ direction restoring the double stranded molecule. In the recipient cell, the transferred strand is also converted to a double stranded DNA. At the end of the process the plasmid DNA strand in the donor and recipient cells assume closed circular form.

The recipient cell (F^- cell) after receiving the plasmid DNA or F-factor from donor cell becomes F^+ cell. In some cells the F-factor integrates into the bacterial chromosome; such cells are called **high-frequency recombinant** (**Hfr**) cells. In the bacterial chromosome there are a few preferred sites where most of the integration can take place. The integration is not absolutely stable; in a population of cells, equilibrium exists between bacteria with integrated F-plasmid (Hfr) and cells where the F-plasmid is not part of bacterial chromosome.


Donor chromosome
F+ cell
Hfr cell
Pilus
F+ cell (Hfr)
F− recipient
F plasmid
Donor DNA
Part of F plasmid
Incomplete F plasmid; cell remains F−
Recombinant cell (F−)
1 F plasmid integrates into chromosome by recombination
2 Cells join via a conjugation pilus
3 Portion of F plasmid partially moves into recipient cell trailing a strand of donor's DNA
4 Conjugation ends with pieces of F plasmid and donor DNA in recipient cell; cells synthesize complementary DNA strands
5 Donor DNA and recipient DNA recombine making a recombinant F− cell

Economic Importance of Bacteria

The bacteria are best known to the general public as the causative agents of diseases. We must not forget that the bacteria do not always mean diseases. Many of them are positively beneficial. Several others are neither harmful nor beneficial. Only very small percentages of bacteria are harmful.

Beneficial Activities

There are many bacteria without which we could not live. They are absolutely essential to the presence of life on earth. They make possible the continued existence of green plants and therefore of animals because the plants are the only source of food for animals. Following is a brief account of the more important activities of the bacteria:

Role in Agriculture

Bacteria play an important role in the field of agriculture. Some of the important activities are discussed below.

Decay and Decomposition

The dead bodies and waste of organisms (both plants and animals) are decomposed by the activities of the saprophytic bacteria. In consequence of a variety of elements of minerals of the earth such as carbon, oxygen, hydrogen, sulphur and phosphorus which make up their bodies are reduced to simple compounds such as carbon monoxide, water, nitrates, suplhates and phosphates. Some of these go back to the soil and the rest to the air. From the soil they can be absorbed as plant food. This activity of the bacterial is also useful in sewage disposal system of the cities.

Soil Fertility

Some bacteria play an important role in maintaining and in increasing the soil fertility. The fertility of soil is proportional to its nitrogen content as nitrogen is an essential ingredient of all living protoplasm. This function of addition of soluble nitrogen in the soil belongs to three categories as follows:

Ammonification

The saprophytic bacteria break down the proteins and other nitrogen containing remains of the pant and animal origin in the soil to amino acids by secreting enzymes. The amino acids are then converted into ammonia by the group of bacteria called the ammonifying bacteria. The liberate ammonia may be combine with carbon dioxide and water in the soil to form ammonium carbonate. A few plants such as the common cereals can make use of ammonium compounds as a source of nitrogen.

Nitrification

The nitrifying bacteria convert nitrogen from the unavailable form of ammonium salts to the available nitrates. This process of converting unavailable ammonium salts into available nitrates is called nitrification. These bacteria are chemosynthetic auto-traphs. e.g. *Nitrosomonas* and *Nitrobacter.*

Nitrogen-Fixation

A considerable amount of nitrogen is lost by denitrification and through drainage. The loss must be made good by equal gains of the soil fertility is to be maintained. This is carried out by the nitrogen fixing bacteria by converting the molecular or atmospheric nitrogen into inorganic nitrogen in the form of nitrate nitrite and ammonia. Some of them live freely in the soil and other in root nodules of leguminous plants. They are able to make use of the atmospheric nitrogen and change it into nitrogenous compounds. The nitrogen-fixing bacteria are thus unique in tapping a source of nitrogen not available to most other plants. This process of nitrogen transformation is called as nitrogen fixation.

Role in Industry

Man has utilized the activities of bacteria for various industrial processes. The butter and cheese industries entirely depend upon the activities of the lactic acid bacteria. The souring and curding of milk by lactic acid bacteria is another common example of application in everyday life. Oxidation of alcohol into vinegar (acetic acid) is brought about by the acetic acid bacteria. The curing of tea, tobacco and manufacture of indigo are other examples of useful chemical activities of bacteria.

The process of tanning hides in leather making and preparing sponges also involve the use of bacteria. The production of linen form the hemp and the flax plants is also depend upon bacterial activity, this process is known as retting. The preparation of coffee and cocoa is also dependent upon bacterial action.

Role in Medicine

Bacteria are also the source of many antibiotics, serums and vaccines. Antibiotics are the chemical substances secreted by certain microorganisms which inhibit the growth and development of other microbes. The numb of antibiotics have been isolated from bacteria mainly from the species of *Streptomyces* and *Bacillus*. The different species of *Bacillus* is used as a source of antibiotics bacitracin, polymyxin-G, colistin (polymyxin-E), tyrothrycin etc.

Harmful Activities

Though the bacteria are important to mankind in various ways; of course, all activities of bacteria are not beneficial. Some of the important harmful activities are described below.

Role in Food Poisoning

Some saprophytic bacteria cause decay of our food and make it unpalatable. The activities of certain bacteria produce powerful toxins such as ptomins in the food. These toxins are powerful enough to cause food poisoning which results in serious illness and even death.

Role in Diseases

Many parasitic bacteria are the causative agents of bacterial diseases. They cause the diseases of our economic plants, domestic animals and human beings. There are more than 170 species of bacteria which cause plant diseases. Some of the plants diseases are citrus canker, angular leaf spot of cotton, wilt disease of potato, soft rot of carrot etc. The principal bacterial diseases of human beings are tetanus, tuberculosis, typhoid, cholera, diphtheria, dysentery, pneumonia and many others.

Role in Denitrification

There are some bacteria in the soil which reverse the nitrifying process. They injure the soil by causing the loss of a part of its combined nitrogen. This they do by breaking down nitrates into nitrites and nitrites into ammonia compounds or to free nitrogen. This free nitrogen enters into the atmosphere and is lost to the soil. This decreases the soil fertility. This process is called denitrification. The bacteria which bring about denitrification are called as denitrifying bacteria.

THE END