1 Viruses

Viruses are defined as '*sub-microscopic, self reproducing particles capable of being introduced into living cells and reproducing inside such cells only*'.

Virus means ***poison*** in Latin. Viruses are certainly not cells (acellular microorganisms). But they do possess some properties of cells.

They are ***intermediate*** between living and non-living things. They are ***neither prokaryotes*** nor ***eukaryotes***. They are the simplest forms of life. They are ***parasitic***.

They live inside the cells. When they live inside cells they are active and they feed, respire, reproduce, grow and move. When they live outside the cells they remain inactive and they do not feed, respire, reproduce, grow and move. Thus, the viruses resemble the living organisms in the intracellular state and the non-living chemicals in the extracellular state. Hence they are called ***living chemicals.***

Viruses are so small that they even pass through filters. Hence viruses are called ***filterable molecules.***

Discovery

The existence of virus was first proved by ***Ivanowski*** in 1892. The first virus was discovered by ***Ivanowski*** in 1899.

Characteristics of Viruses

Viruses are defined as '*sub-microscopic, self reproducing particles capable of being introduced into living cells and reproducing inside such cells only*'.

1. Viruses are extremely smaller in size. They are smaller than bacteria. They are invisible under the light microscope. They are only slightly larger than a larger protein and a nucleic acid. They range in size from 100 A^0 to 2,500 A^0.

2. They ***live inside living cells***. When they live inside cell, they are active and they feed,

respire, reproduce, grow and move. When they live out side, they remain inactive and behave as non-living things. So they are called as ***living chemicals.***

3. They are potentially ***infectious.***

4. They have a ***single nucleic acid*** either DNA or RNA (except RNA-DNA viruses).

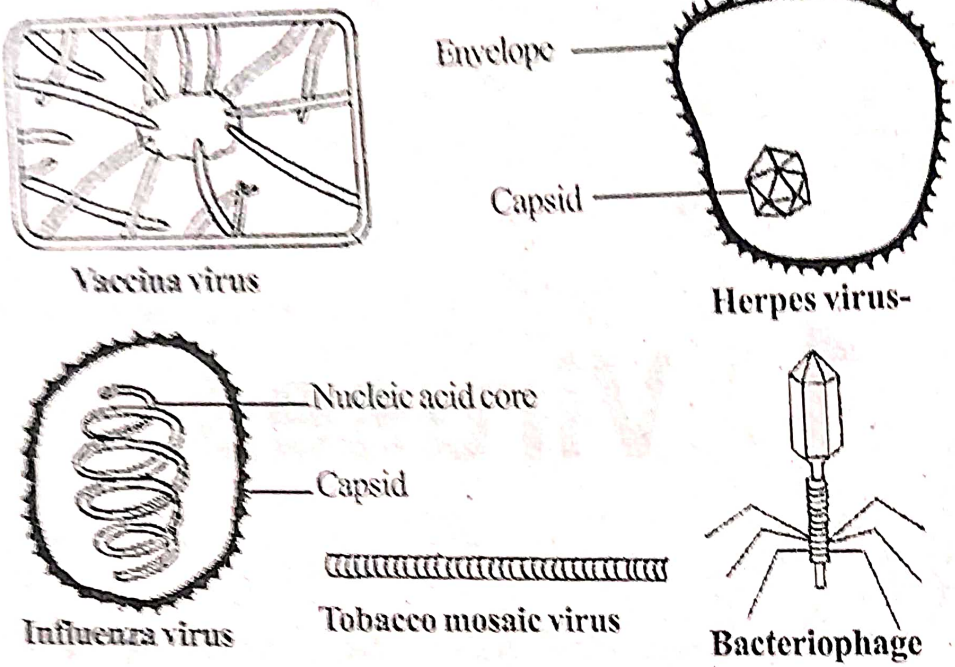


Fig. 1.1: Different types of viruses.

5. Viruses do not contain cellular structures such as, plasma membrane, mitochondria, Golgi complex, lysosomes, ribosomes, etc.

6. They can be crystallised.

7. Viruses do not have the power for growth and division. A fully formed virus does not increase in size by the addition of new molecules. Similarly a virus itself cannot divide. Only its nucleic acids DNA or RNA, divide.

8. They do not contain information for the production of enzymes in energy cycle.

9. They do not contain information for the synthesis of ribosomal protein, rRNA and tRNA.

10. Viruses are intracellular obligatory parasites. They live inside the cells of plants, animals and bacteria.

Structure of Viruses

Viruses are submicroscopic infective molecules that multiply only intracellularly and are potentially pathogenic. They are briefly called ***living molecules.***

Viruses are ***omnipresent***. The viruses living on animals are called ***animal viruses***. The viruses that live on plants are called ***plant viruses***. The viruses that live on bacteria are called ***bacterial viruses*** or ***bacteriophages.***

They are ***ultramicroscopic***. They can be seen only by an electron microscope. Viruses are smaller than bacteria. The smallest virus is 10nm* in diameter. (Eg. *Parvo virus*) The largest virus is about 250nm*.

The shape of viruses varies. They may be rod shaped (Eg. *Poxviruses*), bullet shaped,

brick shaped, spherical, oval or irregular. Some are like a piece of rope.

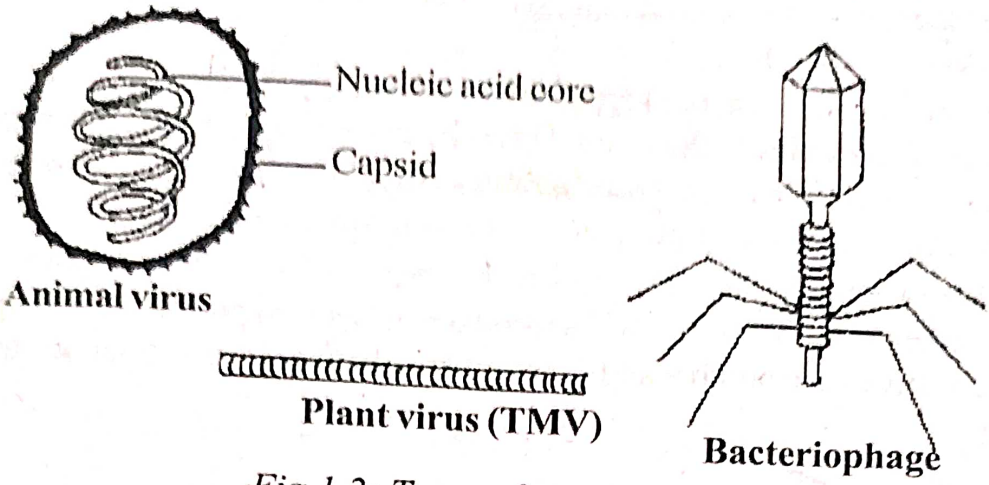


Fig.1.2: Types of viruses.

Most of the viruses fall into two categories, namely ***polyhedral*** or ***helical.***

The virus consists of two major components, namely a protein coat called ***capsid*** and a core made up of ***nucleic acid***. The ***nucleic acid*** with the capsid is called a ***nucleocapsid.***

A virus contains only one type of nucleic acid, either DNA or RNA. The virus containing DNA is called ***deoxy-virus*** or ***DNA virus***. The virus containing RNA is called ***RNA virus*** or ***ribovirus***. Rarely, a virus contains both DNA and RNA. Such viruses are called ***RNA-DNA viruses.***

The nucleic acid of virus may be single stranded or double stranded. Thus there are four types of viruses. They are:

1. Viruses with single stranded DNA (SsDNA) Eg. Coliphage.
2. Viruses with double stranded DNA (DsDNA) Eg. Vaccinia
3. Viruses with single stranded RNA (SsRNA) Eg. TMV
4. *Viruses with double stranded RNA (DsRNA) Eg. Reo virus.*

**nm = nanometer = 1 millimicron = one thousand of a micron = one millionth of a millimetre.*

Majority of animal and bacterial viruses are DNA viruses. Majority of plant viruses are RNA viruses. However, a few plant viruses are known to possess DNA and a few animal viruses are known to possess RNA.

The nucleic acid is surrounded by a protein coat called ***capsid.*** The capsid is made up of

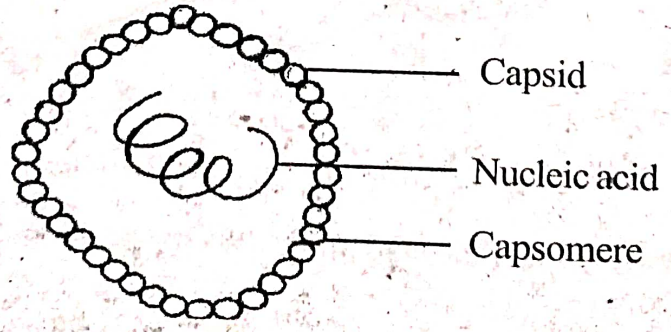


Fig.1.3: Structure of a simple virus.

many smaller units called ***capsomeres***. The capsid provides three main functions. It gives shape to the virus. It protects the nucleic acid; It helps in the attachment of the virus to the host cell (antigen specificity).

The capsomeres are made up of polypeptide chains.

The capsid provides shape to the virus. There are ***two main*** shapes (symmetry). They are ***icosahedral*** (cubical) and ***helical***. An icosahedral is a polygon containing 12 ***corners*** or ***vertices*** and 20 ***facets*** or ***sides***. The shape of each facet is like an equilateral triangle.

The icosahedral capsid is made up of two types of capsomeres namely ***pentons*** (5 neighbours) present at the vertices and ***hexons*** (6 neighbours) present on the facets.

Pentons are always 12 in number and the number of hexons varies. Each penton contains a fibre and a knob.

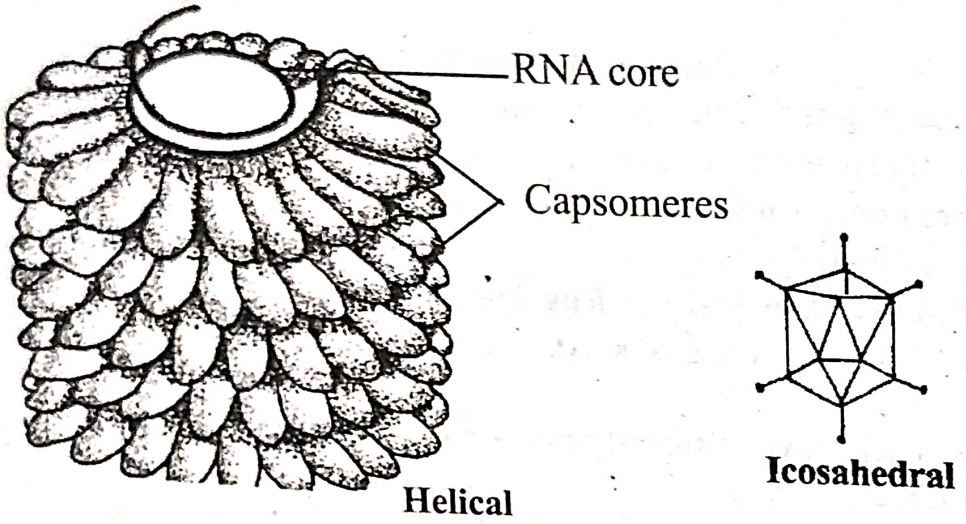


Fig.1.4: Shapes of viruses.

Many icosahedral forms of viruses contain 12 corners, 20 triangular facets and 30 edges with a total of 162 capsomeres. Eg. ***Adenovirus*** and ***Poliovirus.***

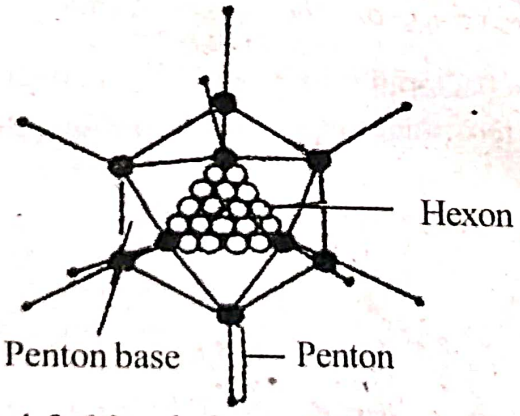
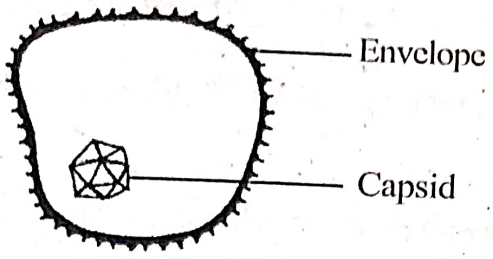


Fig.1.5: Morphology of adenovirus.

In helical capsids, the nucleic acid and capsomeres are held together to form a helical or spiral tube. Eg. *CMV.*

An individual viral particle capable of infecting a specific host is called a ***virion.*** The protein free pathogenic RNA (nucleic acid) of virus is called ***viroid***. The capsid is absent in the viroid.

Some viruses are covered by a protective covering called ***envelope***. The virus with an envelope is called an ***enveloped virus*** Eg. *HIV*. The virus without an envelope is called a ***naked virus.***



Herpes virus

Fig.1.6: Enveloped Virus.

Poliovirus

Fig.1.7: Naked Virus.

The viruses exist in three main shapes. They are spherical or rod shaped or tadpole shaped. *Adenovirus* and *HIV* are spherical in shape. *TMV* is rod shaped. T_4 bacteriophage is tadpole shaped.

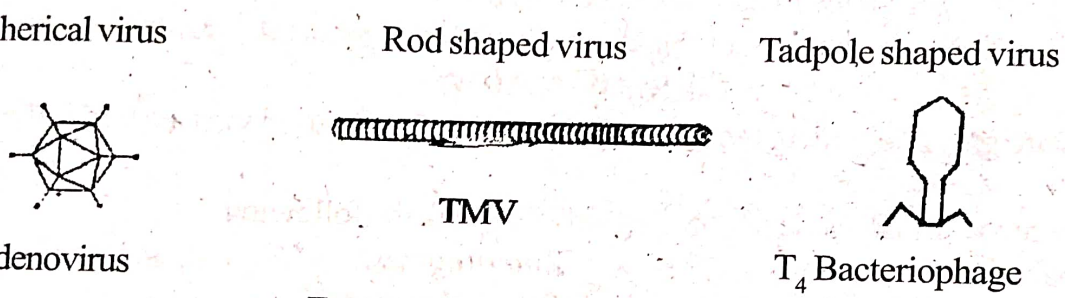


Fig.1.8: Shape of Viruses.

Some viruses cause damage in the cells in which they live. Such viruses are called ***virulent viruses***. These viruses harm the cells by causing lysis of the cell. Hence these viruses exhibit a ***lytic life cycle.*** Eg. *T_4 bacteriophage.*

The viruses which do not cause damage to the host cell are called ***avirulent viruses***. They do not cause lysis of the host cell. They exhibit ***lysogenic life cycle.***

Shape of Viruses

Viruses vary widely in their shape. They may be spherical, polyhedral, helical, cylindrical or rod-like.

Viruses occur in three main shapes, namely

1. Polyhedral
2. Helical
3. Complex

1. Polyhedral

In polyhedral viruses, the capsids are many sided. They are of three types, namely ***tetrahedral, octahedral*** and *icosahedral.*

In ***tetrahedral*** viruses, the capsid has ***4 sides.*** In ***octohedral*** viruses, the capsid has 8 sides. In ***icosahedral viruses,*** the capsid has 20 triangular facets and 12 corners. Most of the viruses are icosahedral.

The icosahedral capsid is made up of many subunits called ***capsomeres***. There are two types of capsomeres, namely ***pentameres*** and ***hexameres***. The pentamere is made up of 5 monomeres. The hexamere is made up of 6 monomeres.

The number of capsomeres will be either 12, 32, 42, 72, 92, 162, 252, 362, 492, 642 or 812.

Icosahedral capsids are found in viruses such as *PHI X 174, Adenovirus, Turnip yellow mosaic virus, Herpes virus*, etc.

2. Helical

In helical viruses, the capsid and the nucleic acid are helically coiled. The monomeres curve into a helix. Eg. *Tobacco mosaic virus, Influenza virus, Mumps virus*, etc.

The *tobacco mosaic virus* is rod-shaped.

The capsid is made up of 2,130 monomeres. The monomeres are arranged in 130 turns.

3. Complex

In complex viruses the capsid may be absent or the capsid may be attached with additional structures. Eg. *Vaccinia virus, phages of T-even series.*

The T_2 bacteriophage, shows a combination of icosahedral symmetry and helical symmetry.

Classification

Viruses are grouped under ***Acaryota. Holmes*** (1948) included viruses under the order ***Virales.***

Viruses are mainly divided into three groups. They are the following:

1. Animal viruses	-	***Zoophaginae***
2. Plant viruses	-	***Phytophaginae***
3. Bacterial viruses (Bacteriophages)	-	***Phaginae***

1. Animal Viruses

Viruses that infect animals are called ***animal viruses***. They are included in the group ***zoophaginae***. Animal viruses contain DNA. Some animal viruses contain RNA. The nucleic acids may be single stranded or double stranded.

The animal viruses cause dangerous diseases in human beings and domestic animals. The following are the common animal viruses :

Poliovirus	Yellow Fever virus
Vaccinia viruses	Rabies virus
Adenovirus	Mumps virus
Herpes virus	Measles virus
Reovirus	Influenza virus
Dengue virus	*HIV.*

2. Plant viruses

Viruses that infect plant cells are called ***plant viruses.*** About 170 plant viruses have been identified. Most of the plant viruses contain RNA as the genetic material. But only one group of plant virus contains DNA. The RNA may be single stranded or double stranded.

The plant viruses have been divided into nineteen groups. The following are the important

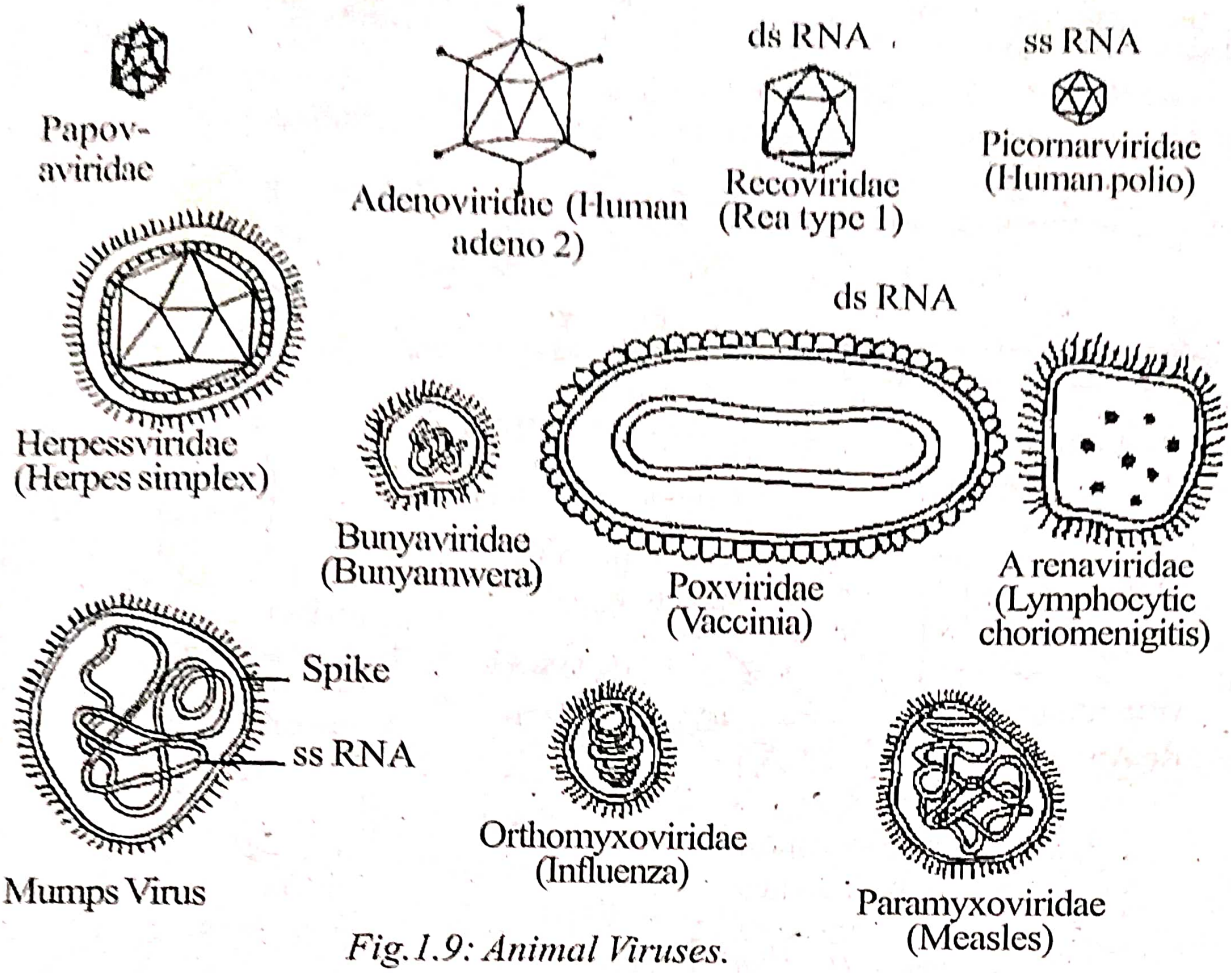


Fig. 1.9: Animal Viruses.

plant viruses:

Tobacco mosaic virus (TMV)	Cucumo virus
Tomato mosaic virus	Tobacco necrosis virus
Potato virus	Alfalfa mosaic virus
Papaya mosaic virus	*Cauliflower mosaic virus.*

3. Bacterial Viruses (Bacteriophages)

Viruses that infect bacterial cells are called ***bacterial viruses*** or ***bacteriophages***. Phage means ***to eat.*** Bacteriophages means ***viruses eating bacteria.***

Bacteriophage was first described by ***Twort*** in 1915.

The genetic material is either DNA or RNA. They may be single stranded or double stranded.

The common bacteriophage is ***T4 Bacteriophage***. It infects the human colon bacterium, *Escherichia coli*. 'T' stands for the 'type'. Bacteriophages are numbered from 1-to 7.

Virions

Virion is an ***entire*** viral particle remaining outside the cell. As it remains outside it is ***inert*** (inactive). It cannot replicate.

It is made up of an outer protein coat called ***capsid*** and an inner ***nucleic acid core.***

Viroids

Viroids are plant viruses containing only ***RNA.*** They do no contain protein coat. They live inside plant cells. They are smaller than viruses.

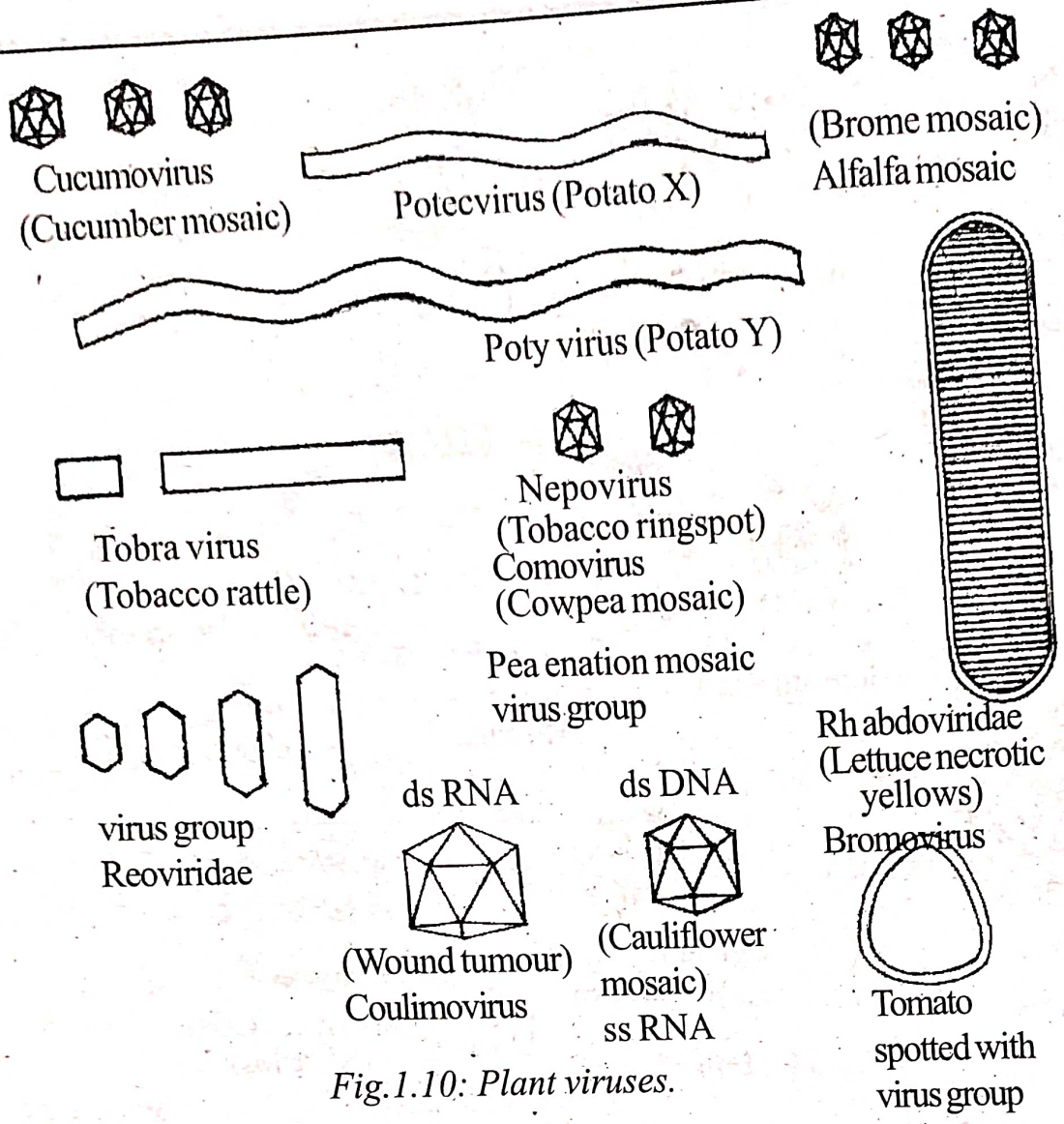


Fig.1.10: Plant viruses.

They are ***pathogenic*** and they can cause plant diseases.
Eg. The virus causing *spindle tuber disease of potatoes.*

Prions

Prions are viral particles containing only ***proteins.*** They do not contain nucleic acid. They are infectious. They are smaller than viruses.

Prions are discovered by ***Prusiner*** for which he was awarded Nobel Prize in 1997.

Prions are rod-shaped. They are found in the ***neurons.***

It causes ***mad cow diseases*** in cattle. It is a ***neuro-degenerative disease.***

Kuru is a human neuro-degenerative disease. It is caused by prions and is transmitted due to the consumption of human brain during funeral rites by the cannibals of Papua, New Guinea.

Tobacco Mosaic Virus (TMV)
(A typical Plant Virus)

Tobacco mosaic virus is a typical plant virus. It is abbreviated as ***TMV.*** It causes a disease called ***tobacco mosaic*** in tobacco plants and hence the name. The infected plants show yellow and green mottling which appears as a mosaic pattern.

The tobacco mosaic virus is an ***RNA virus***. It is a ***helical virus***. It is ***rod shaped***. It is about 3,000 A^0 long and 170A^0 diametre.

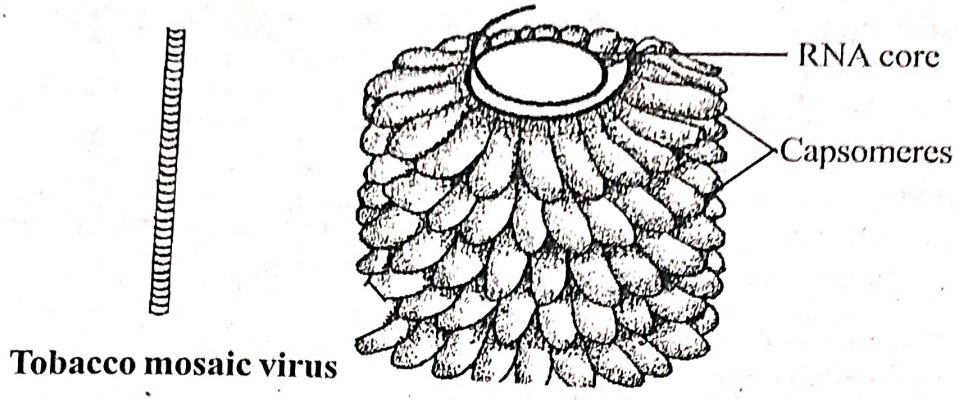


Fig.1.11: Tobacco Mosaic Virus.

The *TMV* is made up of two components, namely an outer ***capsid*** and an inner ***RNA*** molecule.

The capsid is the ***outer coat***. It is formed of ***protein***. The capsid is made up of small subunits called ***capsomeres***. There are about ***2,130 capsomeres*** in a *TMV*. The capsomeres are ***helically arranged*** around the RNA. There are about 129 complete spirals.

The RNA forms the core of the virus. It is a ***single stranded*** nucleic acid. The RNA is also helically coiled like that of capsid. There are about 3 nucleotides in the RNA per capsomere. So there are about 6,400 nucleotides in the RNA.

Adenovirus
(A typical Animal Virus)

Adenovirus is a typical animal virus. It infects eye and alimentary canal. It is a non-enveloped virus. It is a ***polyhedral virus***. It is a ***DNA virus.*** It has the appearance of a ***space vehicle***.

It is made up of two components, namely an outer coat the ***capsid*** and an inner core the ***DNA.*** The capsid is made up of small sub-units called ***capsomeres.***

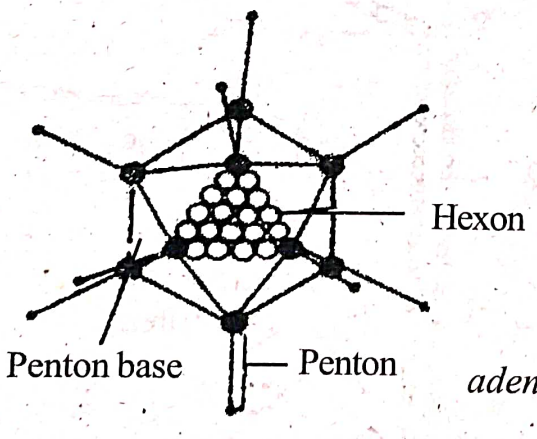


Fig.1.12: Morphology of adenovirus.

There are about 252 capsomeres. The capsomeres are arranged in the form of an ***icosahedran,*** having 20 ***triangular facets,*** and 12 ***vertices***.

The 12 capsomeres at the vertices have 5 neighbours and are called ***pentons***. The remaining 240 capsomeres have six neighbours and are called ***hexons***.

The adenovirus has ***cubical*** symmetry. This symmetry is provided by the capsid. It has a many sided symmetry called ***polyhedron.*** It has a special shape called ***icosahedron***. Icosahedron

is a regular polyhedron with 20 triangular sides called ***facets*** and 12 corners called ***vertices***.

This means that the capsid has 20 equilateral triangulars (facets). These triangles come together to form 12 corners (vertices). There is one capsomere at each corner. This capsomere is called a ***penton*** because it is surrounded by 5 other capsomeres. Each penton contains a ***fibre*** ending in a ***knob.***

The capsomeres present in the facets are called ***hexons*** because they are surrounded by 6 capsomeres. In ***Adenovirus***, there are 240 hexons and 12 pentons.

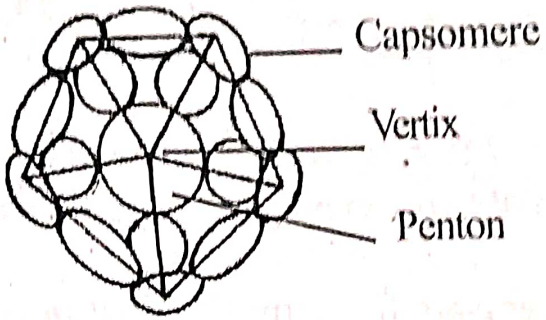


Fig.1.13: A icosahedral capsid showing a penton.

Bacteriophage

Bacteriophage is a ***bacterial virus.*** It is a virus living inside bacterial cells. Bacteriophage means ***bacteria eating agent***. It was first described by ***Twort*** in 1915.

The common bacteriophage is ***T_4 bacteriophage***. It is parasitic on human colon bacteria,

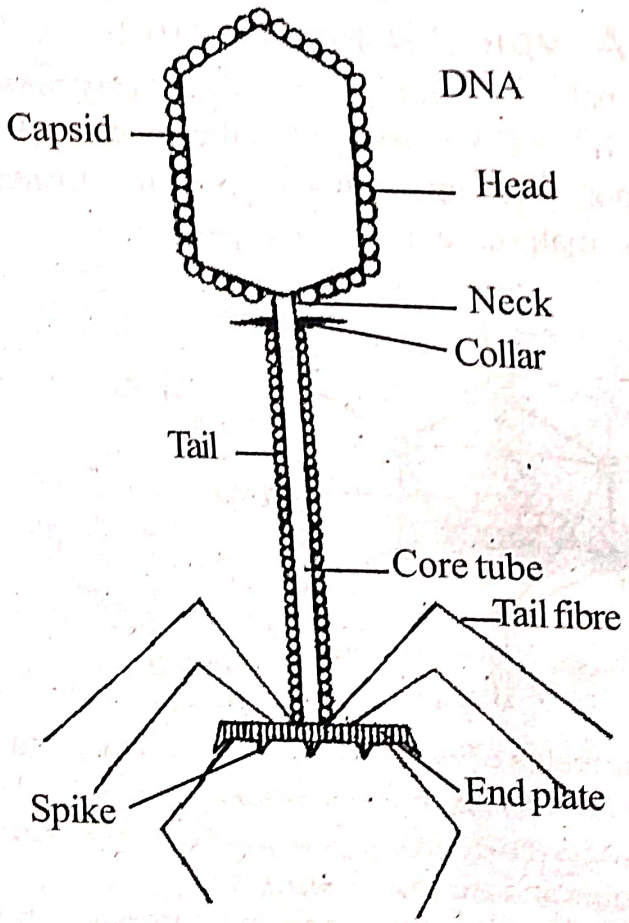


Fig.1.14: A sectional view of T_4 bacteriophage.

Escherichia coli. It is also known as ***coliphage.***

The T_4 phage is ***tadpole-shaped***. It consists of 3 parts, namely a ***head***, a ***neck*** and a ***tail.***

The ***head*** is polyhedral. It is covered by a protein coat called ***capsid***. The capsid is made up of about 2,000 protein sub units called ***capsomeres***.

A ***double stranded*** DNA is present inside the head. The DNA is highly coiled and tightly packed. It contains more than 75 genes.

The neck is very short and it contains ***collar***. It connects the head with the tail.

The tail consists of a central hollow ***core tube***. Through this core tube the DNA of the phage can pass into the bacterial cell. The core tube is covered by a ***sheath*** or tube made up of about 144 protein ***contractile*** subunits.

The free end of the core tube has a ***hexagonal end plate***. The end plate has ***6 spikes*** and ***6 fibres.*** The spikes are used for penetration and the fibres are used for attachment on the host.

The bacteriophage has a ***complex symmetry***. It exhibits a combination of ***icosahedral*** and ***helical*** symmetry. The head is icosahedral in symmetry and the tail is helical in symmetry.

The bacteriophage has 2144 capsomeres. Of these, 2000 capsomeres are present in the head and 144 capsomeres are in the tail. The 2000 capsomeres of the head are arranged in the form of an ***icosahedron*** having 20 triangular sides called ***facets*** and 12 corners called ***vertices.*** There are two types of capsomeres, namely ***pentons*** and ***hexons.*** Pentons are 12 in number and are located on the head. The hexons are located on the facets.

The 144 capsids of the tail are helically arranged to form the core tube.

Multiplication of Bacteriophages

Bacteriophages are capable of multiplication only ***within the bacteria.*** They remain inactive outside the bacterium. They are host specific. For example, *T_4 bacteriophage* infects and multiplies only inside the bacterium ***E.coli.*** The multiplication of phages takes place in the following steps:

1. Attachment of phage on Bacterium: When the phage and the bacterium come close together by random collision, the phage attaches itself to the surface of the bacterium. The tail fibres select specific sites on the bacterial cell wall and attach with it. Then the tail fibres bend to keep the end plate in contact with the bacterial cell wall.

2. Injection of Phage DNA into the Bacterium: The tail secrete the enzyme lysozyme which dissolves the bacterial cell wall to make a hole. The contractile sheath contracts and this forces the tail core into the bacterial cell wall through the hole. The phage DNA is then injected into the bacterium through the tail core. The protein coat does not enter in; it remains outside the bacterium.

3. Disruption of Bacterial Metabolism: The phage DNA disturbs the bacterial metabolism and synthesizes phage DNAs and proteins. The synthesis of normal bacterial proteins stops. Meantime, the phage DNA synthesizes phage proteins using the host's protein synthetic machinery. The viral DNA produces mRNA which later forms phage proteins. The bacterial DNA is degraded into free nucleotides by the action of viral ***deoxyribonuclease.*** Therefore the synthesis of bacterial DNA stops. At the same time, the phage DNA replicates by using the free nucleotides and produces many copies of phage DNA. These biochemical reactions is infected

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bacterium last for 4-10 minutes after the entry of phage DNA.

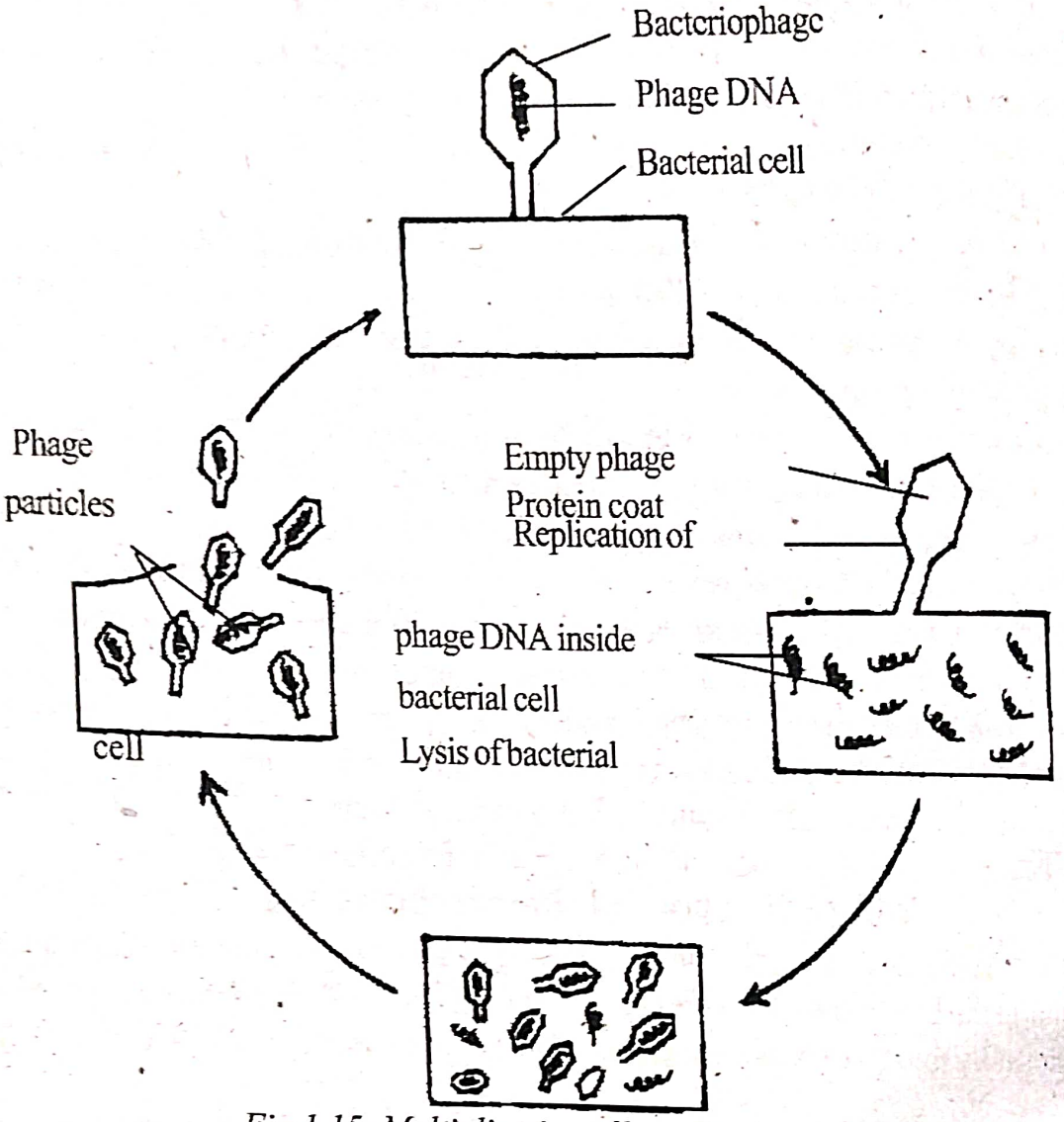


Fig.1.15: Multiplication of bacteriophage.

4. Assembly of Phage Particles: The phage proteins form sub-units of capsids, tail sheaths, tail fibres and end plate. The sub-units form head. Each phage DNA copy then enters the head and becomes tightly packed. The tail sheath and end plate join together to form a tail. This tail then attaches to the head.

Thereafter, the tail fibres join with the end plate to form a new phage particle. Thus about 150-300 phages are produced in a bacterium. The duration between injection of viral DNA and the formation of first phage is called ***eclipse period.*** It takes place between 10 and 20 minutes after infection.

5. Lysis of Bacterium: As many phages have been produced in a bacterium, the bacterial cell wall ruptures suddenly. The new phage particles are released free. It takes place in 20 minutes after infection.

Life Cycle of Phages

Bacteriophages exhibit two types of life cycles. They are:

1. Lytic cycle (virulent cycle) and
2. Lysogenic cycle (temperate cycle)

1. Lytic Cycle

All the T series phages exhibit lytic cycle. These viruses infect bacteria and on completion of life cycle, they cause lysis or rupture of the bacterium. Hence the cycle is called ***lytic cycle***. Lytic cycle involves the following steps:-

1. Infection takes place by random collision between the phage and the bacterium.

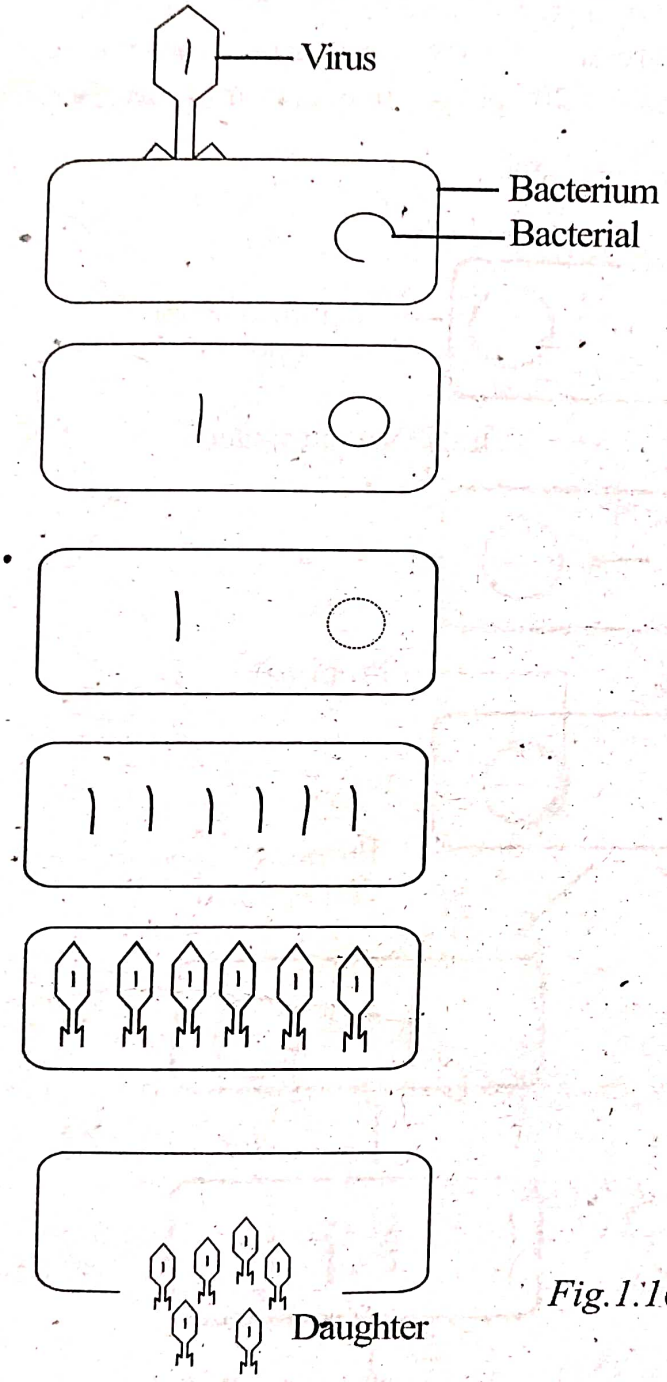
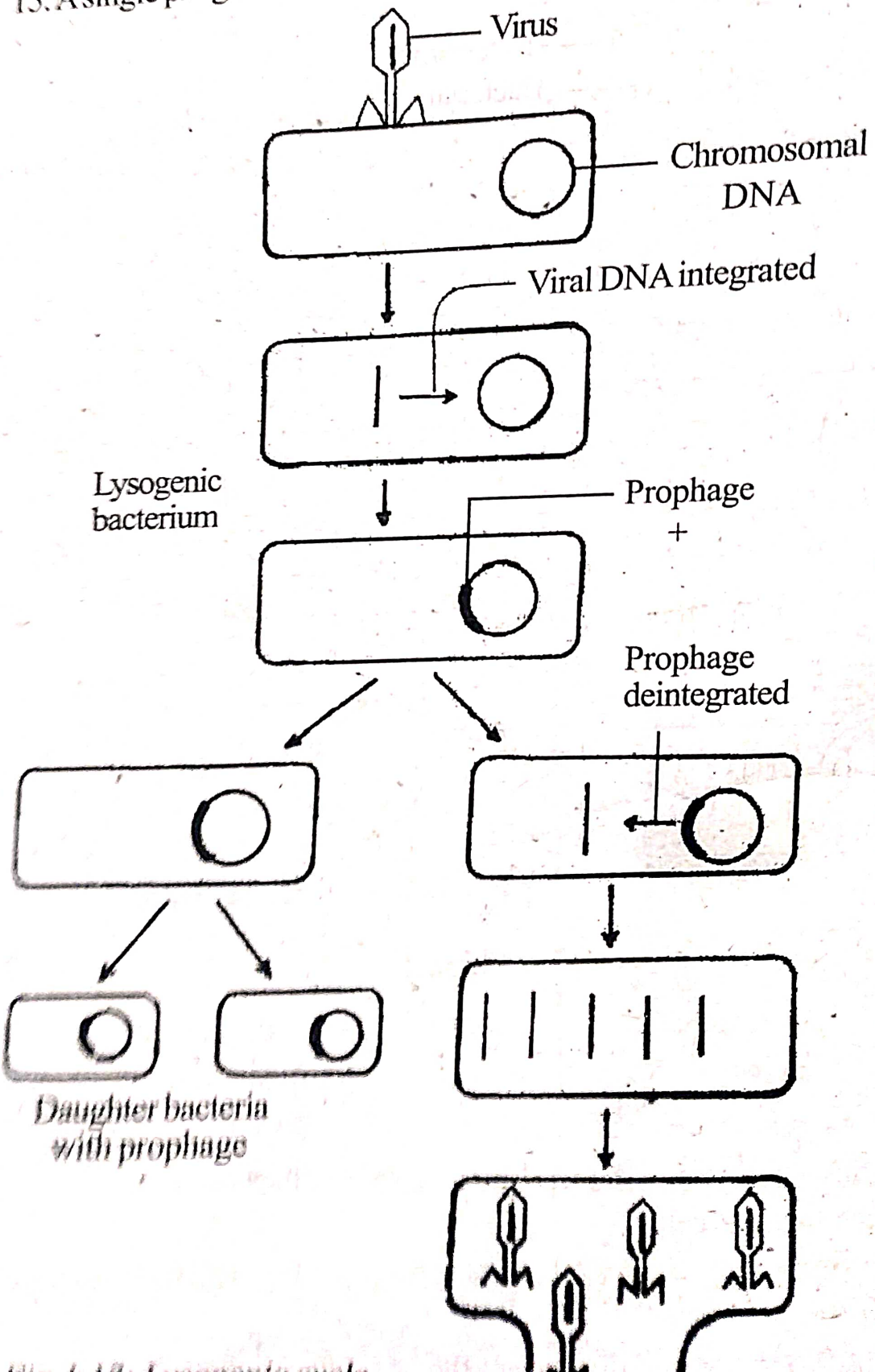


Fig.1.16: Lytic cycle.

2. The tail fibres select specific site on the surface of the bacterium.
3. The spikes anchor firmly.
4. A hole is made in the cell wall of bacterium by the enzyme lysozyme secreted by the tail.
5. The sheath contracts and this causes the tail core to penetrate the cell wall.
6. The DNA of the head is discharged into the cell through the tail core.

7. The protein coat does not enter in; it remains outside the cell.
8. The DNA of the phage takes over the protein synthesizing machinery of the bacterium
9. The host DNA is degraded by the viral ***deoxyribonuclease.***
10. Viral DNA is transcribed into mRNA.
11. The mRNA translates proteins which are utilized for the synthesis of viral proteins.
12. Viral DNA also replicates to produce hundreds of copies.
13. Each DNA copy is enclosed by a protein coat producing new virus.
14. Soon the bacterial wall ruptures and the new viral particles are released.
15. A single phage can produce about 200 phages in twenty minutes after infection.



2. Lysogenic Cycle

All the lambda series bacteriophages exhibit lysogenic cycle. In lysogenic cycle the bacterium is not lysed. As in the lytic cycle the viral DNA enters the bacterial cell. But the viral DNA does not take over the protein synthesizing machinery ofthe host. Instead it gets integrated with the bacterial chromosome. At this stage, the virus is called ***prophage.*** The bacterium with prophage is called ***lysogenic*** and it is resistant to other phages. The viral DNA replicatesalong with the bacterial chromosome.

Rarely, the prophage DNA can disintegrate and enters into lytic cycle.

Transduction

Transfer of genetic material from one bacterium to another through bacteriophages is called ***transduction.*** As in the lysogenic cycle, the viral DNA gets

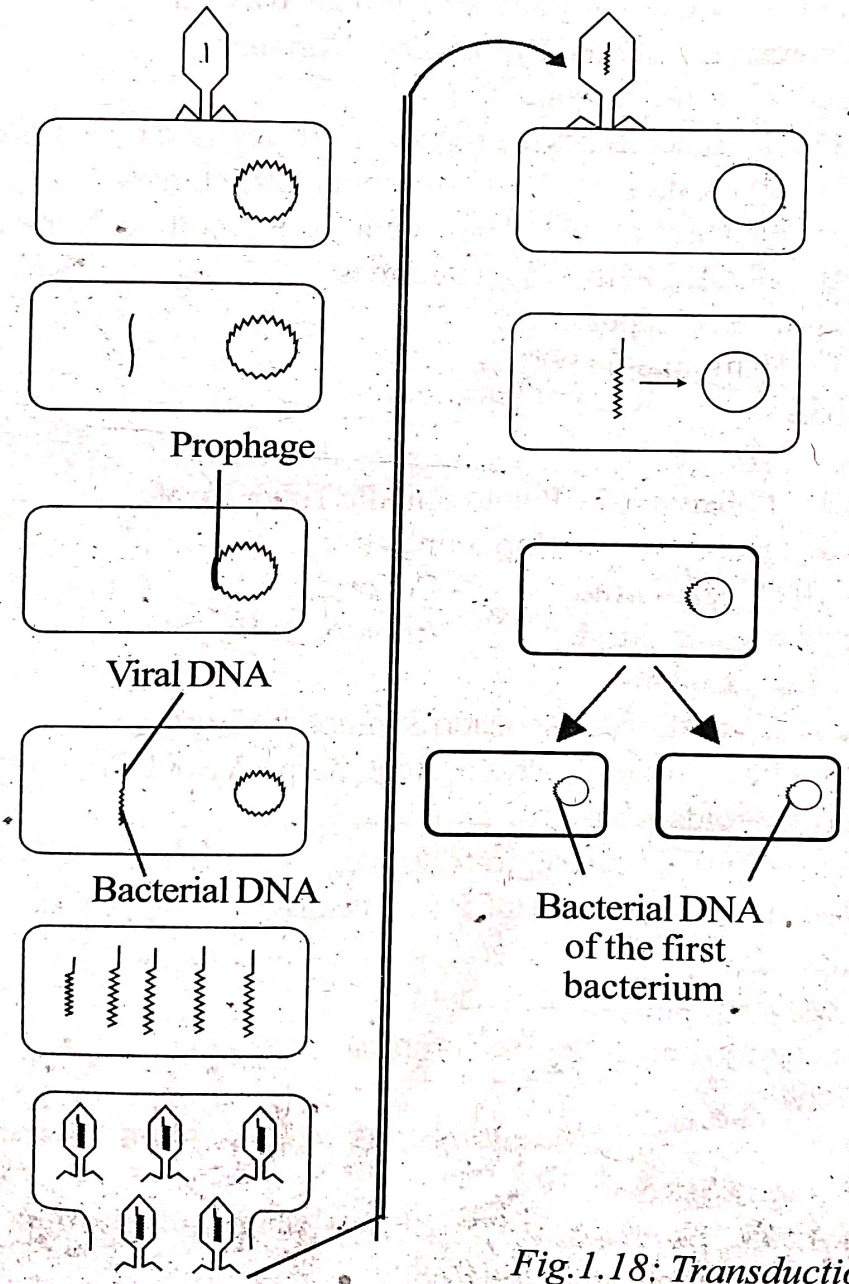


Fig.1.18: Transduction.

integrated with the bacterial chromosome to become prophage. Then the prophage DNA disintegrates. During the process, the prophage DNA gets a fragment of bacterial DNA. This phage DNA replicates several times to produce many viral particles. These are released by the rupture of bacterial cells. These phages containing a portion of bacterial DNA are called ***transducing phages.*** These phages now infect new hosts and the DNA is integrated with the bacterial chromosome. When the viral DNA, disintegrates from the bacterial DNA, it leaves the bacterial DNA drawn from the first bacterium. Thus the bacterium gets a fragment of DNA from the previous bacterium through bacteriophages.

Viroids

Viroids are ***infective nucleic acids that lacks protective capsid.*** They are characterized by the following features:

- Viroids are novel subcellular entities made up of circular, ss RNA molecules.
- They lack protein component. They are abbreviated as Vd.
- Viroids were extensively studied by ***Diener*** and ***Raymer.***
- Diener proposed the name ***"Viroids".***
- More than 16 plant viral diseases are reported to be caused by Viroids.
- Viroids are obligate parasites of cell's transcriptionalmachinery.
- Viroids do not code for any protein. They replicate autonomously in susceptible cells.
- Viroids constitute about 246 to 375 nucleotides.
- They do not require any helper virus.
- They survive for 10 minutes at 90^0 C.

Taxonomy of Viroids

Family I : Popsiviroidae
- Genus I : Popsiviroid - Potato Spindle Tuber Viroid
- Genus II : Hostuviroid - Hop Stunt Viroids
- Genus III : Cocadviroid - Coconut Cadang - Cadang Viroids
- Genus IV : Apscaviroid - Apple Scar Viroid.

Family II : Avsunviroidae
- Genus I : Avsunviroid - Avocado Sunblotch Viroid
- Genus II : Pelamoviroid - Peach latent mosaic Viroid

The classification of Viroids is based on two factors

1. Presence of Conserved Central Region (CCR):

Members of Popsiviroidae contain CCR but A