

VIRUSES

Virus is a *Latin* word. In the dictionary of Philips (1720) it is described as poison, venom, slimy liquid or infectious matter.

What is Virus?

A. Morphologically/Physically:

1. Very small in size
2. Not visible under compound microscope. Visible only under electron microscope.

B. Chemically:

1. Nucleic acid (either RNA or DNA) +Protein= Nucleoprotein. RNA/DNA covered with protein coat (capsid)

C. Biologically:

1. Intracellular obligate parasite.
2. Mesobiotic and noncellular.

D. Clinically:

1. Highly infectious agent and produces disease in suitable hosts.

It has been variously described by many authors.

Green (1935) defines viruses as the smallest unit showing reproductive properties considered typical of life.

Bawden (1949) defines viruses as obligate parasites too small to be seen.

S.E. Luria *et al.* (1978) defined virus as “Entities whose genome are elements of nucleic acid that replicates inside living cells using cellular synthetic machinery (host ribosome) and causing synthesis of specialized elements (complete virions or virus particles) that can transfer the viral genome to other cells.”

L. Bos (1983) has defined viruses as “An infectious agent often causing disease, invisible with light microscope (submicroscopic) small enough to pass through a bacterial filter, lacking the metabolism of its own and depending on living host cells for multiplication”

One more simple definition is “viruses are submicroscopic pockets of nucleic acid (RNA or DNA) enclosed in a protein coat and multiply within a living cell”

The above definitions vary but the central theme remains the same. Whatever may be the precise language to define a virus, the following characteristics will always be included:

1. Viruses contain one or more pieces of single type of nucleic acid, either RNA or DNA, never both.
2. The nucleic acid carries the genome of the virus which differs from one virus to another.
3. The genome in the nucleic acid strand directs the synthesis of specific proteins for the protein coat which must be present in all viruses throughout their active phase except at the time of replication when protein coat and nucleic acid are separated.
4. Viruses depend on the living host cells for most of the enzymes necessary for their replication.

History:

1886: Adolf Mayer, (German Agricultural Chemist): Described tobacco mosaic and showed that it could be transmitted by inoculation of extracts from diseased plants.

1892: Dimitri Ivanovsky, (Russian Botanist): Sap from tobacco mosaic diseased plants remain infective even if it was passed through a bacteria-proof filter suggesting that the agent must be smaller than the bacteria.

1898: Martinus W. Beijerinck, (Dutch Botanist): Used the term **Virus** and considered it different from a bacterium and named it *contagium vivum fluidum* meaning contagious living fluid. He is honoured as **Father of Virology**.

1915: Twort and D' Herelle (1917): Discovered a new kind of viruses which infected bacteria and called them **Bacteriophages**.

- 1935: Stanley, W.M.:** Precipitated an infectious crystalline protein by treating juice from infected tobacco plants with ammonium sulphate and concluded that the virus was autocatalytic protein that could multiply within living cells. Although his results and conclusions were later proved incorrect. For this important discovery, he was awarded with prestigious Nobel Prize.
- 1936: Bawden, F.C. and Pirie, N.W.:** Demonstrated that crystalline preparation of virus actually consisted of protein and ribonucleic acid.
- 1939: Kausche et al.:** Observed virus particles for the first time with the help of electron microscope.
- 1956: Gierrer, A and Schramm, G.:** Experimentally demonstrated that only the nucleic acid in the virus is infective and is capable of synthesizing its own protein coat and forming the complete virus particles.
- 1968: Shepherd et al.:** Observed the first DNA virus in Plants (Cauliflower mosaic virus).
- 1971: Diener, T.O.:** Discovered **viroids** (naked nucleic acid, single stranded, circular molecules of infectious RNA).
- 1981: Randles, T.W. et al.:** Discovered **Virusoids**.
- 1982: Stanley B. Prusiner:** Discovered **Prions** (proteinaceous infectious particles). Later, in late 1990s, he reported the causal agent of the dreaded **mad cow disease** being the prions. For this, he was awarded with **Nobel Prize**.

Nature of Viruses: It has long been a vexing question. In fact, it is still a mystery as to what is the nature of viruses. The biologists hold that the viruses are animate objects. Biochemists strongly oppose living hypothesis. They say that viruses are inanimate objects.

Organism Theory: The supporters of the living hypothesis argue that growth and reproduction are the chief distinctive characteristics of living organisms. Viruses possess both. They grow and reproduce and undergo mutation and become adapted to the environment through natural selection. They possess genetic continuity and occur in definite races, or strains, each with its specific character. In all these respects they show similarity to a typical organism. The characteristics features of life are ability to -

- (1.) Assimilate (metabolize) with the release of energy,
- (2.) Excrete waste products of metabolism,
- (3.) Grow/ multiplication,
- (4.) Mutation and
- (5.) Response to stimuli.

Viruses show all these characteristics and hence, the proponents of the living theory consider them living entities.

Molecular Theory: The proponents of molecular theory argue that viruses have no cellular organization. They do not have anything resembling cytoplasm, nucleus or cell membrane, etc. They show no physiological activity except self duplication. They neither respire nor take food. In fact, they show no sign of metabolism. All these are the characteristics of the inanimate objects. Thus, the general opinion is that viruses are unique entities being neither living nor nonliving and simultaneously both. It has been, therefore, agreed that **viruses are on the threshold of life in the living world**.

Properties of Viruses

Viruses possess certain physical and chemical properties. The most important properties of viruses are:

1. They are so small that they can pass through the minutest pore of the filter.
2. They are transmissible from unhealthy to healthy plants. Some can be transmitted by juice inoculations. Others lose their activity in plant juices.

3. All viruses are parasitic. They can grow and multiply only within the living host cells. No saprophytic virus is known so far. All viruses are, in fact, obligate parasites.
4. They vary greatly in their reactions towards a number of environmental conditions. Some viruses are easily killed by drying, heat or poisons. Others are highly resistant.
A few remain active for years. In dry state, viruses as a rule can resist the action of common germicides such as alcohol.
5. They are highly infectious.
6. They are unaffected by exposure to direct sunlight and many can withstand heat, cold or drought.
7. They can be precipitated from suspensions and redissolved in water.
8. Viruses have host specificity.
9. Antibiotics have no effect on viruses.

Structure and Morphology of Plant Viruses

Chemically viruses are nucleoproteins. The mature particle of a plant virus is called a **virion**. The particle consists of two components, the nucleic acid and protein coat or capsid. Nearly half of the plant virus may be of elongated (rigid rod /flexuous threads) and spherical (isometric / polyhedral) and the remaining are cylindrical bacillus like rods in shape.

1. Rigid rod: E.g. *Tobacco Mosaic Virus* (TMV) and *Tobacco rattle Virus* (TRV)

2. Flexuous rod: E.g. *Potato Virus X* (PVX), *Bean Common Mosaic Virus* (BCMV).

3. Filamentous rod: E.g. Tenuiviruses likes *Rice Grassy Stunt* (RGSV) and *Rice Stripe Virus* (RSV).

4. Isometric: E.g. *Rice Tungro Spherical Virus* (RTSV), *Cucumber Mosaic Virus* (CMV), *Tomato Spotted Wilt Virus* (TSWV).

5. Bacilliform: E.g. *Rice Tungro Bacilliform Virus* (RTBV), *Banana streak virus* (BSV) and *Cocoa Swollen Shoot Virus* (CCSV).

The Protein Coat of Viruses: Protein forms a protective coat (capsid) around the nucleic acid. Plant viruses have only one kind of protein. Individual protein subunits are called as **capsomers**. Protein subunits are spirally arranged in elongated viruses and packed on the side of polyhedral particles of spherical viruses. Proteins provide the basis for serological differentiation of viruses and other strains. Like all proteins, viral protein is made up of amino acids (RCH (NH₂)COOH). Sequence of amino acid within a protein is detected by the sequence of nucleotides in the nucleic acid.

The Nucleic Acid of Viruses: may be of RNA or DNA and never both. Most of the plant viruses have RNA (e.g. *Tobacco mosaic virus* (TMV), *Potato leaf roll virus* (PLRV)). But some plant viruses have DNA (e.g. *Cauliflower mosaic virus* (CaMV), *Rice tungro bacilliform virus*, *Bean golden mosaic virus* and *Banana bunchy top virus*). Nucleic acid (RNA / DNA) may be either single stranded (**ss**) or double stranded (**ds**). These strand may be free at both the ends (linear) or their ends may be joined together to form a circular nucleic acid molecule (circular). In double stranded viruses, the two strands are coiled around each other helically. This forms a ladder like double helix. The nucleic acid may be present as a single continuous strand (**monopartite**) in one particle or it may be present as two (**bipartite**), three (**tripartite**) or many pieces (**multipartite**) in the same or different particles made up of same protein subunit. Bi- or multipartite viruses are called as **split genome viruses**. All types of particles with different segments of the genome must be present in the plant for the successful infection. Nucleic acid and protein coat makes up 5 – 40% and 60 – 95% of the virus respectively. Elongated viruses have less quantities of nucleic acid while the spherical viruses contain more nucleic acid. Some ss DNA viruses appear as twin particles as a result of partial fusion together of two of isometric particles and they are called as **geminiviruses** (E.g. *Maize streak virus*, *Bean golden mosaic virus* and *Beet curly top virus*). Some group of viruses has outer **lipid** envelop around the protein coat (E.g. *Tomato Spotted Wilt Virus*).

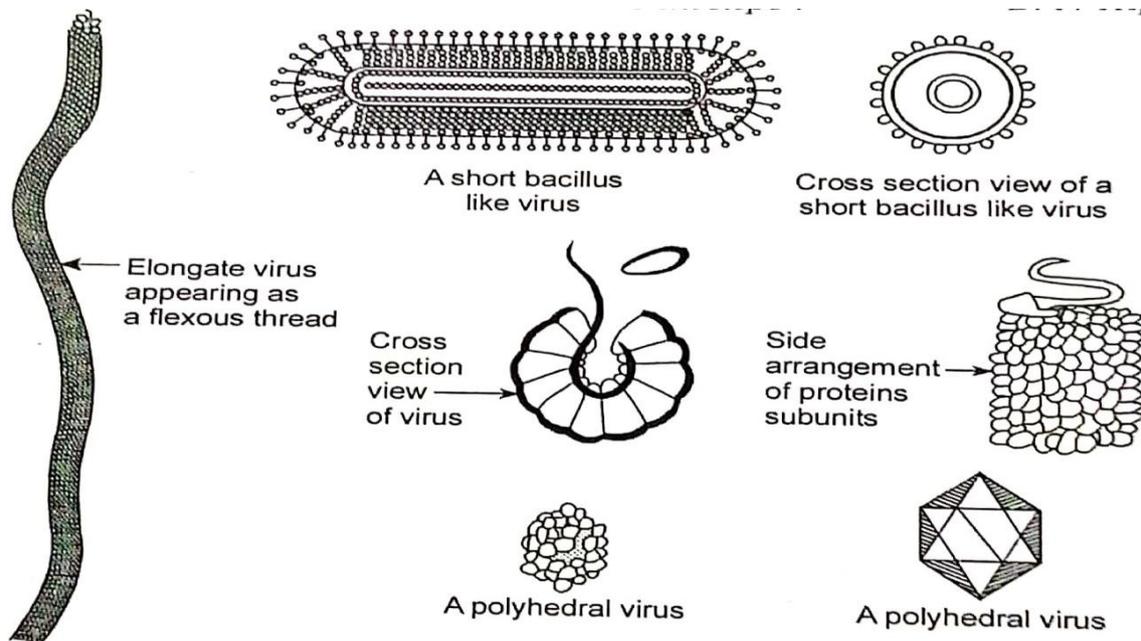


Fig. Different Shapes and Structure of Plant Viruses

Multiplication of virus is different from fungi and bacteria. First step in the multiplication is the separation of nucleic acid from the protein coat in the host cell by the enzymes of host cell. Nucleic acid itself involve in the synthesis of new nucleic acid and protein coat by utilizing the amino acids, ribosome and transfer RNA of the host. Once the new nucleic acids and proteins subunits are formed, the nucleic acid arranges the protein subunit around it to form the **complete virus particle** or **virions**.

TRANSMISSION OF PLANT VIRUSES

Viruses are infectious and may be transmitted through several generations inside a host. They can also be taken out of the host and introduced into other living cells. The chief methods of viral transmission are:

1. Seed Transmission: Seeds play important role in the spread of plant viruses, A few viruses of legumes, wild cucumber, tomato and sugar beet are transmitted through various parts of seeds. The examples of the viruses that are transmitted through the embryo of seeds are barley stripe virus, bean common mosaic virus, cowpea mosaic virus. The example of plant virus that are transmitted through the endosperm of seeds is cucumber mosaic virus whereas bean common mosaic virus, bean yellow mosaic virus and tomato spotted wilt virus are transmitted through the seed coat.

2. Transmission by Vegetative Propagation: It is one of the chief methods of transmission of plant virus diseases, especially of potato, rose, sugarcane, raspberry, strawberry, turnip, bulb plants, fruit trees and many ornamentals plants. The vegetative parts of the infected plants such as the tubers, bulbs, roots, buds and scion which are used for propagation will contain the virus present in the parent. (E.g. *Banana bunchy top virus* and *Indian cassava mosaic virus*)

3. Transmission by Mechanical Means: Many mosaic viruses are transmitted mechanically from diseased plants to the healthy ones by the following methods:

- A.** By contact of infected and healthy leaves brought about by winds.
- B.** By rubbing the juice of the diseased plants over the surface of the leaves of healthy plants.
- C.** By grafting infected scion on to healthy plants.
- D.** Agricultural implements also play quite an important role. The knife used for cutting the

seed pieces and pruning shears will spread the virus.

E. Some viruses spread belowground by contact between the roots of diseased and healthy plant roots.

4. Transmission by Cuscuta: In many cases *Cuscuta* serves as transmitting agent and an effective bridge between the infected host and the healthy plants by establishing intimate biological contacts through its haustoria. The examples of viruses transmitted through *Cuscuta* are pea wilt virus, curly top of beet virus, curly top of French bean virus and cucumber mosaic virus.

5. Insect Transmission: The most common and important means of transmission of viruses in the field is by insect vector. The order Homoptera (aphids and leafhoppers) contains the largest number and the most important insect vectors of plant viruses. Some insects belonging to the order Hemiptera are also vectors of some plant viruses. The examples of viruses transmitted by insect vectors are:

A. Aphids: cauliflower mosaic virus, potato virus X, potato virus Y, potato leaf roll virus, barley yellow dwarf virus are the examples of plant viruses that are transmitted by aphids.

B. Whiteflies: Cotton leaf roll virus, mungbean/urdbean yellow mosaic virus, pigeon pea sterility mosaic viruses are the examples that are transmitted by whiteflies

C. Leafhoppers: Sugar beet curly top virus and sugar beet curly leaf viruses are transmitted through leafhoppers.

6. Mites: Eriophyid mites (*Aceria* spp.) are known to transmit some viruses for example, pigeon pea sterility mosaic virus, wheat streak mosaic virus, Agropyron mosaic virus and ryegrass mosaic virus are known to be definitely transmitted by mites.

7. Nematode Transmission: Plant nematodes play a vital role as vector in transmitting certain virus diseases. Nematode vectors transmit viruses by feeding on roots of infected plants and then moving on roots of healthy plants. Larvae as well as adult nematodes can acquire and transmit viruses, but the virus is not carried through the larval molts or through the eggs. Mainly three genera of nematodes transmit plant viruses. These are ***Xiphinema* spp., *Longidorus* spp. and *Trichodorus* spp.** Tomato ringspot, tobacco ringspot, tobacco rattle virus, arabis mosaic, grapevine fan leaf virus and pea early browning viruses are the examples of plant viruses that are transmitted by nematodes. The important viral diseases transmitted by nematodes are given below:

Virus group	Virus	Vector
Tobra virus (Tobacco rattle group virus)	Pea early browning, Tobacco rattle	<i>Paratrichodorus</i> sp. <i>Trichodorus</i> spp
Nepo virus (Nematode transmitted polyhedral virus)	Grapevine chrome virus Tobacco Ringspot Tomato ringspot	<i>Xiphinema index</i> <i>X. americanum</i> <i>X. americanum</i>

8. Fungal Transmission: The role of fungi as the vectors of plant viruses was first discovered in 1960 by Teak le. The root infecting fungus *Oplidium* spp. transmitted at least four plant viruses, tobacco necrosis, cucumber necrosis, tobacco stunt and lettuce big vein viruses. *Spongospora subterranea* transmits potato mop top virus and *Polymyxa graminis* transmits wheat mosaic virus.

All these fungi are pathogens of the host, which carry of viruses. The zoospores of the fungi are released from the host and the zoospores carry the virus and transmit it to the susceptible hosts during their infection process. In some cases plant viruses are carried on the outside of the fungi. Examples are tobacco necrosis virus and cucumber mosaic virus. The viruses like lettuce big vein virus are found inside the zoospores. They persist for years in viable resting sporangia.

Viroids

Viroids are the smallest known pathogen (mesobiotic agents) similar to viruses but they do not contain protein coat. They are, therefore, naked nucleic acid strands that are infectious to plants. They are single stranded circular molecules of infectious ribonucleic acid (RNA). First disease reported to be caused by a Viroid is **potato spindle tuber disease**. The diseased tubers are changed to the shape of a spindle. **Theodor Otto Diener**, plant pathologist at U.S. Department of Agriculture's Research (1971) is credited with the discovery of this agent. Viroids have not yet been reported to cause disease in animals. Similar to viruses, these agents multiply only inside the host cell and utilize cellular synthesis machinery for their replication. Many diseases caused by viroids like Potato spindle tuber, Citrus exocortis, Cadang cadang of coconut, Avocado sun blotch, apple scar skin, etc. Symptoms of viroid infection in plants include stunting of growth, deformation of leaves and fruit, bark cracking, stem necrosis and death.

Virusoid

Virusoids are single stranded, circular, low molecular weight, Viroid like RNAs dependent on plant viruses for replication and encapsidation. The genome of virusoids consists of several hundred nucleotides and does not code for any proteins. Virusoids are essentially viroids that have been encapsulated by helper virus coat protein. They are thus similar to viroids in their means of replication, but they differ in that viroids do not possess a protein coat. The Virusoid genomes are small, only 220 to 388 nucleotides long. Virusoid genomes do not code for any proteins, but instead serves only to replicate Virusoid RNA. For example, Lucern transient streak virus RNA 2 (vLSTV), *Solanum nodiflorum* mottle virus RNA 2 (vSNMV), Velvet tobacco mottle virus RNA 2 (vVTMoV), Rice yellow mottle Virusoid (vRYMV), etc.