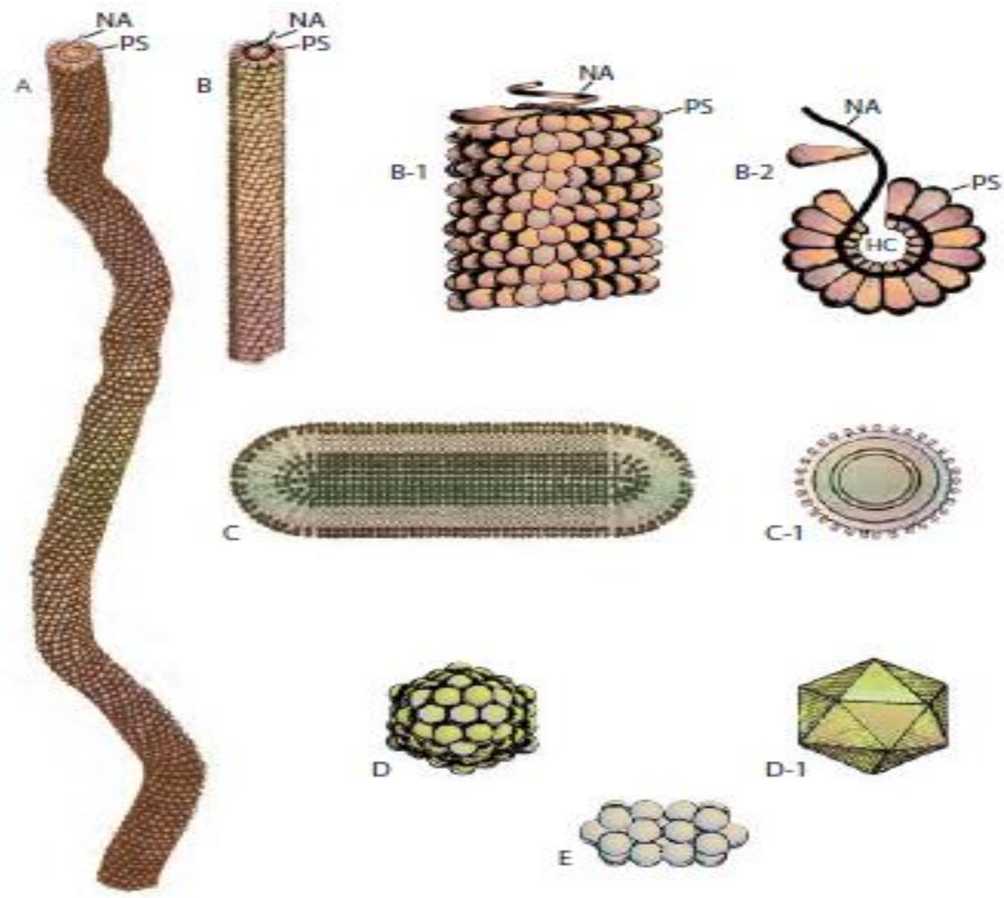
Plant virus Morphology

Plant viruses come in different shapes and sizes. Nearly half of them are elongate (rigid rods or flexuous threads), and almost as many are spherical (isometric or polyhedral), with the remaining being cylindrical bacillus-like rods . Some elongated viruses are rigid rods about 15 by 300 nanometers, but most appear as long, thin, flexible threads that are usually 10 to 13 nanometers wide and range in length from 480 to 2,000 nanometers. Rhabdoviruses are short, bacillus like, cylindrical rods, approximately three to five times as long as they are wide (52–75 by 300– 380nm). Most spherical viruses are actually polyhedral, necrosis satellite virus) to 60 nanometers (wound tumor virus). Tomato spotted wilt virus is surrounded by a membrane and has a flexible, spherical shape about 100 nanometers in diameter. Many plant viruses have split genomes, i.e., they consist of two or more distinct nucleic acid strands encapsidated in different-sized particles made of the same protein subunits. Thus, some, like tobacco rattle virus, consist of two rods, a long one (195 by 25nm) and a shorter one (43 by 25 nm), whereas others, like alfalfa mosaic virus, consist of four components of different sizes . Also, many isometric viruses have two or three different components of the same size but containing nucleic acid strands of different lengths. In multicomponent viruses, all of the nucleic acid strand components must be present in the plant for the virus to multiply and perform in its usual manner. The surface of viruses consists of a definite number of protein subunits, which are arranged spirally in the elongated viruses and packed on the sides of the polyhedral particles of the spherical . In cross section, the elongated viruses appear as hollow tubes with the protein subunits forming the outer coat and the nucleic acid, also arranged spirally, embedded between the inner ends of two successive spirals of the protein subunits. In spherical viruses the visible shell consists of protein subunits, while the nucleic acid is inside the shell and is arranged in an as yet unknown manner. Rhabdoviruses, and a few spherical viruses, are provided with an outer lipoprotein envelope or membrane. Inside the membrane is the nucleocapsid, consisting of nucleic acid and protein subunits.



Relative shapes, sizes, and structures of some representative plant viruses. (A) Flexuous thread-like virus. (B) Rigid rod-shaped virus. (B-1) Side arrangement of protein subunits (PS) and nucleic acid (NA) in viruses A and B. (B-2) Cross-section view of the same viruses. HC, hollow core. (C) Short, bacillus-like virus. (C-1) Cross-section view of such a virus. (D) Isometric polyhedral virus. (D-1) Icosahedron representing the 20-sided symmetry of the protein subunits of the isometric virus. (E) Geminivirus consisting of twin particles.

Composition and Structure

Each plant virus consists of at least a nucleic acid and a protein. Some viruses consist of more than one size of nucleic acid and proteins, and some of them contain enzymes or membrane lipids. The nucleic acid makes up 5 to 40% of the virus, protein making up the remaining 60 to

95%. The lower nucleic acid percentages are found in the elongated viruses, whereas the spherical viruses contain higher percentages of nucleic acid. The total mass of the nucleo-protein of different virus particles varies from 4.6 to 73 million daltons. The weight of the nucleic acid alone, however, ranges only between 1 and 3 million daltons per virus particle for most viruses.

Plant viruses symmetry,
primarily dictated by the arrangement of their capsid proteins. The main types of symmetry found in plant viruses include:

1- Icosahedral Symmetry or cubic symmetry :
Icosahedral symmetry is characterized by a roughly spherical shape with 20 equilateral triangular faces. The capsid proteins assemble into a symmetrical icosahedral structure.
Many plant viruses exhibit icosahedral symmetry, including Turnip Yellow Mosaic Virus (TYMV), Cowpea Mosaic Virus (CPMV), and Beet Curly Top Virus (BCTV).
Helical Symmetry:

2- Helical symmetry results in a cylindrical or rod-like shape, with the capsid proteins arranged in a helical fashion around the viral genome. Tobacco Mosaic Virus (TMV) is a classic example of a plant virus with helical symmetry.
3- Complex Symmetry:

Some plant viruses have more complex capsid structures that do not fit neatly into the categories of icosahedral or helical symmetry.

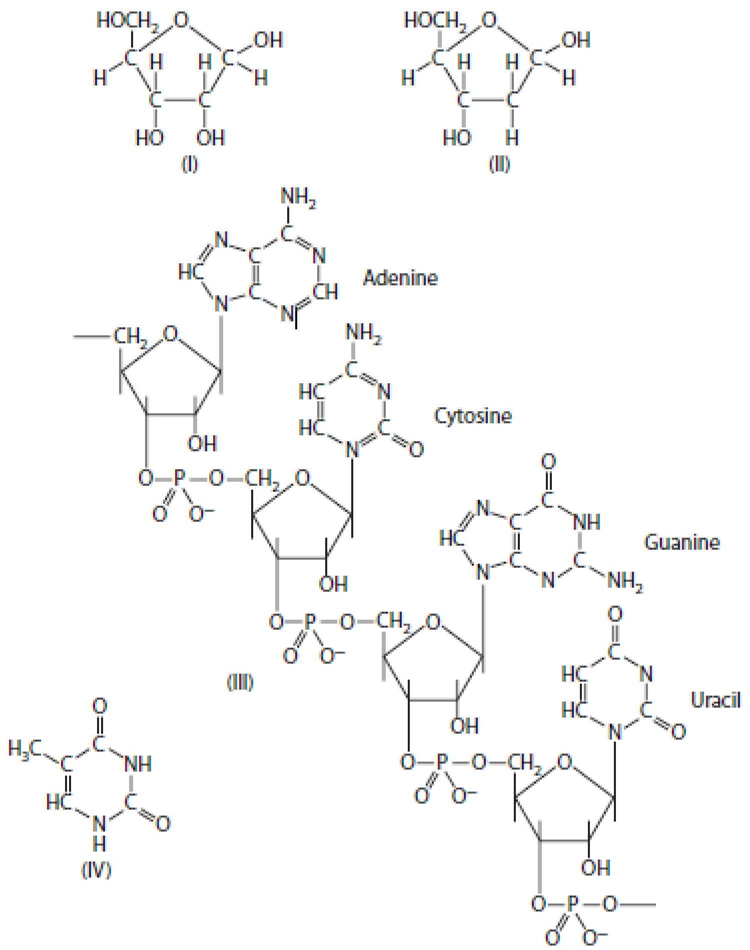
These viruses may have irregular shapes or combinations of helical and icosahedral elements.
Cauliflower Mosaic Virus (CaMV) is an example of a plant virus with a complex capsid structure

Composition and Structure of Viral Protein

Viral proteins, like all proteins, consist of amino acids. The sequence of amino acids within a protein, which is dictated by the sequence of nucleotides in the genetic material, determines the nature and properties of the protein. The protein shells of plant viruses are composed of repeating subunits. The amino acid content and sequence for identical protein subunits of a given virus are constant but vary for different viruses and even for different strains of the same virus. Of course, the amino acid content and sequence are different for different proteins of the same virus particle and even more so for different viruses. The content and sequences of amino acids are known for the proteins of many viruses. For example, the protein subunit of tobacco mosaic virus (TMV) consists of 158 amino acids in a constant sequence and has a mass of 17,600 daltons (often written as 17.6 kDa, 17.6 kd, or 17.6 K).
In TMV the protein subunits are arranged in a helix containing 16 1/3 subunits per turn (or 49 subunits per three turns). The central hole of the virus particle down the axis has a diameter of 4 nanometers, whereas the maximum diameter of the particle is 18 nanometers. Each TMV particle consists of approximately 130 helix turns of protein subunits. The nucleic acid is packed tightly in a groove between the helices of protein subunits. In rhabdoviruses the helical nucleoproteins are enveloped in a membrane. In polyhedral plant viruses the protein subunits are packed tightly in arrangements that produce 20 (or some multiple thereof) facets and form a shell. Within this shell the nucleic acid is folded or otherwise organized.

Composition and Structure of Viral Nucleic Acid

The nucleic acid of most plant viruses consists of RNA, but a large number of viruses have been shown to contain DNA. Both RNA and DNA are long, chain-like molecules consisting of hundreds or, more often, thousands of units called nucleotides. Each nucleotide consists of a ring compound called the base attached to a five-carbon sugar [ribose (**I**) in RNA, deoxyribose (**II**) in DNA], which in turn is attached to phosphoric acid . The sugar of one nucleotide reacts with the phosphate of another nucleotide, which is repeated many times, thus forming the RNA or DNA strand. In viral RNA, only one of four bases, adenine, guanine, cytosine, and uracil, can be attached to each ribose molecule. The first two, adenine and guanine, are purines and interact with the other two, uracil and cytosine, the pyrimidines. The chemical formulas of the bases and one of their possible relative positions in the RNA chain are shown in (structure **III**). DNA is similar to RNA with two small, but very important differences: the oxygen of one sugar hydroxyl is missing and the base uracil is replaced by the base methyl uracil, better known as thymine (**IV**). The size of both RNA and DNA is expressed either in daltons or as the number of bases [kilo bases (kb) for single-stranded RNA and DNA or kilo base pairs (kbp) for double-stranded RNA and DNA], or as the number of nucleotides or nucleotide pairs. The sequence and the frequency of the bases on the RNA strand vary from one RNA to another, but they are fixed within a given RNA and determine its properties. Healthy cells of plants always contain double stranded DNA and single-stranded RNA. Of the nearly 1,000 described plant viruses, most (about 800) contain single-stranded RNA, but 50 contain double-stranded RNA, 40 contain double-stranded DNA, and about 110 contain single-stranded DNA.



Chemical formulas of ribose (I), deoxyribose (II), ribonucleic acid or RNA (III), and thymine (IV).

Genome Organization

1- Single-Stranded RNA (ssRNA) Viruses: These viruses have RNA genomes that serve as templates for protein synthesis and replication within host cells. Examples include Potato Virus Y (PVY) and Cucumber Mosaic Virus (CMV).
2- Double-Stranded RNA (dsRNA) Viruses: Viruses with dsRNA genomes are less common in plants but still significant. Examples include Rice Dwarf Virus (RDV)

3- Single-Stranded DNA (ssDNA) Viruses: Some plant viruses have single-stranded DNA genomes, such as Tomato Yellow Leaf Curl Virus (TYLCV) and Beet Curly Top Virus (BCTV).
4- Double-Stranded DNA (dsDNA) Viruses: Double-stranded DNA plant viruses are relatively rare. Examples include Cauliflower Mosaic Virus (CaMV) and Banana Streak Virus (BSV).

PROPERTIER OF PLANT VIRUSES: THE BIOLOGICAL FUNCTION OF VIRAL COMPONENTS: CODING

The protein coat of a virus not only provides a protective sheathing for the nucleic acid of the virus, but also plays a role in determining vector transmissibility of a virus and the kinds of symptoms it causes. Protein itself has no infectivity, but serves to protect the nucleic acid and its presence generally increases the infectivity of the nucleic acid. The infectivity of viruses is strictly the property of their genomic nucleic acid, which in most plant viruses is RNA. Some viruses carry within them a transcriptase enzyme that they need in order to multiply and infect. The capability, however, of the viral RNA to reproduce both itself and its specific protein indicates that the RNA carries all the genetic determinants of the viral characteristics. The expression of each inherited characteristic depends on the sequence of nucleotides within a certain area (gene) of the viral RNA, which determines the sequence of amino acids in a particular protein, either structural or enzyme. This is called **coding** and seems to be identical in all living organisms and the viruses. The code consists of coding units called **codons**. Each codon consists of three adjacent nucleotides and determines the position of a given amino acid in the protein being synthesized. The amount of RNA, then, contained in each virus indicates the approximate length of, and the number of nucleotides in, the viral RNA. This in turn determines the number of codons in each RNA and, therefore, the number of amino acids that can be coded for. In some viruses, the amount of nucleic acid available for coding is increased by having some genes overlap parts of or whole other genes, or by frame shifting, i.e., reading the nucleotides in a different sequence from the first one and thereby forming entirely different codons and genes. Because the protein subunit of viruses contains relatively few amino acids (158 in TMV), the number of codons utilized for its synthesis is only a fraction of the total number of codons available (158 of 2,130 in TMV). In addition to protecting the viral nucleic acid, the coat protein in some cases affects, as mentioned already, the symptoms caused by the virus, the movement of some viruses in their hosts, and transmission of viruses by their vectors. The remaining codons are presumably involved in the synthesis of other proteins, either structural proteins or enzymes .One of these enzymes is called an RNA polymerase (RNA synthetase or RNA replicase) and is needed to replicate the RNA of the virus. The specific role of some proteins coded for by the viral nucleic acid is still unknown; however, some proteins have been shown to facilitate the movement of the virus through cells; others to be required for transmission of the virus by its vector; some for production of proteins needed for cleaving the nucleic acid of the virus in precise positions; and some for producing the cellular inclusion bodies observed in cells infected by viruses but whose role and function are not known. So far, it appears that the diseased condition induced in plants by viruses is the result of the interference and disruption of normal metabolic processes in infected parenchyma or specialized cells. Such interference is caused by the mere presence and multiplication of the virus and, possibly, by the abnormal or toxic effects of additional virus-induced proteins or their products, although no such substances have been found to date.