STRUCTURE, GENERAL CHARACTERISTICS AND REPRODUCTION OF VIRUSES

Introduction

Viruses are noncellular genetic elements that use a living cell for their replication and have an extracellular state. Viruses are ultramicroscopic particles containing nucleic acid surrounded by protein, and in some cases, other macromolecular components such as a membrane like envelope. Outside the host cell, the virus particle is also known as a **virion.** The virion is metabolically inert and does not grow or carry on respiratory or biosynthetic functions.

At present, there are no technical names for viruses. International committees have recommended genus and family names for certain viruses, but the process is still in a developmental stage.

Viruses vary considerably in size and shape. The smallest viruses are about 0.02 µm (20 nanometers), while the large viruses measure about 0.3 µm (300 nanometers). Smallpox viruses are among the largest viruses; polio viruses are among the smallest.

Virus structure

Certain viruses contain ribonucleic acid (RNA), while other viruses have deoxyribonucleic acid (DNA). The nucleic acid portion of the viruses is known as the **genome.** The nucleic acid may be single-stranded or double-stranded; it may be linear or a closed loop; it may be continuous or occur in segments.

The genome of the virus is surrounded by a protein coat known as a **capsid**, which is formed from a number of individual protein molecules called **capsomeres.** Capsomeres are arranged in a precise and highly repetitive pattern around the nucleic acid. A single type of capsomere or several chemically distinct types may make up the capsid. The capsid accounts for most of the virion mass. It is the protein coat of the virus. It is a complex and highly organized entity which gives form to the virus. Subunits called **protomeres** aggregate to form **capsomeres** which in turn aggregate to form the capsid. The combination of genome and capsid is called the viral **nucleocapsid.**

A number of kinds of viruses contain **envelopes.** An envelope is a membrane-like amorphous structure composed of lipid, protein and carbohydrate which lies to the outside of the capsid. The envelope contains a mosaic of antigens from the virus and from the host cell (obtained from the host cell during the replication process). The envelope encloses the nucleocapsid. A naked virus is one without an envelope. The envelope contains viral-specified proteins that make it unique. Among the envelope viruses are those of herpes simplex, chickenpox, infectious mononucleosis and HIV.

Projections from the envelope are known as **spikes.** These are glycoprotein projections which have enzymatic and/or adsorption and/or hemagglutinating activity. They arise from the envelope and are highly antigenic. The spikes sometimes contain essential elements for attachment of the virus to the host cell. The virus of AIDS, the human immunodeficiency virus, uses its spikes for this purpose.

Virus Morphology (Symmetry) with examples described in Fig. 1 below

1. Icosahedral -The protomeres aggregate in groups of five or six to form the capsomere. In electron micrographs, capsomeres are recognized as regularly spaced rings with a central hole. The shape and dimensions of the icosahedron depends on characteristics of its protomeres. All icosahedral capsids have 12 corners each occupied by a penton capsomere and 20 triangular faces, each containing the same number of hexon capsomeres. Among the icosahedral viruses are those that cause yellow fever, HIV, polio, and head colds. Icosahedral symmetry is identical to cubic symmetry.

2. Helical (Like spring or coil) -The protomeres are not grouped in capsomeres, but are bound to each other so as to form a ribbon-like structure. This structure folds into a helix because the protomeres are thicker at one end than at the other. The diameter of the helical capsid is determined by characteristics of its protomeres, while its length is determined by the length of the nucleic acid it encloses. The virus that causes tobacco mosaic disease, for example, has **helical symmetry.** In this case, the nucleocapsid is wound like a tightly coiled spiral. The rabies virus also has helical symmetry.

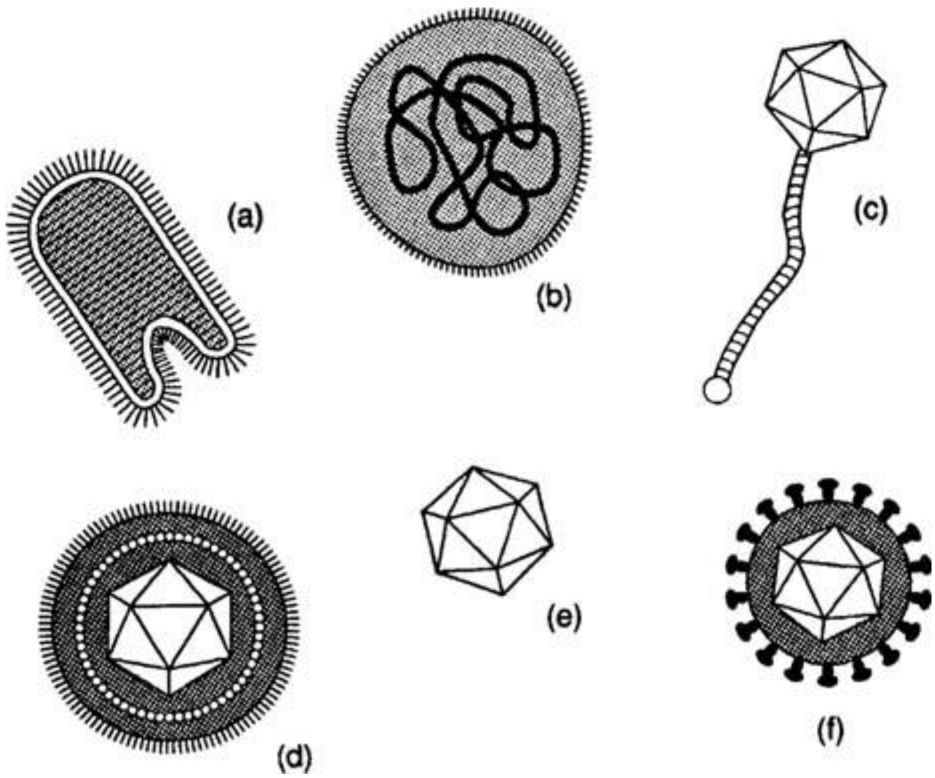
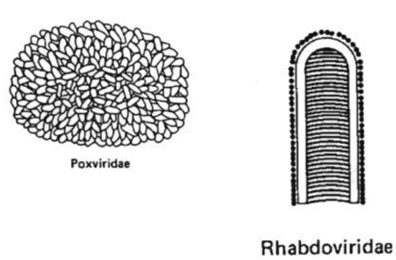


Figure 1

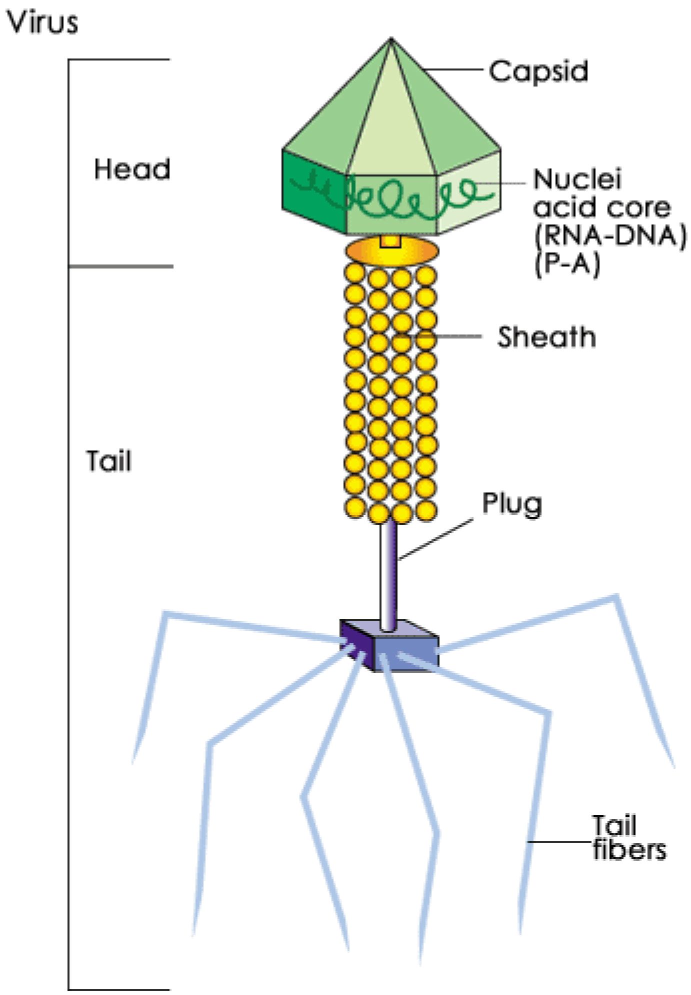
An array of viruses. (a) The helical virus of rabies. (b) The segmented helical virus of influenza. (c) A bacteriophage with an icosahedral head and helical tail. (d) An enveloped icosahedral herpes simplex virus. (e) The unenveloped polio virus. (f) The icosahedral human immunodeficiency virus with spikes on its envelope.

3. Complex -e.g., that exhibited by poxvirus and rhabdovirus. This group comprises all those viruses which do not fit into either of the above two groups.



Structure

Because most viruses are extremely well adapted to their host organism, virus structure varies greatly. However, there are some general structural characteristics that all viruses share.



General virus structure

All viruses have a capsid or head region that contains its genetic material. The capsid is made of proteins and glycoproteins. Capsid contruction varies greatly among viruses, with most being specialized for a particular virus's host organism. Some viruses, mostly of the type infecting animals, have a membranous envelope surrounding their capsid. This allows viruses to penetrate host cells through membrane fusion. The virus's genetical material rests inside the capsid; that material can be either DNA, RNA, or even in some cases a limited number of enzymes. The type of genetic material a virus contains is used in classification. In addition to the head region, some viruses, mostly those that infect bacteria, have a tail region. The tail is an often elaborate protein structure. It aids in binding to the surface of the host cell and in the introduction of virus genetic material to the host cell.

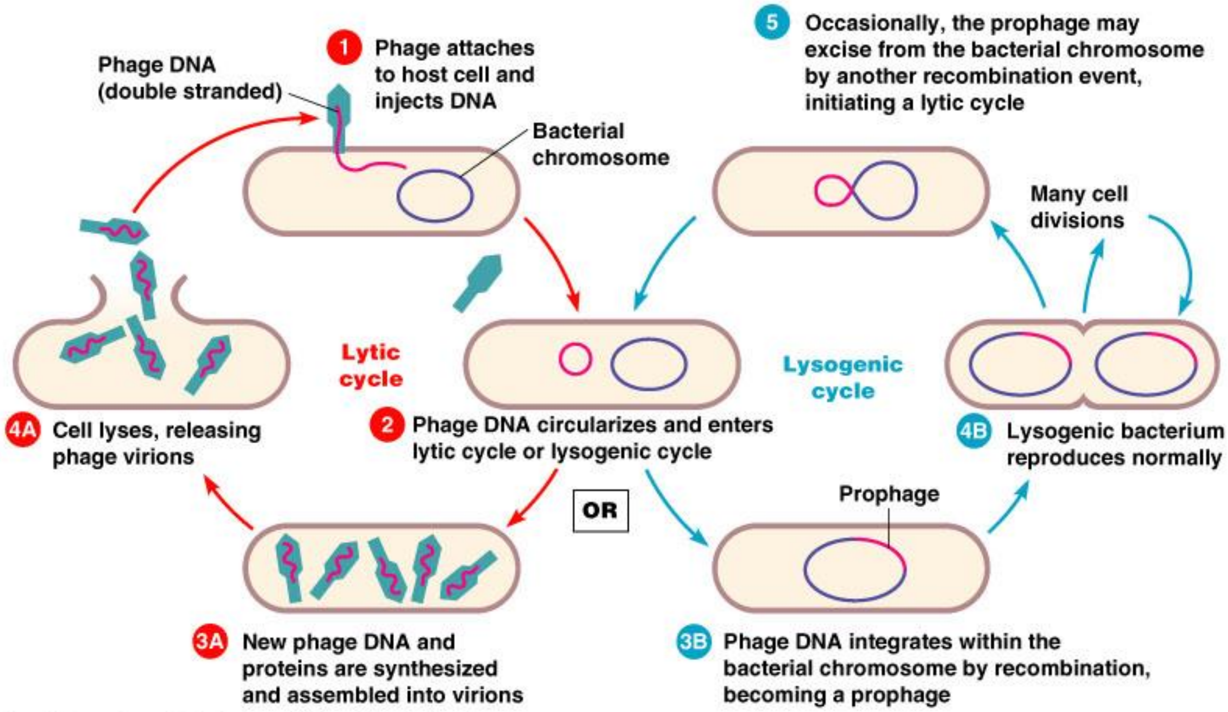
Virus "Life" Cycles

For the **release** of new viral particles, any of a number of processes may occur. For example, the host cell may be "biochemically exhausted," and it may disintegrate, thereby releasing the virions. For enveloped viruses, the nucleocapsids move toward the membrane of the host cell, where they force themselves through that membrane in a process called **budding.** During budding, a portion of cell membrane pinches off and surrounds the nucleocapsid as an envelope. The replication process in which the host cell experiences death is called the **lytic cycle** of reproduction. The viruses so produced are free to infect and replicate in other host cells in the area.

Lysogeny. Not all viruses multiply by the lytic cycle of reproduction. Certain viruses remain active within their host cells for a long period without replicating. This cycle is called the **lysogenic cycle.** The viruses are called **temperate viruses**, or **proviruses**, because they do not bring death to the host cell immediately. In lysogeny, the temperate virus exists in a latent form within the host cell and is usually integrated into the chromosome. Bacteriophages that remain latent within their bacterial host cell are called **prophages.** This process is a key element in the recombination process known as **transduction.**

An example of lysogeny occurs in **HIV infection.** In this case, the human immunodeficiency virus remains latent within the host T-lymphocyte. An individual whose infection is at this stage will not experience the symptoms of AIDS until a later date.

Bacteriophages are viruses that multiply within bacteria. These viruses are among the more complex viruses and have been use to study the life cycles of viruses in their host cells. They often have icosahedral heads and helical tails. The virus that attacks and replicates in *Escherichia coli* has 20 different proteins in its helical tail and a set of numerous fibers and "pins." Bacteriophages contain DNA and are important tools for viral research.



Lytic and Lysogenic Cycles

As shown in Fig. 2, the virus must first attach itself to the host cell. This is usually accomplished through special glycoprotiens on the exterior of the capsid, envelope or tail. Next, penetration occurs, either of the whole virus or just the contents of the capsid. If the entire capsid enters, the genetic material must be uncoated to make it available to the cell's replication machinery. Replication of genetic material takes place, as well as the production of capsid and tail proteins. Once all of the necessary parts have been replicated, individual virus particles are assembled and released. Release often takes place in a destructive manner, bursting and killing the host cell.

Some viruses have a slightly more complicated replication cycle involving lytic and lysogenic phases. The lytic phase is similar to that described above, with virus particles infecting and being replicated. In the lysogenic phase, however, viral genetic material that has entered the host cell becomes incorportated in the cell and lies dormant. It is passed on to the progeny of the infected cells. Eventually, the lytic phase will start again, and cells that were never infected themselves, but carry the viral genetic material will begin to produce new virus particles.

Summary

1. Viruses contain either DNA or RNA as their genetic material, but not both.
2. Viral nucleic acid is enclosed in a capsid made up of protein subunits called protomeres.
3. Some species of viruses have a membrane, the envelope, surrounding the capsid; other species do not have an envelope, i.e., they are naked. Enveloped viruses have glyco-protein spikes arising from their envelope. These spikes have enzymatic, absorptive, hemagglutinating and/or antigenic activity.
4. The morphology of a virus is determined by the arrangement of the protomeres. When protomeres aggregate into units of five or six (capsomeres) and then condense to form a geometric figure having 20 equal triangular faces and 12 apices, the virus is said to have icosahedral (cubic) morphology. When protomeres aggregate to form a capped tube, they are said to have helical morphology. Any other arrangement of the protomeres results in a complex morphology.
5. All viruses undergo a replication cycle in their host cell consisting of adsorption, penetration, uncoating, nucleic acid replication (macromolecular synthesis), maturation and release stages.
6. During the viral replication cycle, an accumulation of mature viruses, incomplete viruses and viral parts occurs within the cell. This accumulation is the inclusion body. The size, shape, location and chemical properties of the inclusion body are useful for diagnosis of viral infections.
7. A virally-infected cell generally presents three signals that it is infected. The first is the production of double-stranded RNA, which induces interferon; the second is the expression of viral protein on the surface of the plasma membrane, thus causing activation of cytotoxic T-cells, natural killer cells and sometimes induction of antibody synthesis. The third is the formation of an inclusion body either within the cytoplasm or the nucleus or very rarely within both the cytoplasm and nucleus.
8. In general, all DNA-containing viruses replicate in the host cell nucleus. The exceptions to the rule are the poxviruses. In general, all RNA-containing viruses replicate in the host cell cytoplasm. The exceptions to the rule are the retroviruses and the orthomyxoviruses.