Chapter VI
Basic Concepts of Mycology and Virology

2. Virology

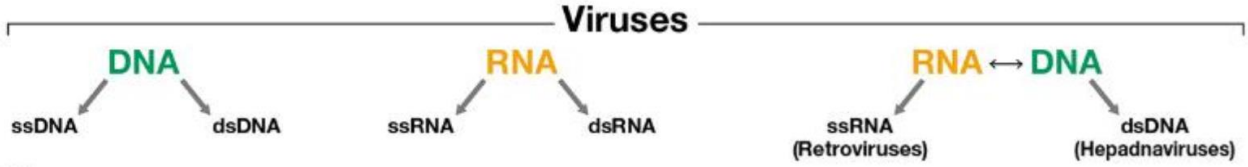
2.1. Definitions

- **Virology** is the branch of microbiology that studies viruses, including their structure, function, and interactions with host organisms.
- The word **virus** is Latin for "**poison**". This **acaryotic** infectious agent is a biological entity incapable of reproducing on its own, requiring a host cell, whose components it uses to replicate—hence the term **obligate intracellular parasite**.
- The **virion** is the free viral particle found in the external environment. It has no metabolism, no capacity for replication, and no autonomous activity.

2.2. Morphology

Viruses are generally small in size (ranging from 18 to 400 nm). They are acellular and lack most components found in cells, such as organelles, ribosomes, and the plasma membrane. A virion consists of a nucleic acid core, an outer protein coat called a *capsid*, and sometimes an outer envelope derived from the host cell. Viruses may also contain additional proteins, such as enzymes.

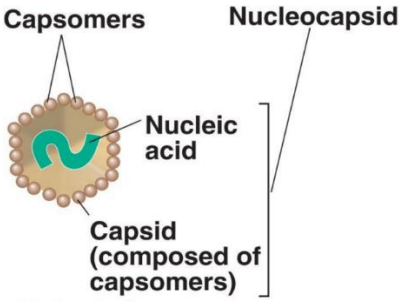
2.2.1. **The *genome*** (which carries the genetic material) consists of a single type of nucleic acid, either DNA or RNA. This genome can be single-stranded or double-stranded, segmented or non-segmented, and linear or circular. The viral genome typically contains anywhere from a few genes to about 1200 genes.



2.2.2. **The *capsid*** (from the Latin *capsa* = box) is a structured protein shell made up of many copies of protein subunits called ***capsomeres***, which are themselves composed of one or more smaller protein subunits called ***protomers***. The capsid serves two main functions:

- It encloses and protects the genome
- It allows naked viruses to attach to the host cell

The combination of the capsid and the nucleic acid forms the **nucleocapsid**.

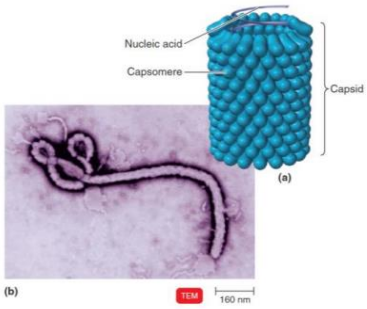


The nucleocapsid can be organized according to the following symmetry types:

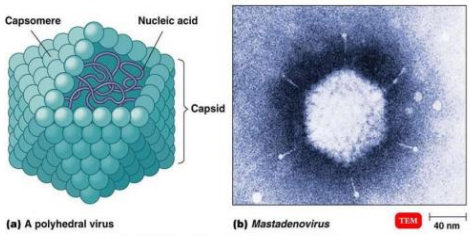
✓ **Icosahedral (polyhedral) symmetry**: These capsids have the geometric shape of an icosahedron (a regular polyhedron with 12 vertices and 20 equilateral triangular faces).

✓ **Helical symmetry**: The nucleocapsid has a helical shape. The capsomeres are attached to the RNA strand, which is coiled into a helix (this capsid shape does not occur in DNA viruses).

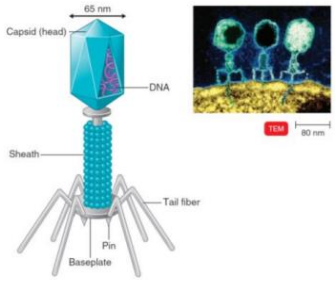
✓ **Other forms**: A limited number of viruses have **complex** capsid symmetry. Some bacteriophages, for example, have a polyhedral "head" and a helical "tail," sometimes with additional structures like tail fibers and spikes.



▷ Helical Viruses



▷ Polyhedral Viruses



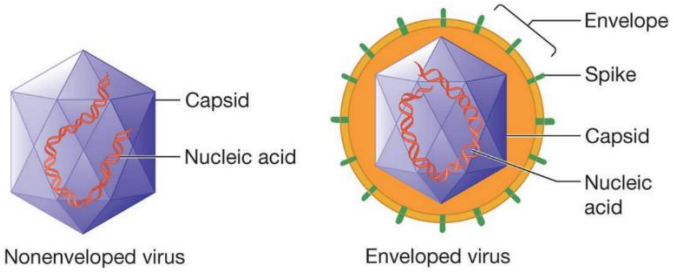
▷ Complex Viruses

2.2.3. **The envelope**: In some viral families, the nucleocapsid is surrounded by an optional outer structure called the *envelope* or *peplos* (coat), in which case the virus is referred to as an *enveloped virus*. Conversely, viruses that lack this envelope are called *naked viruses*.

The envelope is a phospholipid bilayer derived from the host cell, within which proteins and glycoproteins encoded by the viral genome are embedded. It plays a role in host cell recognition during attachment and in the release of virions.

This envelope, which is not present in all viruses, has important antigenic properties due to glycoproteins called *spikes*.

Note: The envelope does not provide protection for the virus. On the contrary, because of its lipid content, it represents a point of vulnerability, making the virus more sensitive to environmental conditions and to treatment with organic solvents.



2.3. Classification of viruses

Biologists have used several classification systems based on different criteria:

2.3.1. Classification by host type

- Plant viruses: These viruses infect plants and can cause diseases in agricultural crops. *Example: Tobacco mosaic virus.*
- Animal viruses: These infect animals, including humans, and can cause a range of diseases from the common cold to more serious infections such as HIV, influenza, or Ebola fever.
- Bacterial viruses (bacteriophages): These viruses infect bacteria and use them as hosts to replicate.

2.3.2. Classification by mode of transmission

– Respiratory transmission : Influenza, SARS-CoV-2

- Oral/Fecal transmission: Norovirus, rotavirus, hepatitis A
- Vector-borne transmission: Dengue, Zika, Rift Valley fever
- Blood/body fluid transmission: HIV, hepatitis B and C, Ebola
- Vertical (mother-to-child) transmission: Cytomegalovirus, Zika, rubella
- Cutaneous/direct contact transmission: Herpes, human papillomavirus
- Sexual transmission : HIV, human papillomavirus
- Zoonotic transmission: Rabies, SARS-CoV-2, Ebola

2.3.3. Classification based on the genome structure (Baltimore classification)

The most commonly used system of virus classification was developed by Nobel Prize-winning biologist David Baltimore in the early 1970s. This classification groups viruses based on the **type of nucleic acid** and how the mRNA is produced during the replicative cycle of the virus. There are **7 classes**:

Group I viruses contain double-stranded DNA (dsDNA) as their genome. Their mRNA is produced by transcription in much the same way as with cellular DNA.

Group II viruses have single-stranded DNA (ssDNA) as their genome. They convert their single-stranded genomes into a dsDNA intermediate before transcription to mRNA can occur.

Group III viruses use dsRNA as their genome. The strands separate, and one of them is used as a template for the generation of mRNA using the RNA-dependent RNA polymerase encoded by the virus.

Group IV viruses have ssRNA as their genome with a positive polarity. The genomic RNA can serve directly as mRNA.

Group V viruses contain ssRNA genomes with a **negative polarity**. It must be transcribed into +ssRNA before translation

Group VI viruses have ssRNA genomes that must be converted, using the enzyme **reverse transcriptase**, to dsDNA; the dsDNA is then transported to the nucleus of the host cell and inserted into the host genome. Then, mRNA can be produced by transcription of the viral DNA that was integrated into the host genome.

Group VII viruses have partial dsDNA genomes and make ssRNA intermediates that act as mRNA, but are also converted back into dsDNA genomes by reverse transcriptase, necessary for genome replication.

2.4. Virus replication

Viruses reproduce by using living cells to replicate their nucleic acids. The life cycle of viruses can differ greatly between species and category of virus, but they follow the same basic stages for viral replication. Viral infection and replication can be summarized in six steps:

- **Attachment**: The virus binds to the surface of the host cell using capsid proteins or envelope glycoproteins.
- **Penetration**: Naked viruses may enter via pinocytosis, while enveloped viruses may fuse with the cell membrane or be internalized by endocytosis.

There are several mechanisms depending on the nature of the virus:

a) Membrane fusion *(enveloped viruses)*

The virus fuses its lipid membrane with that of the host cell. Then, the viral content (capsid or genome) is released into the cytoplasm.

Examples: HIV, influenza virus (after endosomal acidification).

b) Endocytosis *(enveloped and non-enveloped viruses)*

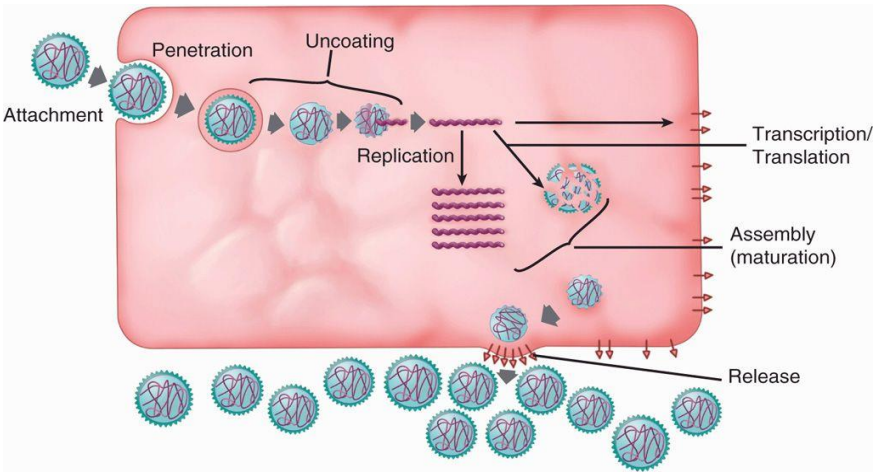
The virus is internalized by the host cell via endocytic vesicles.

Then, the virus is released from the endosome (often due to a pH change) to reach the cytoplasm.

c) Direct injection *(non-enveloped viruses or bacteriophages)*

The virus directly injects its genome through the plasma membrane. This mechanism is typical of bacteriophages (viruses that infect bacteria): the capsid remains outside the cell.

- **Uncoating**: Once inside the cell, viral structures are degraded, releasing the viral genome.
- **Replication** or Viral Multiplication: The released viral genome takes control of the host's cellular machinery and uses viral mRNA to synthesize new copies of the genome and viral proteins.
- **Assembly**: Newly synthesized viral components are assembled into complete virions within the infected cell. Enveloped viruses acquire their lipid envelope by budding through the host cell membrane, incorporating viral glycoproteins.
- **Release**: Newly assembled virions leave the host cell either through lysis—commonly observed with non-enveloped viruses—or through budding from the plasma membrane, a process typical of enveloped viruses.



The viral life cycle (virus replication)

<u>Case of Bacteriophages:</u>

Their replication is unique and involves several specific steps:

- **Disruption of the bacterial cell wall** by enzymes located in the bacteriophage tail, which hydrolyze the glycosidic bonds of the macromolecules that make up the wall.
- **Tail contraction** (via conformational changes in the tail proteins), allowing the tubular core to penetrate the bacterial wall and plasma membrane.
- The **linear DNA from the phage head** is then directly injected into the bacterium through the tail.
- Once inside the bacterium, the **viral DNA blocks bacterial protein biosynthesis** by inhibiting the initiation of translation of bacterial mRNAs—only viral mRNAs are translated.