Viral Structure and Classification

Date: 10/11/2024

Dr. Sulaiman Mahmoud Bani Abdel-Rahman

Bachelor degree in Medicine and Surgery - Mutah university

MSC Medical Microbiology – University of Manchester

PhD Medical Virology - University of Manchester

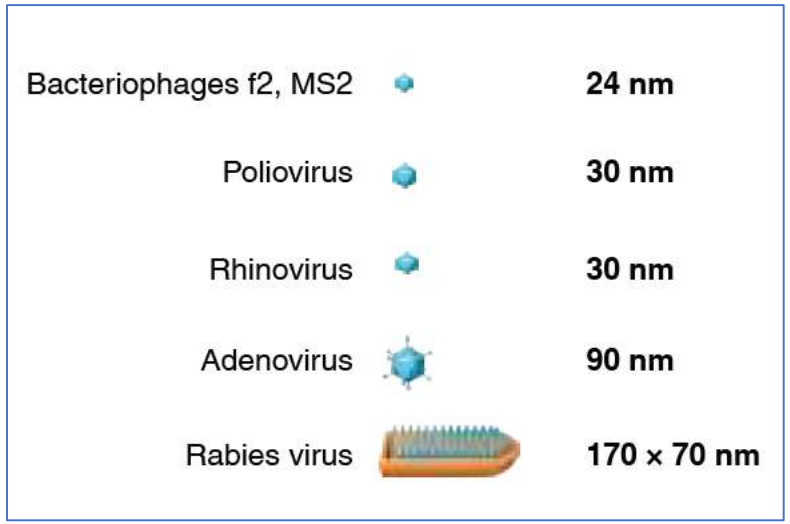
Introduction to Virology

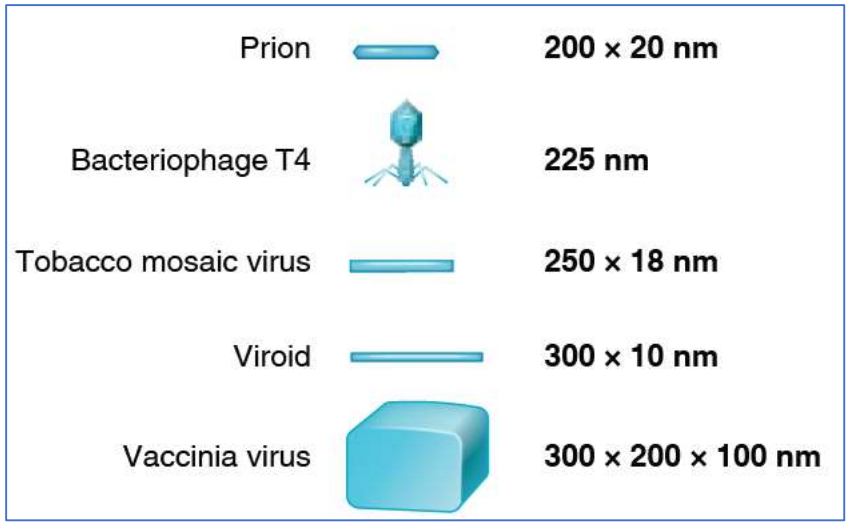
- **Definition:** The smallest unicellular organisms that are obligate intracellular.
- Virus particles can only be observed by an electron microscope
- Their size ranges from 10 nm - 250 nm

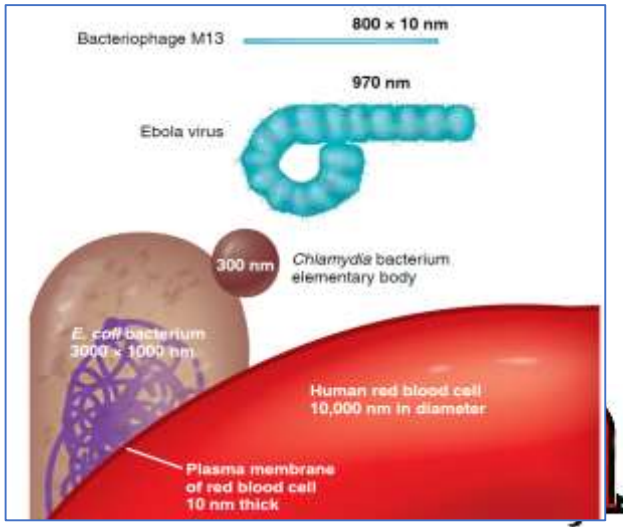
Common Characteristics of Viruses

1. Viruses are Small in Size:

- Their size ranges from 10 nm – 250 nm
- Most bacteria are typically 2000 – 3000 nm
- Average human cells are 10–30 µm (microns) in diameter, which means that they are generally 100 to 1000 times larger than the viruses that are infecting them.







Common Characteristics of Viruses (cont.)

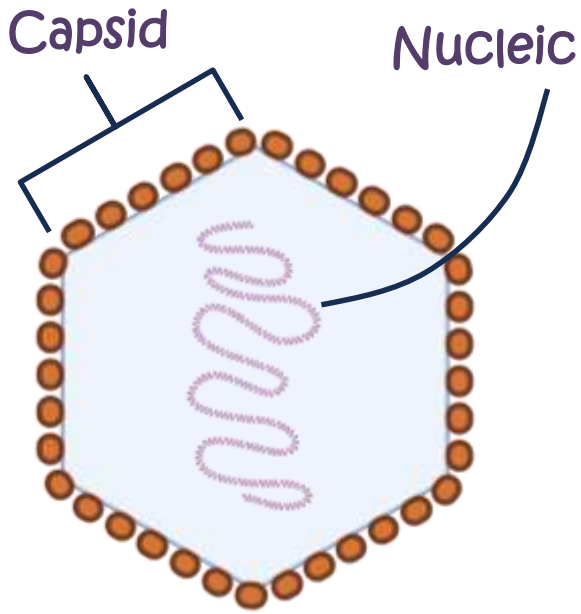
2. Viruses are obligate intracellular parasites:

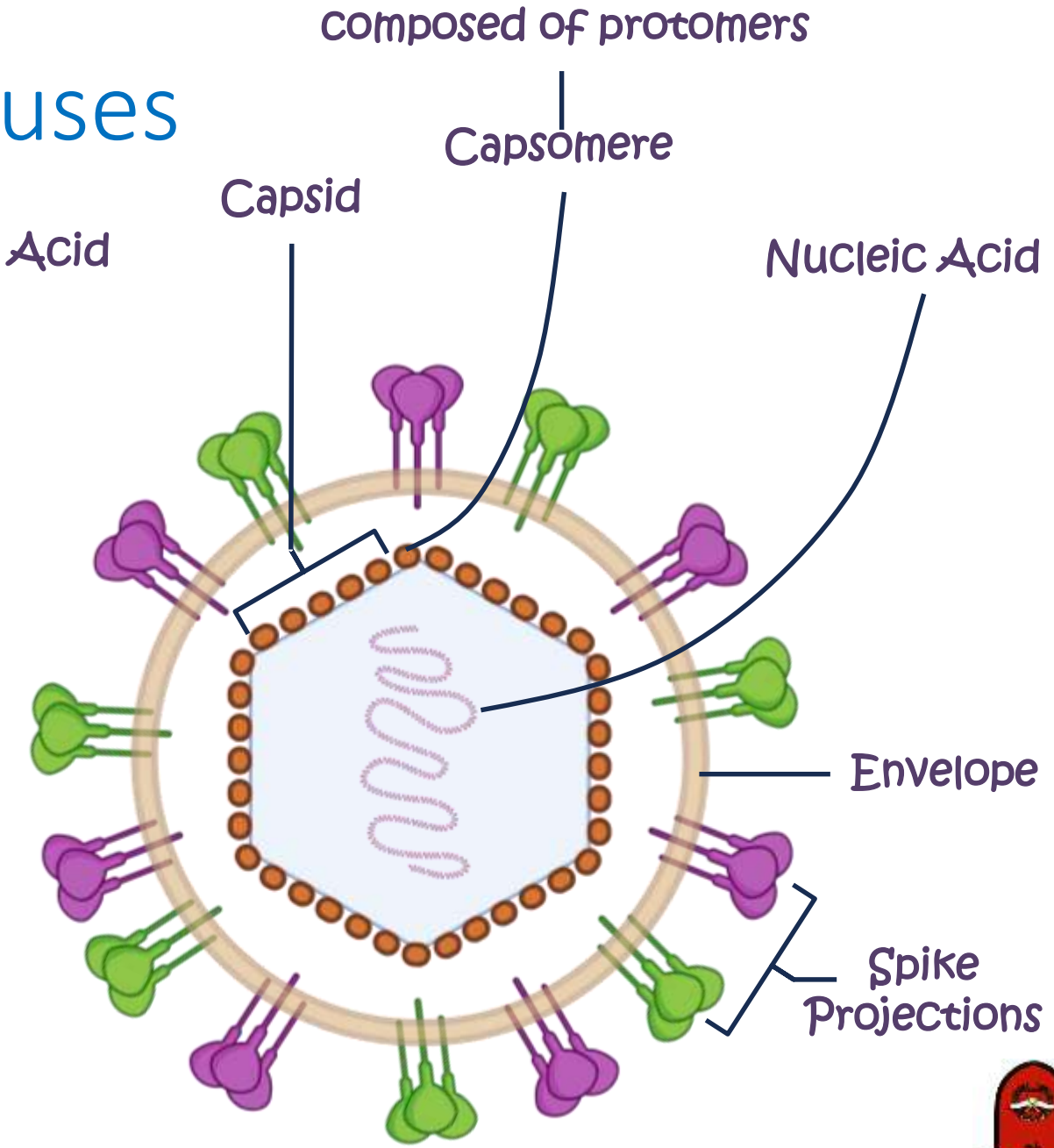
- Meaning that they are completely dependent upon the internal environment of the cell to create new infectious virus particles, or virions.
- Viruses use the cell's energy and machinery to create and assemble new virions.

3. The genetic material of viruses:

- All living cells, whether human, animal, plant, or bacterial, have double-stranded DNA (dsDNA).
- Viruses have genomes that are composed of DNA or RNA (**but not both**).
- The viral genome is dsDNA, ssDNA, dsRNA, or ssRNA,

General Structure of Viruses



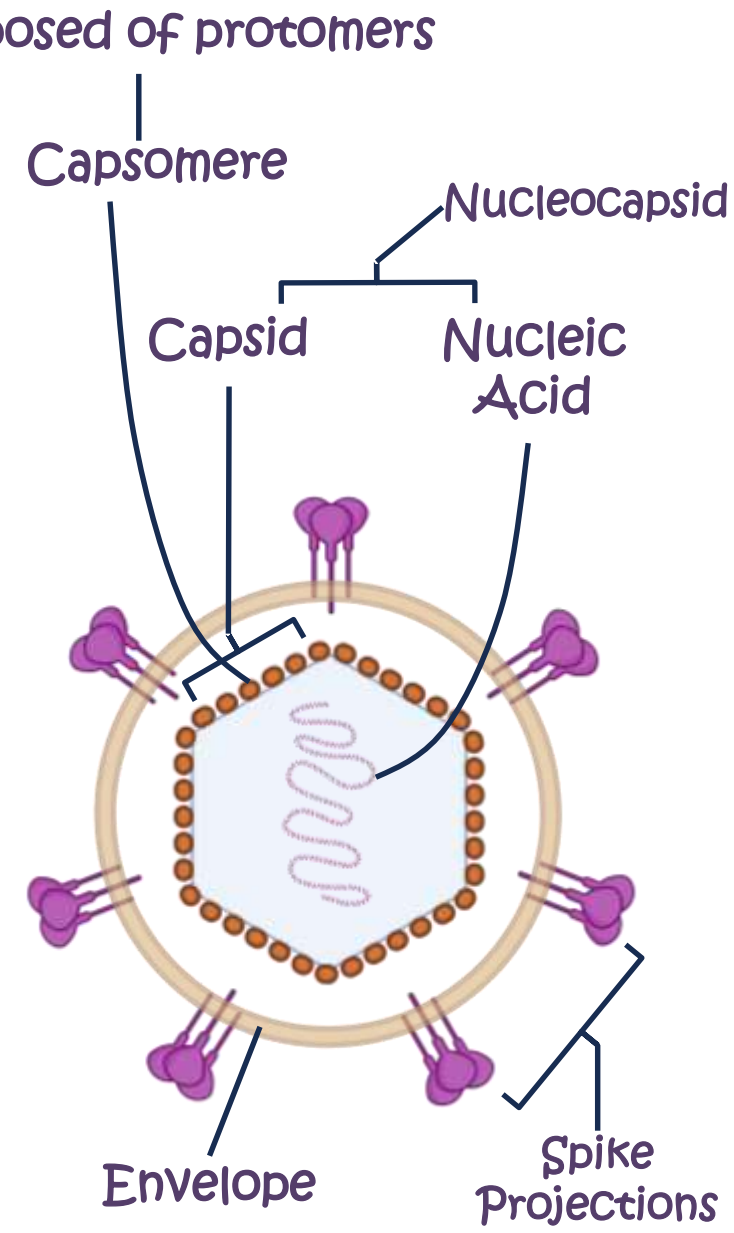


- **Core components:**
  - Genetic material (DNA OR RNA)
  - Capsid (protein coat)
- **Optional components:**
  - Envelope
  - Surface proteins
  - Enzymes

Structure of Viruses - terminology

- **Genome:** Nucleic acid of the virus (RNA or DNA).
- **Capsid:** The protein shell directly surrounding viral nucleic acid (coat, shell). Composed of capsomeres.
- **Nucleocapsid:** capsid + genome.
- **Envelope:** The lipid bilayer and associated glycoproteins that surround some viruses.

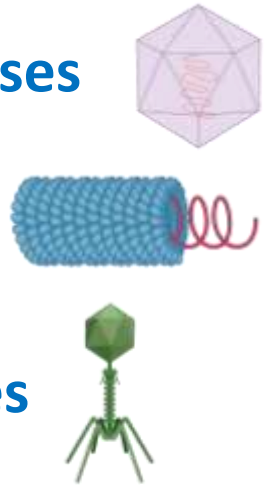
All these components form the entire infectious virus particle called the **Virion**



Virus Classification

- **Based on Envelope**
  - **Non- enveloped viruses**
  - **Enveloped viruses**

- **Based on capsid Shape**
  - **Polyhedral viruses**
  - **Helical Viruses**
  - **Complex viruses**

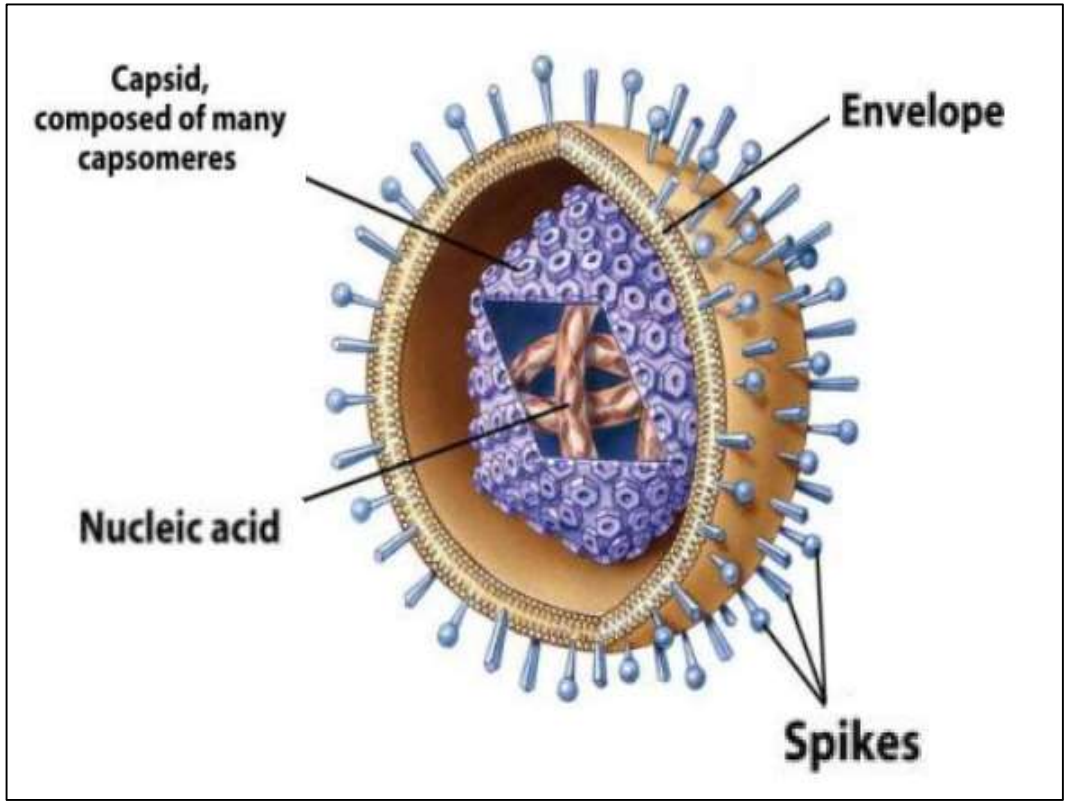


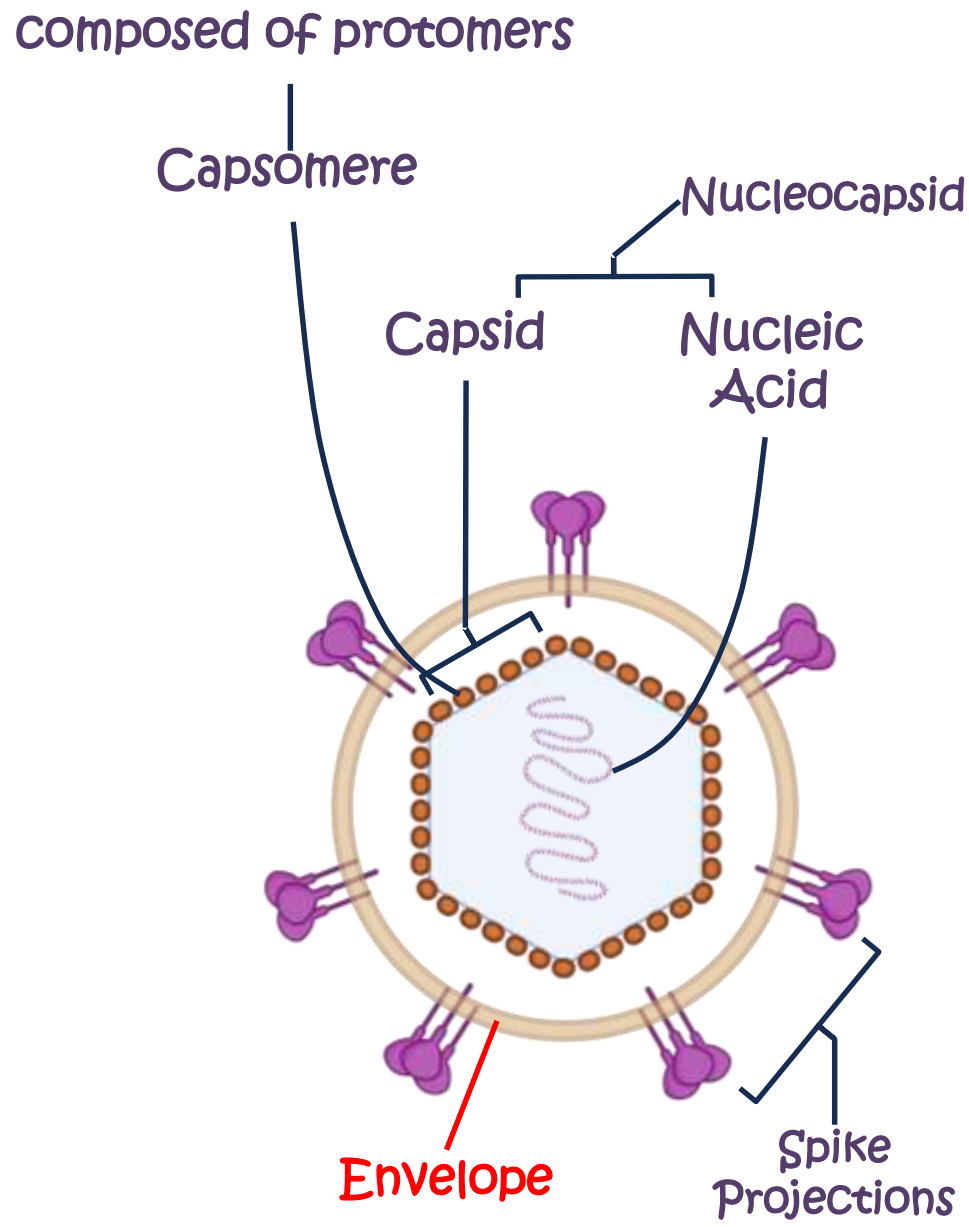
- **Type of nucleic acid genome**
  - **DNA**
  - **RNA**

Structure of Viruses
Envelope

Functions:

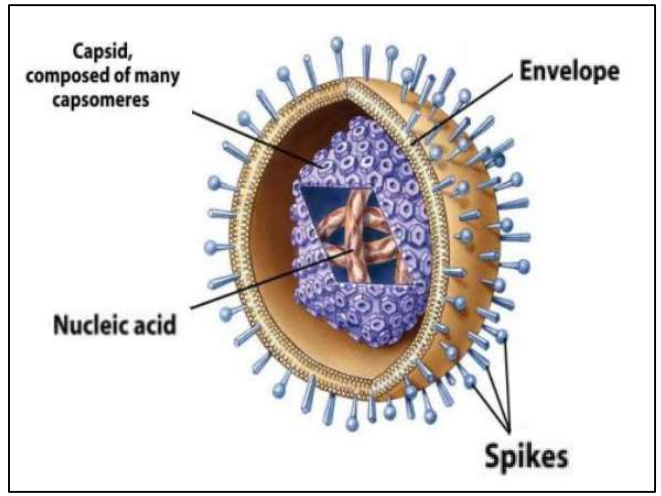
- Attachment to host cells
- Evasion of the host immune system





Structure of Viruses
Envelope (cont.)

- Most viruses have an envelope surrounding the capsid.
- The envelope usually consists of some combination of **lipids, proteins, and carbohydrates** derived from one of the cell's membranes, most often the plasma membrane, endoplasmic reticulum, Golgi complex, or even the nuclear membrane.
- Enveloped viruses are more sensitive to heat , drying, detergents, and lipid solvents such as alcohol and ether than are nonenveloped viruses, which are composed only of nucleic acid and capsid proteins.



Structure of Viruses
Envelope (cont.) - clinical correlation

- Virtually all viruses that are transmitted **by the fecal–oral route** (those that have to survive in the environment) **do not have an envelope**, that is, they are naked nucleocapsid viruses. These include viruses such as hepatitis A virus, poliovirus, Coxsackievirus, echovirus, Norwalk virus, and rotavirus.
- In contrast, **enveloped** viruses are most often **transmitted by direct contact**, such as by blood or by sexual transmission. Examples of these include HIV, herpes simplex virus type2, and HBV and HCV. Other enveloped viruses are transmitted directly by insect bite (e.g.,yellow fever virus and West Nile virus) or by animal bite (e.g.,rabies virus).
- **Many other enveloped viruses** are transmitted **from person to person in respiratory aerosol droplets**, such as influenza virus, measles virus, rubella virus, respiratory syncytial virus, and varicella-zoster virus. If the droplets do not infect directly, they can dry out in the environment, and these enveloped viruses are rapidly inactivated.

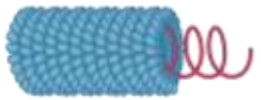
Structure of Viruses
Non-Enveloped vs. Enveloped Viruses

- **Non-Enveloped (Naked) Viruses:**
  - More resistant to environmental factors
  - Spread via fecal-oral route
- **Enveloped Viruses:**
  - Sensitive to desiccation, heat, detergents
  - Spread through close contact

Virus Classification

- **Based on Envelope**
  - Non- enveloped viruses
  - Enveloped viruses

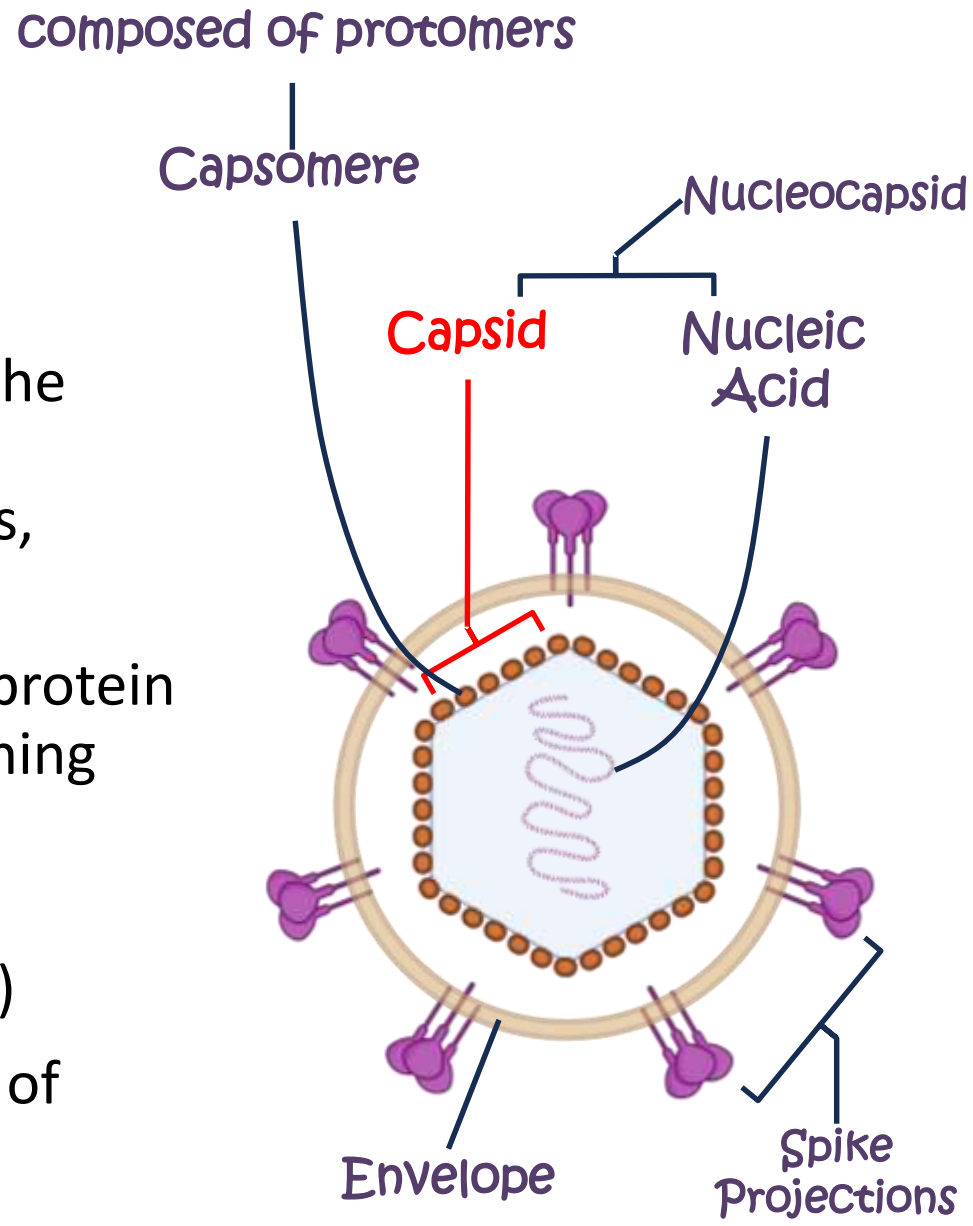
- **Based on capsid Shape**
  - Polyhedral viruses
  - Helical Viruses
  - Complex viruses



- **Type of nucleic acid genome**
  - DNA
  - RNA

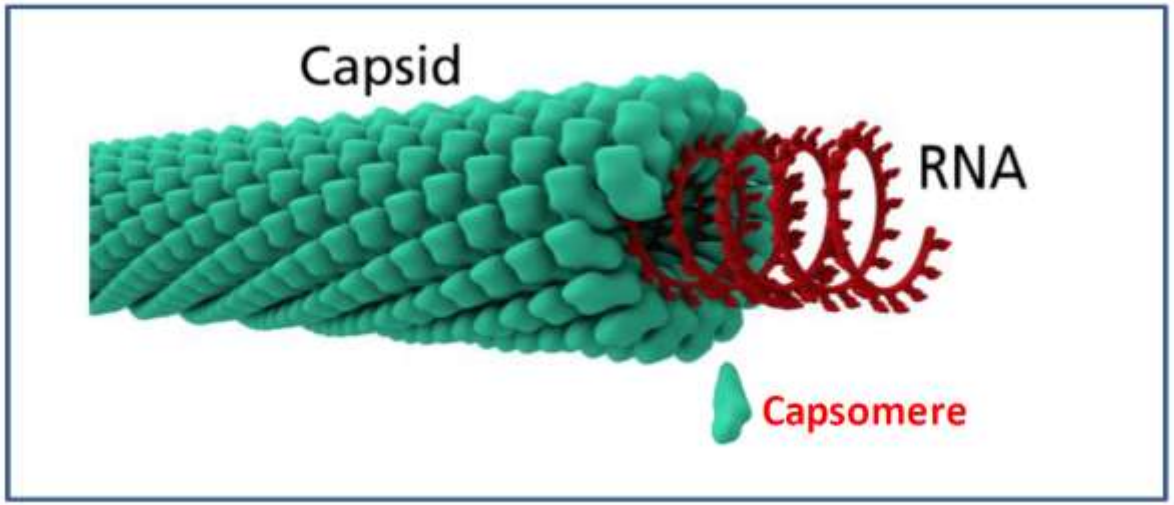
Structure of Viruses
Capsid

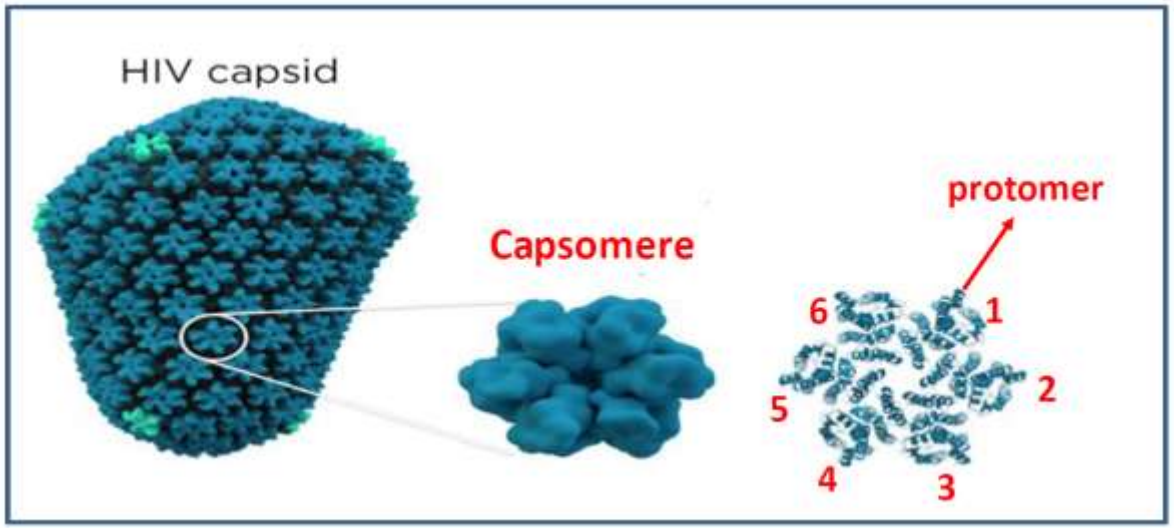
- The nucleic acid of the virus that is released from the host cell must be protected from the extracellular environment (degrading enzymes, physical stresses, ultraviolet).
- This is done by surrounding its nucleic acid with a protein shell, called the **capsid**, from the Latin **capsa**, meaning "box."
- **Capsid** is made up from a repeated units called capsomeres (capso: capsid, mere: part or segment)
- **Each capsomere** is composed of one type or more of proteins called **protomers**



Structure of Viruses

Capsid



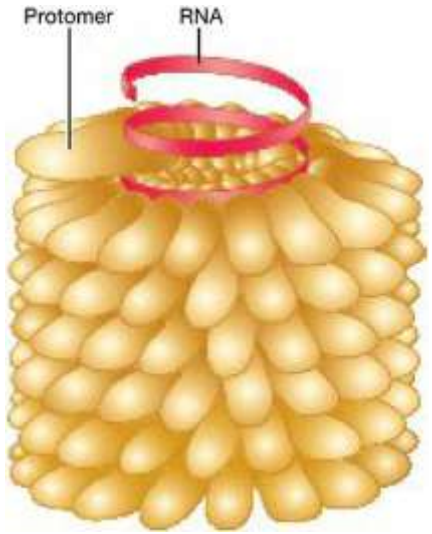


Structure of Viruses
Capsid

- Capsomeres are made up of aggregates of polypeptides called protomers.
- Protomers self-assemble in capsomers.
- Capsomers self-assemble into capsids.
- In **non-enveloped viruses**, the capsid has **attachment proteins** that facilitate the attachment of the virus to the host cell, the first step in gaining entry into a cell (In enveloped viruses, the viral envelope contains glycoproteins).
- Some capsids are composed of only a single type of capsomer, others are made up of several/multiple types. But viruses have relatively small genomes so as few as possible.
  - Probably the most important advantage of this design strategy is that the viral genome is used with maximum efficiency. **HOW?** → Next slide

Structure of Viruses
Capsid

- The *tobacco mosaic* virus (TMV) capsid is constructed using a single type of protomer.
- Recall that the building blocks of proteins are amino acids and that each amino acid is encoded by three nucleotides, the building blocks of nucleic acids.
- The TMV protomer is 158 amino acids in length. Therefore only about 474 nucleotides are required to code for the coat protein. The TMV genome consists of 6,400 nucleotides. Thus only a small fraction of the genome is used to code for the capsid.
- Suppose, however, that the TMV capsid were composed of six different protomers, all about 158 amino acids in length. If this were the case, about 2,844 of the 6,400 nucleotides in the TMV genome would be required just for capsid construction, and much less genetic material would be available for other purposes.
- 6 protomers × 158 amino acids/protomer × 3 nucleotides/amino acid = 2,844 nucleotides

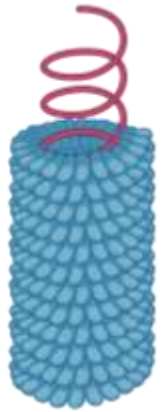


Tobacco Mosaic Virus (TMV) Virions

Only understand the concept → the viral genome is used with maximum efficiency

Structure of Viruses

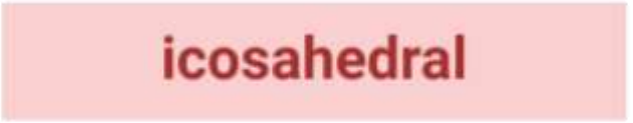
Capsid (cont.) - Symmetry Types

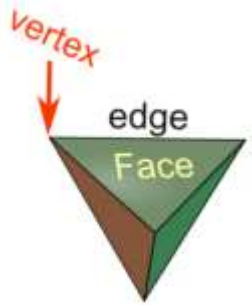
icosahedral	helical	complex
		

Structure of Viruses

Capsid (cont.) - Symmetry Types - Icosahedral

- In this arrangement, the nucleic acids are arranged inside a shell, which is in the shape of an icosahedron.
- From Ancient Greek (eíkosi) 'twenty’ and (hédra) 'seat’.
- Icosahedron is a geometrical figure with 12 vertices (corners) and 20 identical facets (faces) and 30 edges.

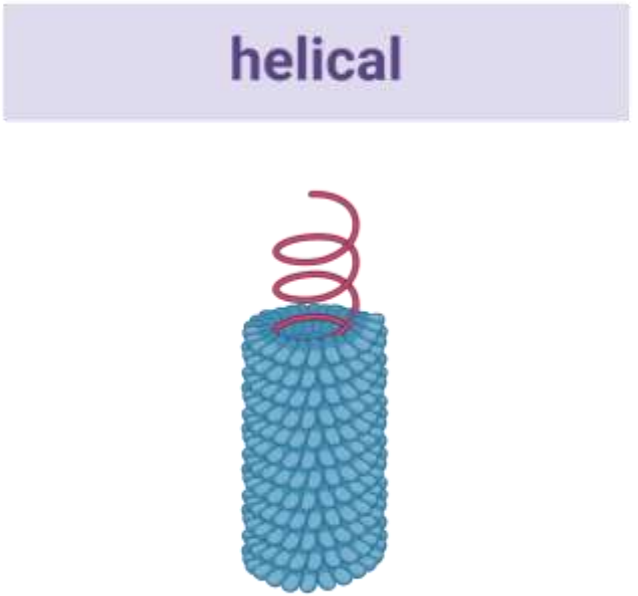


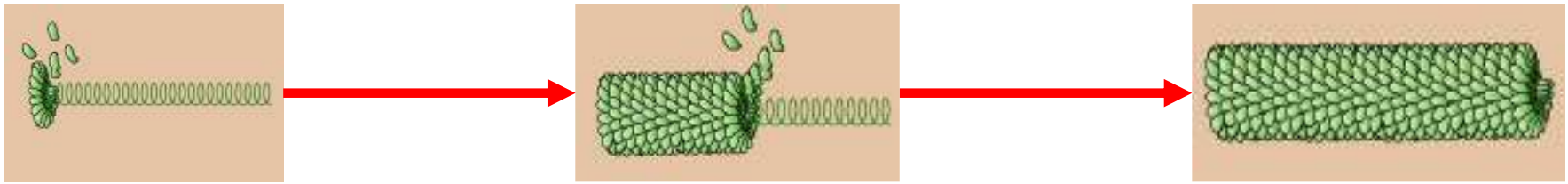


Structure of Viruses

Capsid (cont.) - Symmetry Types - Helical

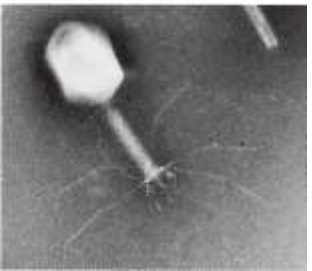
- The nucleic acid and capsomeres are helically coiled together.
- The length of the helical viral nucleocapsid is determined by the length of the nucleic acid.
- In this symmetry the identical protein subunits are arranged in a circular form.

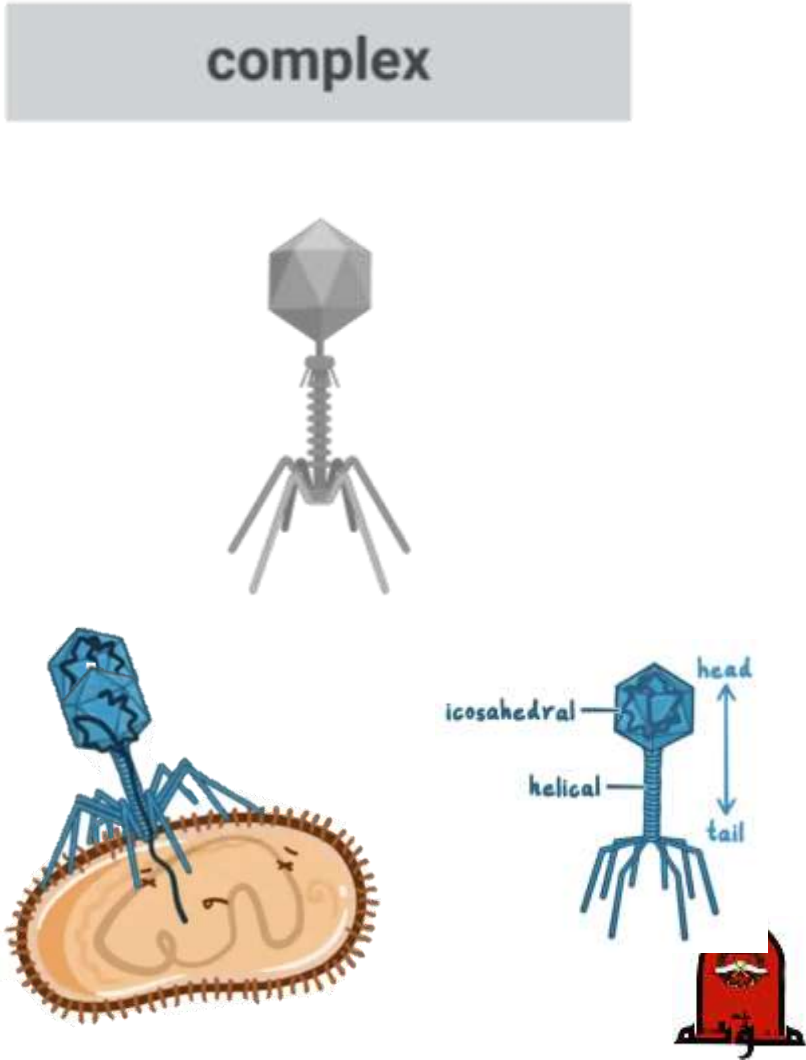




Structure of Viruses
Capsid (cont.) - Symmetry Types - Complex

- It is also referred as undefined symmetry.
- This arrangement does not fit into either helical or polyhedral symmetries.
- It has the feature of both polyhedral and helical symmetries.
  - Capsid (head): polyhedral head contains the nucleic acid.
  - The tail is helical.
    - The tail fibers - involved in the binding of the phage to the bacterial cell.

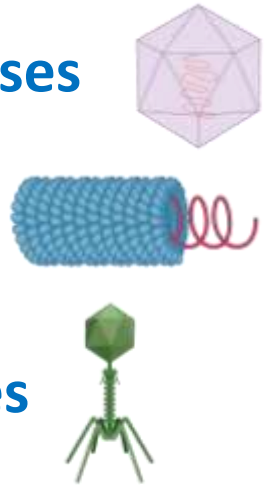




Virus Classification

- **Based on Envelope**
  - Non- enveloped viruses
  - Enveloped viruses

- **Based on capsid Shape**
  - Polyhedral viruses
  - Helical Viruses
  - Complex viruses

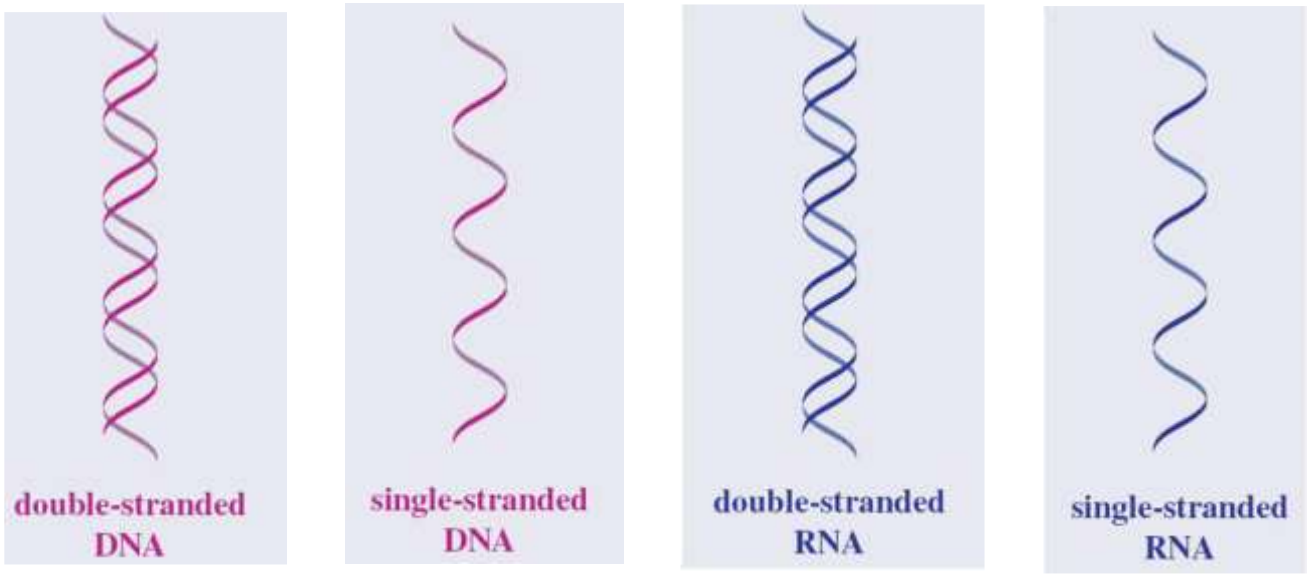


- **Type of nucleic acid genome**
  - DNA
  - RNA

Structure of Viruses
Nucleic Acid

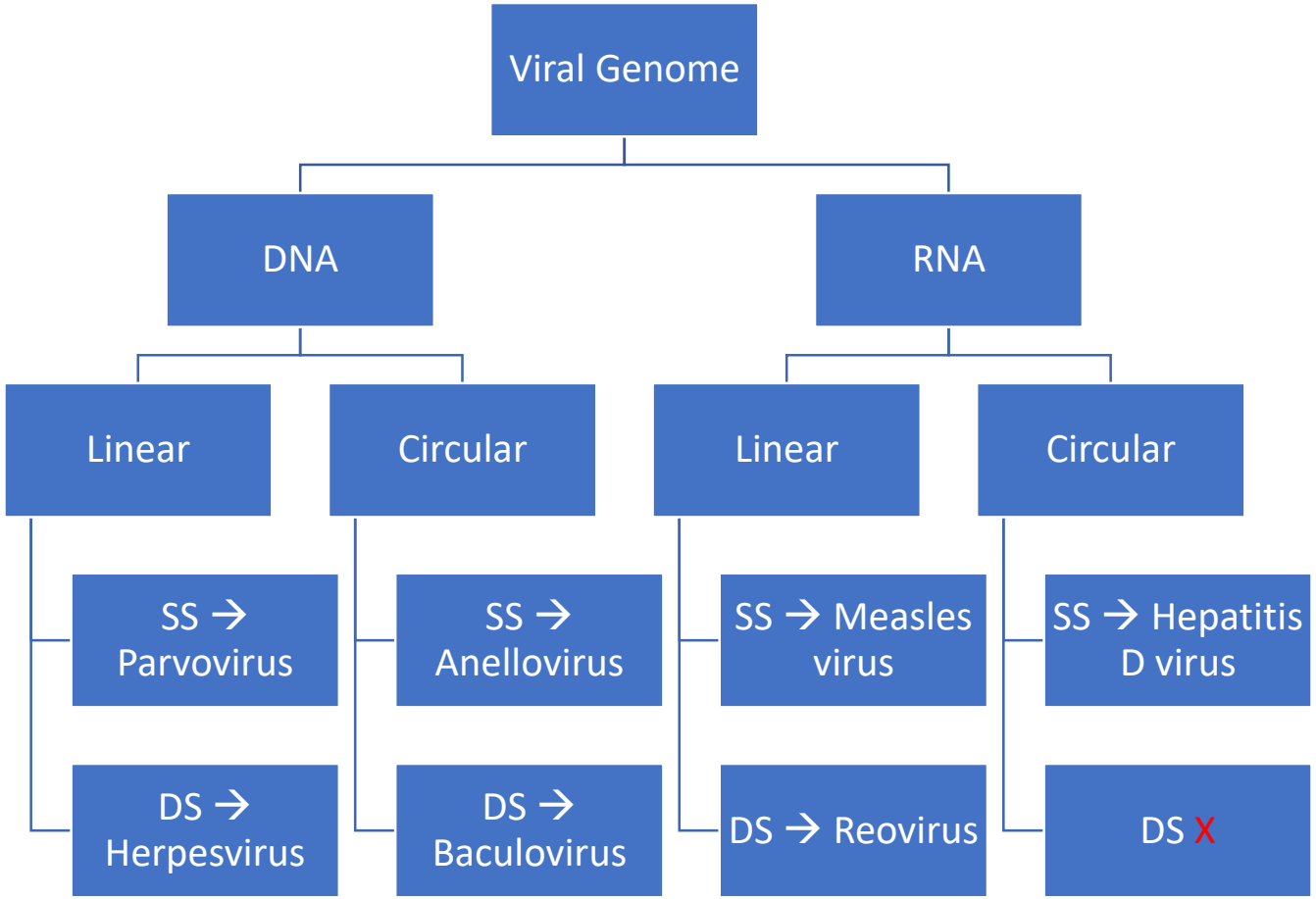
Classification based on the type of nucleic acid genome:

- The viral genome is either
  - dsDNA
  - ssDNA
  - dsRNA
  - ssRNA



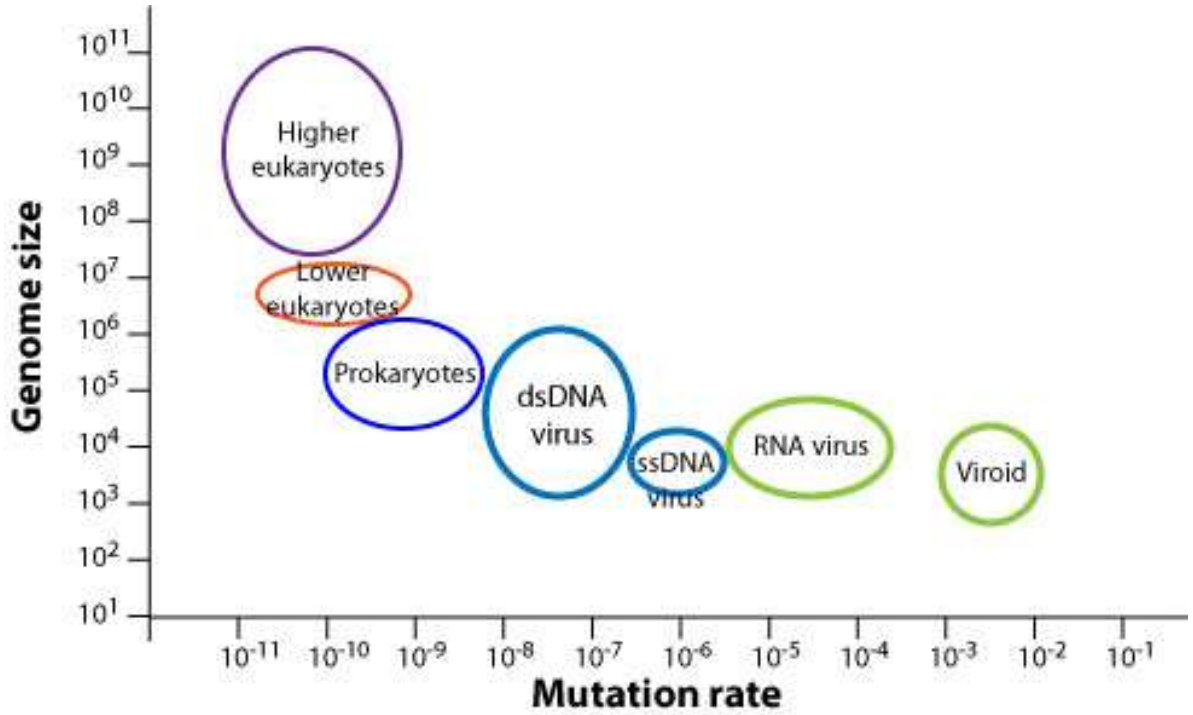
- In some viruses (such as the influenza virus), the nucleic acid is in several separate segments.

Structure of Viruses
Nucleic Acid (Cont.)



Structure of Viruses
Nucleic Acid (Cont.)

- Understand the concept only
- RNA viruses have higher mutation rate than DNA viruses



STRUCTURE OF VIRUSES

Viral proteins

The important functions of viral proteins

- The surface proteins of the virus, whether they are the capsid proteins or the envelope glycoproteins, are the principal antigens against which the host mounts its immune response to viruses.
- Mediate the attachment of the virus to specific receptors on the host cell surface.
- They induce neutralizing antibodies that inhibit the virus from entering the cell and replicating
- They activate cytotoxic T cells to kill virus-infected cells.

STRUCTURE OF VIRUSES
Serotypes and Antigenic Determinants

Definition of Serotype:

- A subdivision of a virus species distinguished by its unique surface antigens.

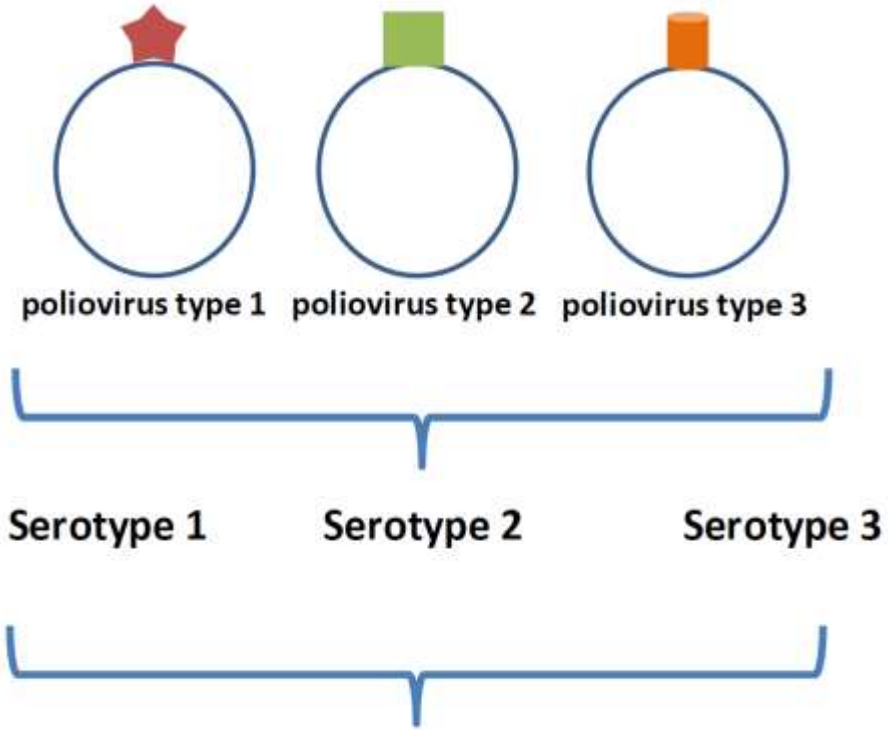
Significance:

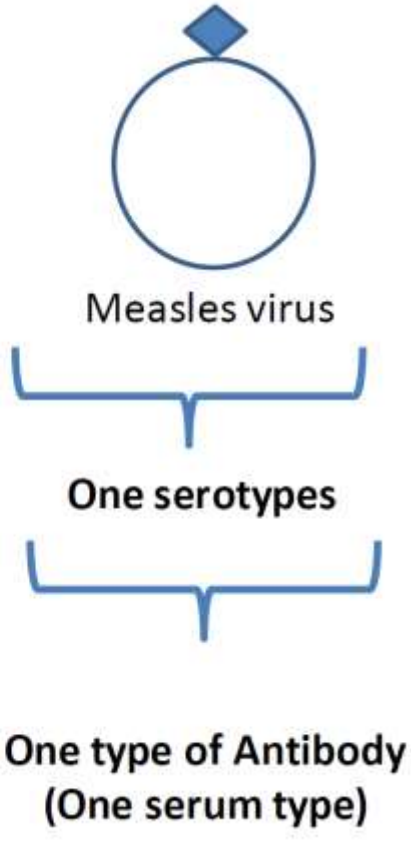
- Surface antigens (antigenic determinants) elicit specific immune responses.
- Variations in these antigens lead to different serotypes within the same virus species.

Examples:

- Measles Virus:
  - Only one serotype.
  - Uniform antigenic determinants induce a consistent immune response.
- Polioviruses:
  - Three distinct serotypes.
  - Each serotype has unique surface antigens requiring specific antibodies.
- Rhinoviruses:
  - Over 100 serotypes.
  - High antigenic variability explains the frequency of the common cold.

STRUCTURE OF VIRUSES
Serotypes and Antigenic Determinants





STRUCTURE OF VIRUSES
Serotypes and Antigenic Determinants

Medical implications related to serotypes:

- Person can be immune (have antibodies) to poliovirus type 1 and still get the disease, poliomyelitis caused by poliovirus types 2 or 3.
- The other implication is the polio vaccine must contain all three serotypes in order to be completely protective.