Viral Capsid Ultrastructure

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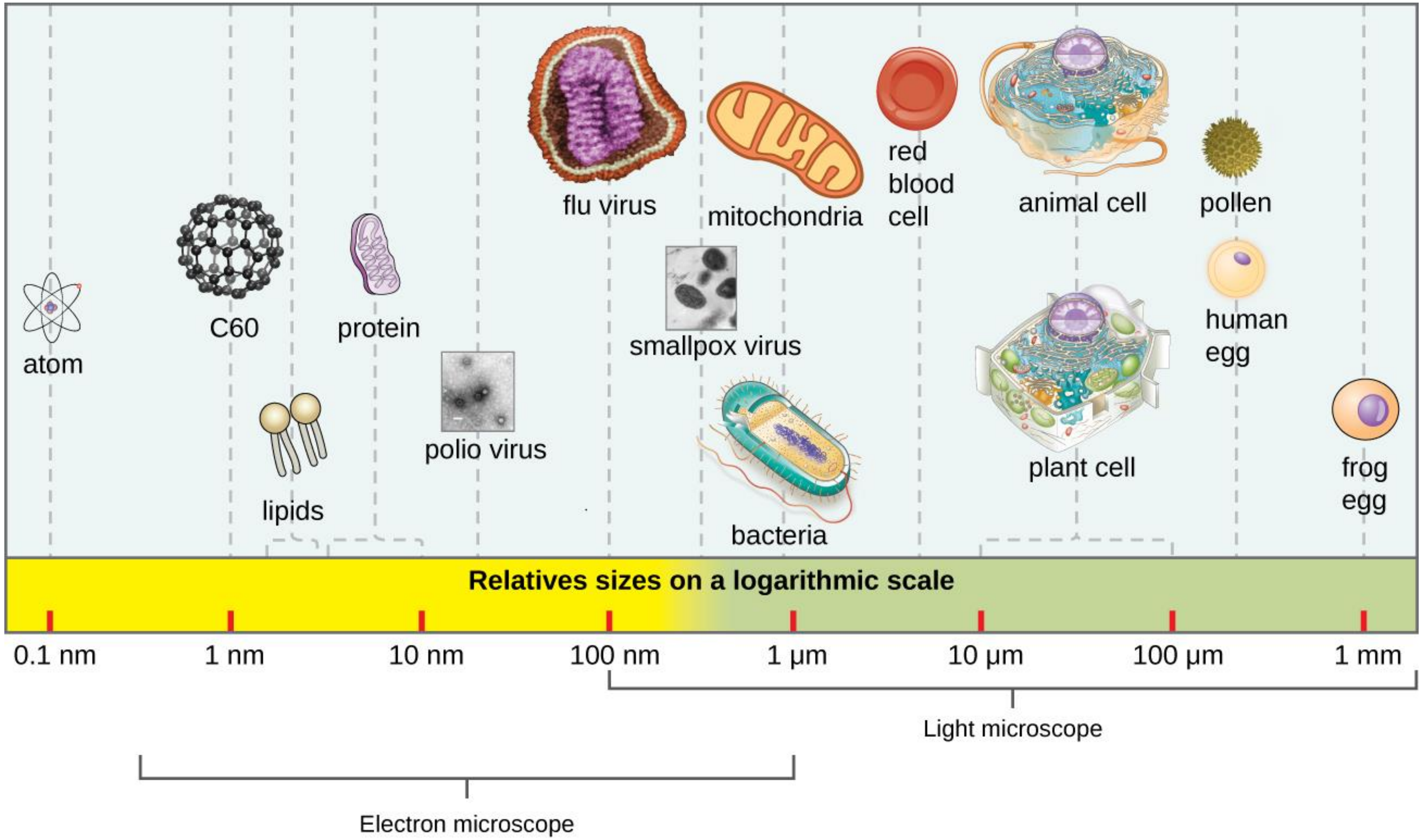


OpenStax Microbiology Publishers: OpenStax Microbiology Latest Version: 4.4 First Publication Date: Oct 17, 2016 Latest Revision: Nov 11, 2016 Last Edited By: OpenStax Microbiology https://cnx.org/contents/5CvTdmJL@4.4

Viral Capsid

- Capsid is the outer layer. Sometime it is refered as coat or shell.
- Capsid serves as impenetrable shell around the nucleic acid core.
- Capsid also helps to introduce viral genome into host cell during infection.
- The protein coat or capsid is made up of number of morphological similar sub units called capsomere. Each capsomere is further composed of protomere.
- Capsomere are arranged precisely and tightly together in a repetitive pattern to form complete capsid.
- The number of capsomere in a capsid varies from virus to virus.
- The complete complex of nucleic acid and protein coat of a virus particle is called as virus nucleo-capsid.
- Structure of capsid give the symmetry to the virus. Virus particle may be either cubicl or helical or binal or complex symmetry.

Capsid composition

- The capsid surrounds the virus and is composed of a finite number of protein subunits known as capsomeres, which usually associate with, or are found close to, the virion nucleic acid.
- Virus capsids are composed of viral protein subunits that form structural units.
- Capsid made up of repeated polymers known as capsomeres
- Capsomeres are protein subunits that are held together by non-covalent interactions, not covalent bonds. These interactions include:
    - Hydrogen bonding
    - Ionic interactions
    - Protein-protein interactions
- Self Assembly and Disassembly when non covalent interactions are favored by environmental conditions

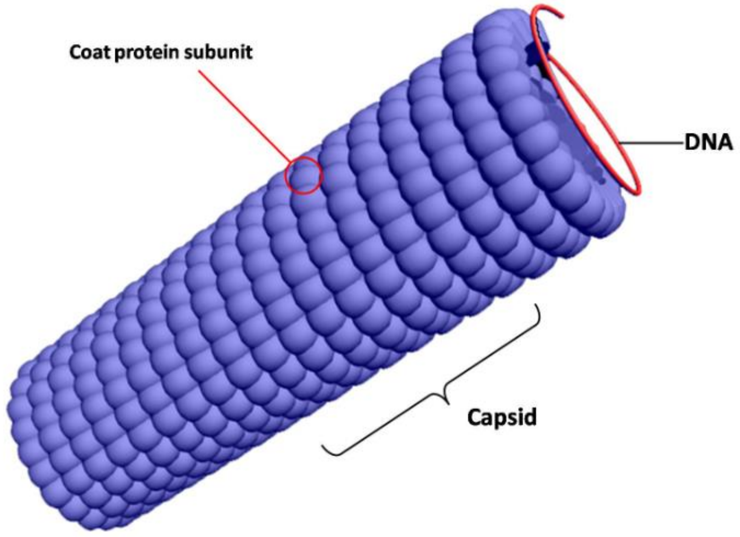
- Capsid can be : Naked or Enveloped

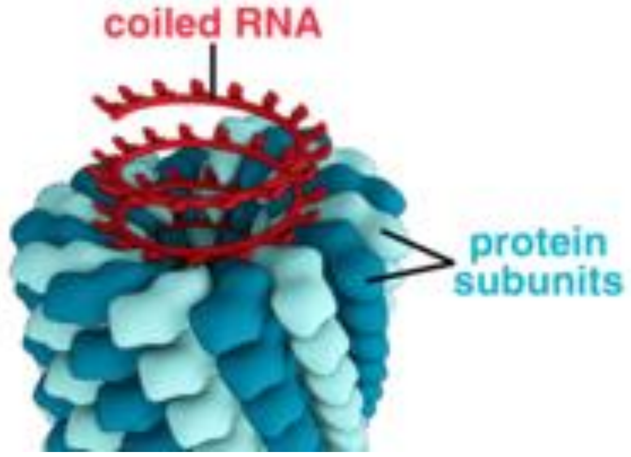
Viral Symmetry

- Viral symmetry is the arrangement of capsomere units in a viral capsid.
- There are two types of viral symmetry, which correspond to the two primary shapes of viruses: rod and spherical.
  - Rod-shaped viruses have helical symmetry, while
  - spherical-shaped viruses have icosahedral symmetry

Helical (spiral) symmetry:

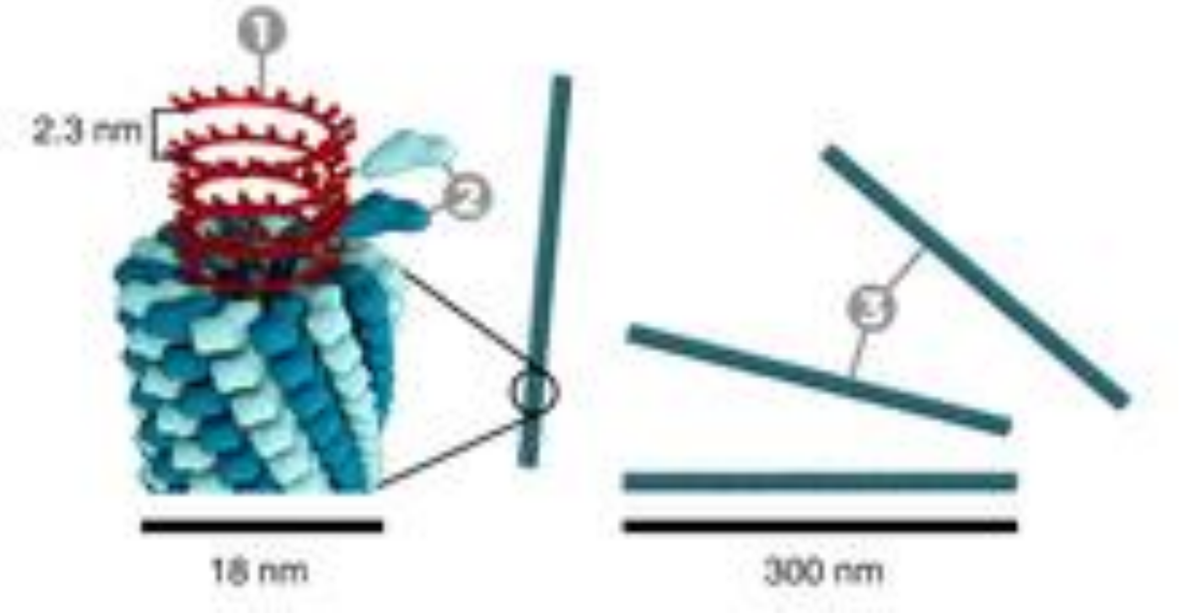
- The capsomere and nucleic acid are wined together to form helical or spiral tube like structure.
- Most of the helical viruses are enveloped and all are RNA viruses.
- Helical symmetry is a pattern of self-assembly for virus capsids. In this pattern, the protein subunits and nucleic acid are arranged in a helix.
- Rigid or flexible filamentous rods





https://en.wikipedia.org/wiki/Virus

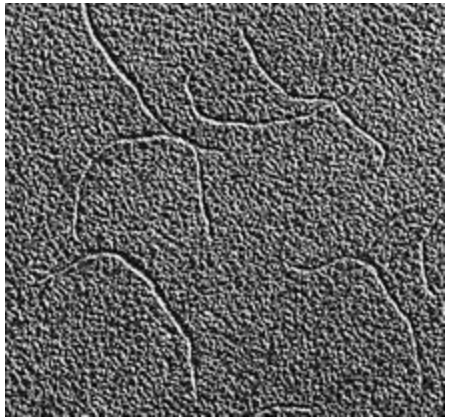
- Helical nucleocapsids are characterized by length, width, pitch of the helix, and number of protomers per helical turn.
- Tobacco mosaic virus (TMV; Tobamovirus, Virgaviridae) is a rodlike virus with a length of 300 nm and diameter of 18 nm.
- TMV capsids are composed of 2130 identical protein subunits, which assemble around the viral ssRNA to form a helical structure, with a hollow central cavity of 4 nm diameter

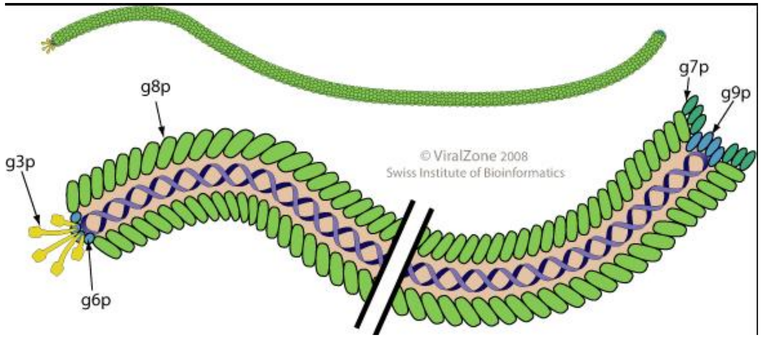


The most extensively studied helical virus is tobacco mosaic virus
The typical virus with naked helical symmetry is tobacco mosaic virus (TMV), which is a RNA virus with 2130 identical capsomeres arranged in a helix.
wikipedia

https://en.wikipedia.org/wiki/Tobacco_mosaic_virus

Helical Symmetry





- Filamentous Viruses
- eg,. Inovirus
  - Fd, F1, M13
  - Ebola virus is a highly pathogenic filovirus causing severe hemorrhagic fever with high mortality rates.
  - It assembles heterogenous, filamentous, enveloped virus particles containing a negative-sense, single-stranded RNA genome packaged within a helical nucleocapsid (NC)

https://viralzone.expasy.org/

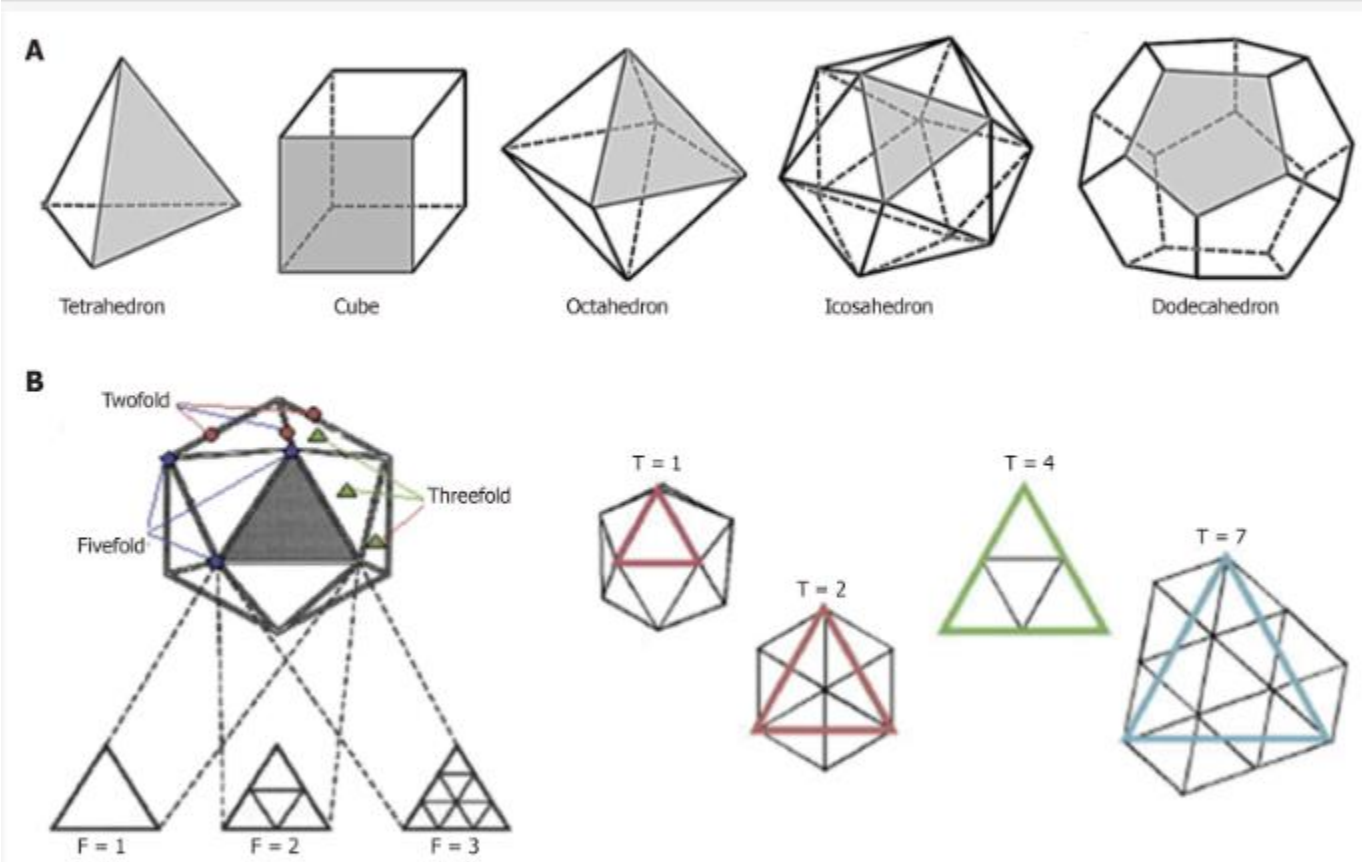
Icosahedral (cubical) symmetry:

- An icosahedral is a polygon with 12 vertices (corner), 20 facet (sides) and 30 edges.
- Each facet is an equilateral triange.
- Icosahedral capsid is the most stable and found in human pathogenic virus eg. Adenovirus, Picornavirus, Papovavirus, herpes virus etc.
- Icosahedral capsid are of two types;
- **Pentagon;** Pentagonal capsomere at the vertices
- **Hexagon;** Hexagonal capsomere at the vertices

Triangulation Number

- In a given capsid, the minimum number of protein subunits is determined by the symmetry of the face (i.e. triangle, square, tetrahedron etc.), and multiplying it by the number of all faces gives the total number of subunits.
- The triangulation number (T) is the smaller, identical equilateral-triangles that compose each triangular face, and is calculated using the law of solid geometry (T = Pf2; where P is a positive integer i.e., 1, 3 and 7; and f is face number i.e., 1, 2, 3, 4, etc.).

  Parvez MK. Geometric architecture of viruses. *World J Virol* 2020; 9(2): 5-18 [PMID: 32923381 DOI: 10.5501/wjv.v9.i2.5]



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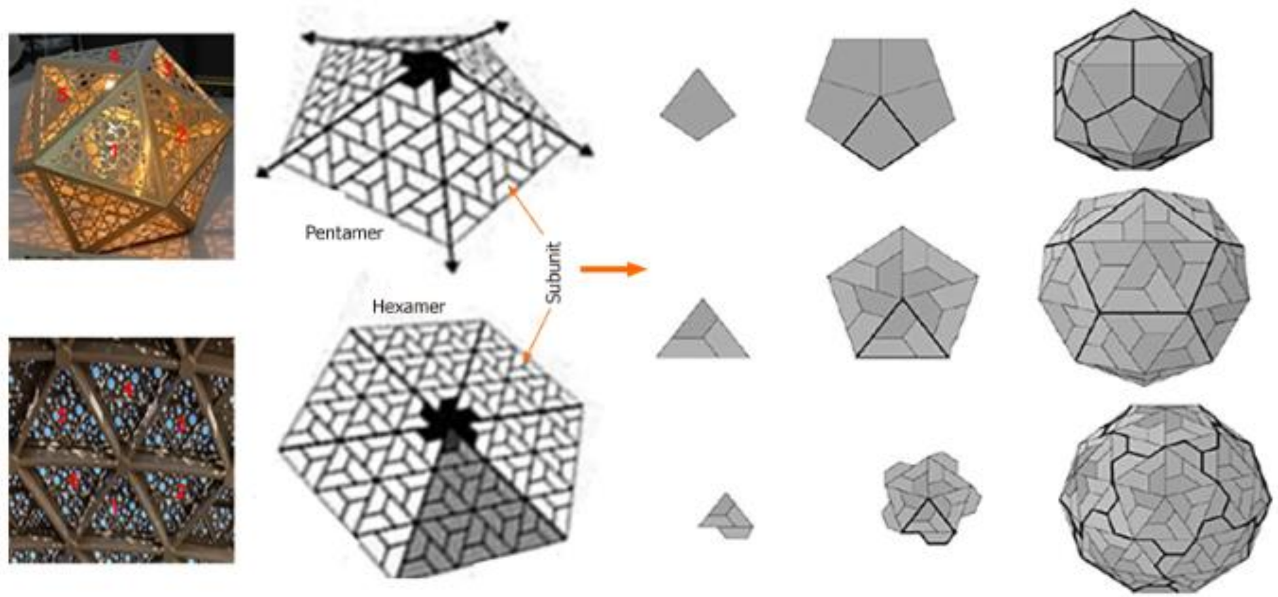

Figure 4 Icosahedral capsid formation. Capsid formation with rings of five subunits *i.e.*, pentamers or six subunits *i.e.* hexamers at the vertices of each of the faces (Left panel; Penta-/hexameric artifacts, Gallery Mall, Riyadh, Saudi Arabia).

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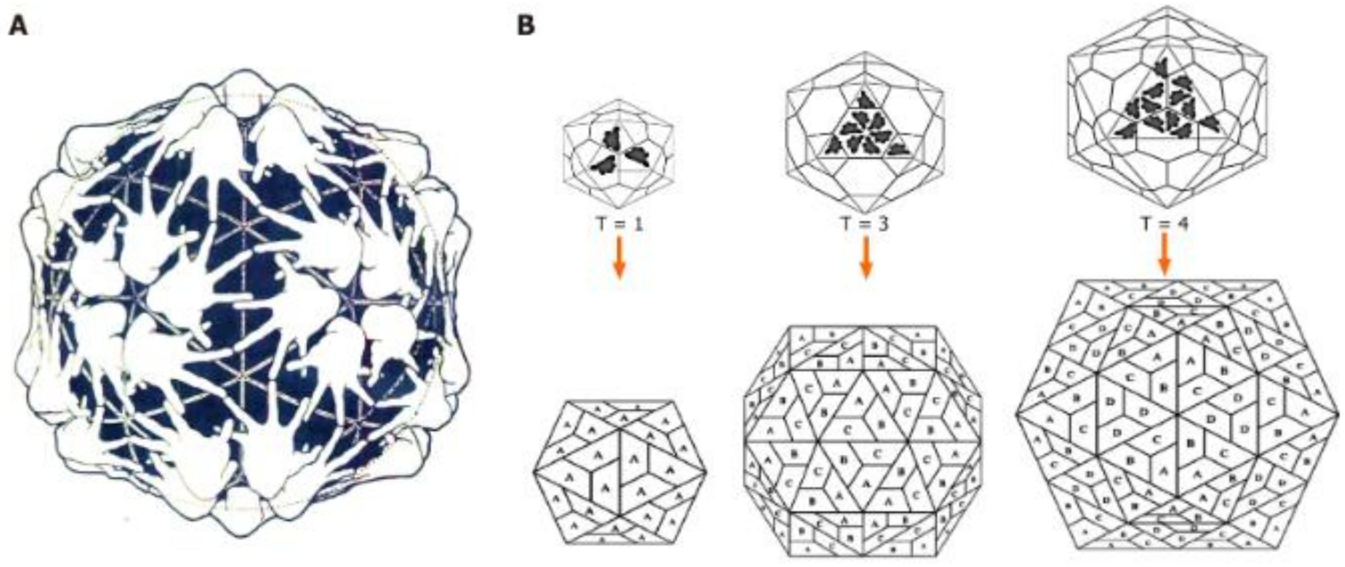

Figure 5 Schematic presentation of icosahedral capsids. A: A Clug model of icosahedral capsid assembly; B: Formation of icosahedral T = 1 (subunit $_{A}$), T = 3 (subunits $_{A}$, $_{B}$ and $_{C}$) and T = 4 (subunits $_{A}$, $_{B}$, $_{C}$ and $_{D}$) capsids.

Triangulation Number

- T = 1 icosahedron The smallest and simplest known viruses have T = 1 capsids made of a single symmetrical protein. The small plant satellite viruses, like satellite tobacco necrosis virus (STNV) icosahedron is T = 1, n = 60[18].
- T = 3 icosahedron Some virus capsids have T = 3, n = 180 structure where in each triangular face (n = 3), the subunits are asymmetrical (e.g., pentamers or hexamers). For example, in TBSV (T = 3, n = 180), each triangle is made of three identical subunits but in different conformations to accommodate the quasi-equivalent assembly. In contrast, picornavirus icosahedral capsids are made of 60 copies of each of four subunits (VP1 = 60, VP2 = 60, VP3 = 60 and VP4 = 60)
- T = 7 icosahedron Bacteriophage T7 icosahedron is composed of 12 pentamer and 60 hexamers with a T = 7 symmetry[8,20].

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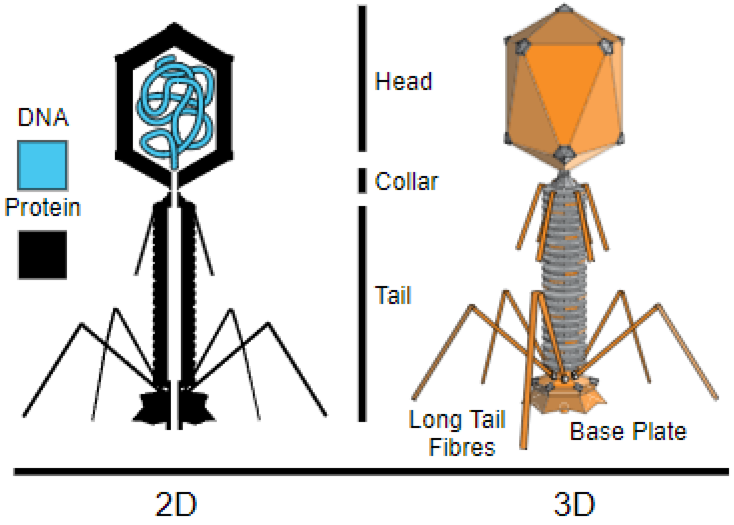
Complex symmetry:

- Some virus are more complex, being composed of several separate capsomere with separate shape and symmetry.
- They do not have either icosahedral or helical symmetry due to c
- **Binal symmetry:** it is a type of complex symmerty
- Some viruses such as T-phage (T2,T4 etc) have compex symmetry including head and tail
- The most complicated virus in terms of structure are some bacteriophage which possess icosahedral head and helical tail. Such structure is called binal symmetry.
- Complexity of their capsid structure. Eg. Pox virus, Bacteriophage.

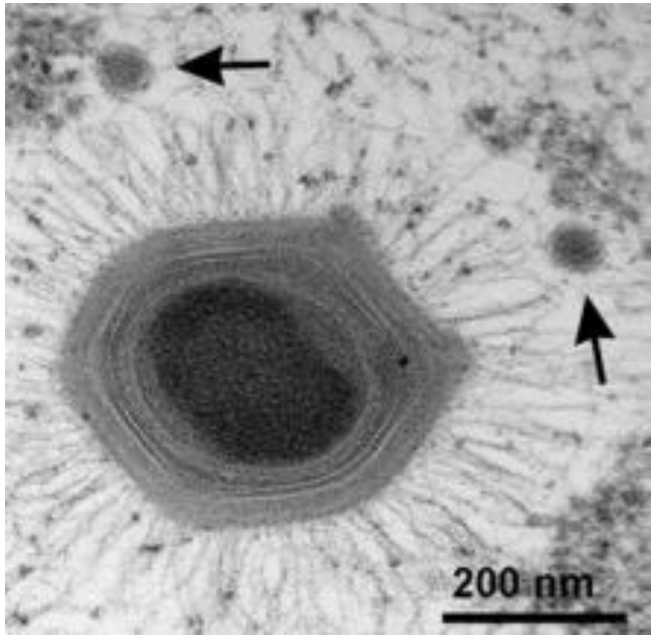
Bacteriophage

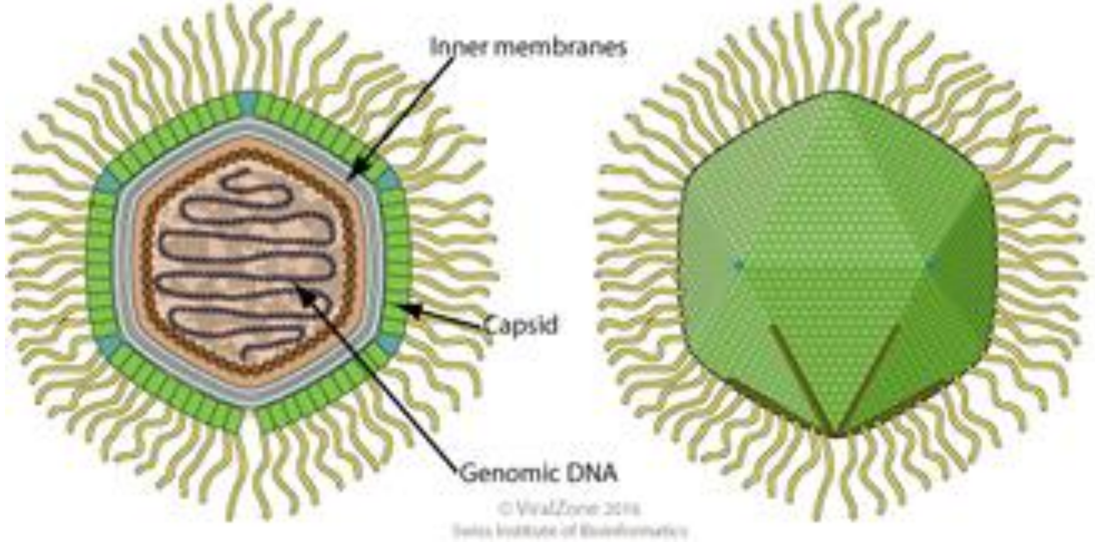
- A characteristic feature of complex viruses is the presence of multiple proteins in the virion, playing specific architectural or functional roles during the viral cycle.



https://bio.libretexts.org/

Complex Virus





- Mimi Virus- largest complex virus
- ***Mimivirus*** is a genus of giant viruses, in the family *Mimiviridae*. Amoeba serve as their natural hosts.[2][3] This genus contains a single identified species named ***Acanthamoeba polyphaga mimivirus*** (APMV). It also refers to a group of phylogenetically related large viruses