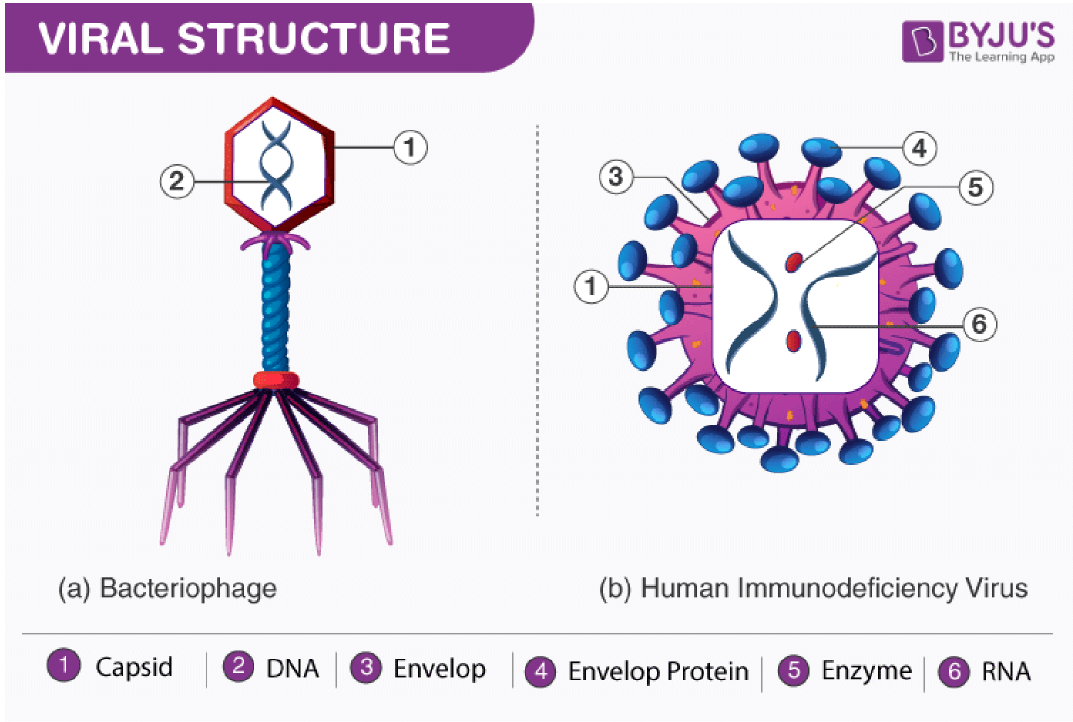
Viral Structure

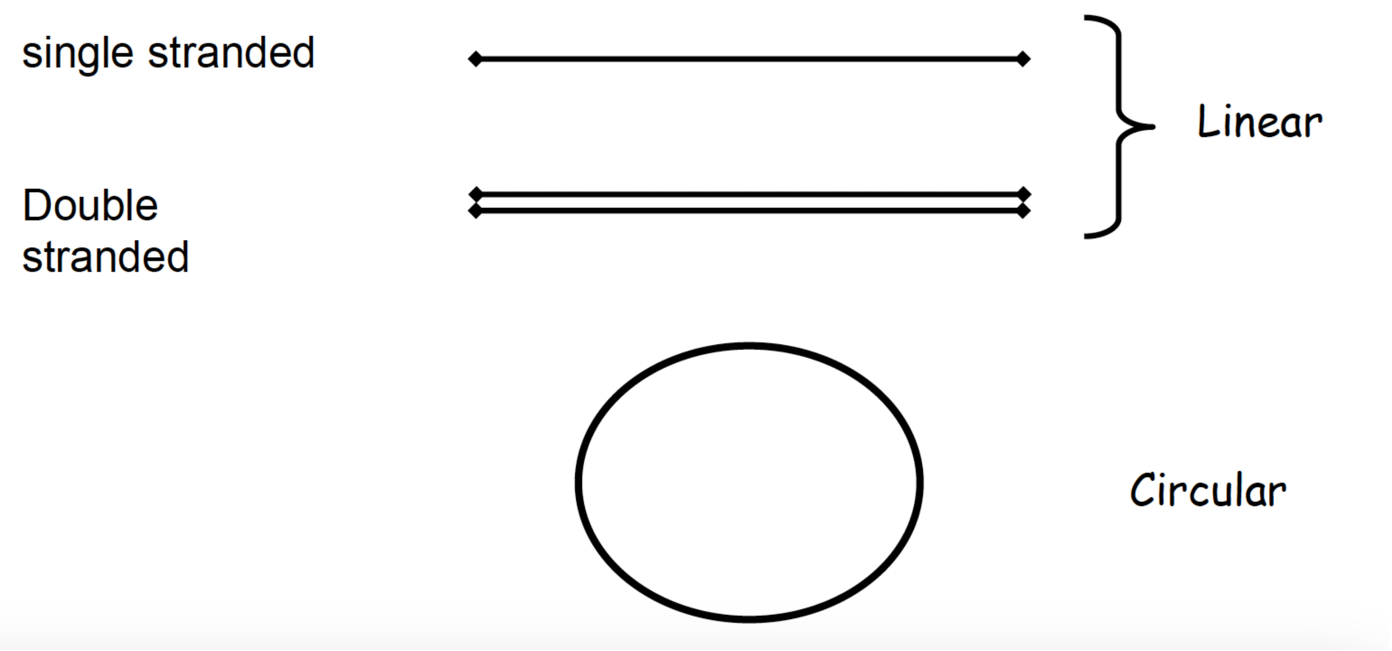
- Nucleic Acid
- Protein
- Envelope (Peplos)
- Viral enzymes



https://byjus.com/biology/virus/

Nucleic Acid

- NA is the genome that contains the information necessary for virus replication
  - Virus nucleic acid (n.a.) can be single or double stranded, linear or circular in structure. Except for retroviruses, all virus genes are haploid (there is a single copy of each gene).

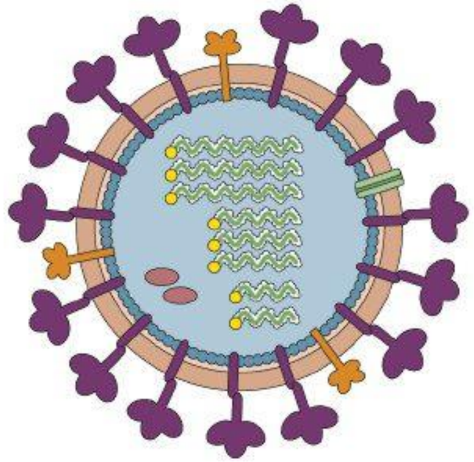


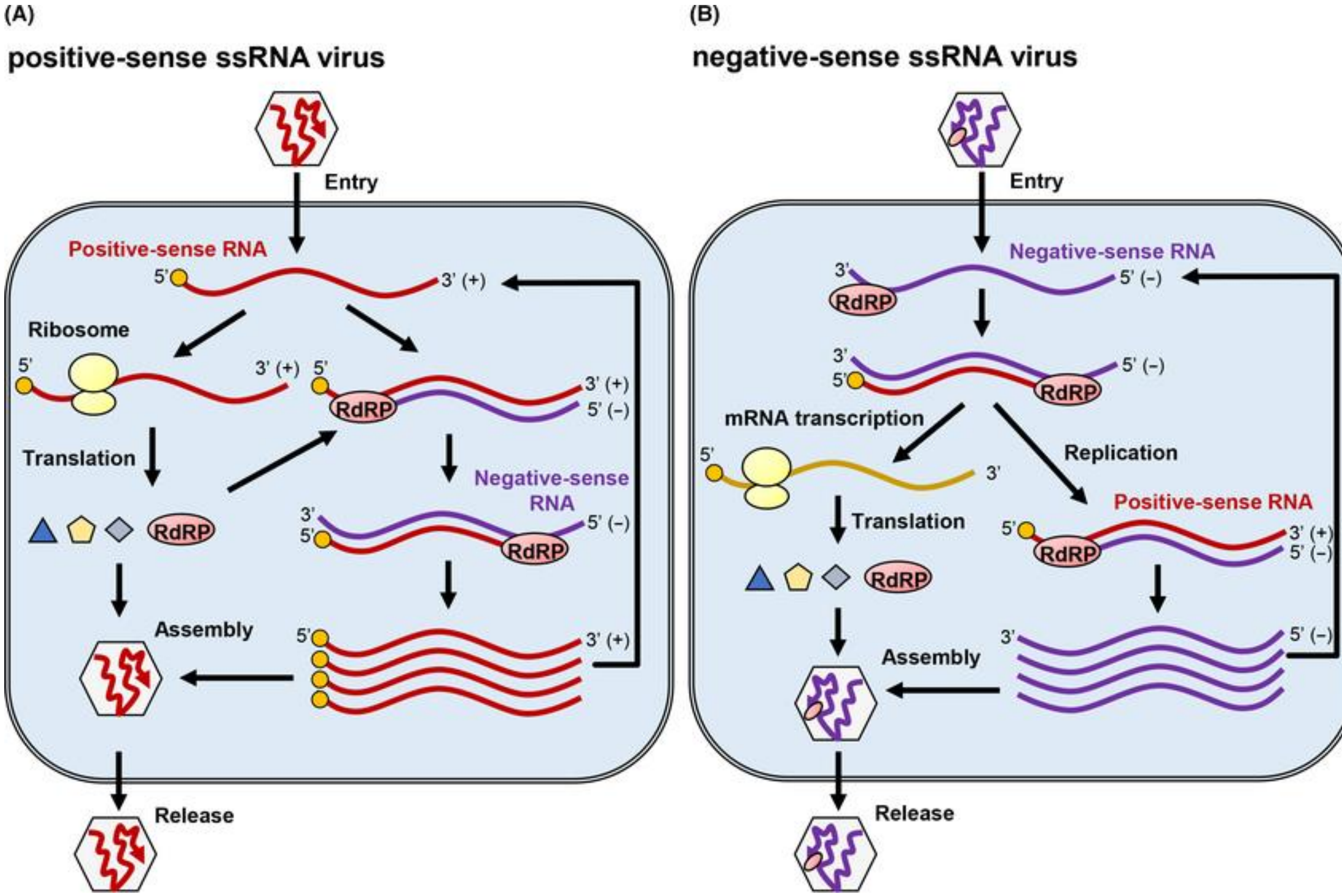
RNA Viruses

- **They can be of positive or negative-sense (polarity),**
  - **In (+) sense viruses**, the nucleotide sequence is in the 5‘-3' direction and they undergo direct translation.
  - **In (-) sense viruses,** the nucleotide sequence is in the reverse direction, 3‘-5‘, and they require absolute transcription.

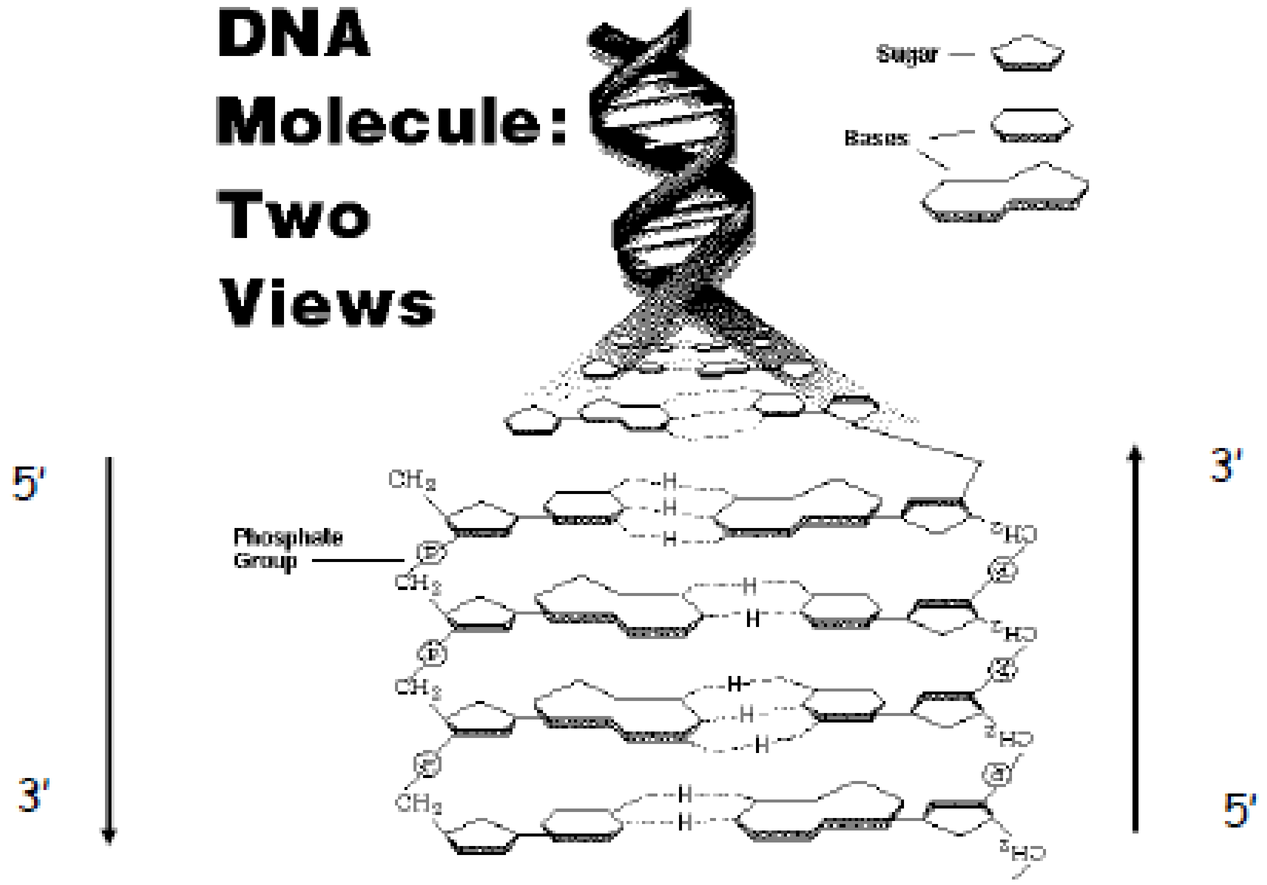
  Therefore positive sense RNAs are INFECTIOUS! ! ! ! !

  - Viruses showing both polarities are called ambisense (Bunyaviruses).
- **Some RNA viruses are segmented.**
  - Reoviruses ⟹ 9-11 segments,
  - Orthomyxoviruses ⟹ 8 segments
  - Birnaviruses ⟹ 2 segments





Machitani, M., Yasukawa, M., Nakashima, J., Furuichi, Y., & Masutomi, K. (2020). RNA-dependent RNA polymerase, RdRP, a promising therapeutic target for cancer and potentially COVID-19. *Cancer Science*, *111*(11), 3976-3984.



http://penexcite.com/worksheet/dna-molecule-two-views-answers-worksheet.html

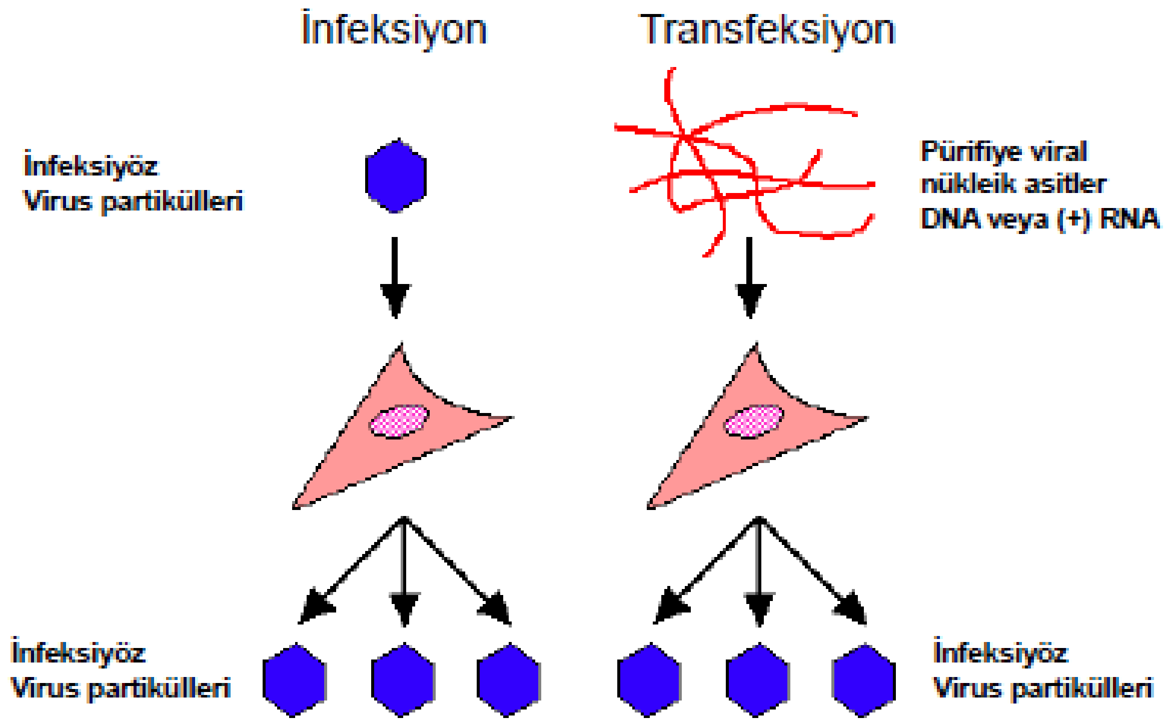
DNA Viruses

Viruses with deoxyribonucleic acid (DNA) genomes are called DNA viruses.

They exhibit general structural diversity,

- While some viruses encode the replication enzymes they need (e.g. Poxviruses), some viruses prefer cellular sources for these enzymes (e.g. Herpesviruses).
- For this reason, the second group are defined as INFECTIOUS.

- Transfection: It is the infection caused by the direct introduction of viral genetic material into the cell.



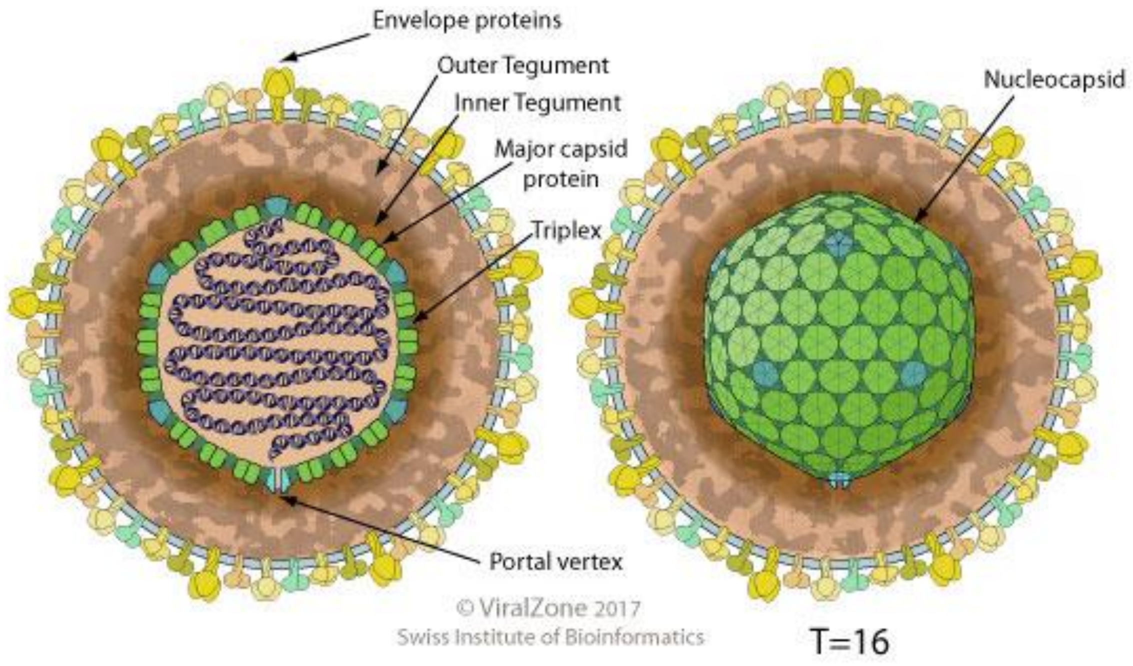
Family	Structure of nucleic acid
Papovaviridae	Circular superhelical dsDNA (see Plate 1-2)
Adenoviridae	Linear dsDNA with inverted terminal repeats and a covalently bound protein (see Fig. 1-3A)
Herpesviridae	Linear dsDNA; two unique sequences flanked by reiterated sequences; isomeric configurations occur (see Fig. 1-3B)
Poxviridae African swine fever virus	Linear dsDNA; both ends covalently closed, with inverted terminal repeats (see Fig. 1-3C)
Parvoviridae	Linear ssDNA, (−) sense; with repeated sequences and a hairpin structure at one end (see Fig. 1-3D)
Hepadnaviridae	Circular dsDNA with ss region
Picornaviridae *Caliciviridae* *Togaviridae* *Flaviviridae* *Coronaviridae*	Linear ssRNA, (+) sense; serves as mRNA; 3’ end polyadenylated (except *Flaviviridae*); 5’ end capped, or protein covalently bound (*Picornaviridae, Caliciviridae*)
Paramyxoviridae *Rhabdoviridae*	Linear ssRNA, (−) sense
Rhabdoviridae	
Orthomyxoviridae	Segmented genome; 7 or 8 molecules of linear ssRNA, (−) sense
Arenaviridae	Segmented genome; 2 molecules of ssRNA, (−) sense or ambisense[b]; “sticky ends” allow circularization
Bunyaviridae	Segmented genome; 3 molecules of ssRNA, (−) sense or ambisense; “sticky ends” allow circularization
Retroviridae	Diploid genome, dimer of linear ssRNA, (+) sense; hydrogen bonded at 5’ ends; terminal redundancy; both 3’ termini polyadenylated, both 5’ ends capped; may carry oncogene
Reoviridae	Segmented genome; 10, 11, or 12 molecules of linear dsRNA
Birnaviridae	Segmented genome; 2 molecules of linear dsRNA

[a]There is considerable variation within some families, e.g., *Herpesviridae, Reoviridae*.

[b]Ambisense indicates that part of molecule is (+) and part (−) sense.

FENNER F, BACHMANN PA, GIBBS EPJ, MURPHY FA, STUDDERT MJ, WHITE DO. Structure and Composition of Viruses. Veterinary Virology. 1987:3–19. doi: 10.1016/B978-0-12-253055-5.50005-0. Epub 2014 Jun 27. PMCID: PMC7173599.

Proteins



- The vast majority of the proteins exist
  - in the capsid surrounding the nucleic acid,
  - in the membrane of enveloped viruses and
  - as structural or functional enzymes.

Proteins (structural proteins--coded for by viral genome)

•sole component of the capsid

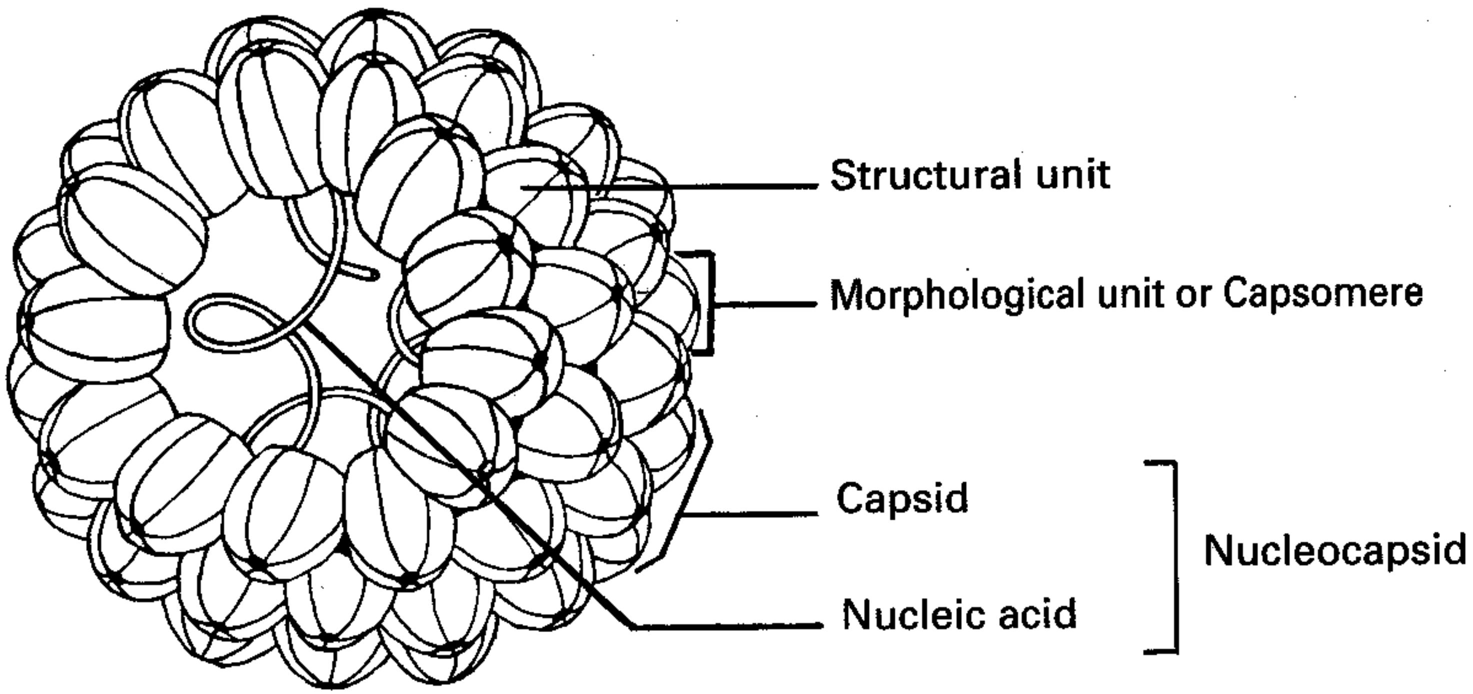
•major component of the envelope

•associated with nucleic acids as internal core proteins

Functions of proteins

- Protection and delivery of the genome;
- Binding host cell receptors
- Uncoating of the genome
- Fusion with cell membranes
- Transport of genome to the appropriate site
- Determining the shape (morphology / symmetry) of the virus
- playing a role in the entry of the virus into the cell and stopping infection.

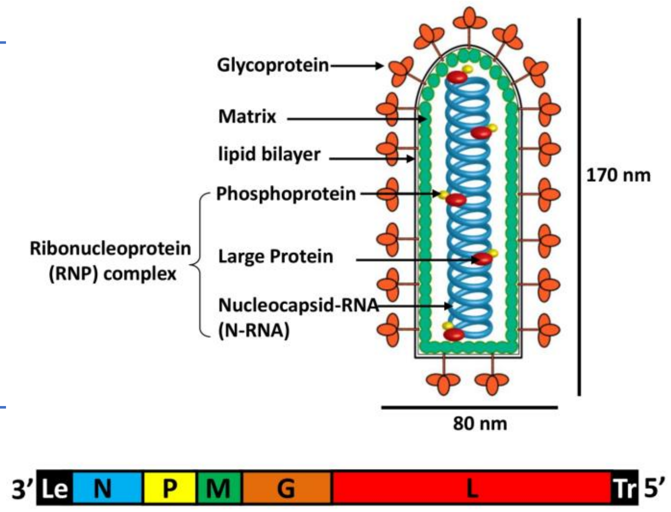
- CAPSID: The protein layer that surrounds the nucleic acid.
- The capsid consists of protein subunits called capsomer (morphological unit) and they consist of several oligomeric structural subunits made of protein called protomers.
- **The capsid together with nucleic acid is called Nucleocapsid.**

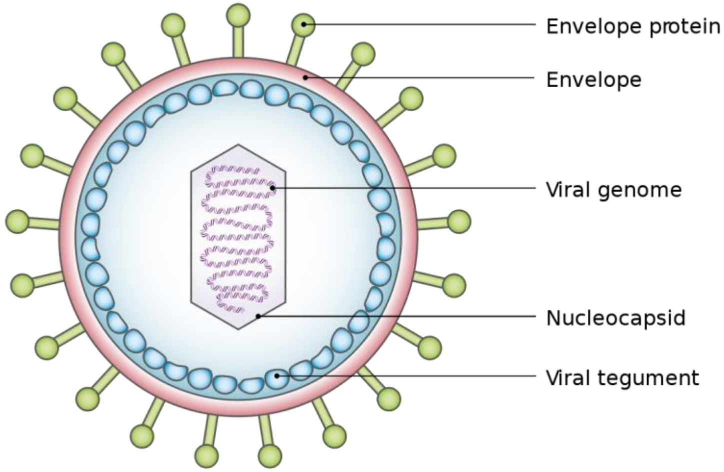


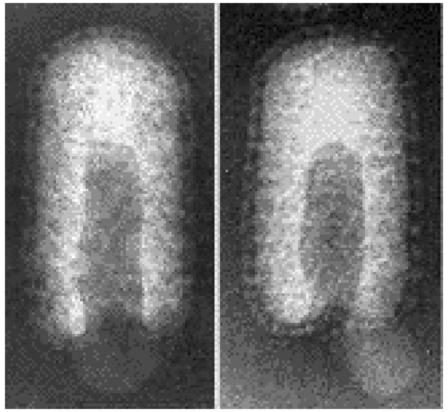
Some of the Structural Proteins accumulate between the capsid and envelope and act as filling material.

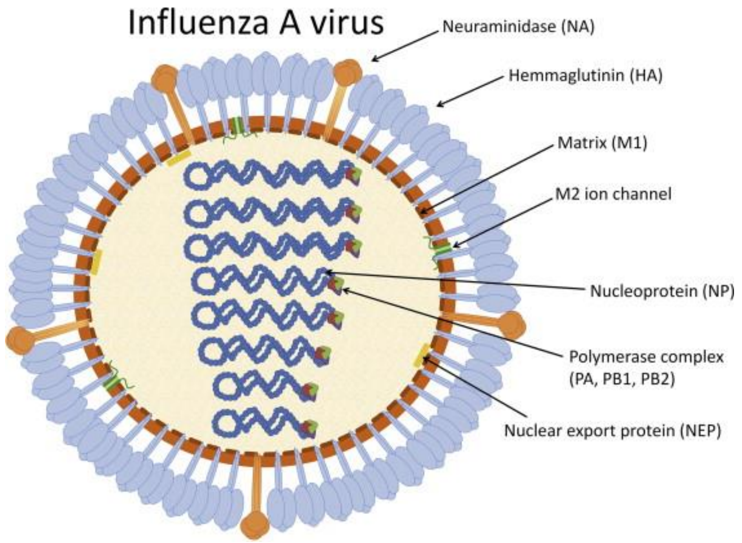
Especially in viruses with helical symmetry (Rhabdovirus, Orthomyxovirus, Paramyxovirus, Coronavirus, etc.), such proteins are called Matrix proteins.

Functional Proteins, neuraminidase, RNA polymerase, DNA polymerase, Reverse transcriptase, Tegument protein









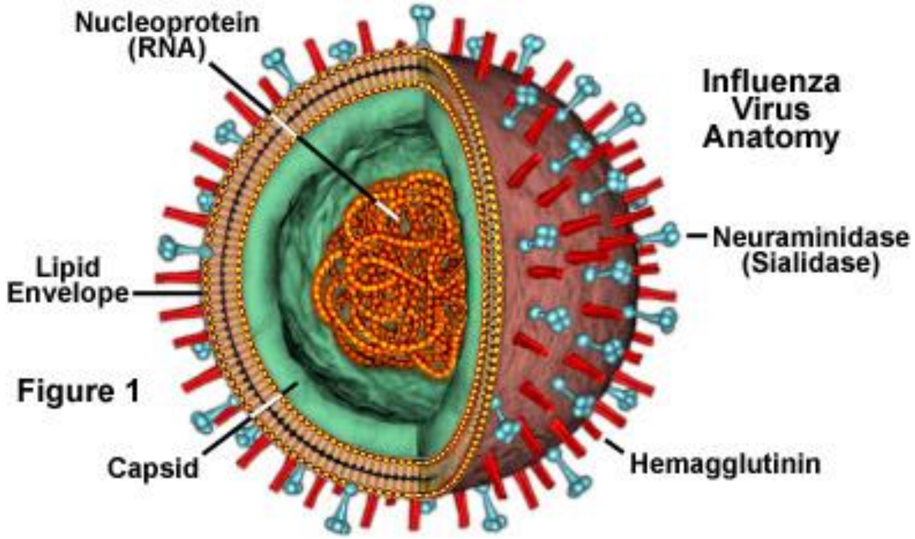
https://en.wikipedia.org/wiki/Viral_tegument https://www.sciencedirect.com/topics/biochemistry-genetics-and-molecular-biology/viral-matrix-protein https://en.wikipedia.org/wiki/Rhabdoviridae

Envelope

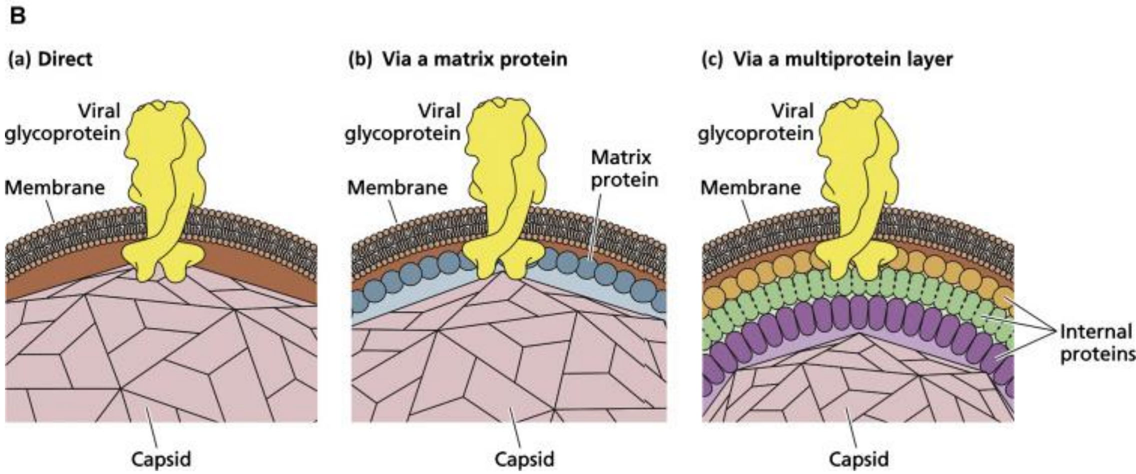
For some viruses, the capsid is surrounded by a lipid bilayer containing viral proteins. This layer, called the **envelope**, helps the virus attach to host cells and also contains proteins and virally encoded glycoproteins (spikes).

The capsid and envelope play many roles in viral infection, including;

- virus attachment to cells,
- entry into cells,
- release of the capsid contents into the cells,
- packaging of newly formed viral particles.



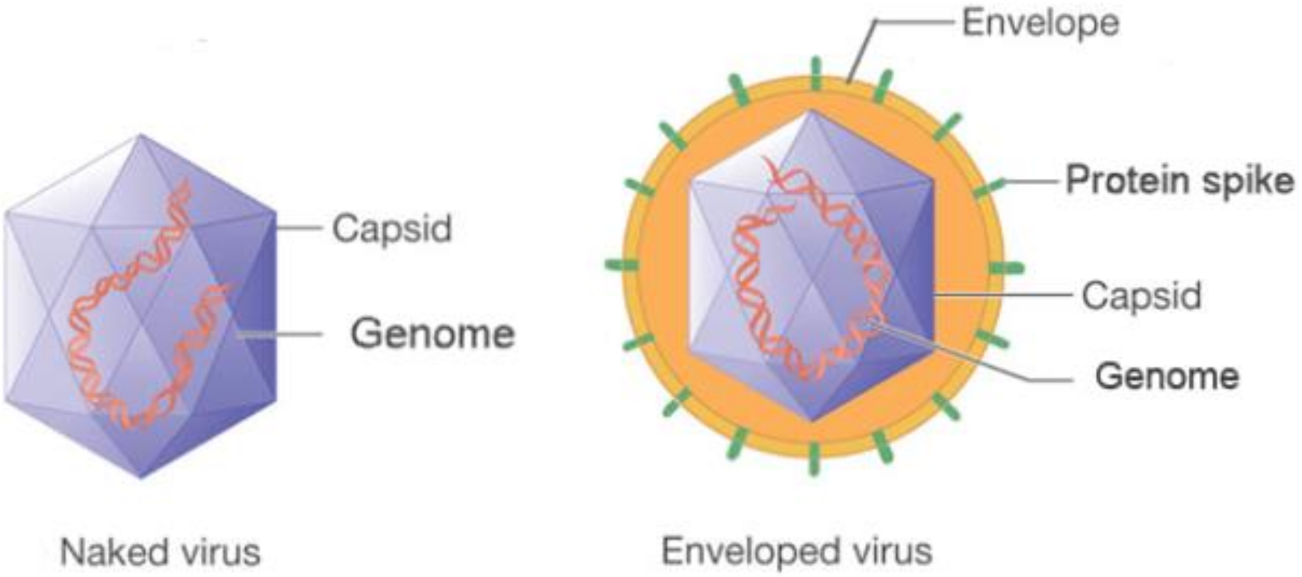
https://micro.magnet.fsu.edu/cells/viruses/influenzavirus.html



Fenner and White's Medical Virology. DOI: http://dx.doi.org/10.1016/B978-0-12-375156-0.00003-5 Chapter 3. Virion Structure and Composition

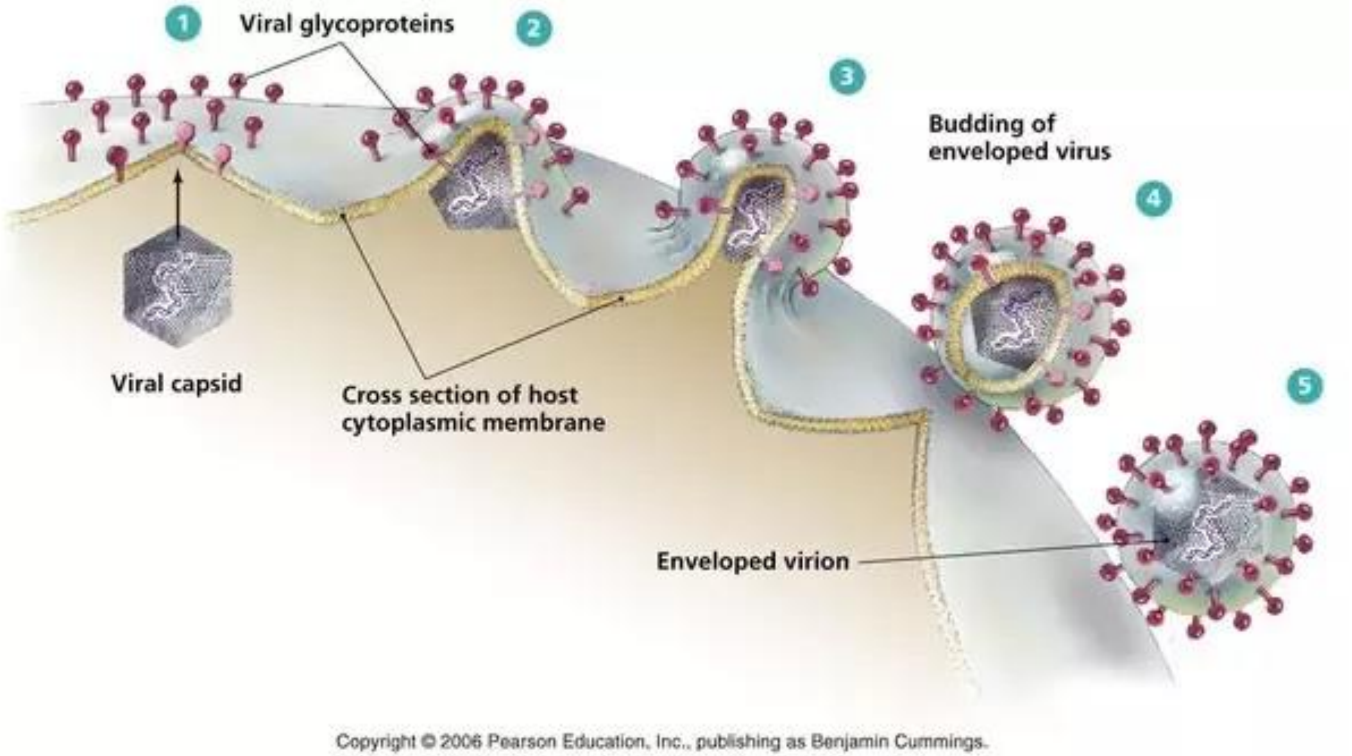
- One of the major and best-known virus classifications is the separation of enveloped from non-enveloped viruses. In general, what distinguishes them is the presence (for enveloped viruses) or absence (for non-enveloped viruses) of a lipid bilayer membrane on the outer part of the virus.

If a virus doesn't have an envelope, it is called a non-enveloped (naked) virus. If the virus particle contains an extra lipid bilayer membrane surrounding the protein capsid, it's called an enveloped virus.



(Image courtesy of McGraw-Hill.)

https://virologyresearchservices.com/2022/05/22/enveloped-vs-non-enveloped-viruses/



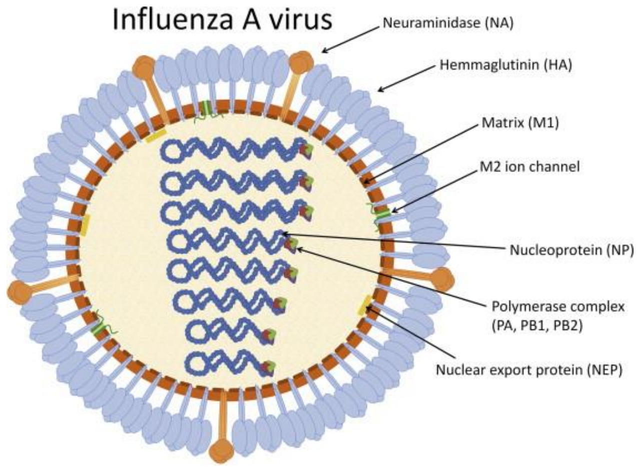
It originates from the envelope cell (retrovirus) or nucleus (herpesvirus) membrane.

It consists of subunits called peplomers.

It carries hemagglutinin and neuraminidase activity in some viruses.

Damaging of the envelope causes immediate loss of infectivity.

Only few families of animal viruses exist as naked nucleocapsids, all the others are enclosed by lipid envelopes that are acquired by the *budding of viruses* through the host cell membrane.



Non-enveloped Viruses	Enveloped Viruses
•They are durable and resistant to environmental influences, e.g. they can withstand dry air and treatment with soap	•The envelope is sensitive to environmental influences, e.g. dry air, treatment with soap and ether chloroform etc.
•As a feature of their life cycle, they kill the cell they infect.	•They are shed from the cell after a long and chronic infection. The envelope is always of cellular origin and has a lipoprotein nature. This event is called Budding.

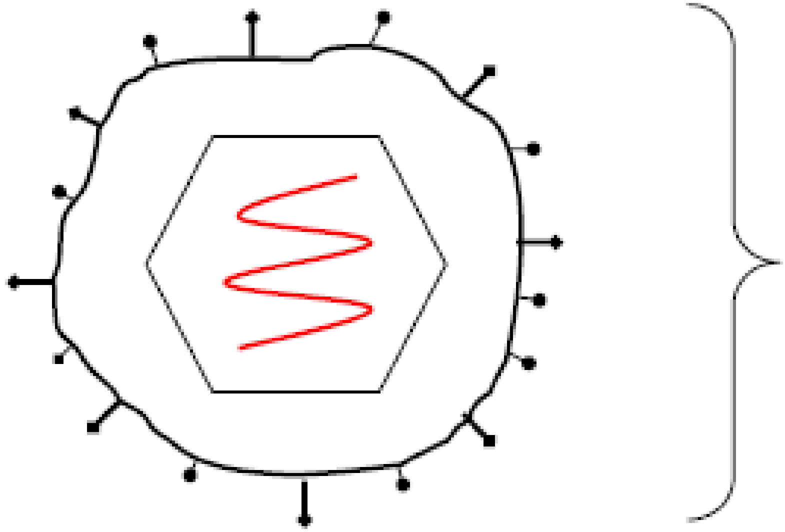
Viral enzymes

- Viruses do not contain many enzymes in their structure.
- Some viruses must carry some enzymes within the virion in order to initiate viral nucleic acid synthesis in infected cells. The main function of these enzymes is to synthesize mRNA using viral RNA as a template.
- In negative polarity RNA viruses, the RNA-dependent RNA polymerase enzyme is found within the virion.
- Retroviruses have an RNA-dependent DNA polymerase enzyme. This enzyme, also known as reverse transcriptase, allows the retrovirus genome in **RNA** character to proliferate by transcribing it into **DNA**.

- Most viruses with a DNA genome replicate in the cell nucleus and can synthesize mRNA using the cellular RNA polymerase enzyme present there.
- Although poxviruses have a DNA genome, they must carry the viral DNA-dependent RNA polymerase enzyme within the virion in order to synthesize RNA due to their proliferation in the cytoplasm of the cell.
- Apart from these enzymes, enzymes such as integrase, protease, etc. may be found in different virus groups.

Virion

The complete virus particle with infective properties is called **VIRION.**

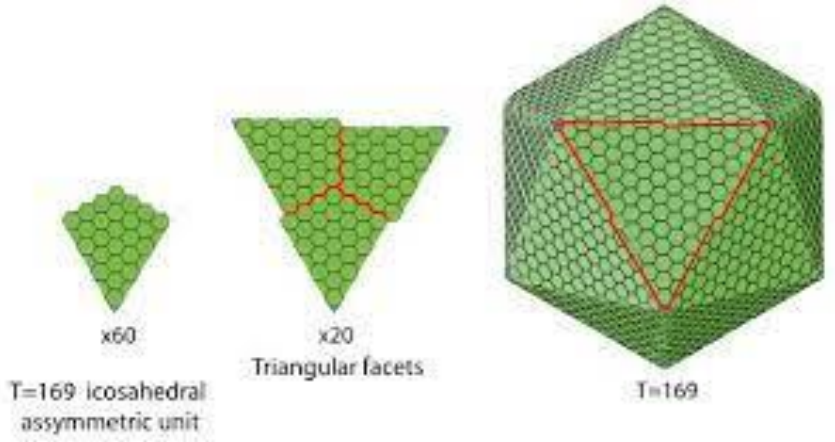


Nucleic acid (DNA or RNA)
Capsid
Envelope (if there is)

Nucleocapsid morphology

1. Icosahedral symmetry → Herpes-, Adeno-ve Rotaviruses
2. Helical symmetry → Orthomyxo-, Paramyxo-, Rhabdo-ve Coronaviruses
3. Complex structure → Poxviruses
4. Binal (combine) structure → Bacteriophage

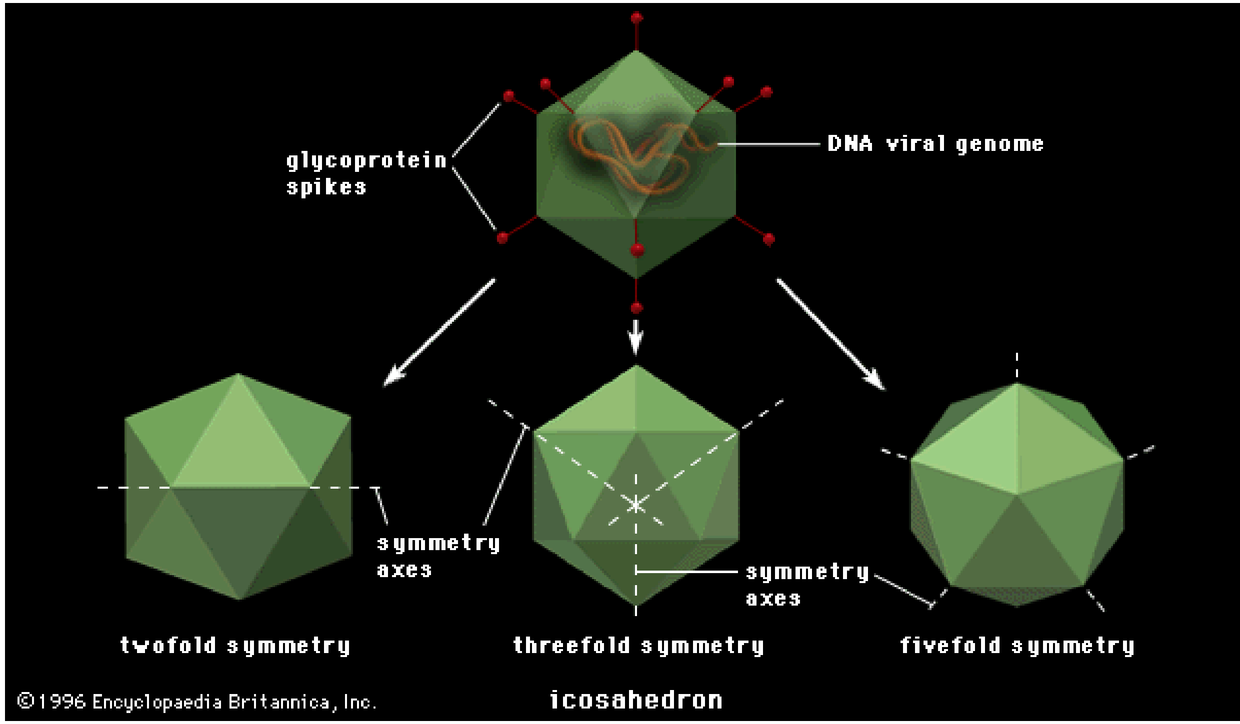
1. Icosahedral (Cubic) Symmetry



- It is a form of symmetry observed in both DNA and RNA viruses.
- They can be with or without envelopes.
- Enveloped viruses with icosahedral symmetry are more fragile than non-enveloped viruses.
- Among the viruses, the viruses that are most resistant to environmental conditions are non-enveloped viruses.

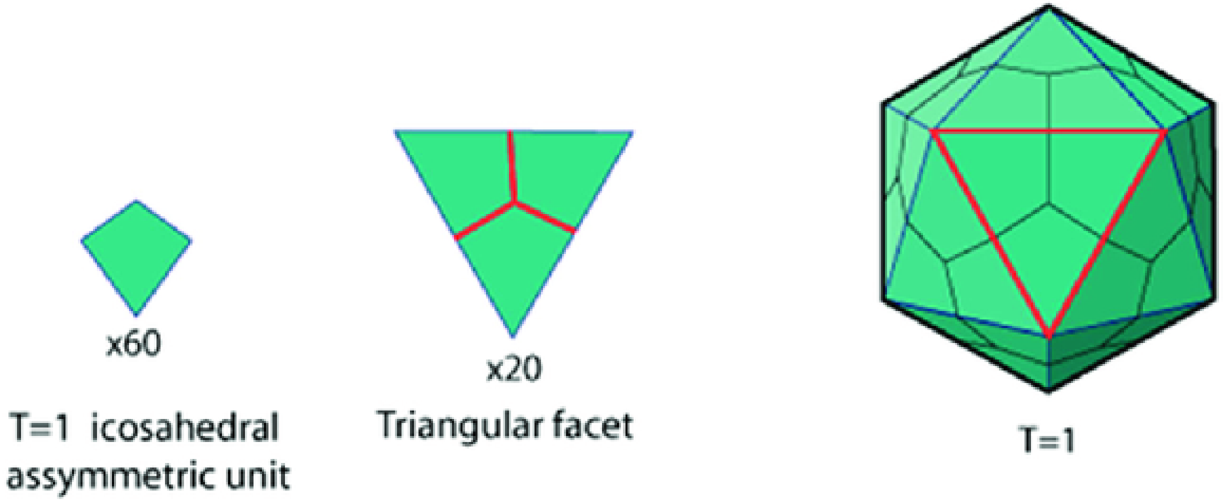
https://viralzone.expasy.org/10117

- Icosahedron is a very complex geometric structure and is considered as the mechanism by which virus proteins come together to form cubic capsid symmetry.
- The simplest icosahedron consists of 20 equilateral triangles joined at certain degrees of angle.
- Its angular features result in variable images due to three basic axes.
- Identical capsomers, each composed of different proteins, each located equidistantly from a common center, which results in a spherical capsid.

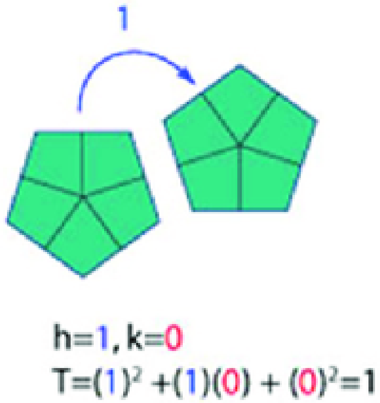


https://www.britannica.com/science/icosahedral-virus

T=1 icosahedral capsid protein



The capsid is composed 60 asymmetric units made of 1 protein (T=1), for a total of 60 capsid proteins.

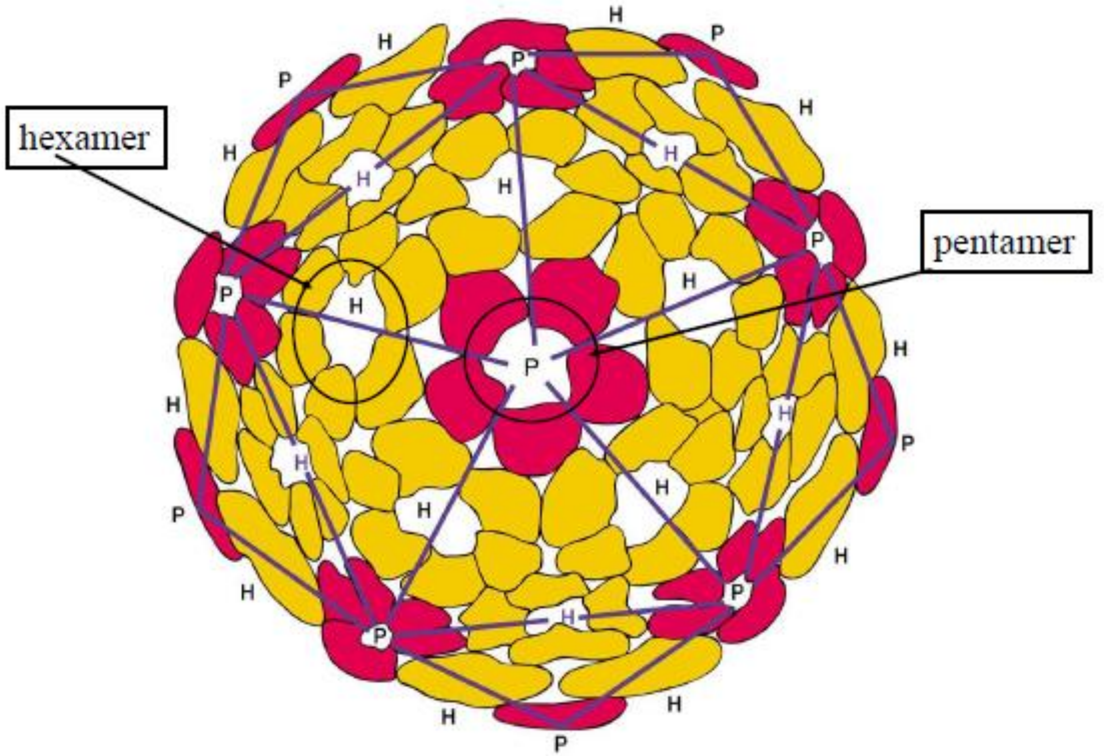


Icosahedric triangulation number is calculated following Caspar and Klug system

ungck JR, Brittain S, Plante D, Flynn J. Self-Assembly, Self-Folding, and Origami: Comparative Design Principles. *Biomimetics*. 2023; 8(1):12. https://doi.org/10.3390/biomimetics8010012

Capsomere

- They are structural subunits consisting of 5 or 6 protomers in the form of a ring or knot.
- *pentamer (penton)* – capsomer with five subunits
- *hexamer (hexon)*– capsomer with six subunits



https://www.studyblue.com/notes/note/n/microbio-lecture-4/deck/9774817

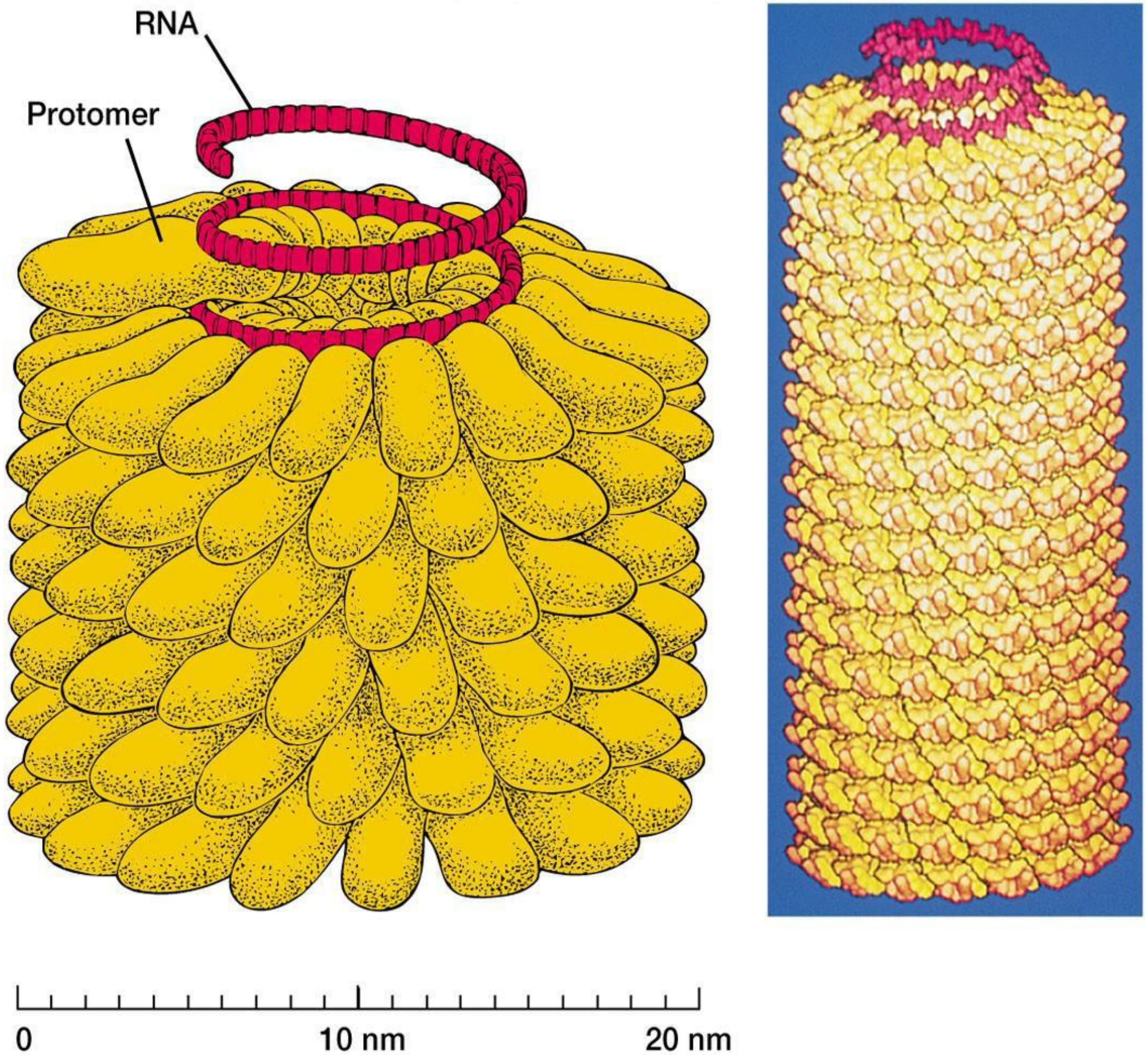
Capsid vs Capsomere

More Information Online WWW.DIFFERENCEBETWEEN.COM

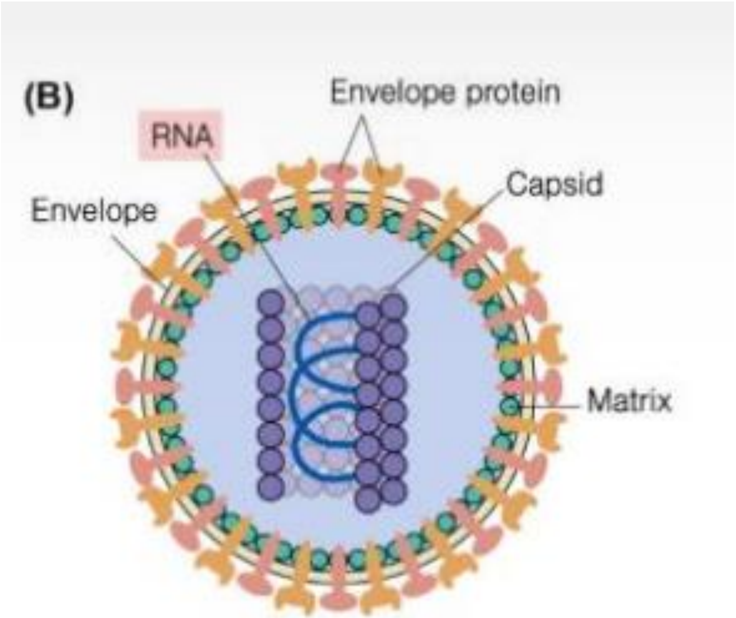
	Capsid	Capsomere
DEFINITION	Capsid is the protein coat that surrounds the nucleic acid of the virus particle	Capsomere is the basic morphological subunit of the viral capsid
ASSEMBLING UNITS	Capsomeres self assemble to form the capsid	Protomers self assemble to form a capsomere
IN A VIRUS	There is only one capsid	There are many capsomeres in one capsid
MAIN FUNCTION	Protecting the viral genome	Making the viral capsid

2. Helical symmetry

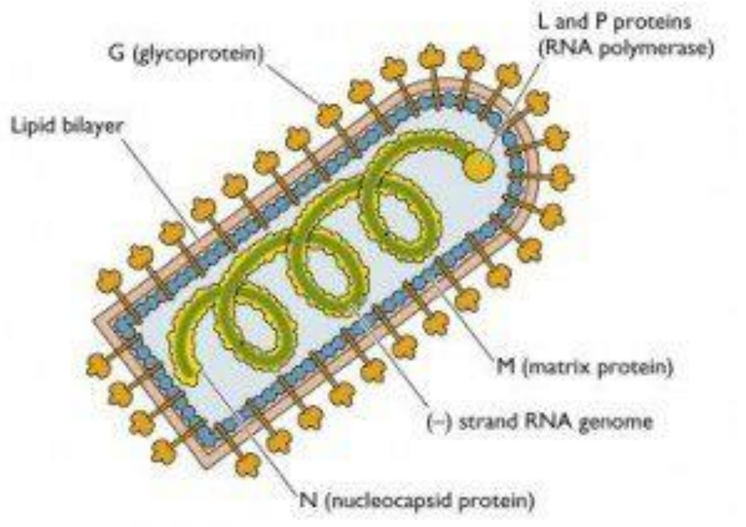
- This structure emerges as a result of protein subunits binding in a certain order to the genome on the helix-shaped RNA base in the middle.
- **This structure is found only in RNA viruses; DNA viruses do not exhibit the principle of helical structure.**
- Coat protein molecules engage in identical, equivalent interactions with one another and with the viral genome to allow construction of a large, stable structure from a single protein subunit.



- The dimensions of the resulting helical structure are related to the RNA located in the center.
- All viruses with helical symmetry are enveloped viruses.
- Viruses with helical symmetry are defined as the most fragile viruses. They are very sensitive to the external environment and physical and chemical agents.



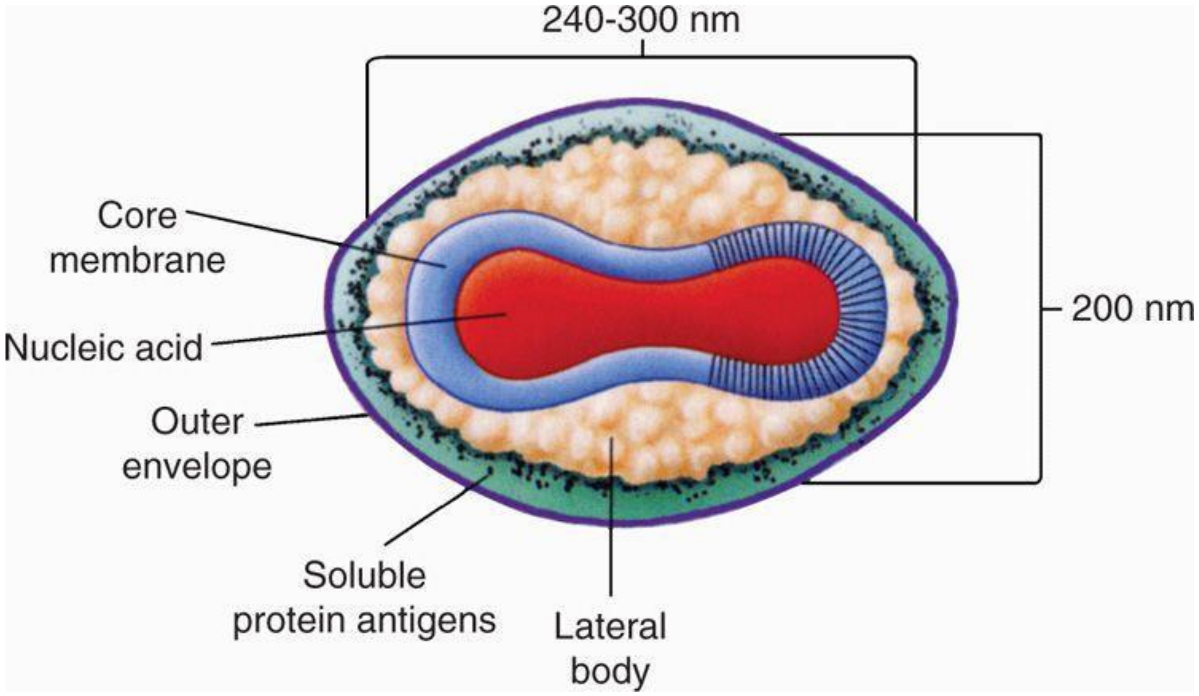
https://www.creative-biostructure.com/structural-biology-of-viruses.htm

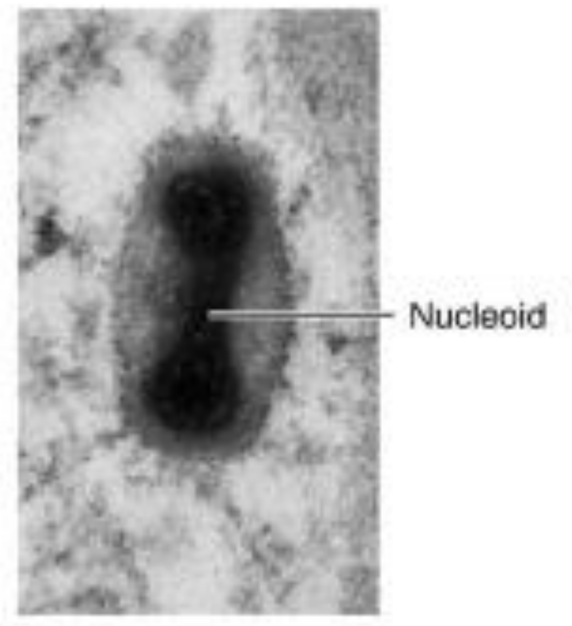


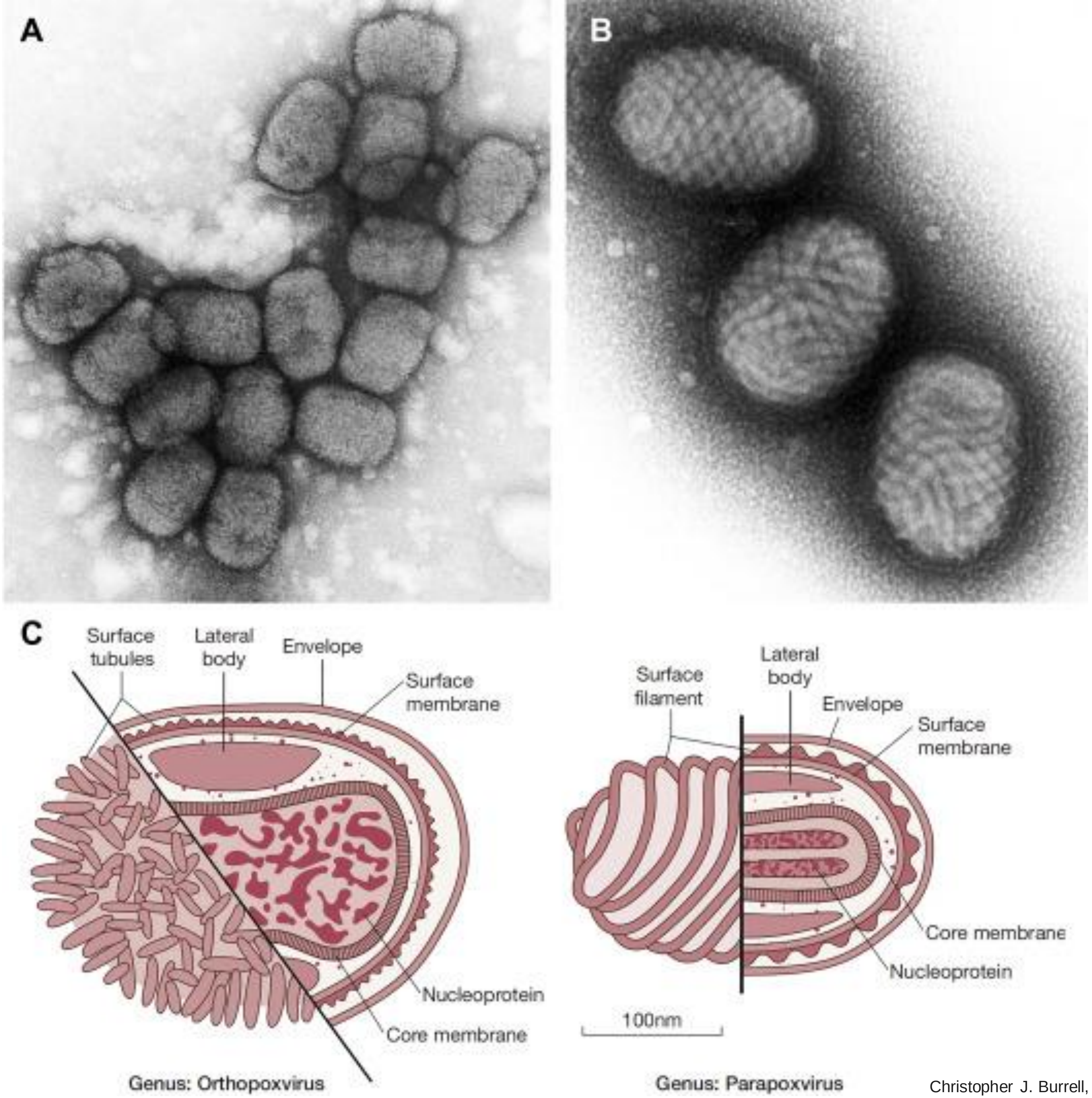
https://virology.ws/2010/02/23/architecture-of-a-bullet-shaped-virus/

3. Complex Symmetry

- Oval shaped, brick-like viruses.
- It is only the symmetry seen in Poxviridae family.



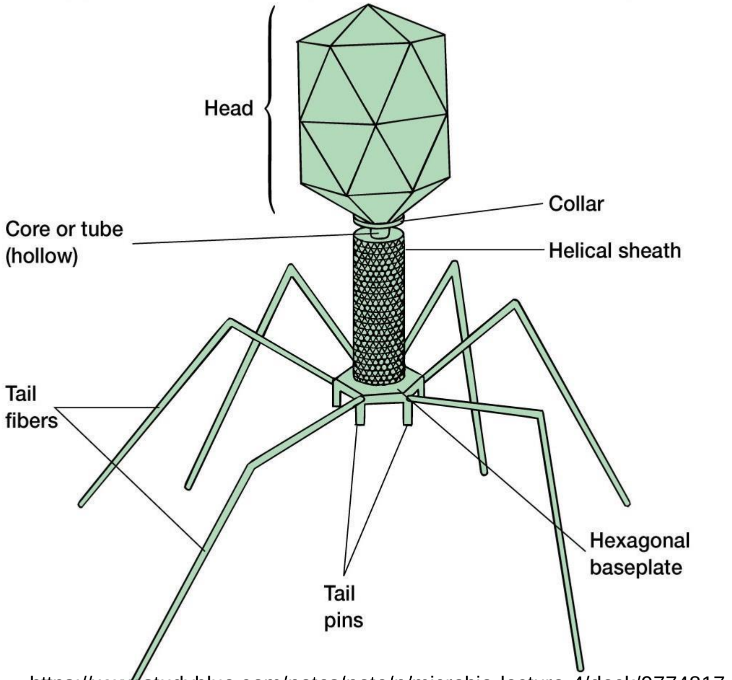




Christopher J. Burrell, ... Frederick A. Murphy, in Fenner and White's Medical Virology (Fifth Edition), 2017

4. Binal (Combined) Symmetry

- The head of the structure, which contains the genetic material, features icosahedral symmetry, whereas the tail features helical symmetry.
- Only in Bacteriophages



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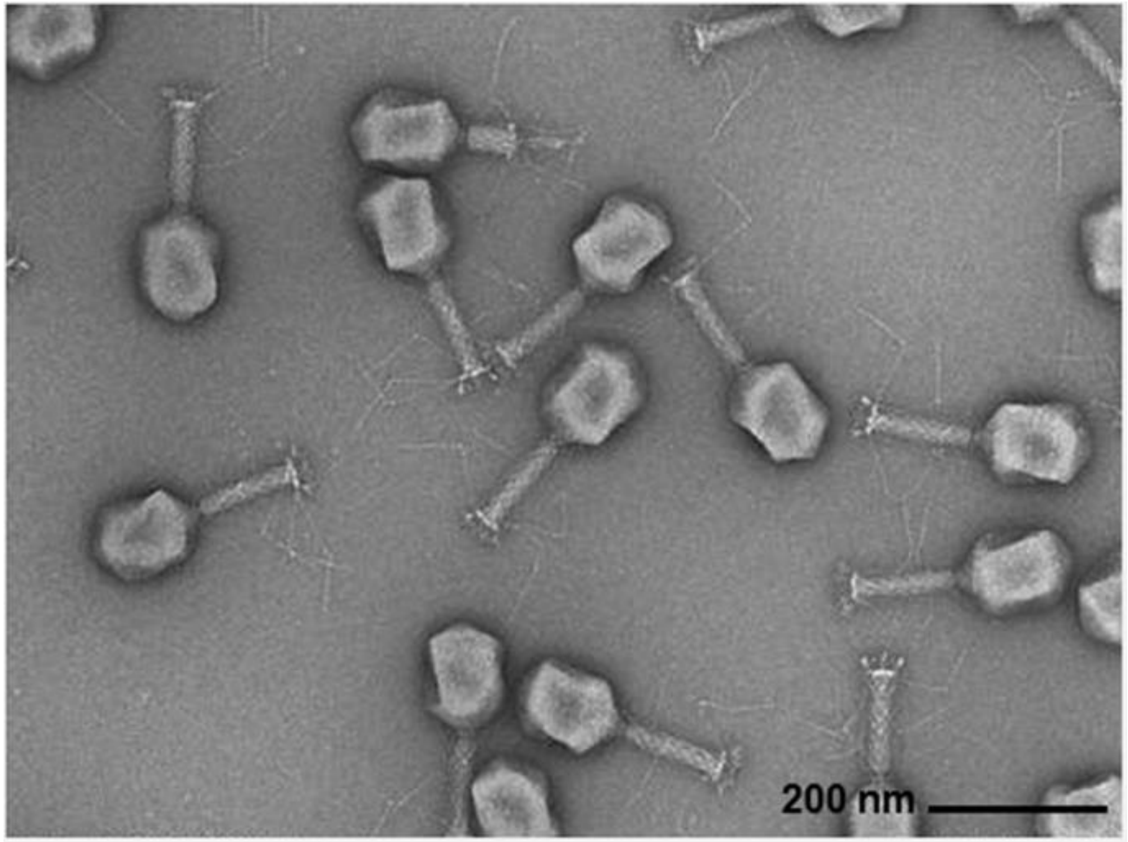
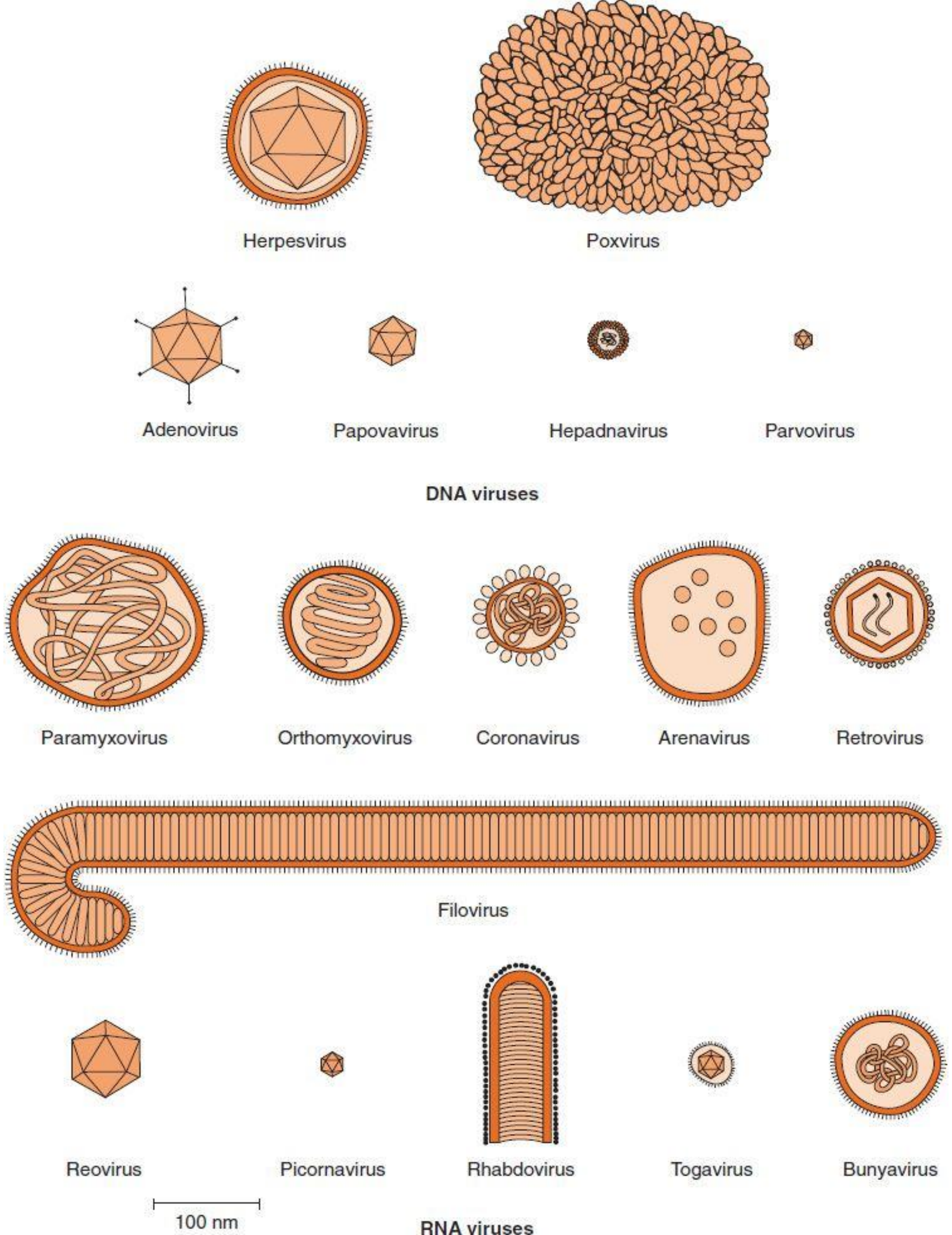


Leitner, L., McCallin, S. & Kessler, T.M. Bacteriophages: what role may they play in life after spinal cord injury?. *Spinal Cord* **59**, 967–970 (2021). https://doi.org/10.1038/s41393-021-00636-2



Herpesvirus
Poxvirus
Adenovirus
Papovavirus
Hepadnavirus
Parvovirus
DNA viruses
Paramyxovirus
Orthomyxovirus
Coronavirus
Arenavirus
Retrovirus
Filovirus
Reovirus
Picornavirus
Rhabdovirus
Togavirus
Bunyavirus
100 nm
RNA viruses

SENSITIVITY OF VIRUSES TO PHYSICAL AND CHEMICAL EFFECTS

➢1. Heat

- Viruses have very different sensitivities to changing temperatures.
- Enveloped viruses are more sensitive to rising temperatures than non-enveloped viruses.
- Likewise, it is known that viruses with icosahedral symmetry are more resistant to rising temperatures than viruses with helical symmetry.
- In general, the infectivity of viruses disappears within a few minutes at temperatures above 50°C. Many enveloped viruses become inactive within a few hours at room temperature (21-25°C) or 37°C.
- The main reason for the heat sensitivity of viruses is the denaturation of surface proteins.
- As the environmental temperature decreases, the resistance of viruses increases. Virus suspensions can be preserved for a long time by freezing or lyophilization.
    - Frozen viruses can be stored at (-20) °C or lower temperatures, and lyophilized viruses can be stored in the refrigerator (2-8 °C). Virus suspensions that will be stored for a very long time are kept at (-70) or (-196) °C.

➢2. pH

- Viruses should ideally be maintained at physiological pH. Many viruses maintain their infectivity between pH values of 5.0-9.0.Most enteric viruses are not affected by acidic pH values, but alkaline pH values (>9.0) negatively affect all viruses.

➢3. Radiation

- Radiation sources such as ultraviolet rays, X-rays, etc. inactivate viruses. These rays act directly on the viral nucleic acid.

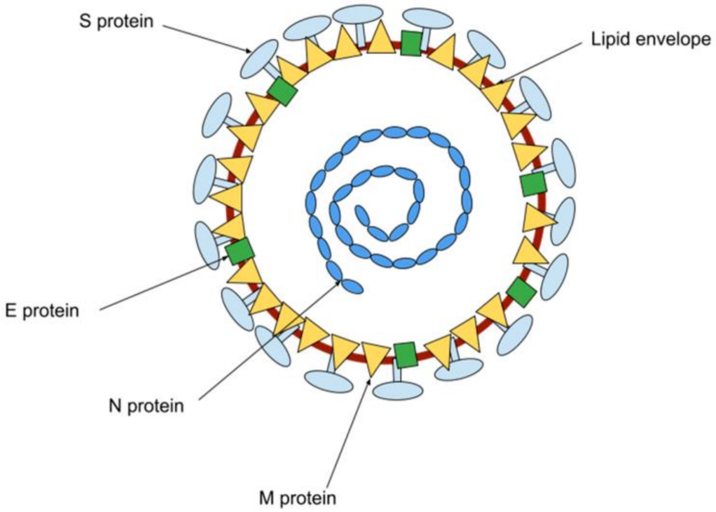
➢4.Photodynamic inactivation

- Vital dyes such as neutral red, proflavin and toluidine blue can penetrate into the virion at varying levels.
- These dyes, which subsequently bind to viral nucleic acid, can increase the rate of inactivation of the virus by sunlight.
  - This is especially important when purifying the virus using plaque testing.

➢5.Stabilization with salt solutions

- Salt solutions such as MgCl2, MgSO4, and Na2SO increase the resistance of many viruses to high temperatures.
  - For example, salt solutions prepared at 1M concentration can extend the resistance of viruses at 50°C for 1 hour.
  - This feature is important in the identification of viruses and in increasing the resistance of live virus vaccines to environmental conditions.

➢6. Sensitivity to lipid dissolvers



- Due to the high content of lipids in the structure of the envelope, the infectivity of enveloped viruses is affected by ether and chloroform. The same effect applies to detergent derivatives. The sensitivity of poxviruses, which are enveloped viruses, to ether varies.

➢7. Formaldehyde

- Formaldehyde affects the viral nucleic acid and eliminates the infectivity of the virus.
- Single-stranded viral nucleic acids are much more sensitive to formaldehyde than double-stranded ones.
- Since its negative effect on viral proteins is limited, formaldehyde can be used as an inactivating substance in the preparation of inactive vaccines.
- Due to its inactivating effect, the use of formaldehyde should be strictly avoided when sending samples for virus diagnosis.

Kononova, P.A.; Selyutina, O.Y.; Polyakov, N.E. The Interaction of the Transmembrane Domain of SARS-CoV-2 E-Protein with Glycyrrhizic Acid in Lipid Bilayer. *Membranes* **2023**, *13*, 505. https://doi.org/10.3390/membranes13050505

➢8.Other chemicals and antibacterial agents

- The infectivity of viruses is not affected by antibiotics and sulfonamides.
- It is generally accepted that quarterner ammonium compounds and phenol-derived compounds affect viruses at low levels.
- Organic iodine preparations have limited effectiveness against viruses. High levels of chlorine compounds can affect viruses.
- Alcohol (ethanol, isopropyl alcohol) has limited activity against non-enveloped viruses.
- One of the most effective chemicals in virus inactivation is bleach.