جـامـعـة الملك سعود
King Saud University

Lecture 3 :

Virus Structure

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Capsid symmetry and virus architecture

By the end of this lecture students will be able to:

- Describe the functional organization of viral particles.
- Explain the different of viral symmetry.
- Describe the basic virus components.
- Define viral capsid, types of viral genome, viral symmetry, nucleoscapsid and capsomers.

Capsid symmetry and virus architecture

- In 1957, Fraenkel-Conrat and Williams showed that incubation of a mixture of purified TMV RNA and coat protein resulted in the formation of particles.

- This means that the particle is in the free energy minimum state and is the most energetically favored structure of the components.

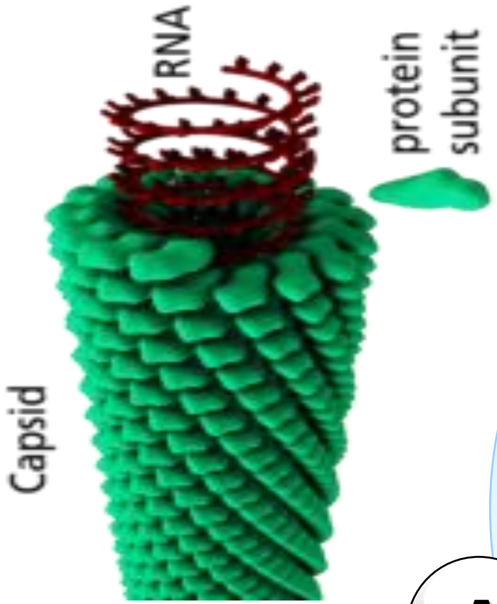
- The forces that drive the assembly of virus particles include hydrophobic and electrostatic interactions.

Capsid symmetry and virus architecture

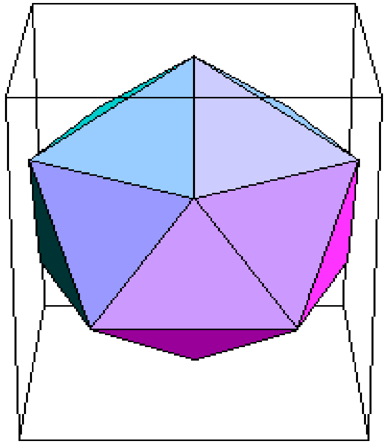
- In order to form particles, viruses must overcome two fundamental problems.
  - First: they must assemble the particle using only the information available from the components that make up the particle itself.
  - Second: virus particles form regular geometric shapes, even though the proteins from which they are made are irregular.
- How do these simple organisms solve these difficulties?
- The solutions to both problems lie in the rules of symmetry.
- In biological terms, this means that protein-protein, protein-nucleic acid, and protein-lipid interactions are involved

The Capsid Symmetry

Capsid Symmetry

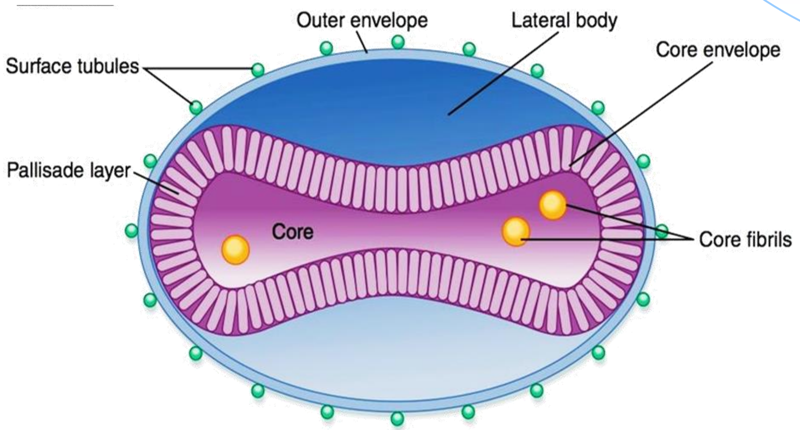


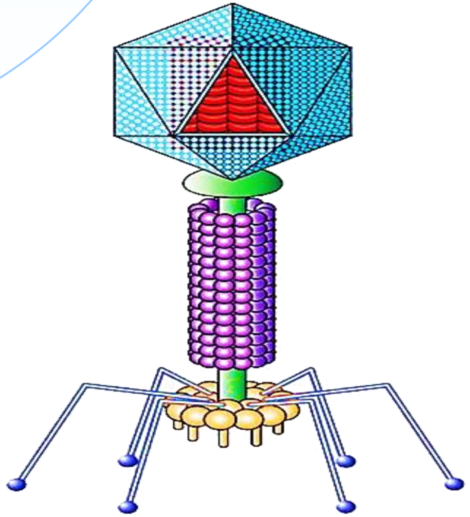
A Helical Symmetry



B Icosahedral Symmetry

C Complex

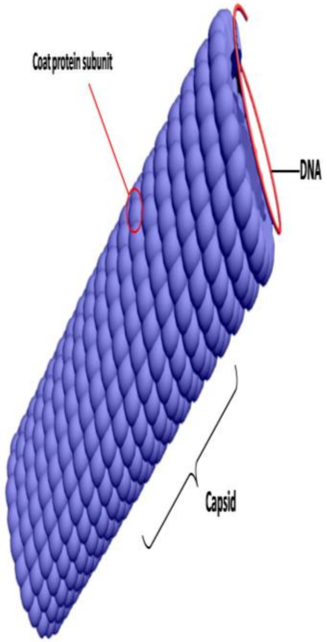


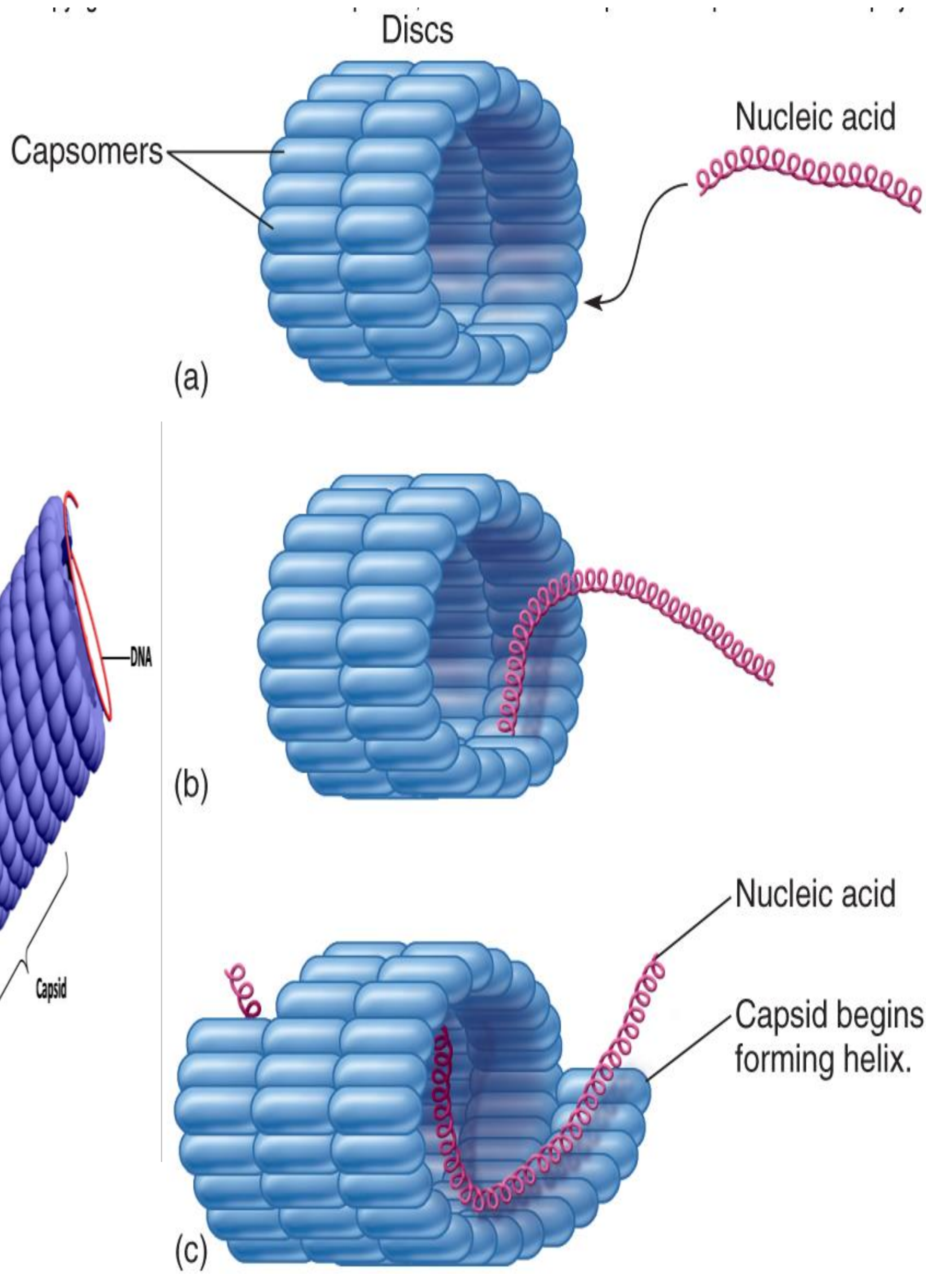


The Capsid Symmetry

A- Helical Symmetry

- Rod shaped, varying widths and specific architectures; no theoretical limit to the amount of nucleic acid that can be packaged.
- • Organized around a single axis (the "helix axis")
  - Allow flexibility (bending)
  - Helical viruses form a closely related spring like helix instead.
  - The best studied is the TMV but many animal viruses and phage use this general arrangement.





• Note-all animal viruses that are helical are enveloped, unlike many of the phage and plant viruses.

The Capsid Symmetry

A- Helical Capsid Symmetry

- TMV particles are rigid, rod-like structures, but some helical viruses demonstrate considerable flexibility, and longer helical virus particles are often curved or bent.

- Flexibility is an important property. Long helical particles are likely to be subject to shear forces and the ability to bend reduces the likelihood of breakage or damage.

- Unlike plant viruses, **helical non-enveloped animal viruses do not exist**. A large number of animal viruses are based on helical symmetry, but they all have an outer lipid envelope

- influenza virus (Orthomyxoviridae), mumps and measles viruses (Paramyxoviridae), and rabies virus (Rhabdoviridae).

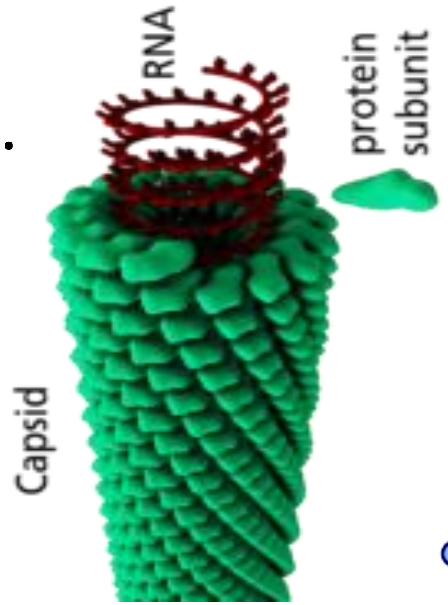
The Capsid Symmetry

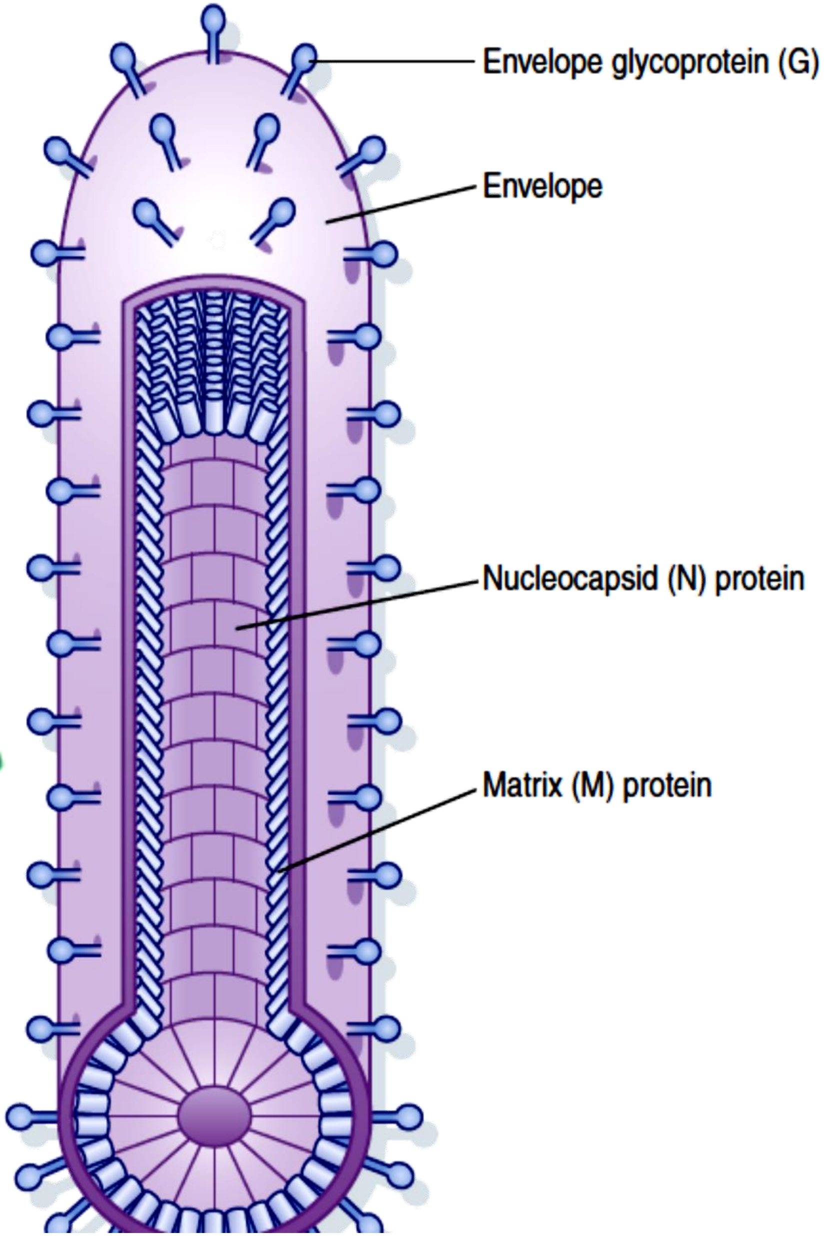
A- Helical Capsid Symmetry

Rhabdovirus particles, such as those of vesicular stomatitis virus, have an inner helical nucleocapsid surrounded by an outer lipid envelope and its associated glycoproteins.

Long tube of proteins, with genome inside.

Tube length reflects size of viral genome.





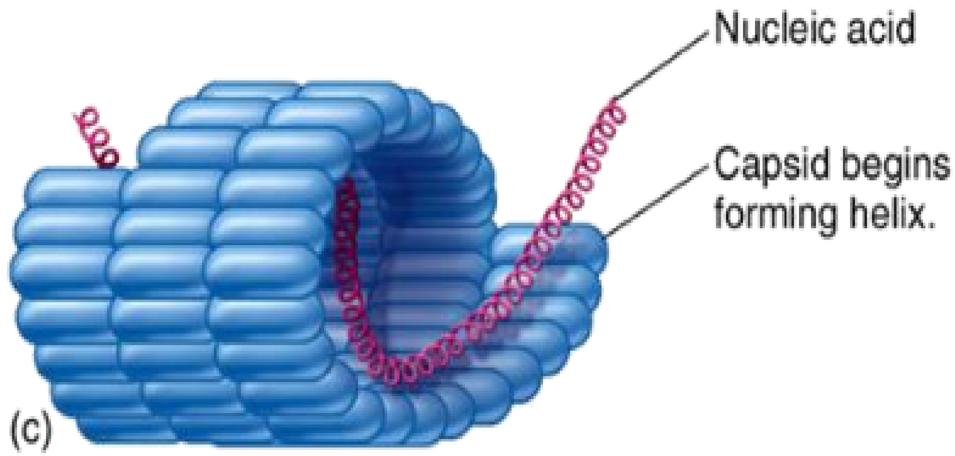
The Capsid Symmetry

A- Helical Capsid Symmetry

Capsid and Envelope

Non-enveloped

Helical



Capsid:

- Protect viral nucleic acid
- Interact with the nucleic acid for packaging
- Interact with vector for specific transmission
- Interact with host receptors for entry to cell and to release of nucleic acid

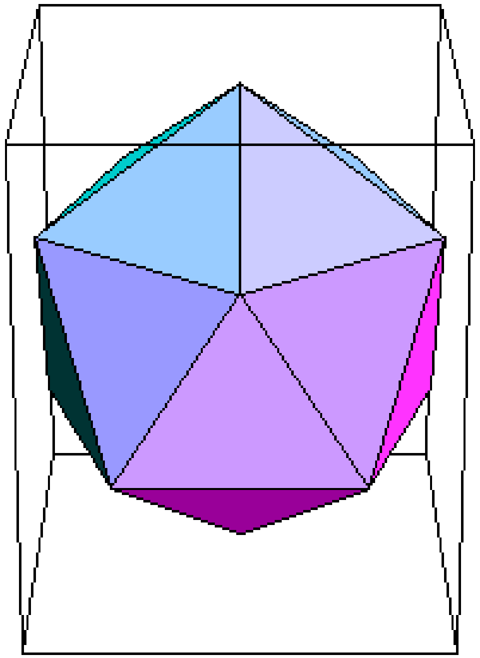
The Capsid- *Icosahedral Symmetry*

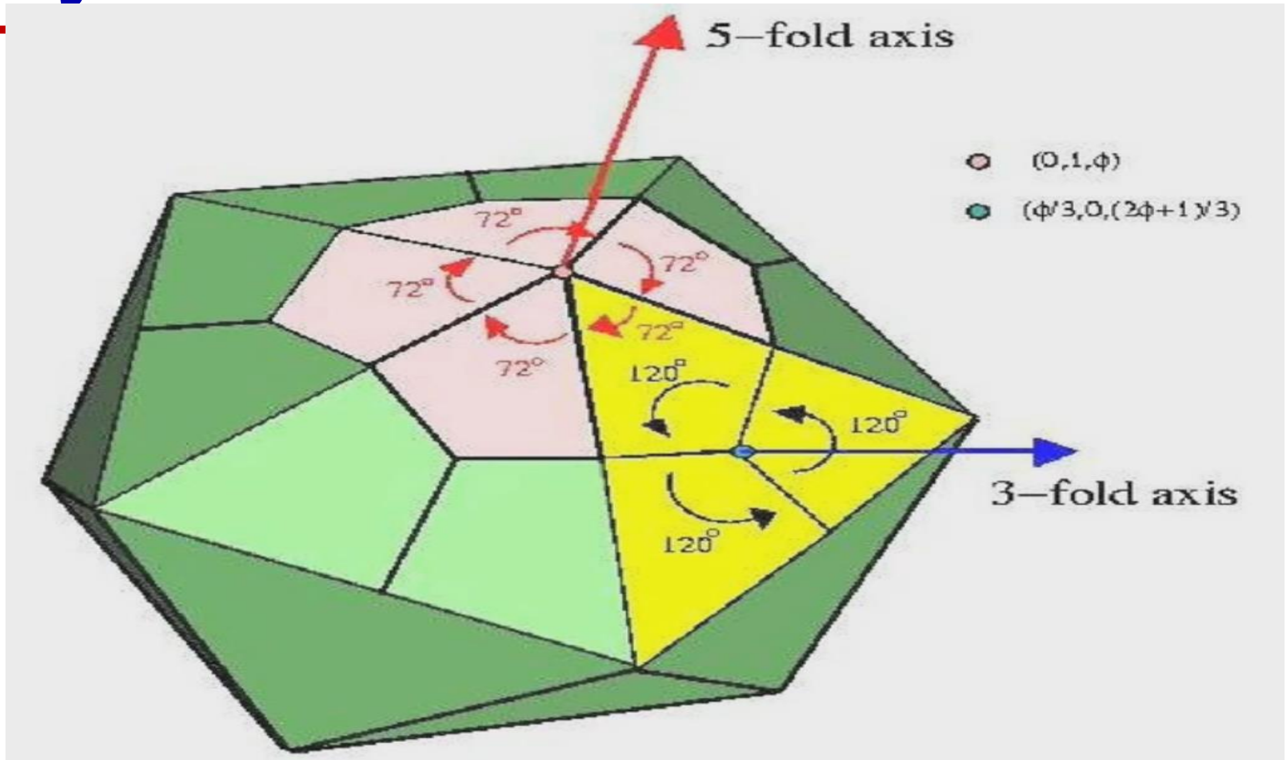
B- Icosahedral Capsid Symmetry

An alternative way of building a virus capsid is to arrange protein subunits in the form of a hollow quasispherical.

The Capsid- *Icosahedral Symmetry*

B- Icosahedral Capsid Symmetry





5-fold symmetry at the vertices
2-fold through the edges
3-fold through the center of each triangular face.

The Capsid- *Icosahedral Symmetry*

- The simplest icosahedral capsids are built up by using three identical subunits to form each triangular face (20 triangular faces, 3 subunits per face, 60 identical subunits).

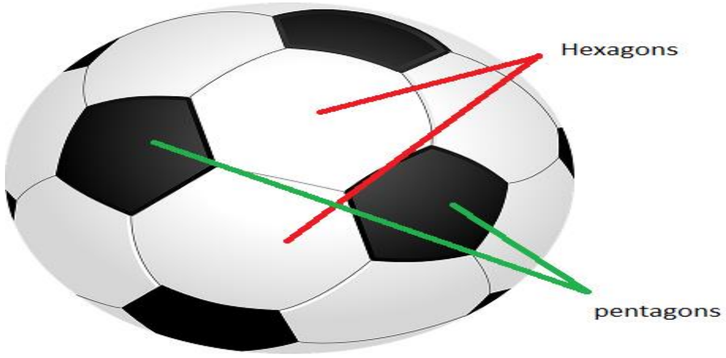
- Icosahedron with 60 identical subunits is a very stable structure because all the subunits are equivalently bonded (i.e., they show the same spacing relative to one another and each occupies the minimum free energy state).

- With more than 60 subunits it is impossible for them all (subunits) to be arranged completely symmetrically with exactly equivalent bonds to all their neighbors, since a true regular icosahedron consists of only 20 subunits.

The Capsid- *Icosahedral Symmetry*

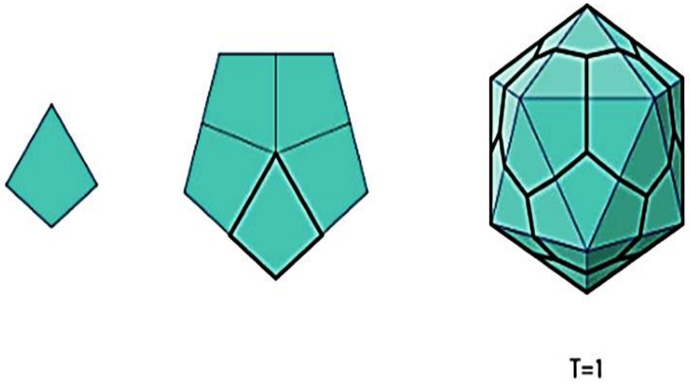
Quasi-equivalence (*Caspar and Klug, 1962*).

Subunits in nearly the same local environment form nearly equivalent bonds with their neighbors, permitting self-assembly of icosahedral capsids from multiple subunits.

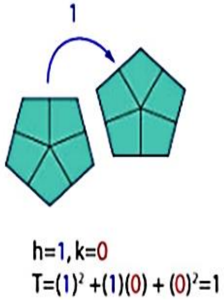


- **20 triangular sides each side made up of at least 3 identical capsid proteins**
- **12 conrners**

T=1 icosahedral capsid protein



T=1 icosahedral capsid is composed of 12 pentameric capsomeres for a total of 60 capsid proteins.



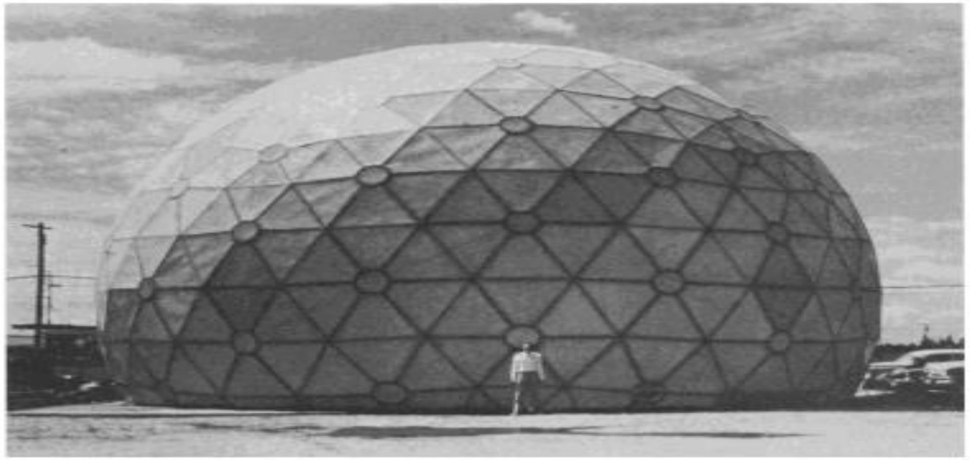
The Capsid- *Icosahedral Symmetry*

Quasi-equivalence (*Caspar and Klug, 1962*).

QUASI-EQUIVALENCE

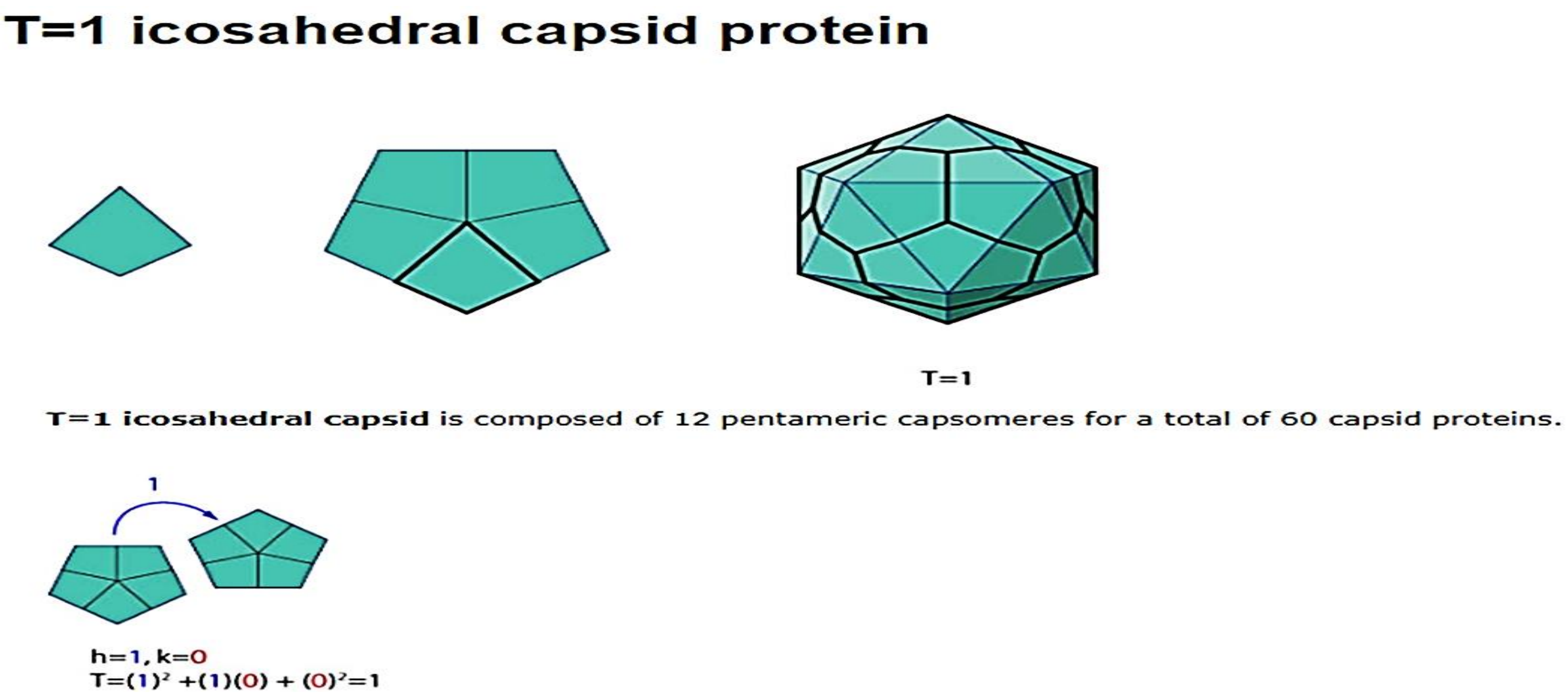
1962, Caspar and Klug – found a principal of building icosahedral structures from similar blocks

- Shell is built from the same blocks
- Bonds are deformed in a slightly different ways
- Assumed a possibility of 5 degrees deformation
- Shell can contain 60n subunits



A Fuller geodesic dome That inspired Caspar and Klug

The Capsid- *Icosahedral Symmetry*



- 20 triangular sides each side made up of at least 3 identical capsid proteins
- 12 conrners

The Capsid- *Icosahedral Symmetry*

- Structural units on faces to give morphological capsomers Pentons (5 fold axis of symmetry) Hexons

- 3 fold through face

- 2 fold through edge

The Capsid- *Complex Symmetry*

C- Complex Capsid

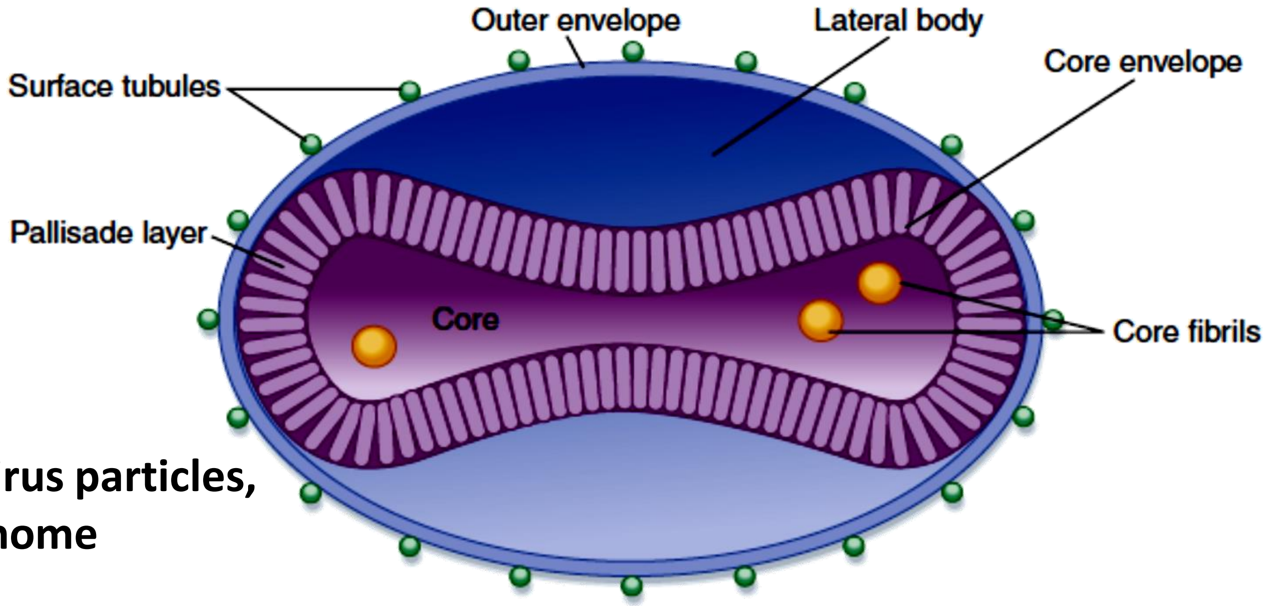
Complex capsid viruses cannot be simply defined by a mathematical equation as can a simple helix or icosahedron.

Poxviruses

These viruses have oval or brickshaped particles 200 to 400 nm long.

The particles are extremely complex and contain more than 100 different proteins

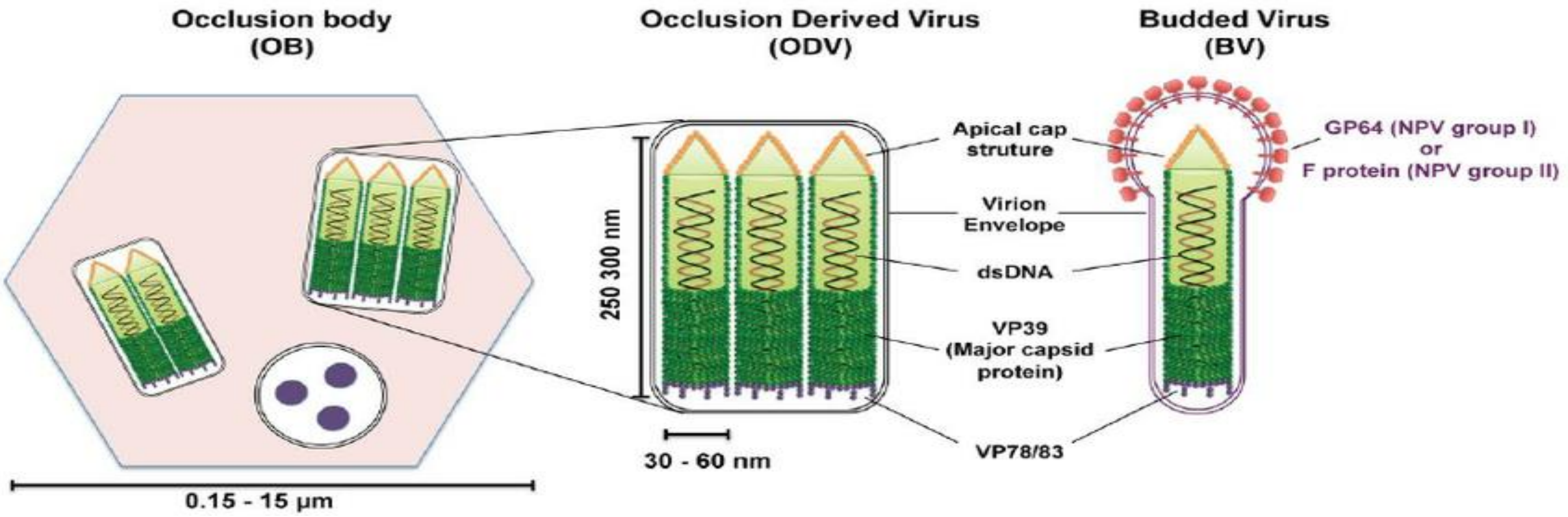
Two forms; extracellular forms that contain two membranes and intracellular particles that have only an inner membrane.



There are at least ten enzymes present in poxvirus particles, mostly involved in nucleic acid metabolism/genome replication.

The Capsid- *Complex Symmetry*

Baculovirus



These complex viruses contain 12 to 30 structural proteins.

Rod-like (hence, “baculo”) nucleocapsid that is 30 to 90 nm in diameter and 200 to 450 nm long

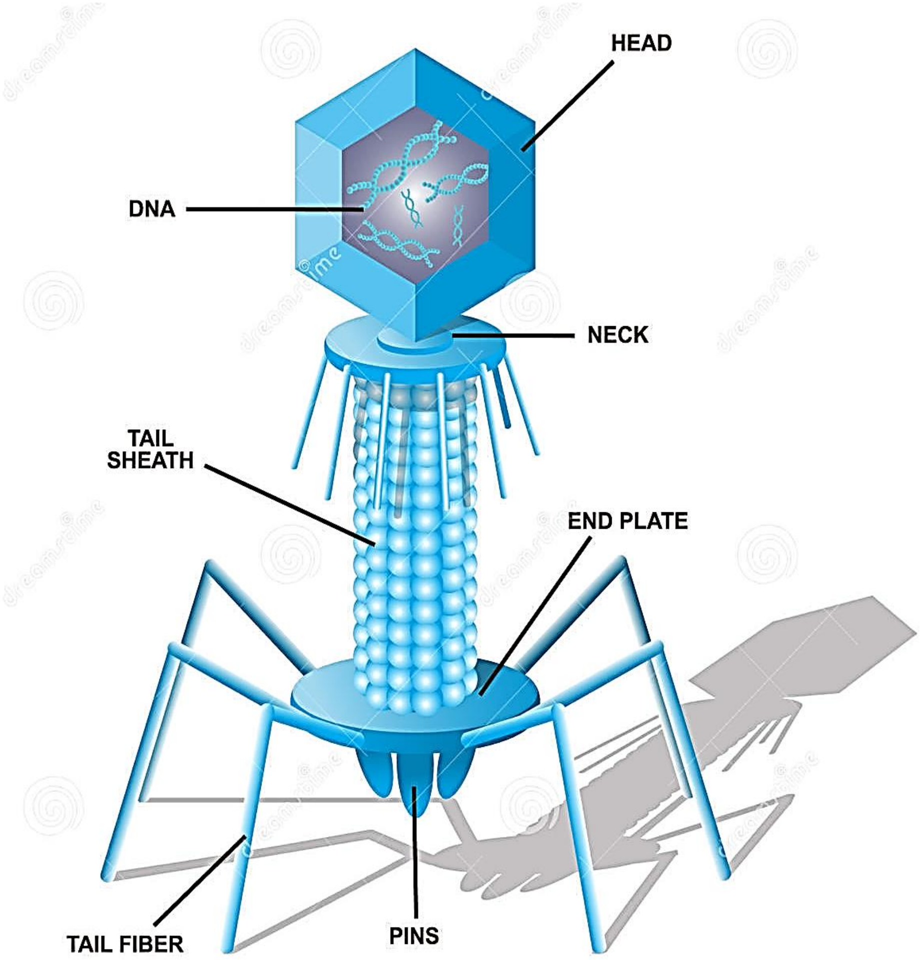
Nucleocapsid contains the 90- to 230-kbp double-stranded DNA genome

The nucleocapsid is surrounded by an envelope, outside which there may be a crystalline protein matrix.

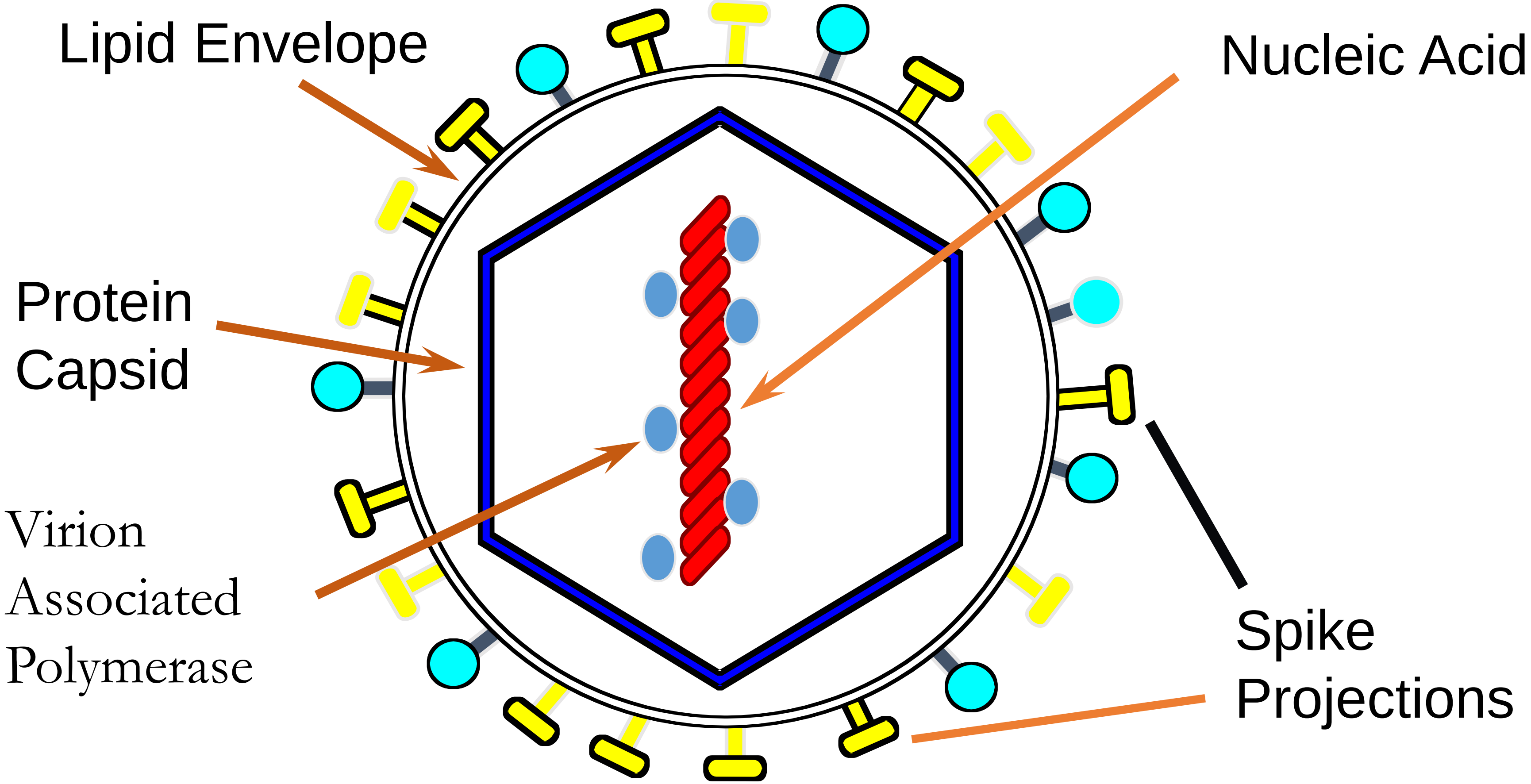
The Capsid- *Complex Symmetry*

Bacteriophage

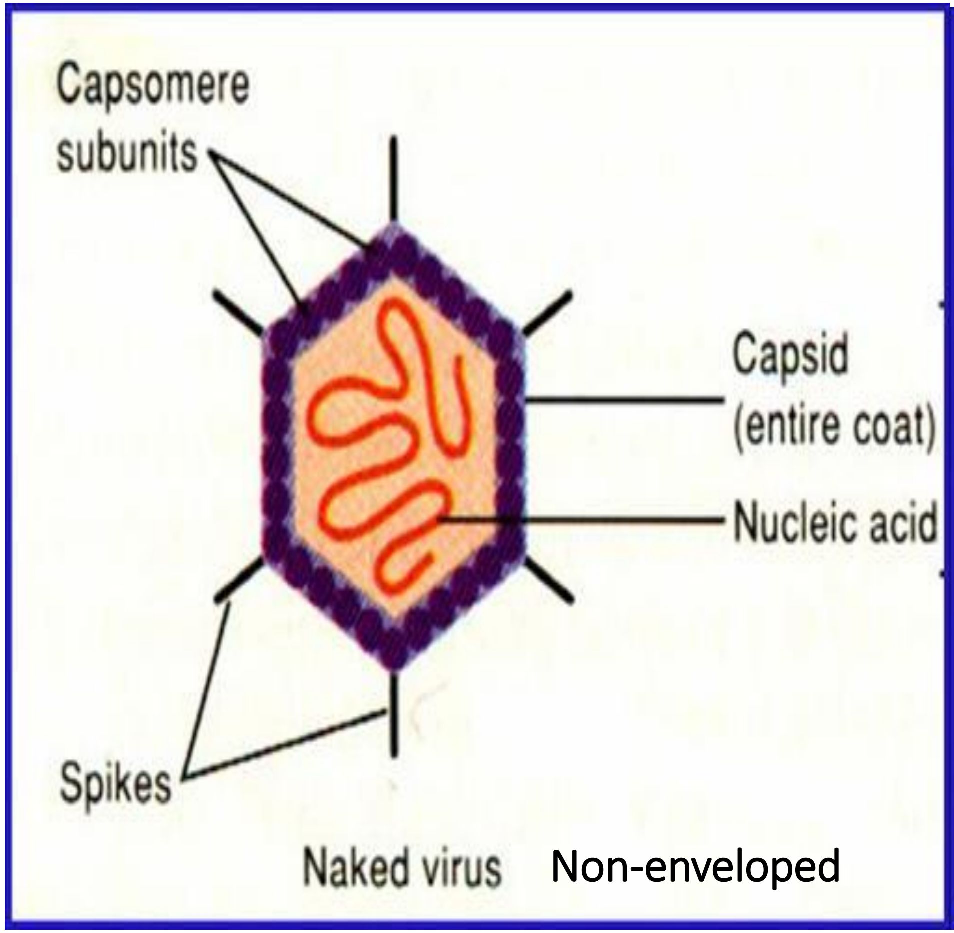
The heads of these particles consist of an icosahedral shell with T = 7 symmetry attached by a collar to a contractile, helical tail.

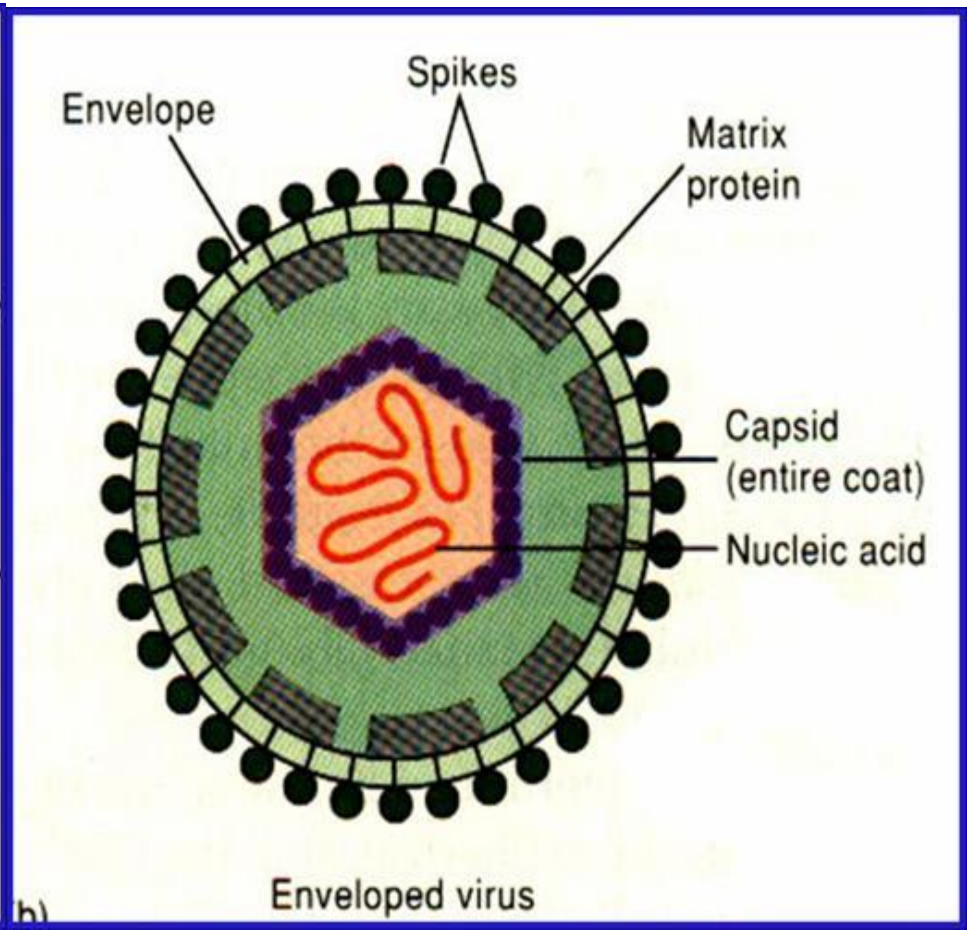


Basic Virus Components



Two Types of Viruses

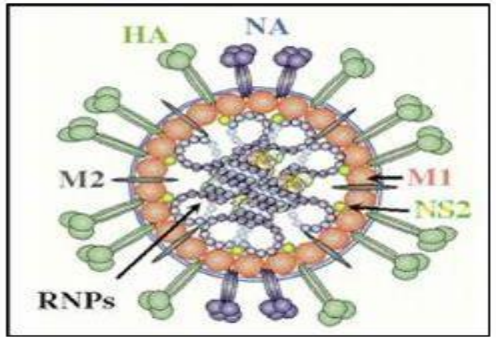


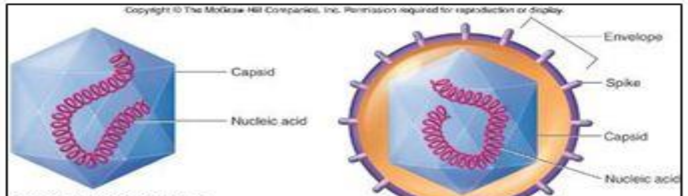


Basic Virus Components

General Structure of Viruses

- Viral envelope
  - mostly animal viruses
  - acquired when virus leaves host cell
  - Protects the nucleic acid when the virion is outside the host cell
  - **spikes**
    - exposed proteins on the outside of the envelope
    - essential for attachment of the virus to the host cell
  - **Naked**
    - composed only of a nucleocapsid
  - **Enveloped**
    - surrounded by an envelope



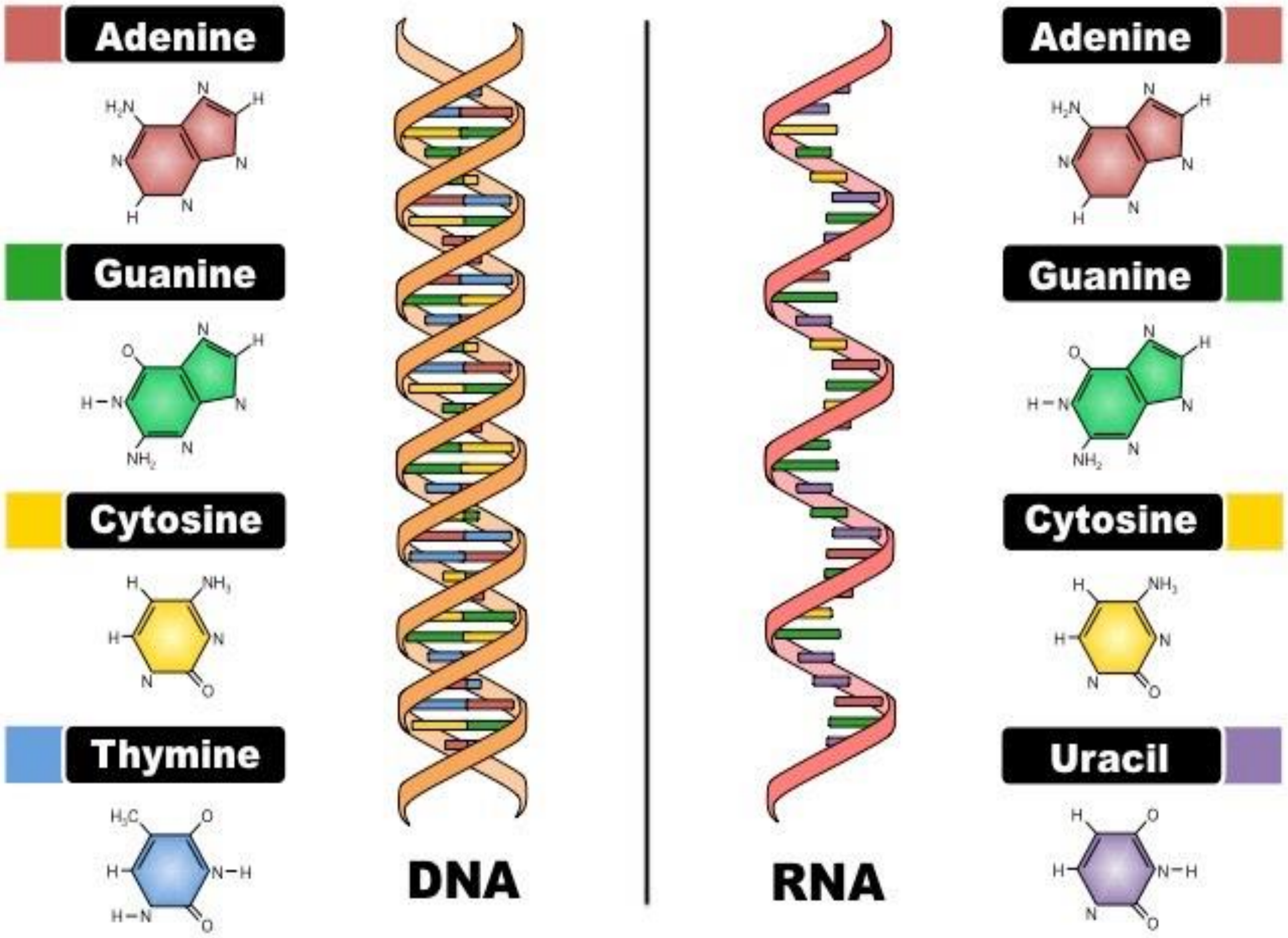


(a) Naked Nucleocapsid Virus

(b) Enveloped Virus

Virus Nucleic Acid (Genome)

1- Type:



Virus Nucleic Acid (Genome)

2- Strandness:

dsDNA

Most DNA Viruses

Pox - Herpes

ssDNA

Rare

Parvo - Circo

ds RNA

Rare

Reo - Birna

ss RNA

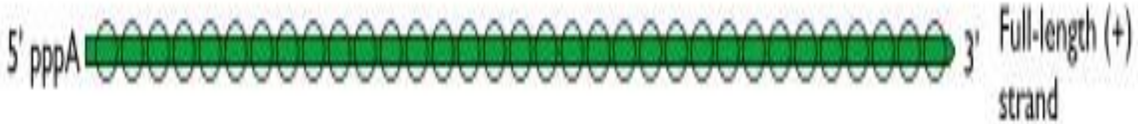
Most RNA Viruses

Influenza

Virus Nucleic Acid (Genome)

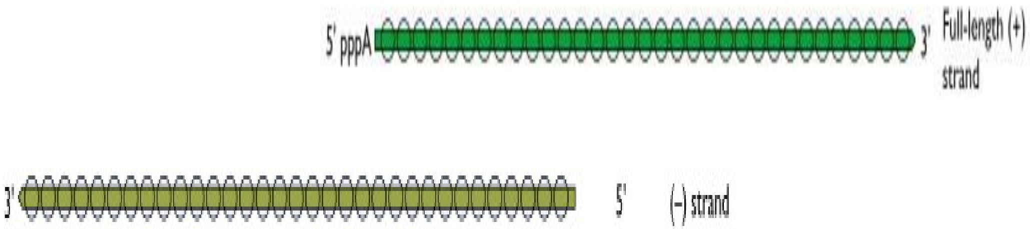
3- Sense (polarity):

Positive Sense



Negative Sense

AmbiSense

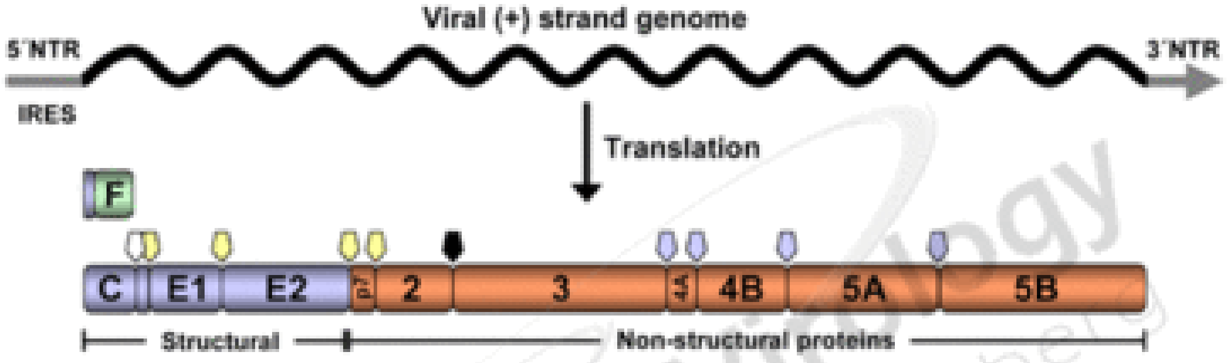


Virus Nucleic Acid (Genome)

4- Linearity:

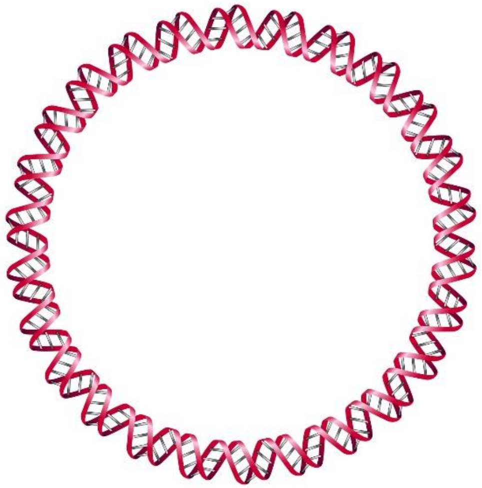
Linear:

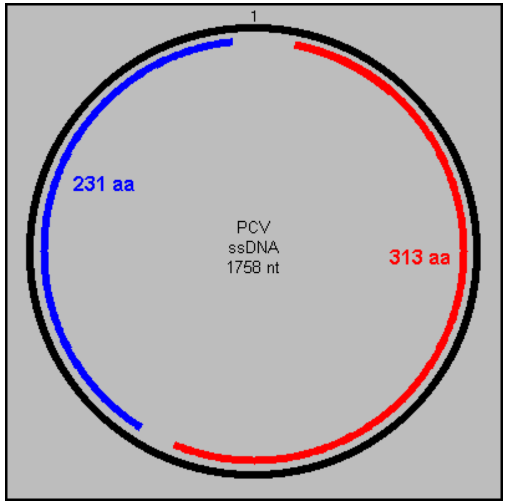
HIV - HCV



Circular:

Circo - HBV

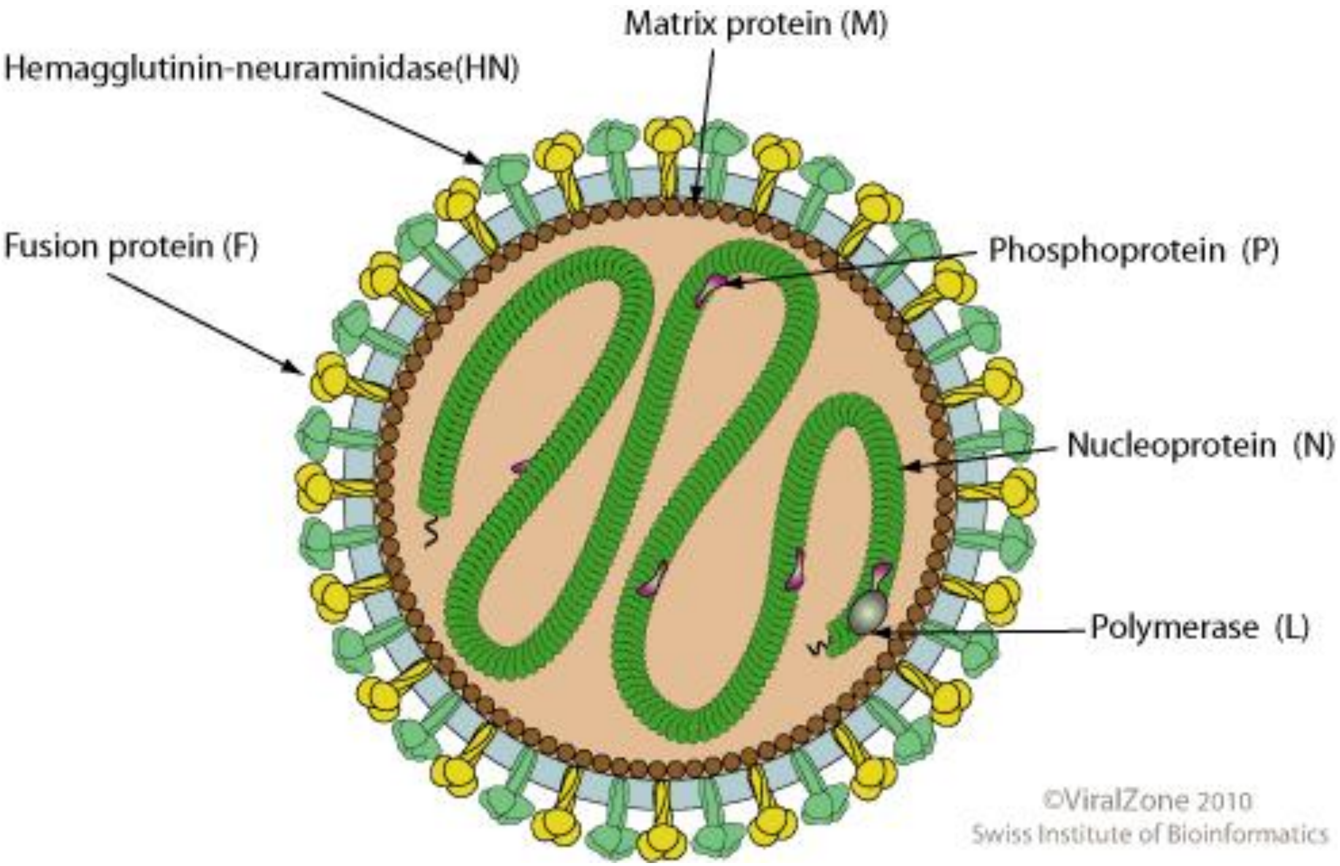




Virus Nucleic Acid (Genome)

5- Segmentation:

Single molecule:

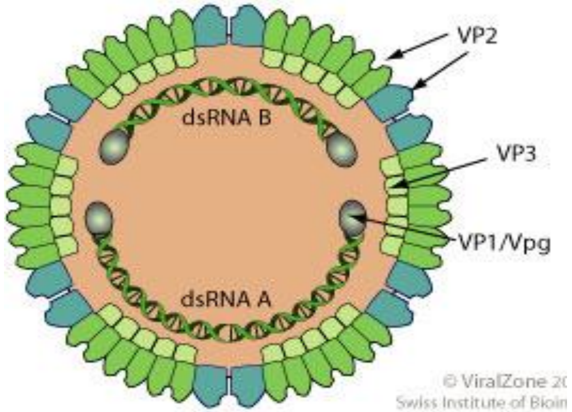


Measles

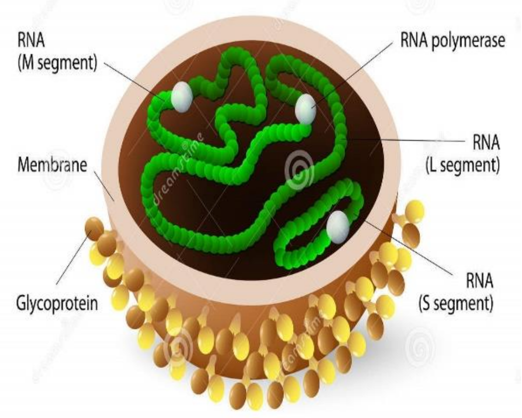
Virus Nucleic Acid (Genome)

5- Segmentation:

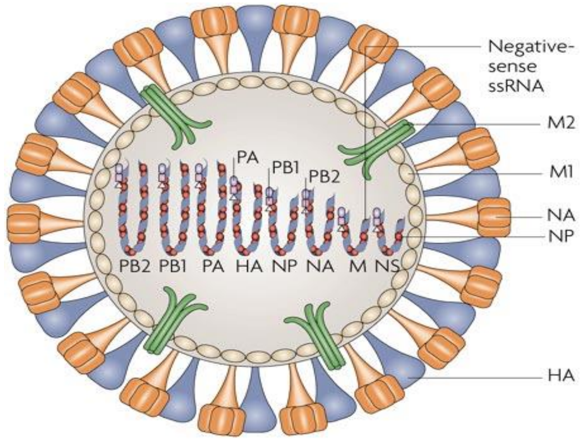
Segmented Genome:



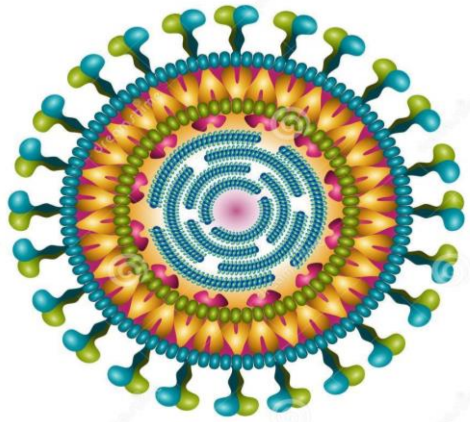
2 segments (Birna)



3 segments (RVF)



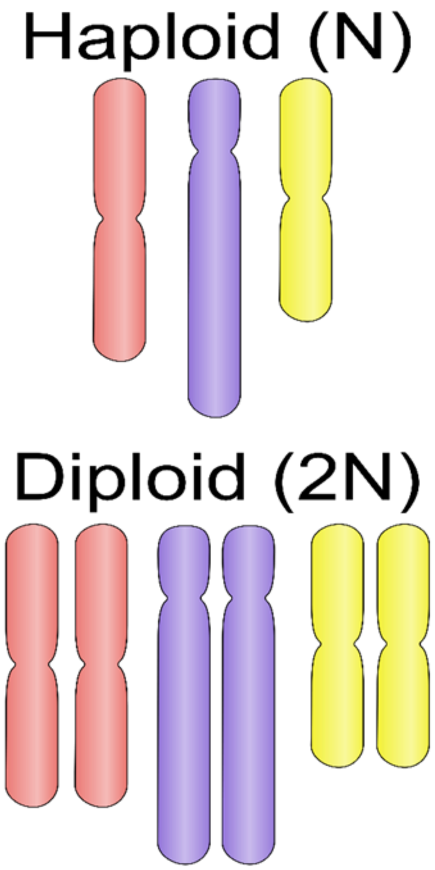
8 segments (Influenza)



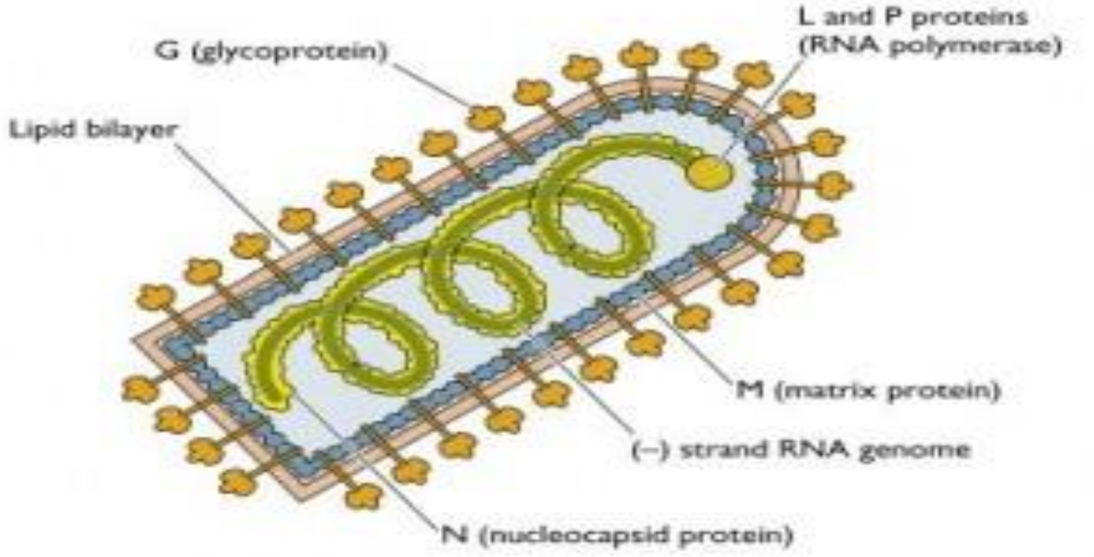
11 segments (Rota)

Virus Nucleic Acid (Genome)

6- Ploidy:

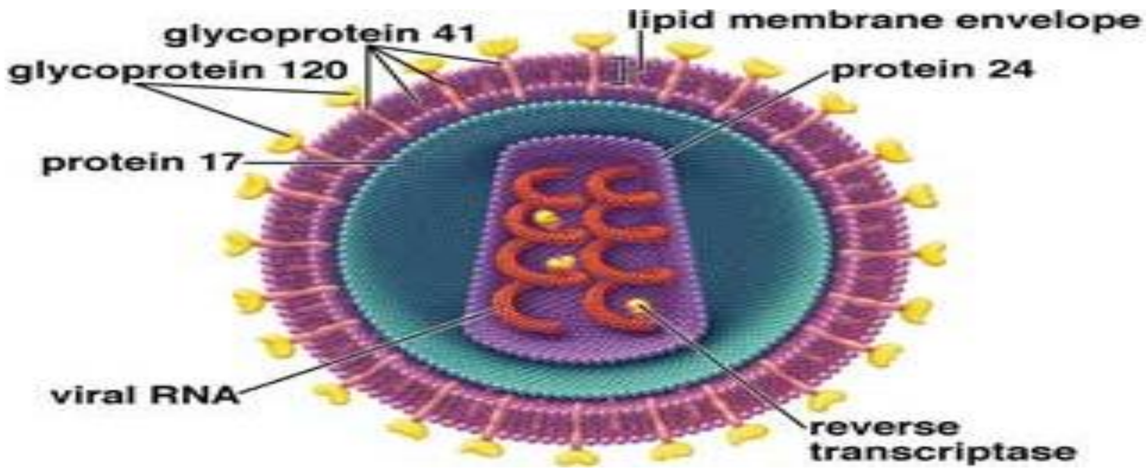


Haploid:



Diploid:

HIV



Virus Nucleic Acid (Genome)

Example: Influenza Virus

RNA

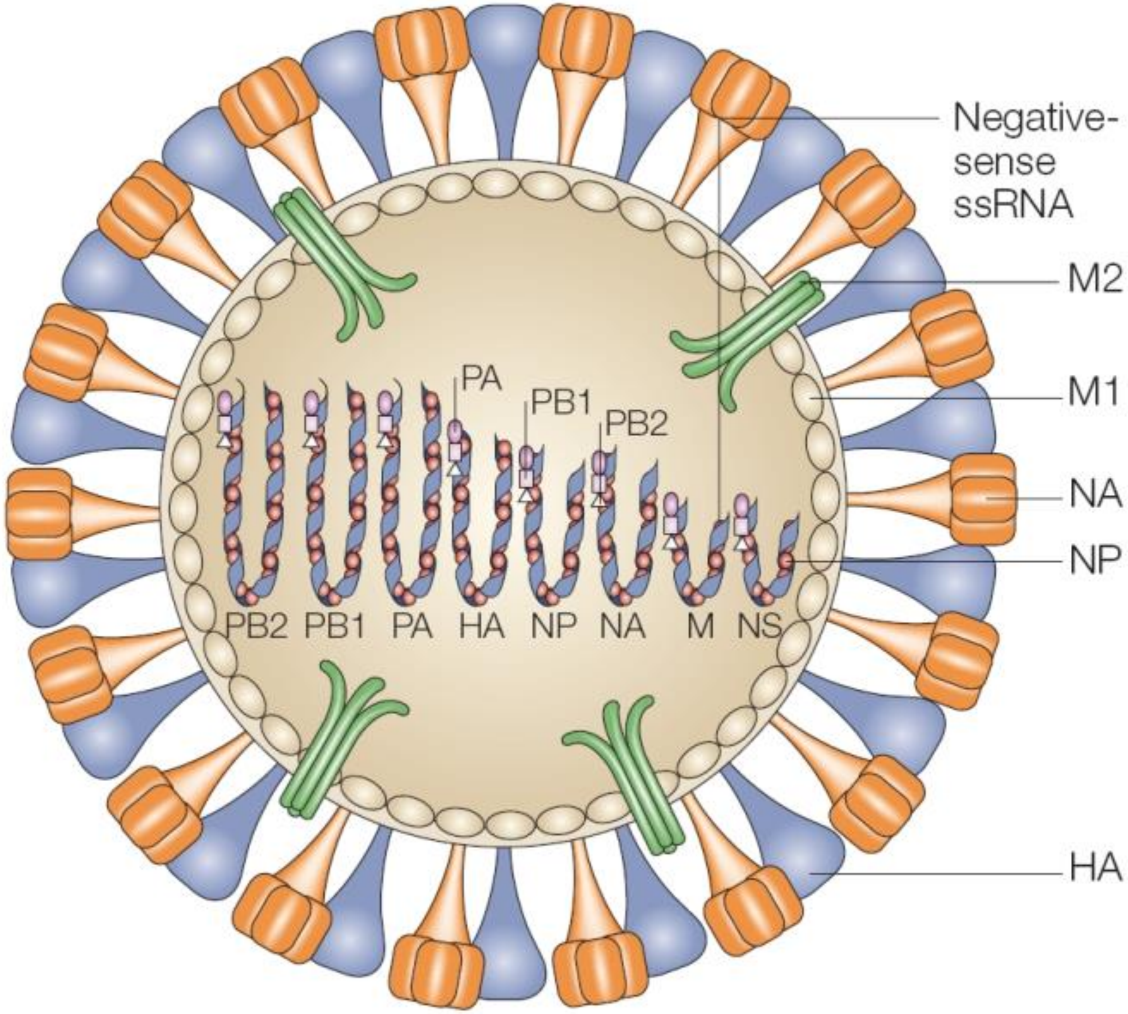
Single stranded

Negative sense

Linear

Segmented (6-8 seg

Haploid



General Structure of Viruses

Capsids

- All viruses have capsids-protein coats that enclose and protect their nucleic acid.
- Each capsid is constructed from identical subunits called capsomers made of protein.
- The capsid together with the nucleic acid are nucleoscapsid.

Summary

DNA or RNA

Single or double stranded

Positive or negative sense

Linear or circular

Segmented or non-segmented

Diploid or haploid

Virus particle central core

- Nucleic acid molecules (DNA/RNA)
- Matrix proteins enzymes (not in all)

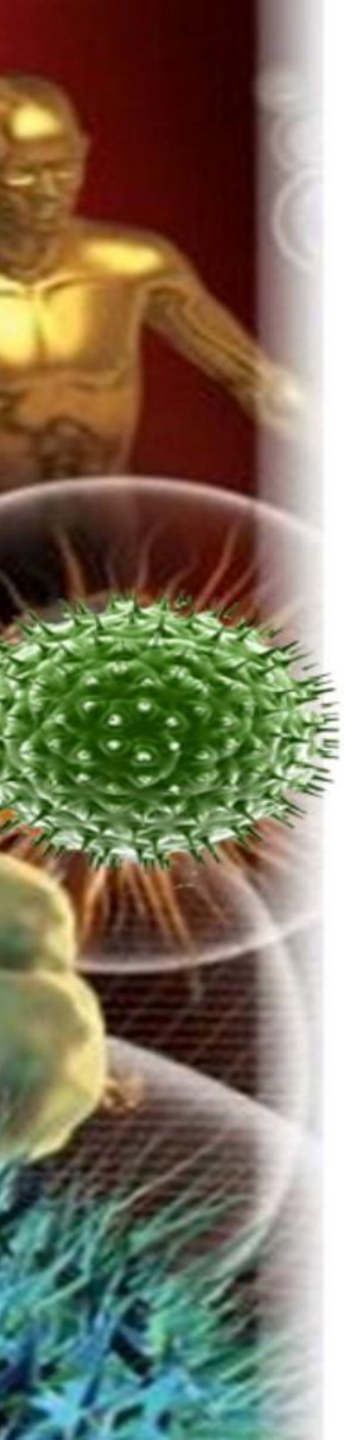
The Capsid- Functions

Capsid functions

1. Protect genome from atmosphere (May include damaging UV-light, shearing forces, nucleases either leaked or secreted by cells).

2. Virus-attachment protein- interacts with cellular receptor to initiate infection.

3. Delivery of genome in infectious form. May simply "dump" genome into cytoplasm (most +ssRNA viruses) or serve as the core for replication (retroviruses and rotaviruses)-----allow virus to establish infection.



Questions

1. Discuss the geometric differences among helical, polyhedral, and complex viruses.
2. In order to form particles, viruses must overcome two fundamental problems, briefly discuss.?
3. What are the THREE (3) main shapes (morphology) of viruses?
4. How many fold does the virus have - at the vertices?, the edges? and through the center of each triangular face?.
5. Mention TWO (2) viral capsid functions?
6. The envelope of a virus is derived from the host's -----------?
7. A virus containing only nucleic acid and a capsid is called a/an ------- virus or ------ virus.
8. What is building subunits of capsid?

If today wasn't a good day, tomorrow will always give you a second chance


Thank You