General Virology 304

Lecture Series II

Virus Structure

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Virus

Infectious units (obligate intracellular parasites) consisting of either RNA or DNA enclosed in a protective coat.

Submicroscopic agents that infect living organisms often causing disease. They are unable to replicate without a host cell and are not typically considered as living organisms.

Ultramicroscopic metabolically inert infectious agent that replicates only within cells of living hosts; mainly human, animals, plants and bacteria.

Virus

Virus can infect all types of organisms:

Human, animals, plants, bacteria, fungi, algae, protozoa, ….. viruses

Virus exists in two forms:

1- Extracellular (transmissible form) ….. Virion

2- Intracellular (replicative form)

Properties common to all viruses

- **Viruses** are very small (they are not detected by light microscope – pass from bacterial filters).
- **Viruses** are subcellular composition (No cell wall – No organelles – No metabolic pathways).
- **Viruses** have a genome of either DNA or RNA.
- **Viruses** can only reproduce in living cells since they lack the metabolic enzymes essential for energy production and protein synthesis.

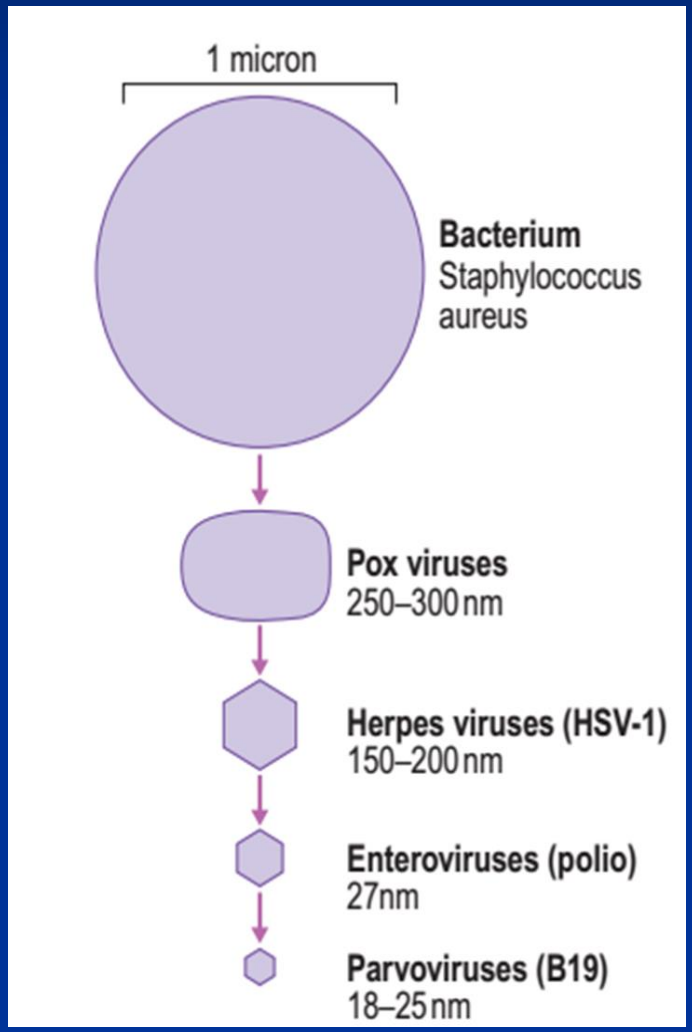
Are Viruses Living?

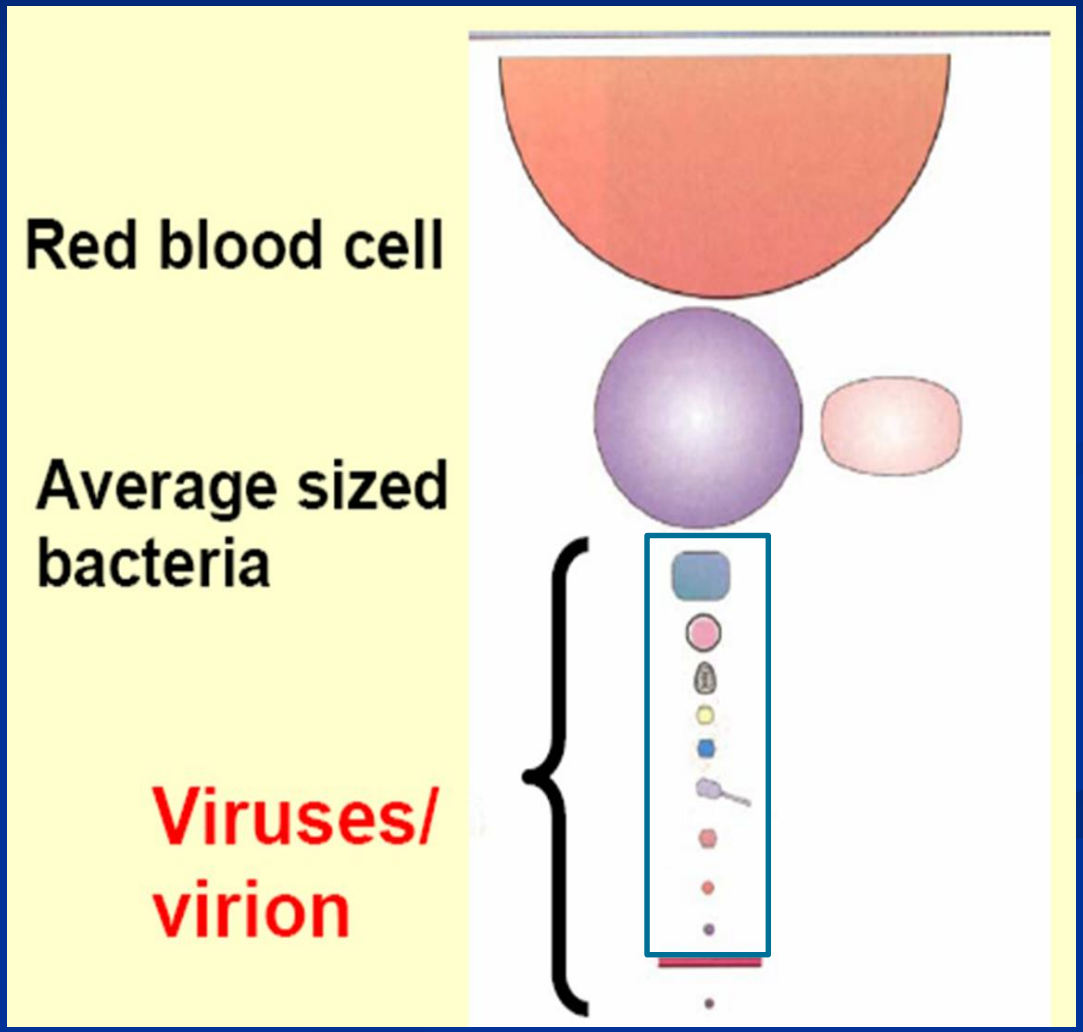
Properties of Living Organisms	*Properties of Viruses*
Breathes (respires)	Doesn't breathe
Metabolizes	Doesn't metabolize
Grows	Doesn't grow
Reproduces	Reproduces

Viruses are not typical living organisms

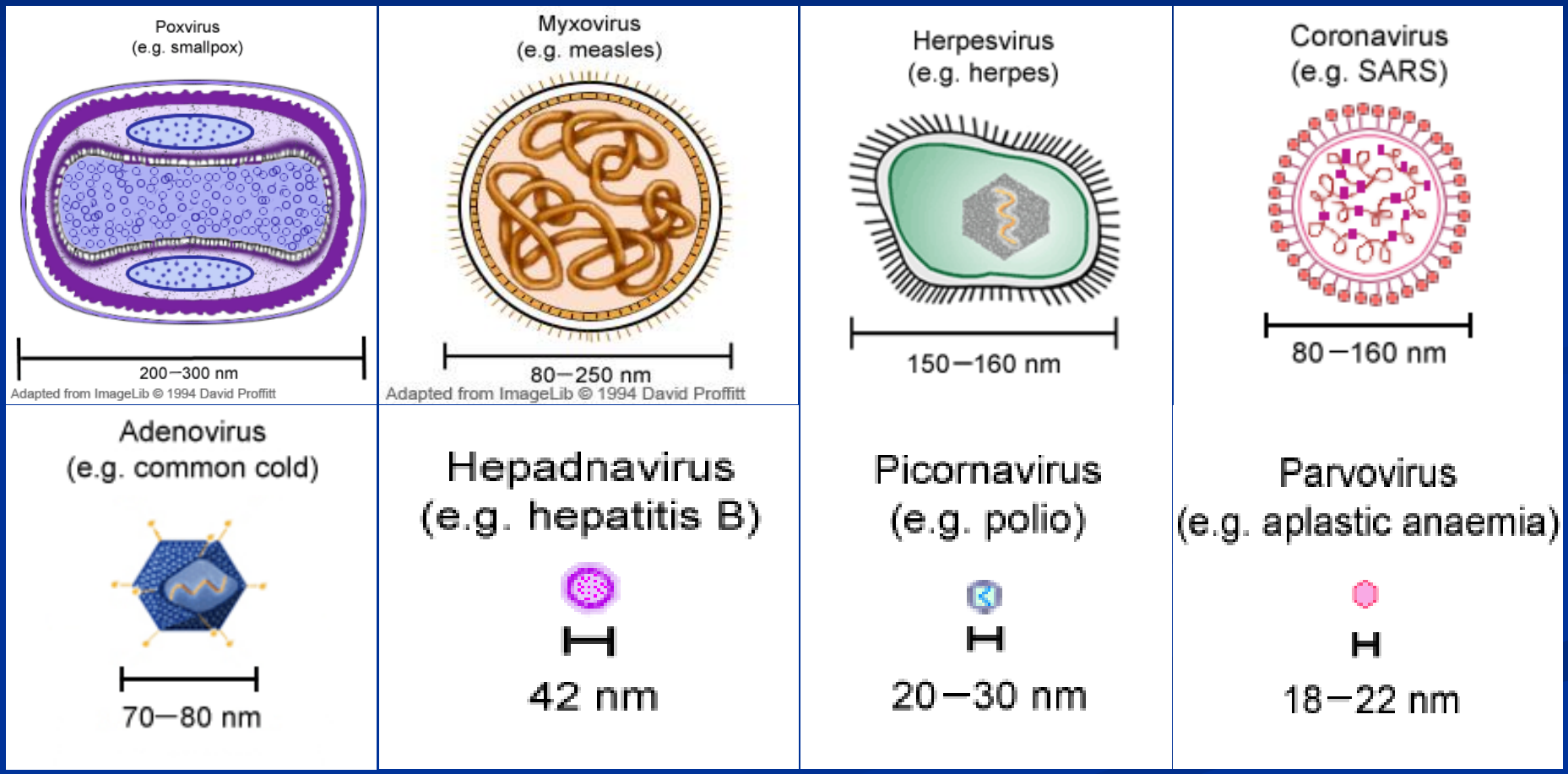
Virus: It is a life but not as we know it … …

Virus Size


1 micron
Bacterium
Staphylococcus
aureus
Pox viruses
250–300 nm
Herpes viruses (HSV-1)
150–200 nm
Enteroviruses (polio)
27nm
Parvoviruses (B19)
18–25 nm


Red blood cell
Average sized
bacteria
Viruses/
virion

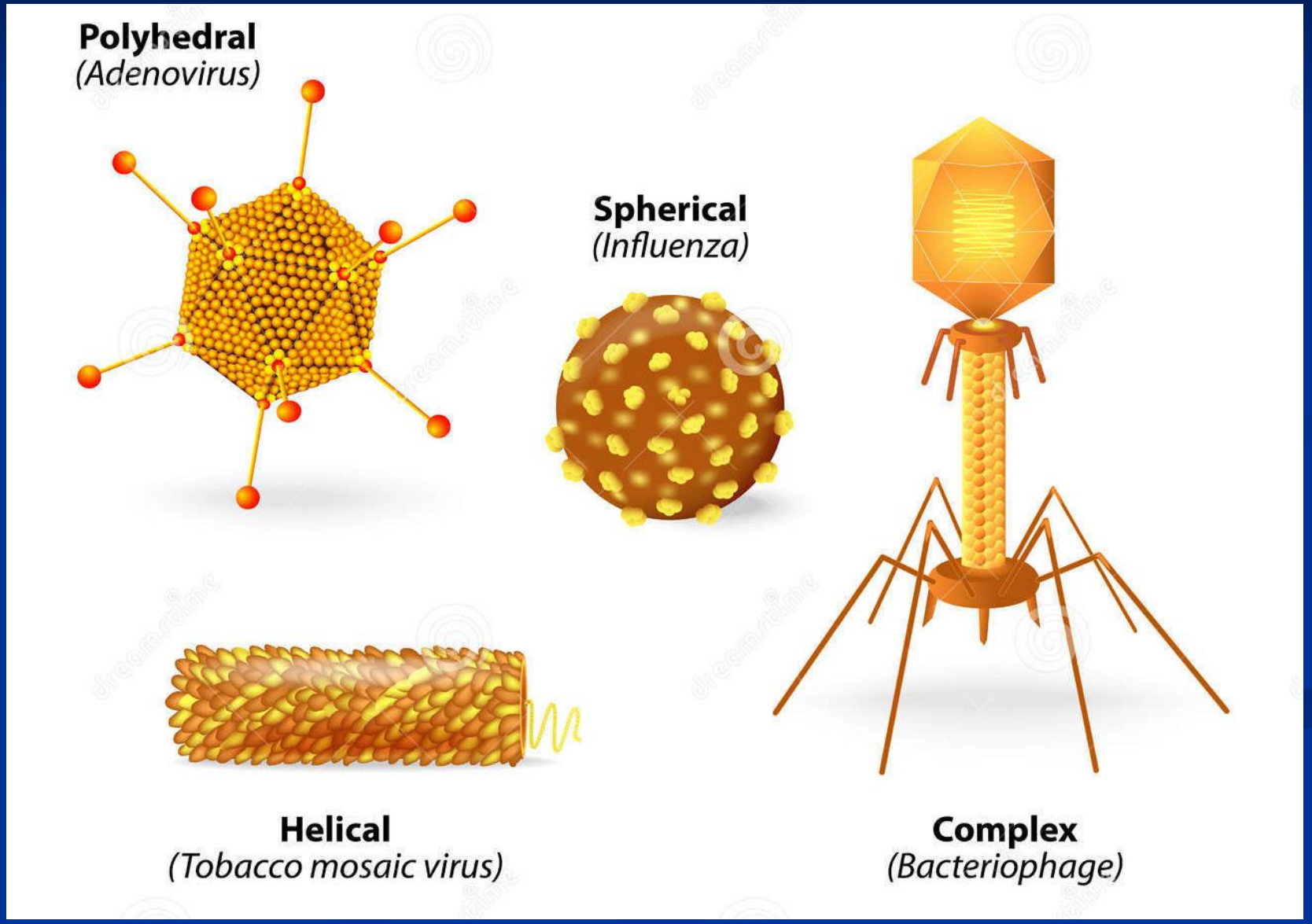
Virus Size



18-300 nm

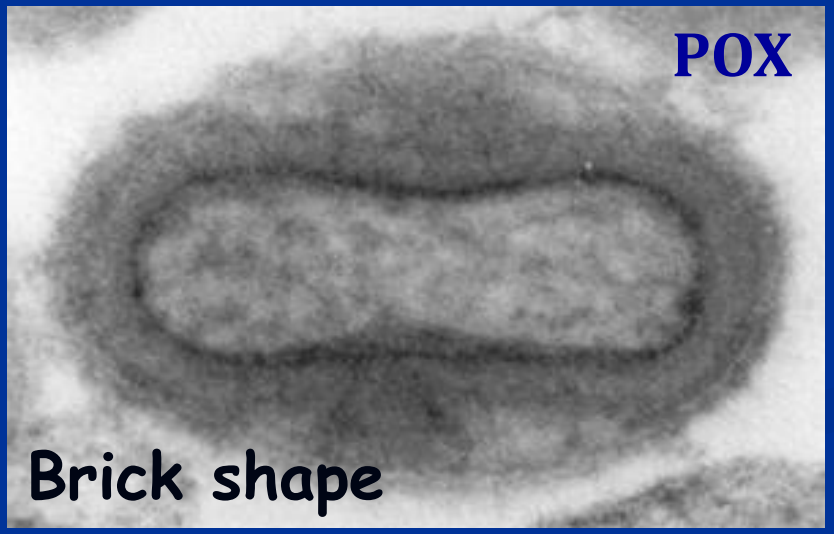
Virus shape

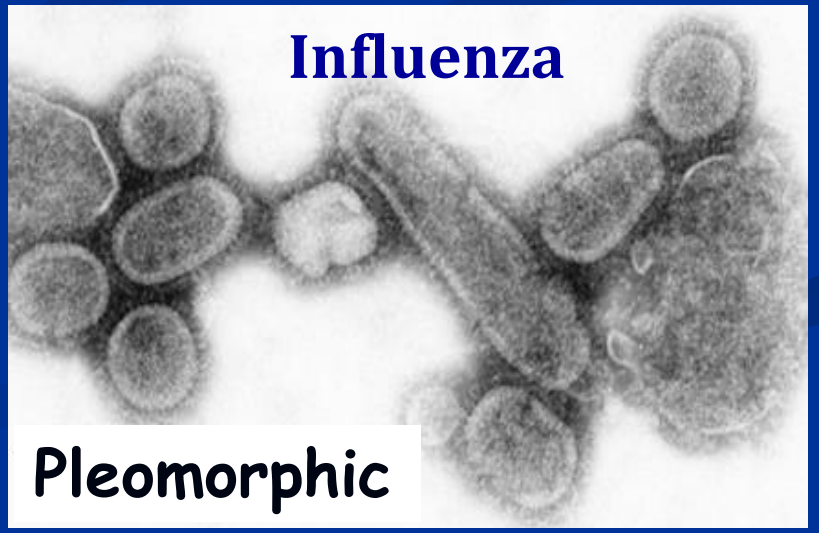
COMMON SHAPES



Virus shape

INFREQUENT SHAPES

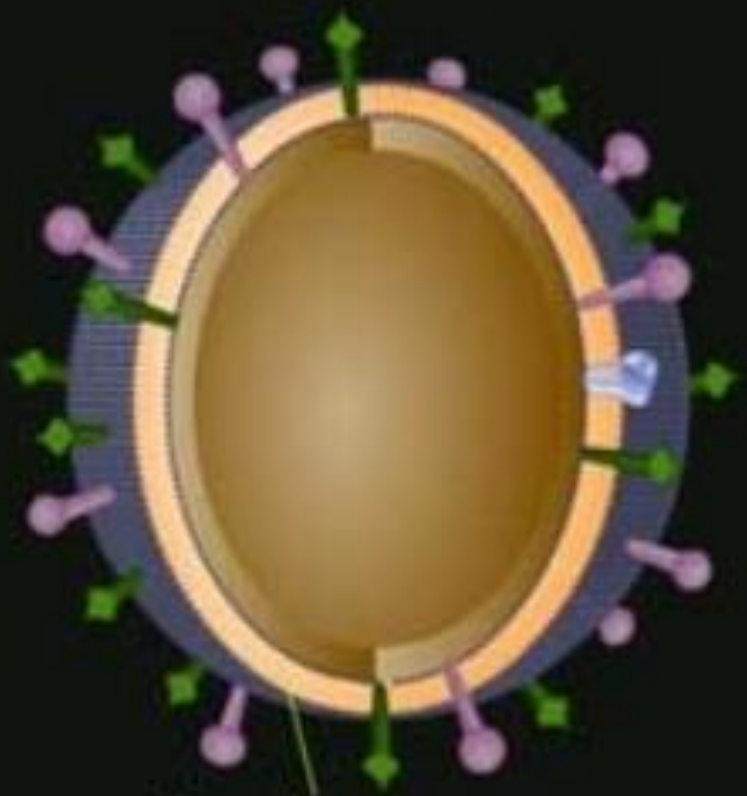




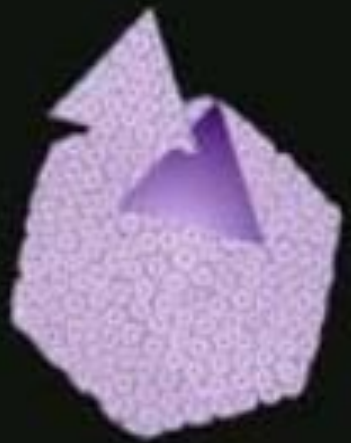
What is a virus made up of?

Thus the major components of virions are:

a) Nucleic acid b) Protein coat-capsid c) Lipid envelope



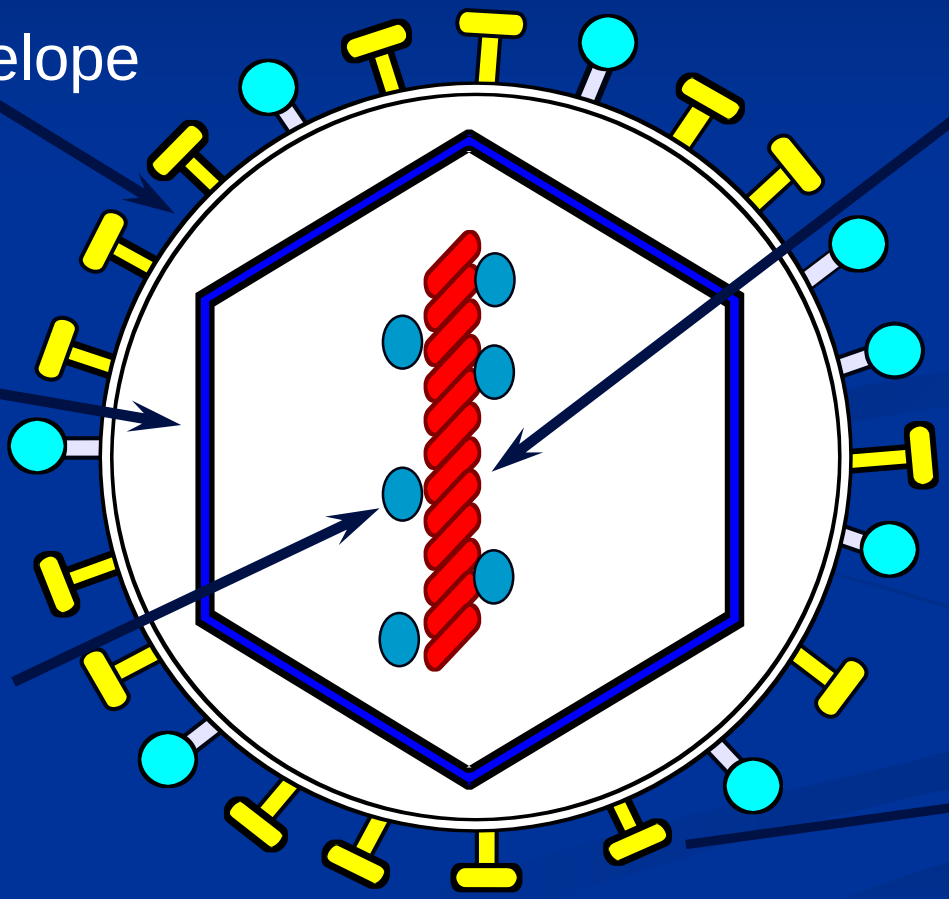
Envelope
(Phospholipid bilayer.)



Capsid

Nucleic acid
(Genome)

Basic Virus Components



Lipid Envelope

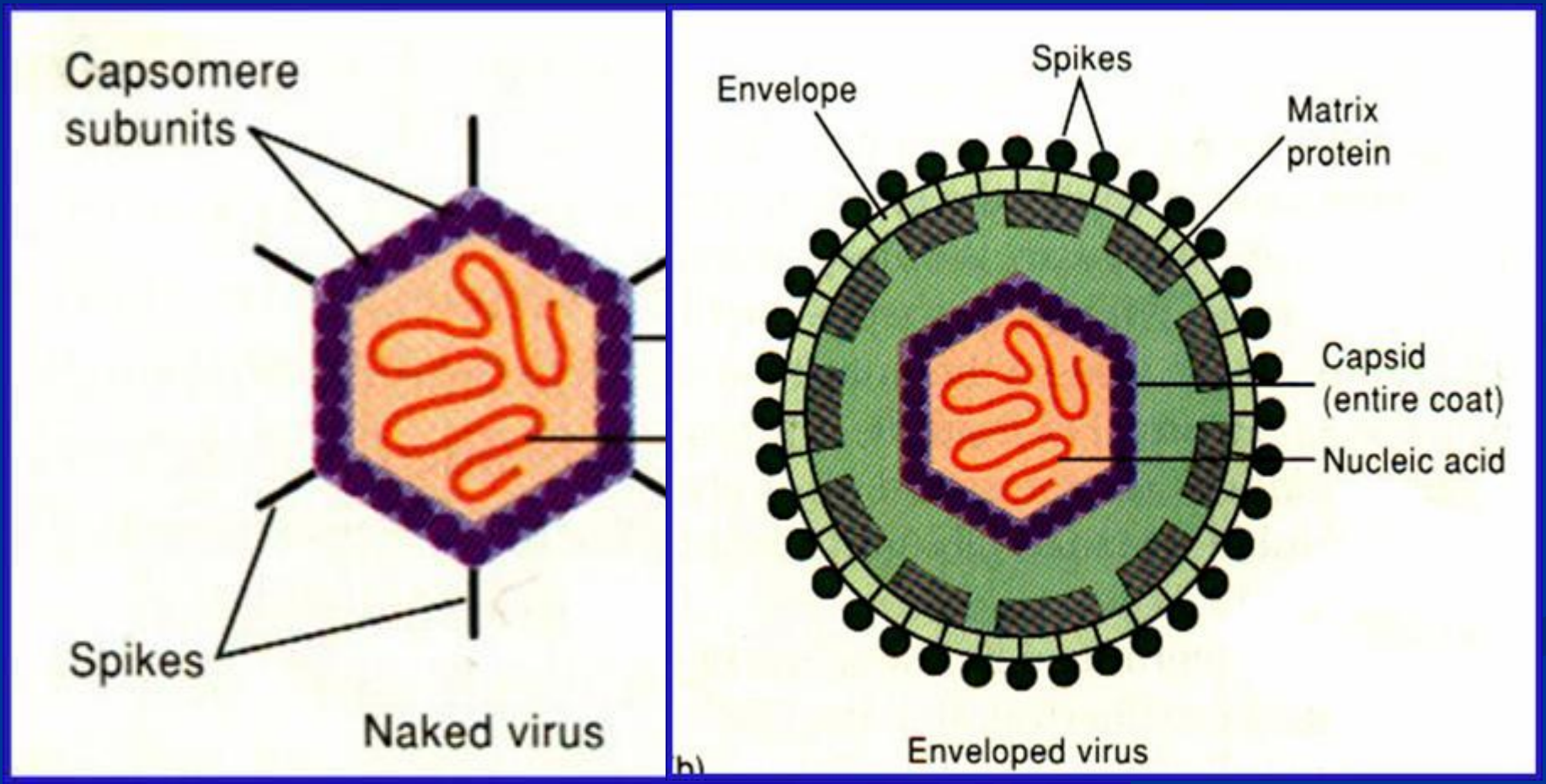
Nucleic Acid

Protein Capsid

Virion Associated Polymerase

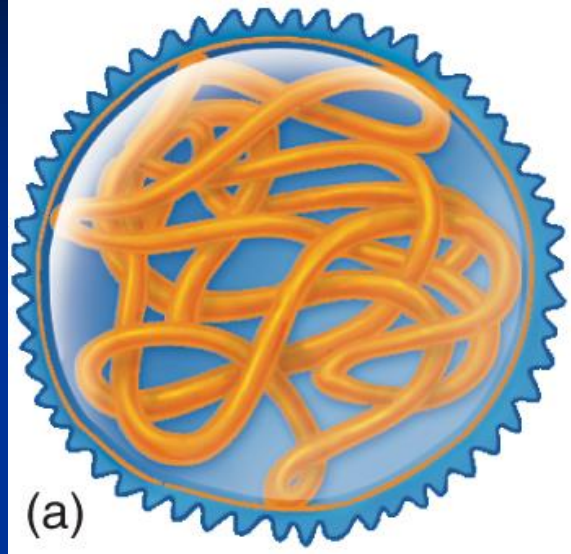
Spike Projections

Two Types of Viruses

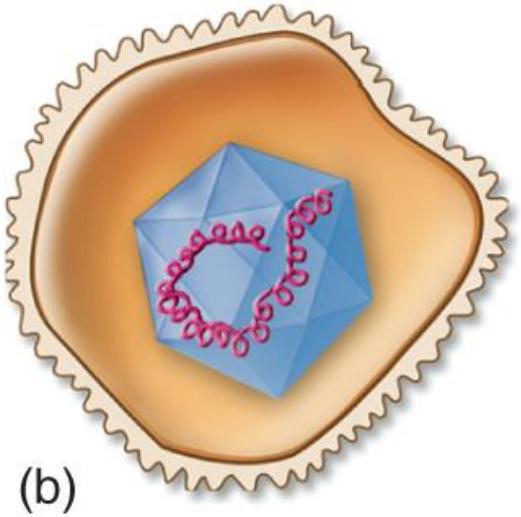


Enveloped Viruses

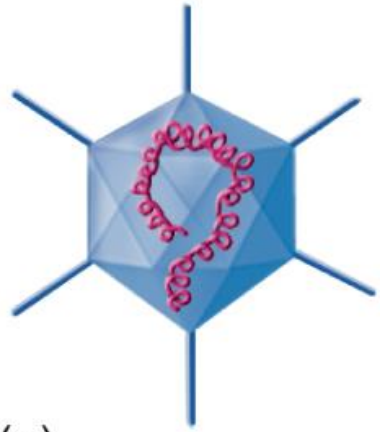
Naked Viruses



(a)

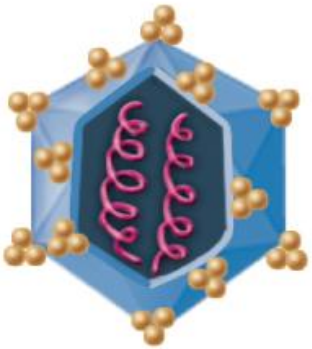


(b)

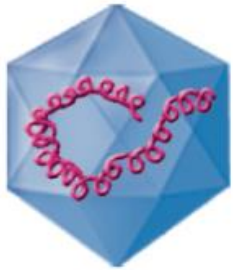


(e)

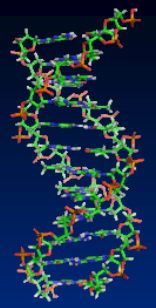
(c)



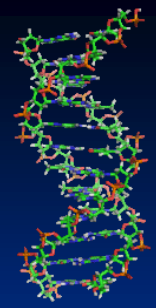
(d)



(f)

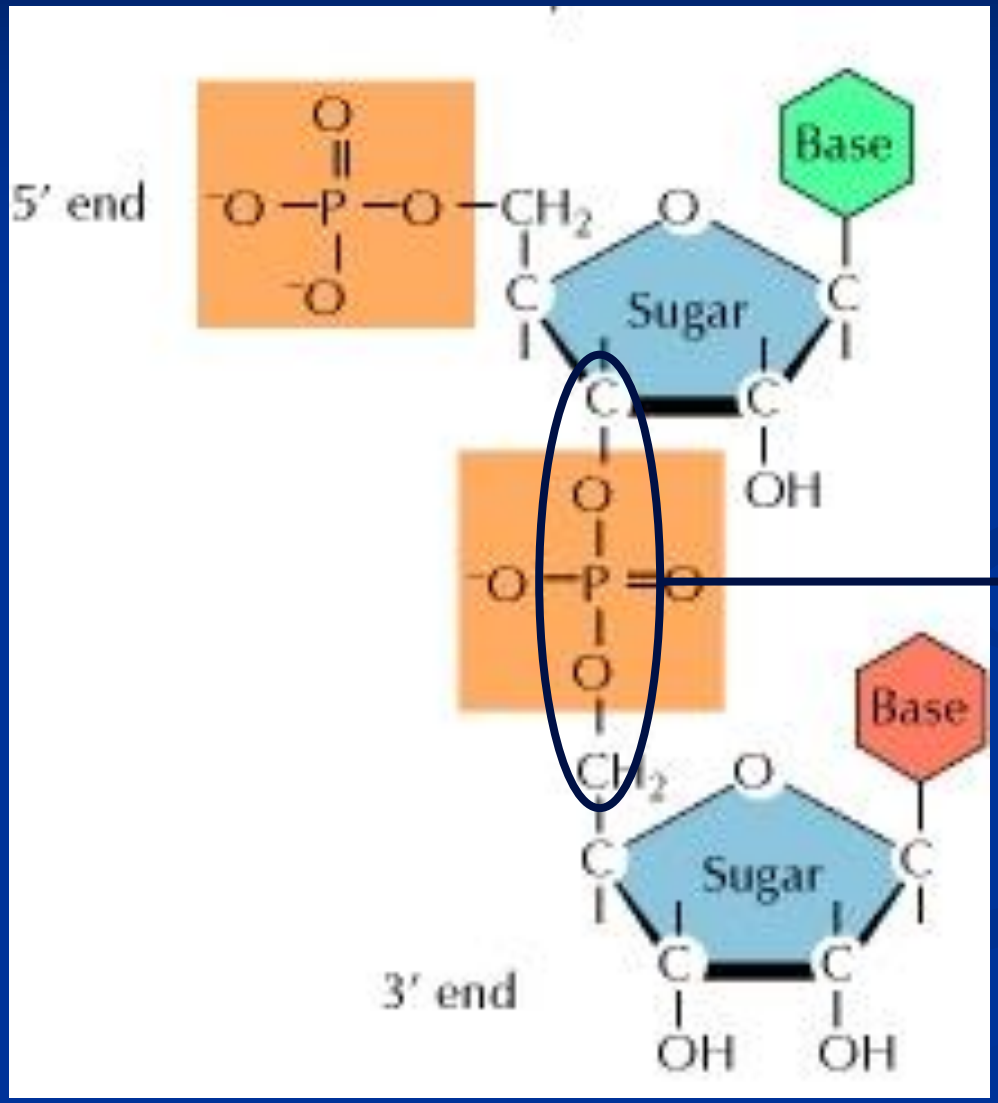


1- Nucleic Acid

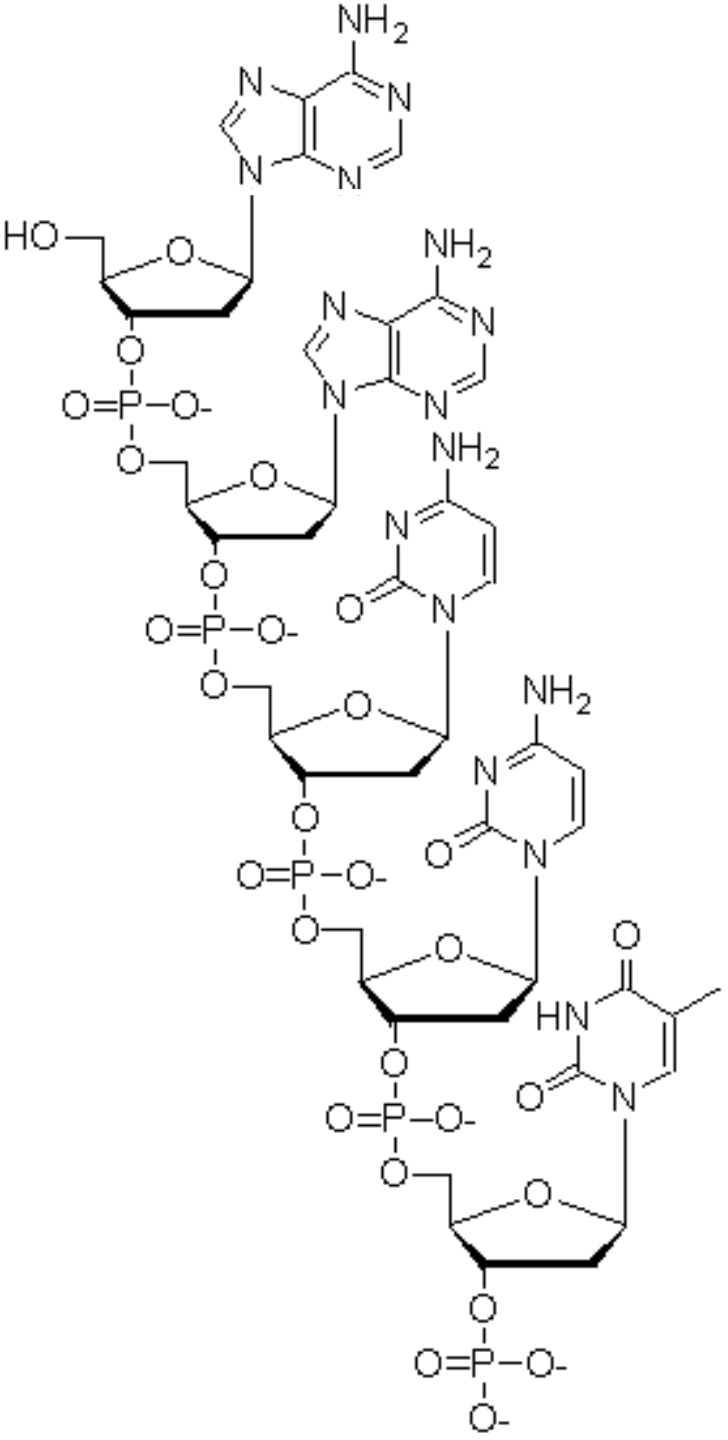


- A complex, high-molecular-weight biochemical macromolecule
- A polymer that composed of a long chain of nucleotides (blocking units).
- Carry, store and transfer the genetic information of nearly all organisms.
- The most common nucleic acids are:
  - Deoxy ribonucleic acid (DNA).
  - Ribonucleic acid (RNA).

Poly-nucleotide Chain



Phospho-diester bond



3` end (terminus)

Negative strand (polarity) or

(Template) strand

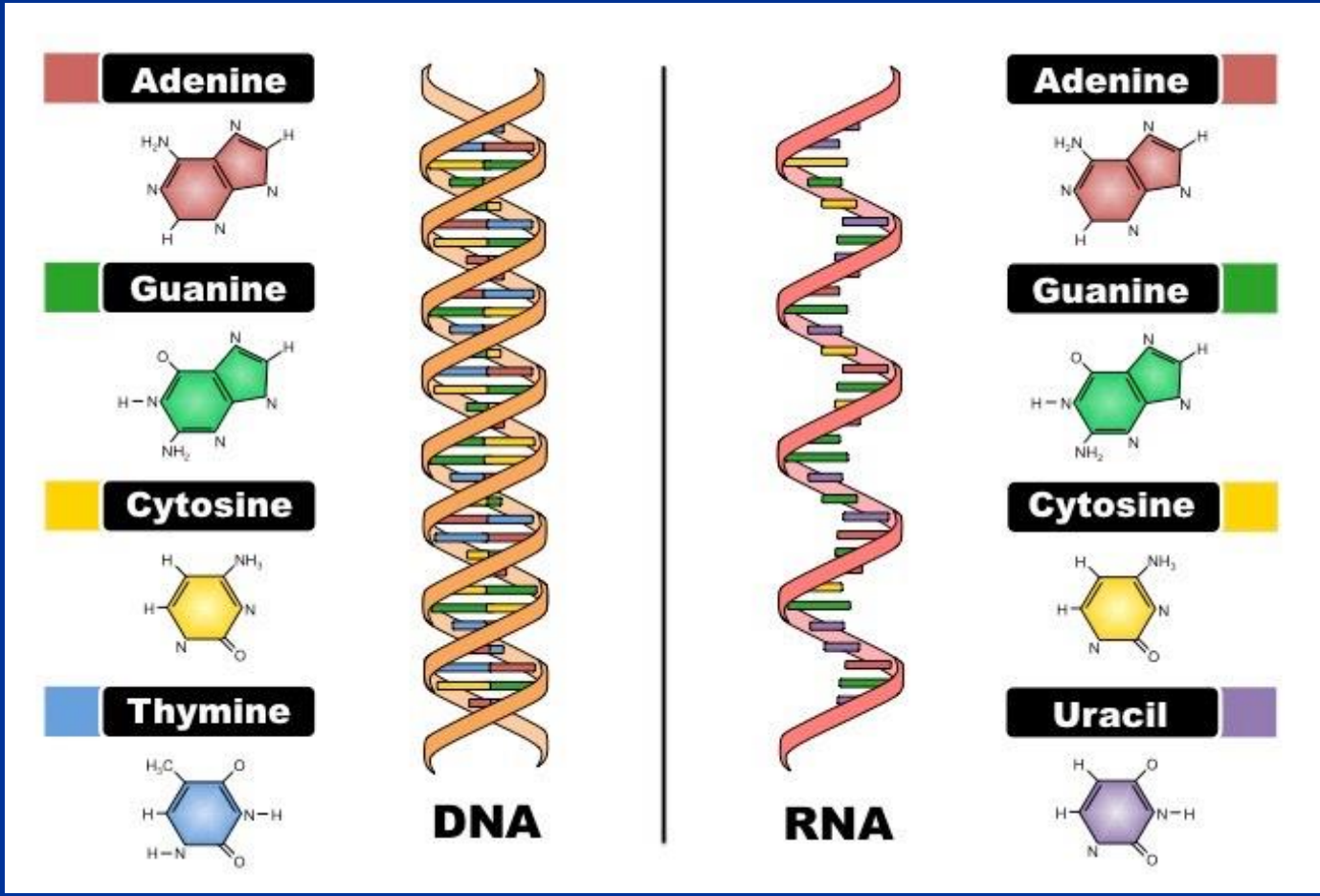
Positive strand (polarity) or (coding) strand

5` end (terminus)

Virus Nucleic Acid (Genome)

Viruses have perhaps exploited all possible means of nucleic acid replication for an entity at the subcellular level.

1- Type:



Virus Nucleic Acid (Genome)

2- Strandness:

Most DNA Viruses

Pox - Herpes

Rare

Parvo - Circo

Rare

Reo - Birna

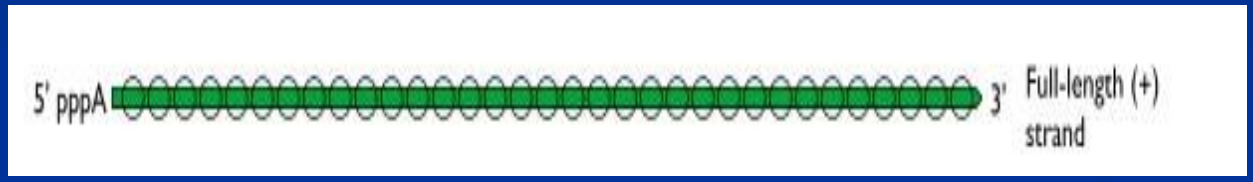
Most RNA Viruses

Influenza

Virus Nucleic Acid (Genome)

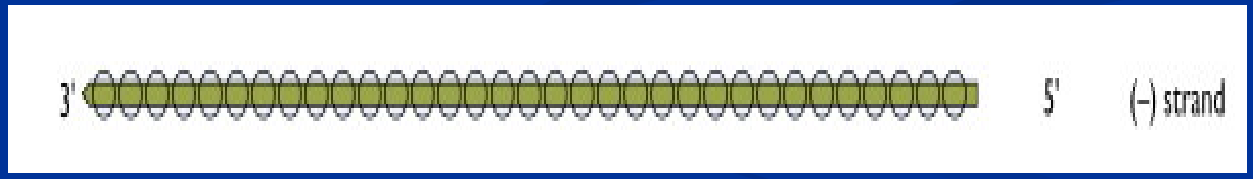
3- Sense (polarity):

Positive Sense



directly capable of translation to protein

Negative Sense



Requires transcription of mRNA strand

AmbiSense

In part positive sense and in part negative sense

Virus Nucleic Acid (Genome)

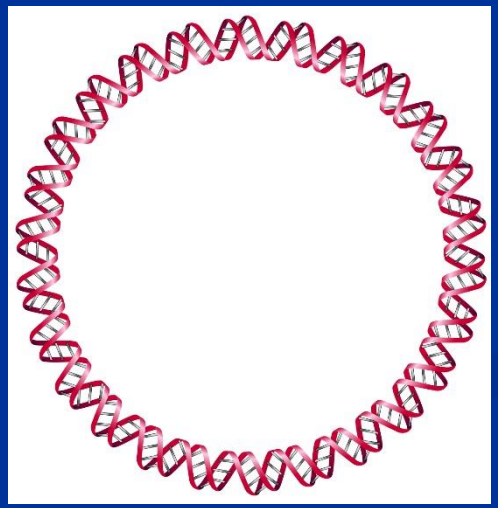
4- Linearity:

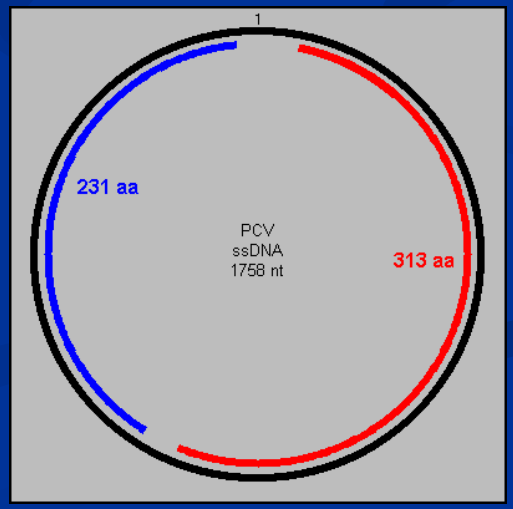
Linear:

Poxviridae
Coronaviridae

Circular:

Circoviridae
Hepadnaviridae

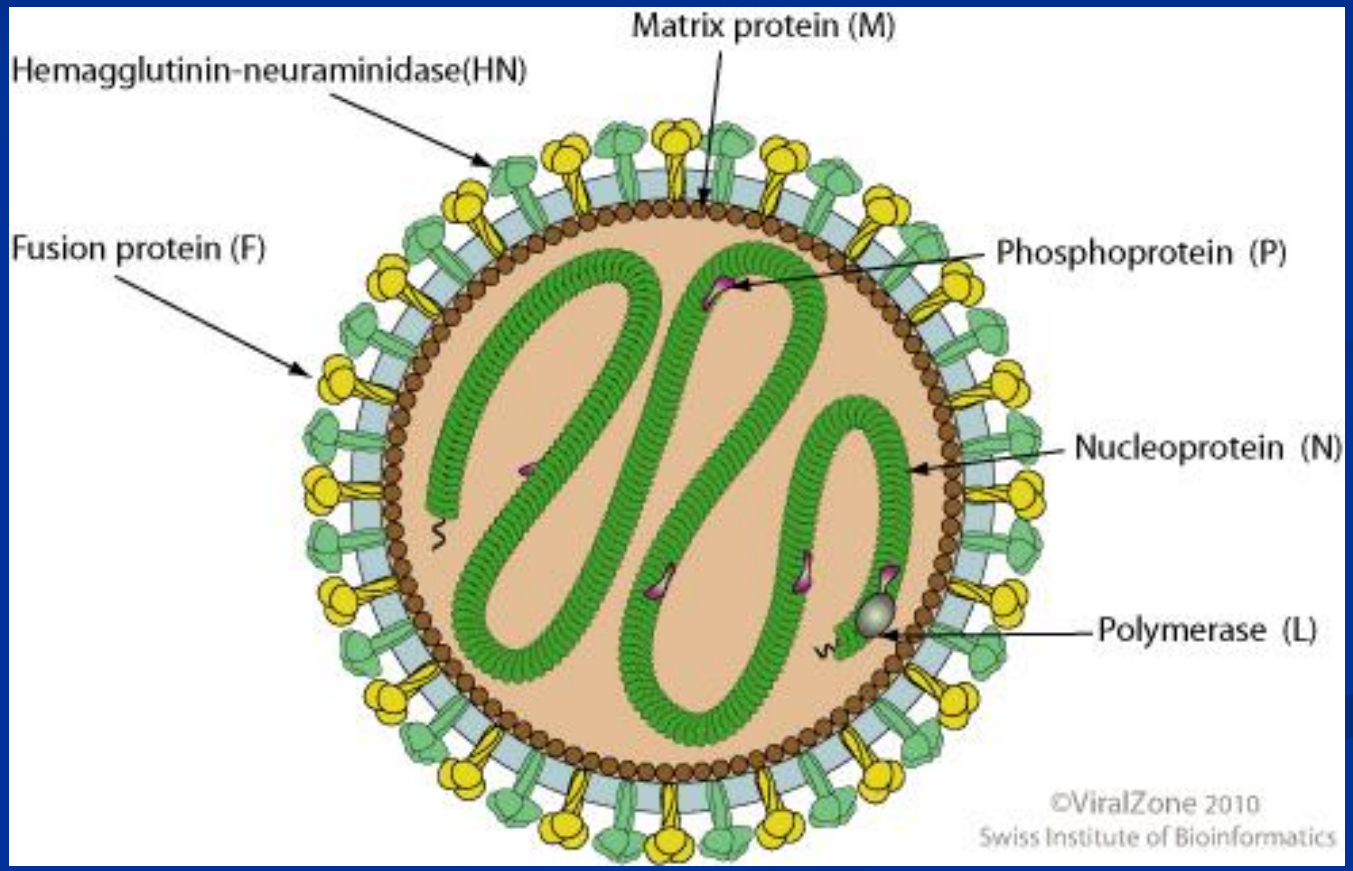




Virus Nucleic Acid (Genome)

5- Segmentation:

Single molecule:

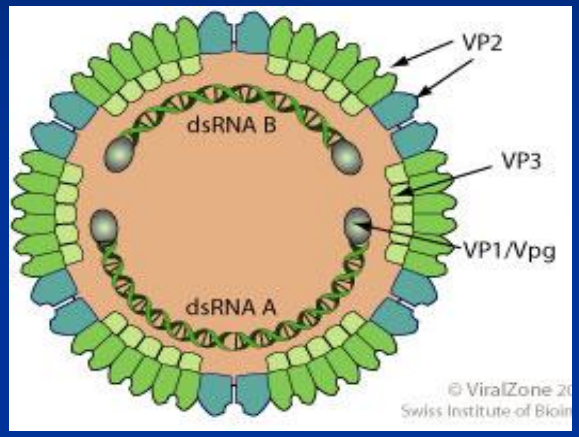


Paramyxoviruses

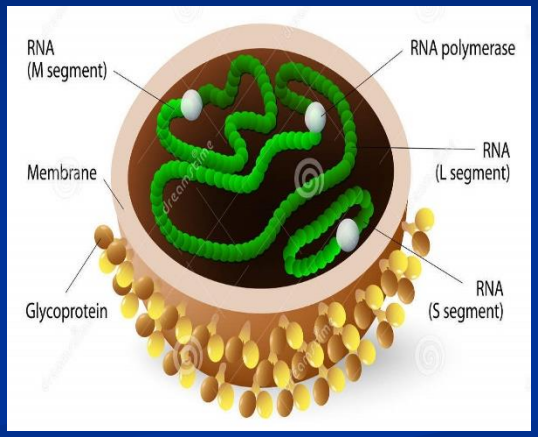
Virus Nucleic Acid (Genome)

5- Segmentation:

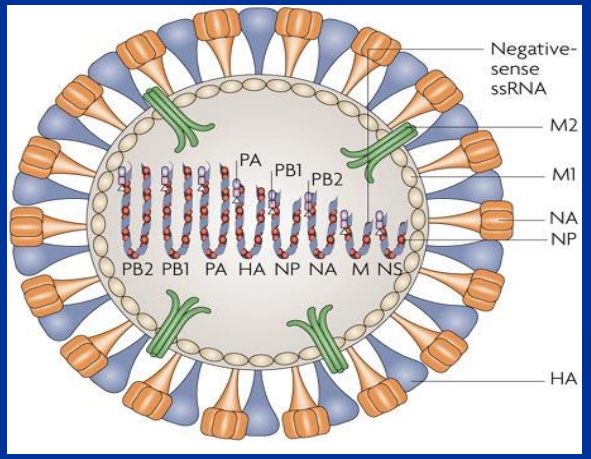
Segmented Genome:



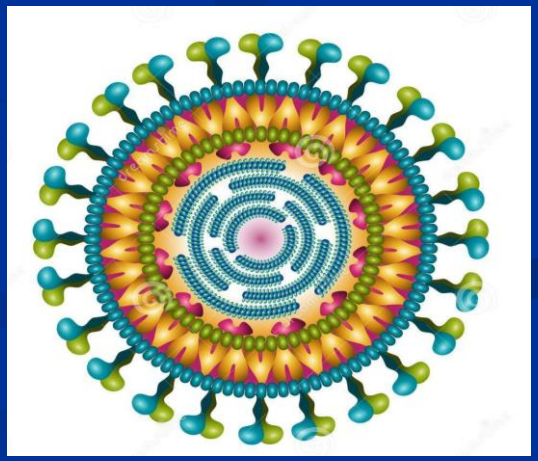
2 segments (Birna-Arena)



3 segments (Bunya)



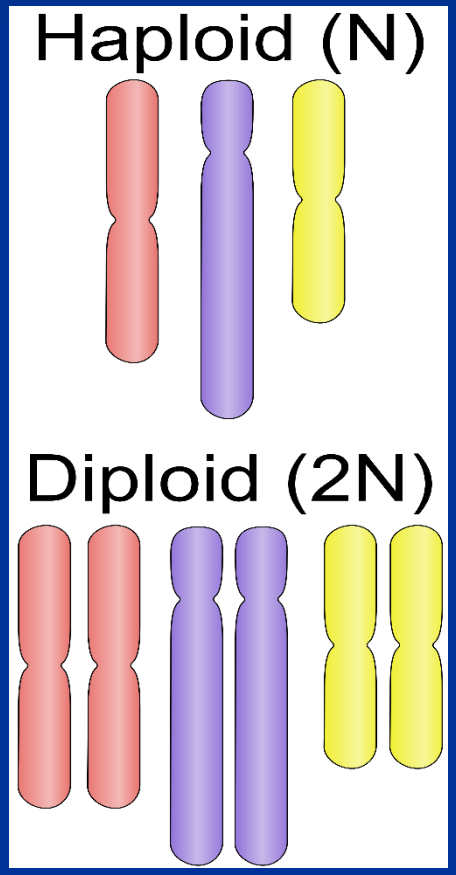
6-8 segments (Influenza)



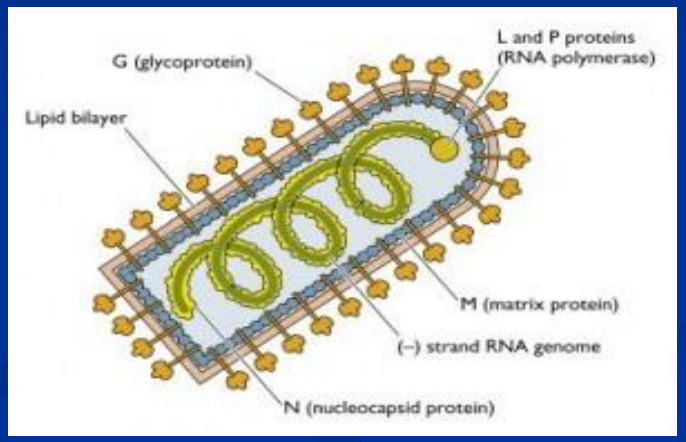
10-12 segments (REO)

Virus Nucleic Acid (Genome)

6- Ploidy:

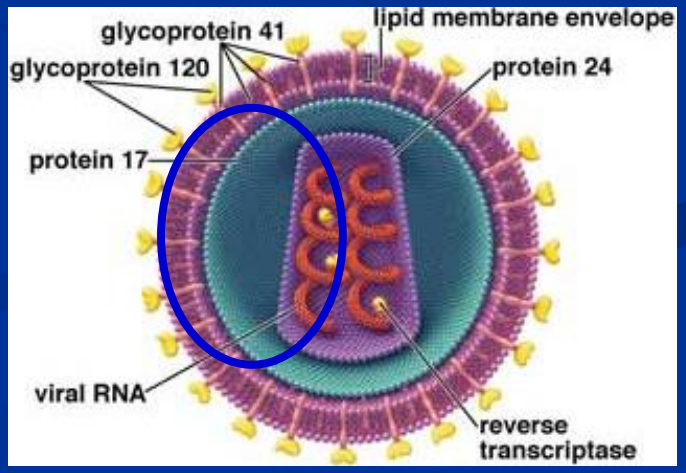


Haploid:



Diploid:

Retroviridae



Virus Nucleic Acid (Genome)

7- Length/Size:

Largest

Megavirus : Up to 1,300,000 Base pair in length
1120 genes

Poxvirus : Up to 300,000 Base pair in length
150 genes

Smallest

Deltavirus: Less than 1,700 Base in length
One gene

Example: Influenza Virus

RNA

Single stranded

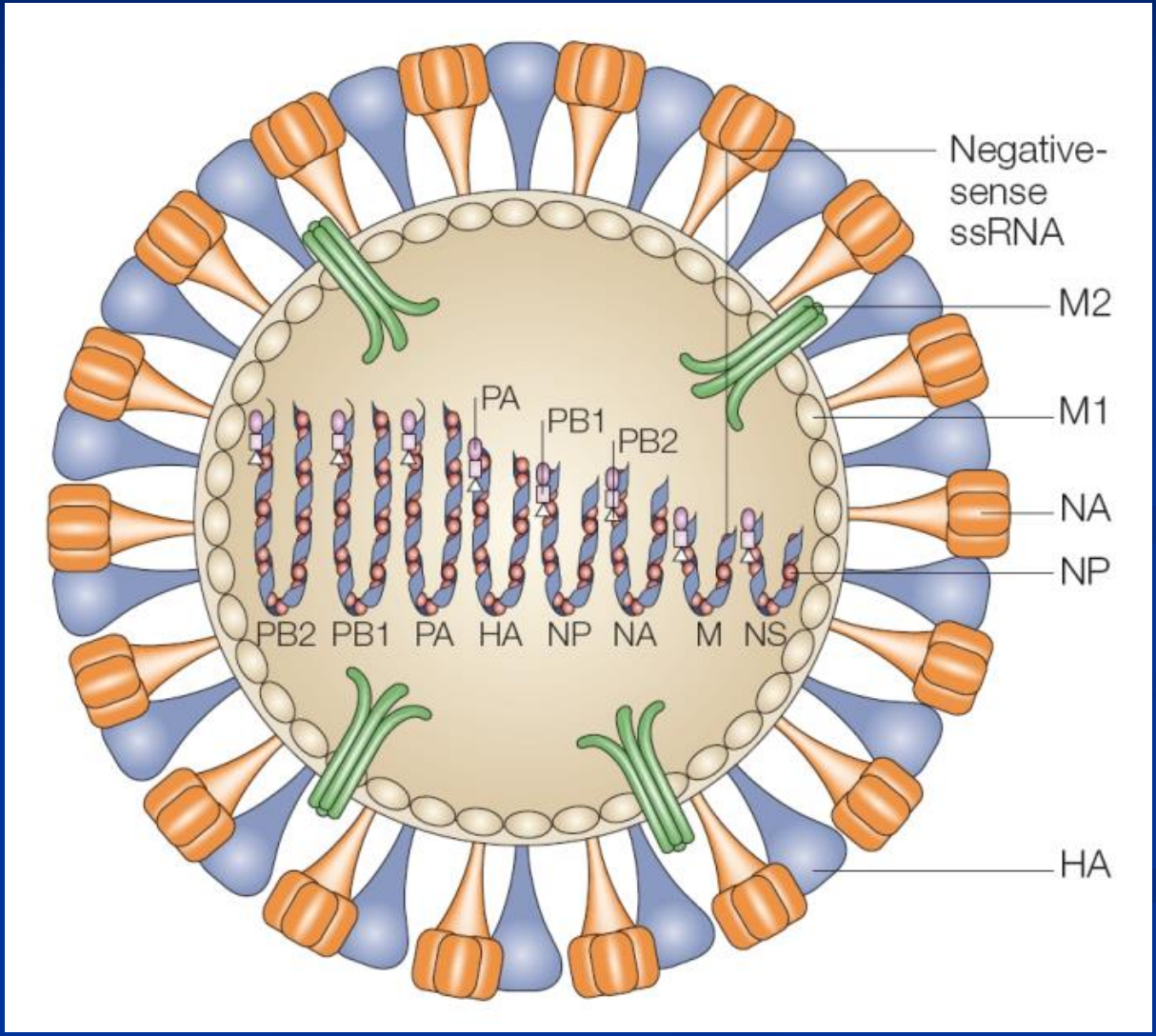
Negative sense

Linear

Segmented (6-8 segments)

Haploid

Example: Influenza Virus



Type and structure of the genome are used to classify viruses

Family	Nature of the Genome	Presence of an Envelope	Morphology	Genome Configuration	Genome Siz (kb or kbp)
Poxviridae	dsDNA	+	pleomorphic	1 linear	130–375
Iridoviridae	dsDNA	+/−	isometric	1 linear	135–303
Asfarviridae	dsDNA	+	spherical	1 linear	170–190
Herpesviridae	dsDNA	+	isometric	1 linear	125–240
Adenoviridae	dsDNA	−	isometric	1 linear	26–45
Polyomaviridae	dsDNA	−	isometric	1 circular	5
Papillomaviridae	dsDNA	−	isometric	1 circular	7–8
Hepadnaviridae	dsDNA-RT	+	spherical	1 linear	3–4
Circoviridae	ssDNA	−	isometric	1 – or +/− circular	2
Parvoviridae	ssDNA	−	isometric	1 +/− linear	4–6
Retroviridae	ssRNA-RT	+	spherical	1 + (dimer)	7–13
Reoviridae	dsRNA	−	isometric	10–12 segments	19–32
Birnaviridae	dsRNA	−	isometric	2 segments	5–6
Paramyxoviridae	NssRNA	+	pleomorphic	1 − segment	13–18
Rhabdoviridae	NssRNA	+	bullet-shaped	1 − segment	11–15
Filoviridae	NssRNA	+	filamentous	1 − segment	≈19

Type and structure of the genome are used to classify viruses

Family	Nature of the Genome	Presence of an Envelope	Morphology	Genome Configuration	Genome Siz (kb or kbp)
Bornaviridae	NssRNA	+	spherical	1 − segment	9
Orthomyxoviridae	NssRNA	+	pleomorphic	6–8 − segments	10–15
Bunyaviridae	NssRNA	+	spherical	3 − or +/− segments	11–19
Arenaviridae	NssRNA	+	spherical	2 +/− segments	11
Coronaviridae	ssRNA	+	spherical	1 + segment	38–31
Arteriviridae	ssRNA	+	spherical	1 + segment	13–16
Picornaviridae	ssRNA	−	isometric	1 + segment	7–9
Caliciviridae	ssRNA	−	isometric	1 + segment	7–8
Astroviridae	ssRNA	−	isometric	1 + segment	6–7
Togaviridae	ssRNA	+	spherical	1 + segment	10–12
Flaviviridae	ssRNA	+	spherical	1 + segment	10–12
Hepevirus (unassigned)	ssRNA	−	isometric	1 + segment	7
Anellovirus (unassigned)	ssDNA	−	isometric	1 − circular	3–4

2- Capsid

* Capsid is formed from protein sub-units arranged in a precise and highly repetitive pattern around NA
* Protein sub-units: **Protomers**
* Associate in a specific way to form larger assemblies /structures: **Capsomers**
* Capsomers make up the: **Capsid**

2- Capsid

Complex of NA and proteins packaged together:

NUCLEOCAPSID

2- Capsid

Two kinds of symmetry:

Correspond to two primary shapes

Rod:

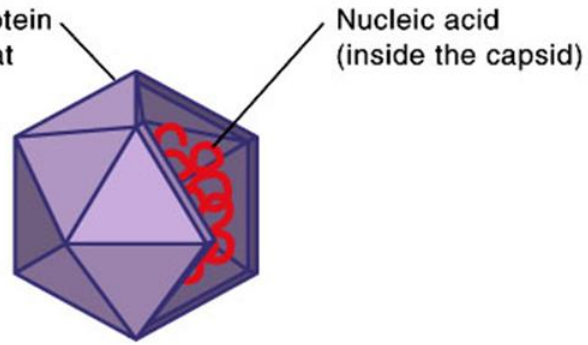
Helical symmetry

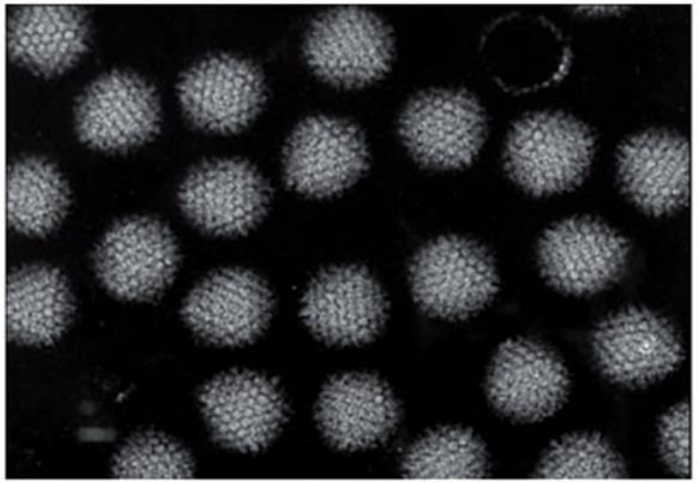
Spherical:

Icosahedral symmetry

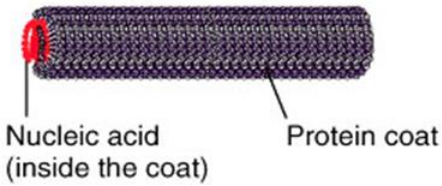
2- Capsid

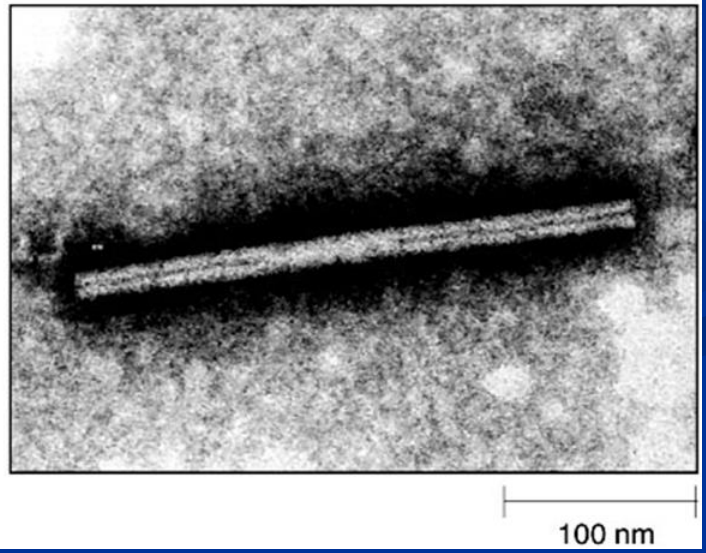
(a) Isometric (adenovirus)





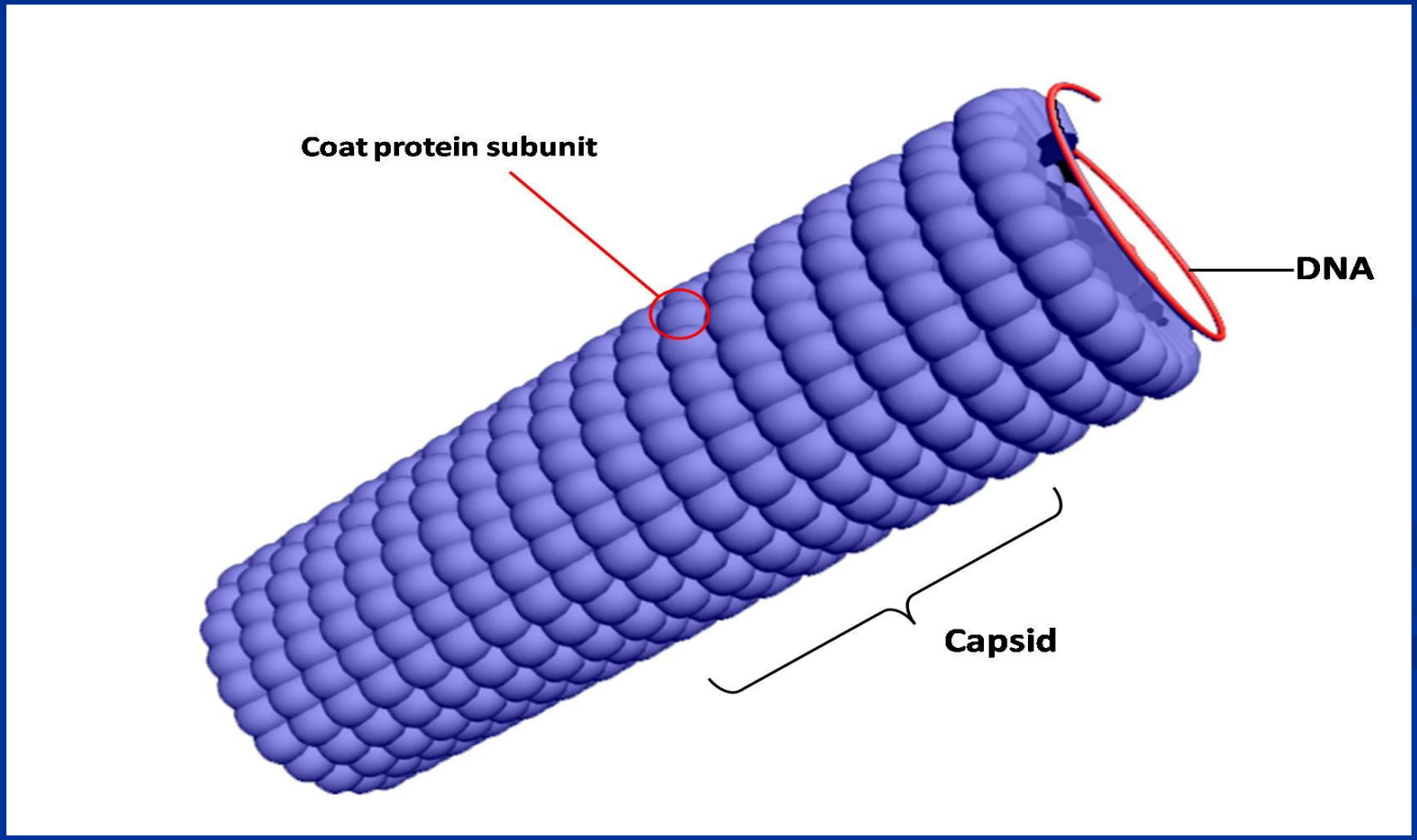
(b) Helical (tobacco mosaic virus)





2- Capsid

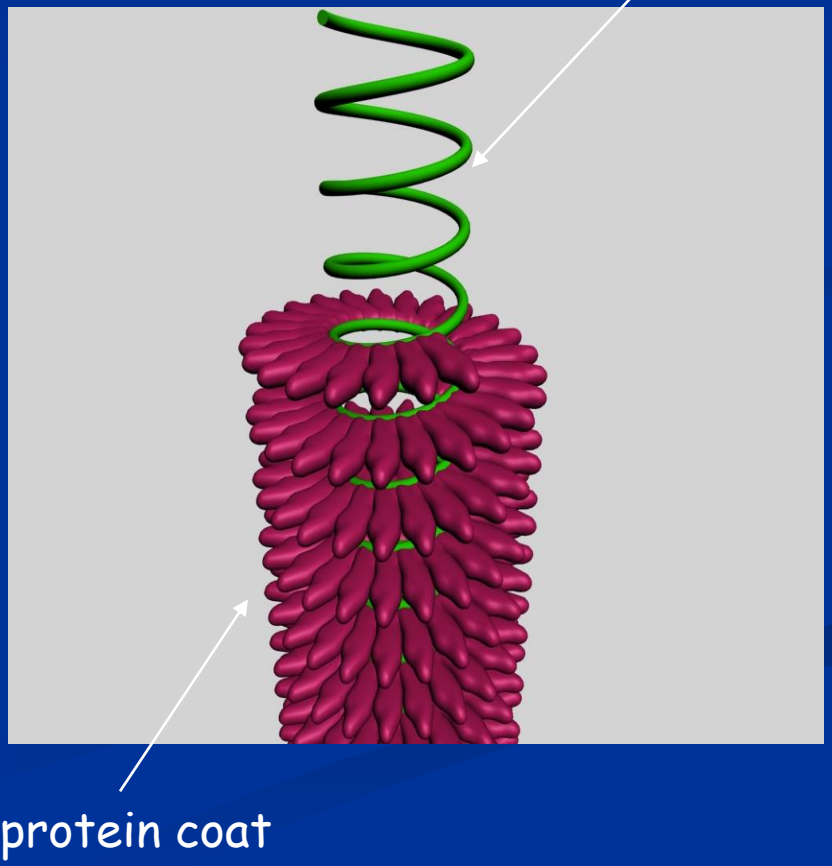
Helical Capsid:

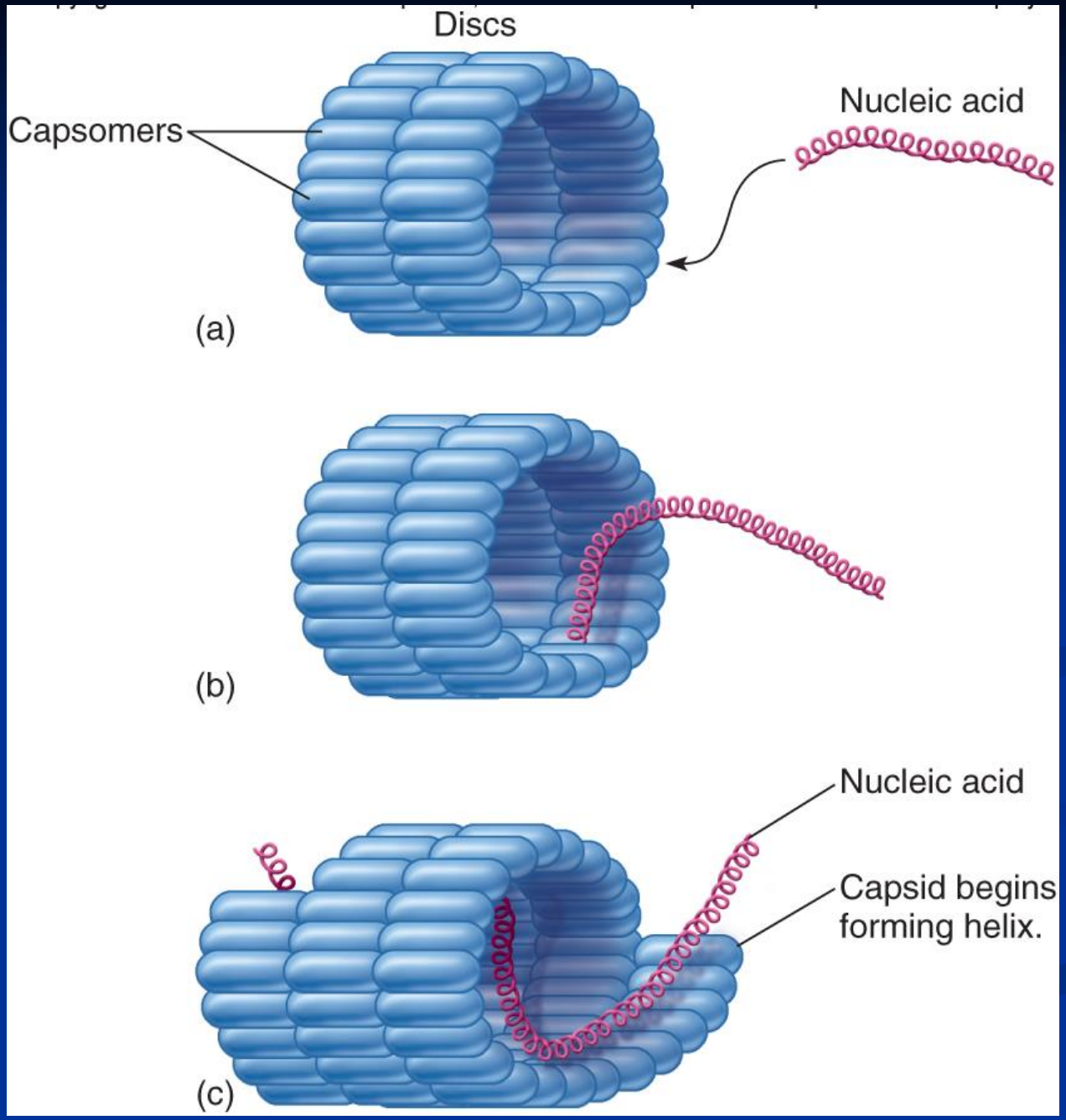


2- Capsid

Helical Capsid:

- Rod-like structures.
- RNA in the center of the helix.
- A helix is made by stacking repeating units in a spiral.




Discs
Capsomers
Nucleic acid
(a)
(b)
Nucleic acid
Capsid begins forming helix.
(c)

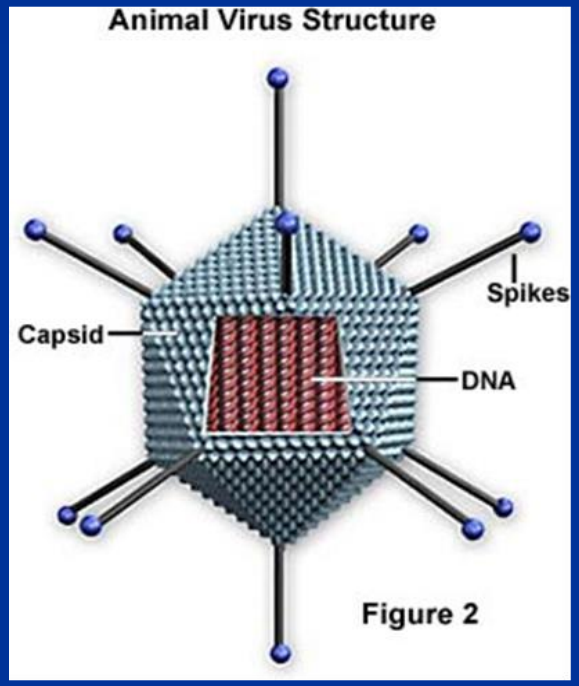
2- Capsid

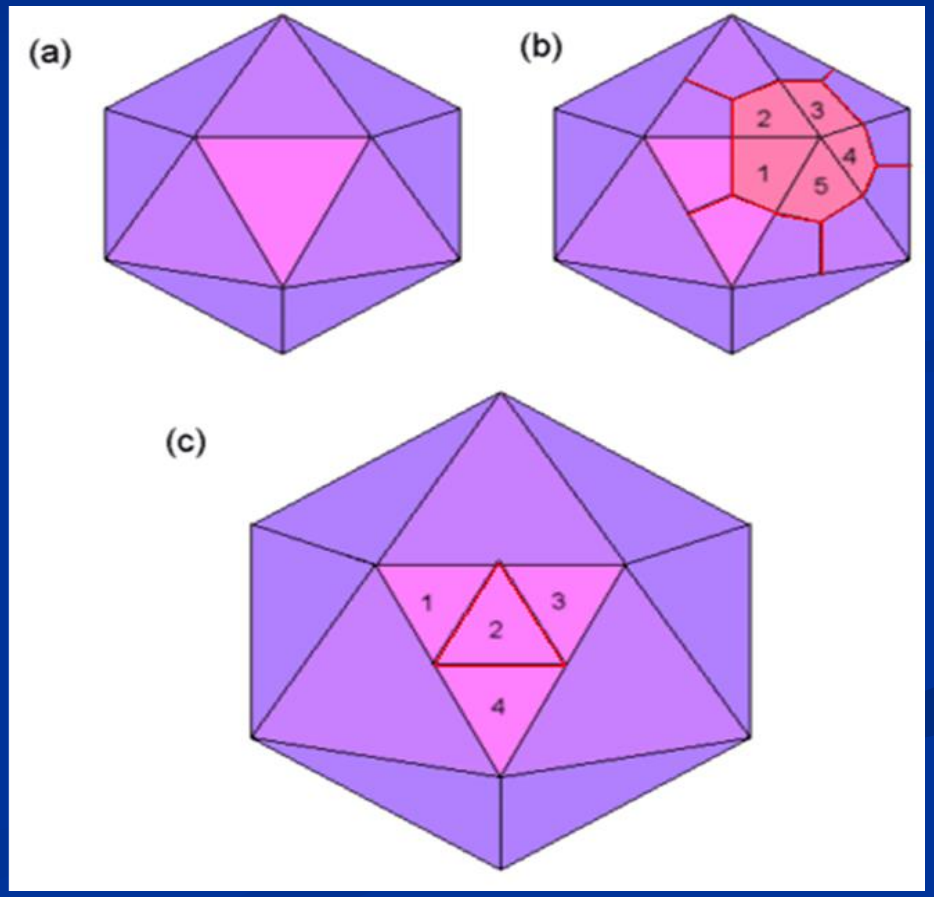
Helical Capsid:

- Helical, naked (i.e. non-enveloped) animal viruses do not exist, but the reasons are not clear.
- This category includes many of the best known human and animal pathogens
  e.g. Influenza, Rabies, Paramyxo, and corona viruses
- Most helical animal viruses possess single-stranded, negative-sense RNA genomes

2- Capsid

Icosahedral Capsid:

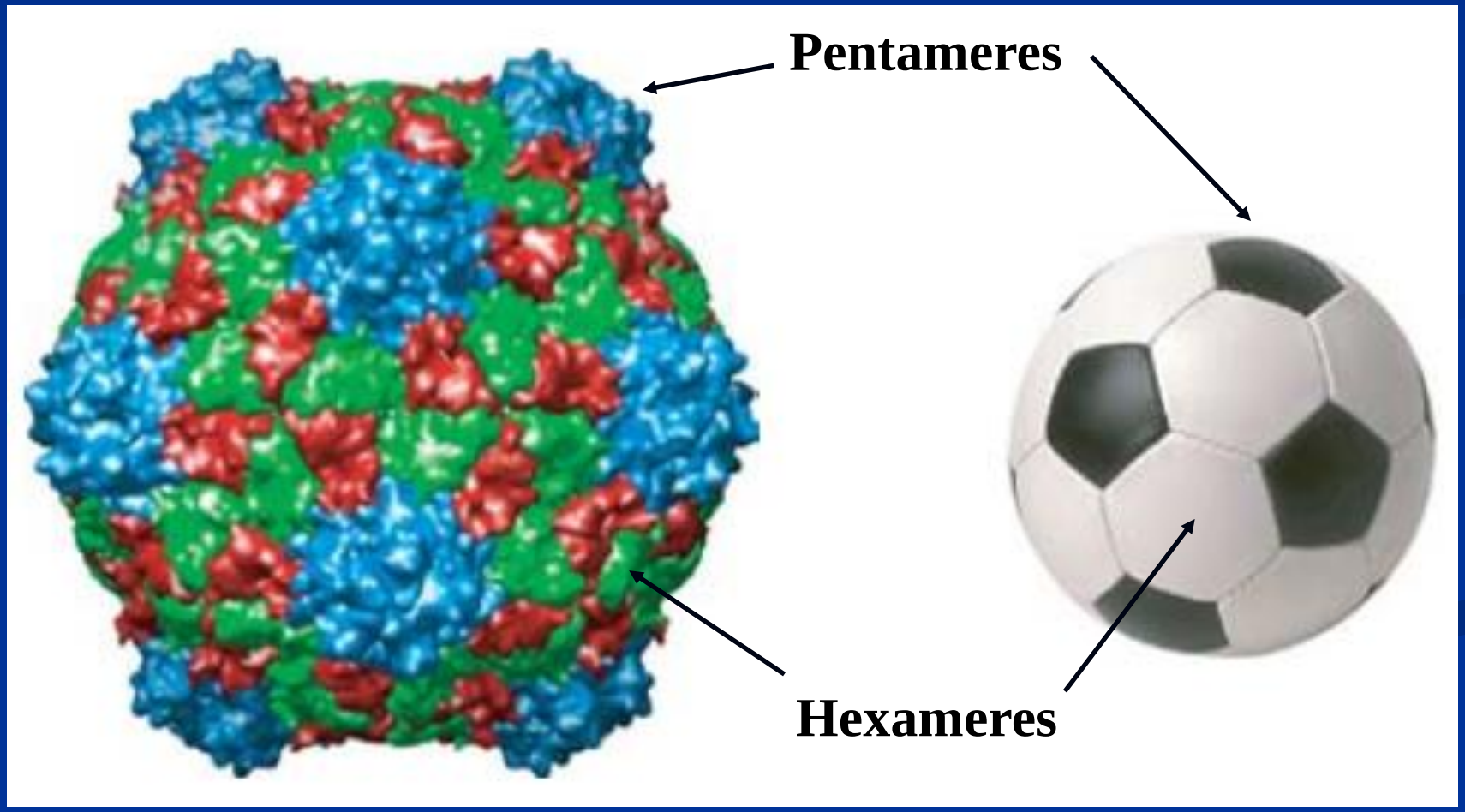




20 faces (equilateral triangle)
30 borders - 12 angles

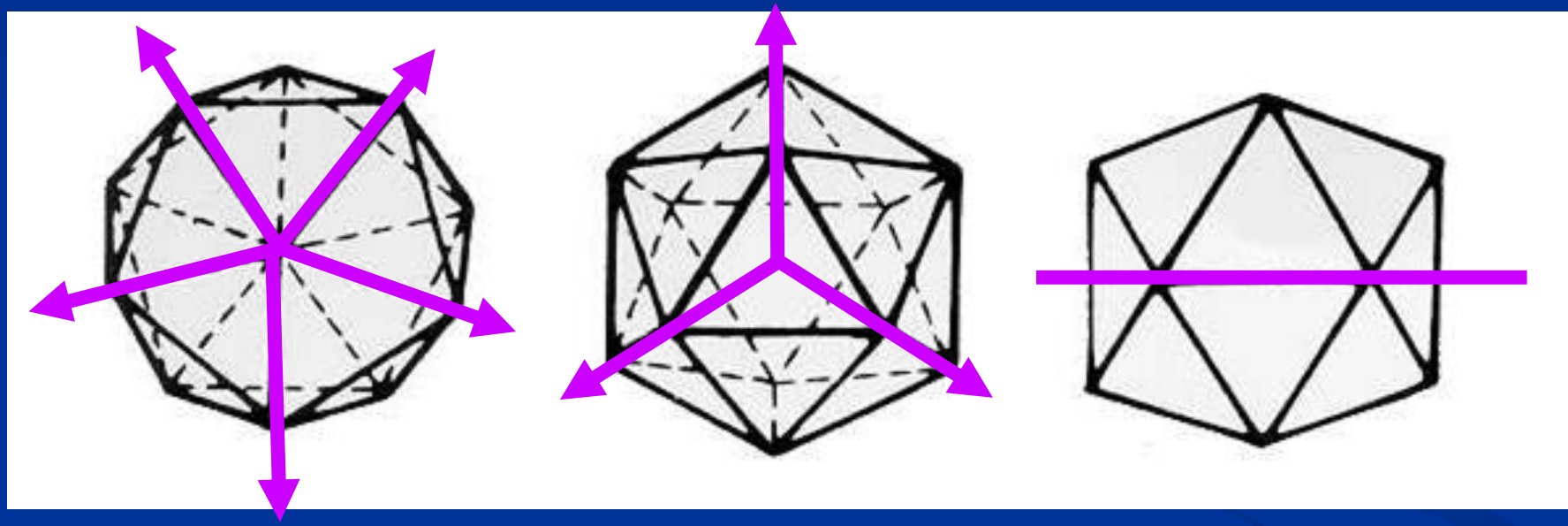
2- Capsid

Icosahedral Capsid:



2- Capsid

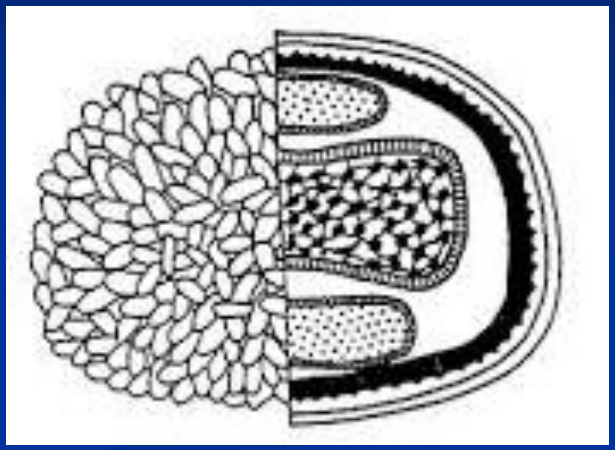
Icosahedral Capsid:



5-FOLD **3-FOLD** **2-FOLD**

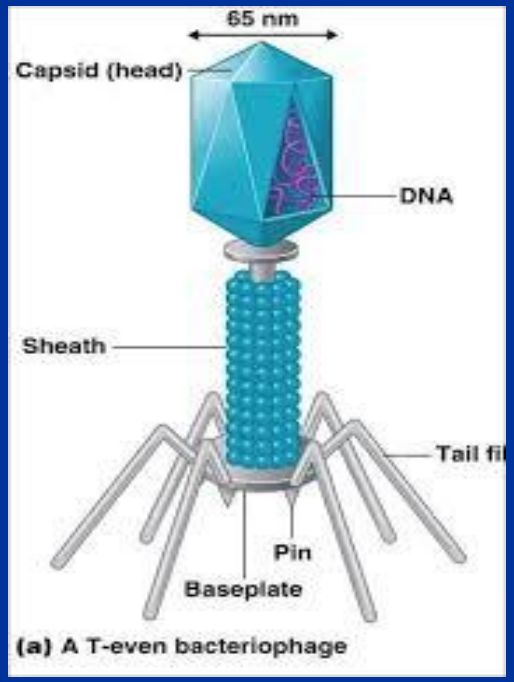
2- Capsid

Complex Capsid:



- **Neither icosahedral nor helical**

e.g. pox virus

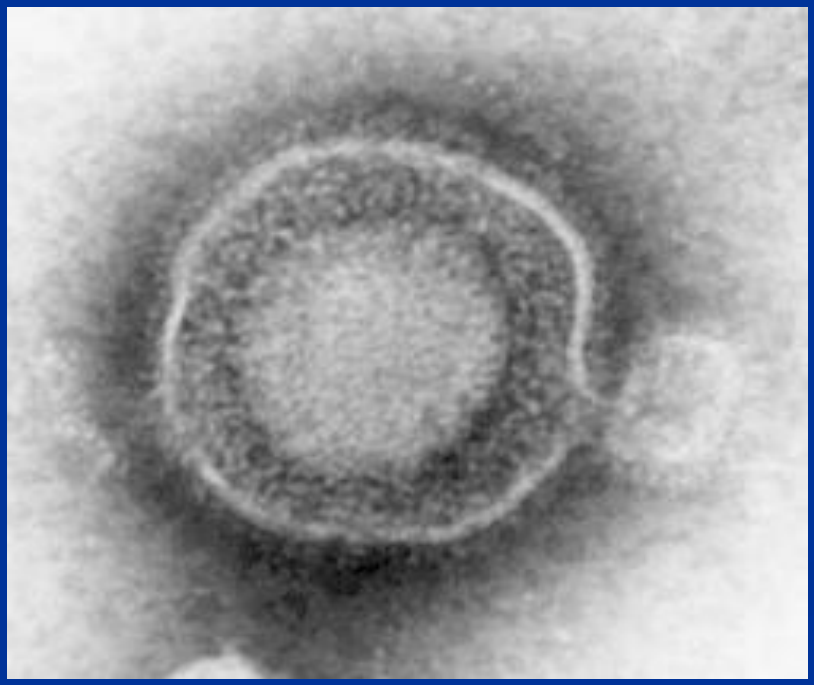


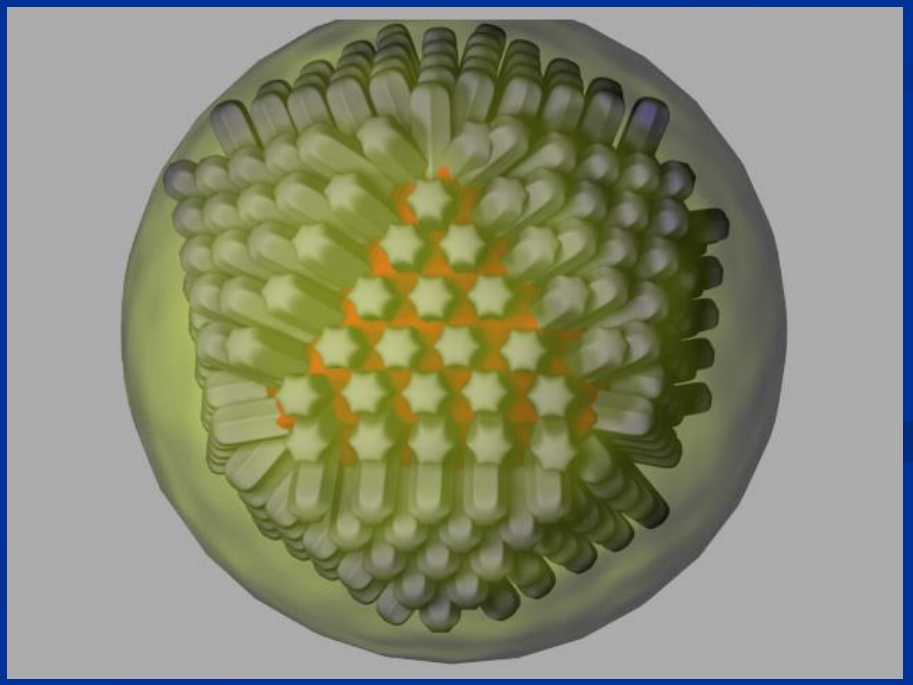
- **Both icosahedral nor helical (Binal)**

e.g. Bacteriophage

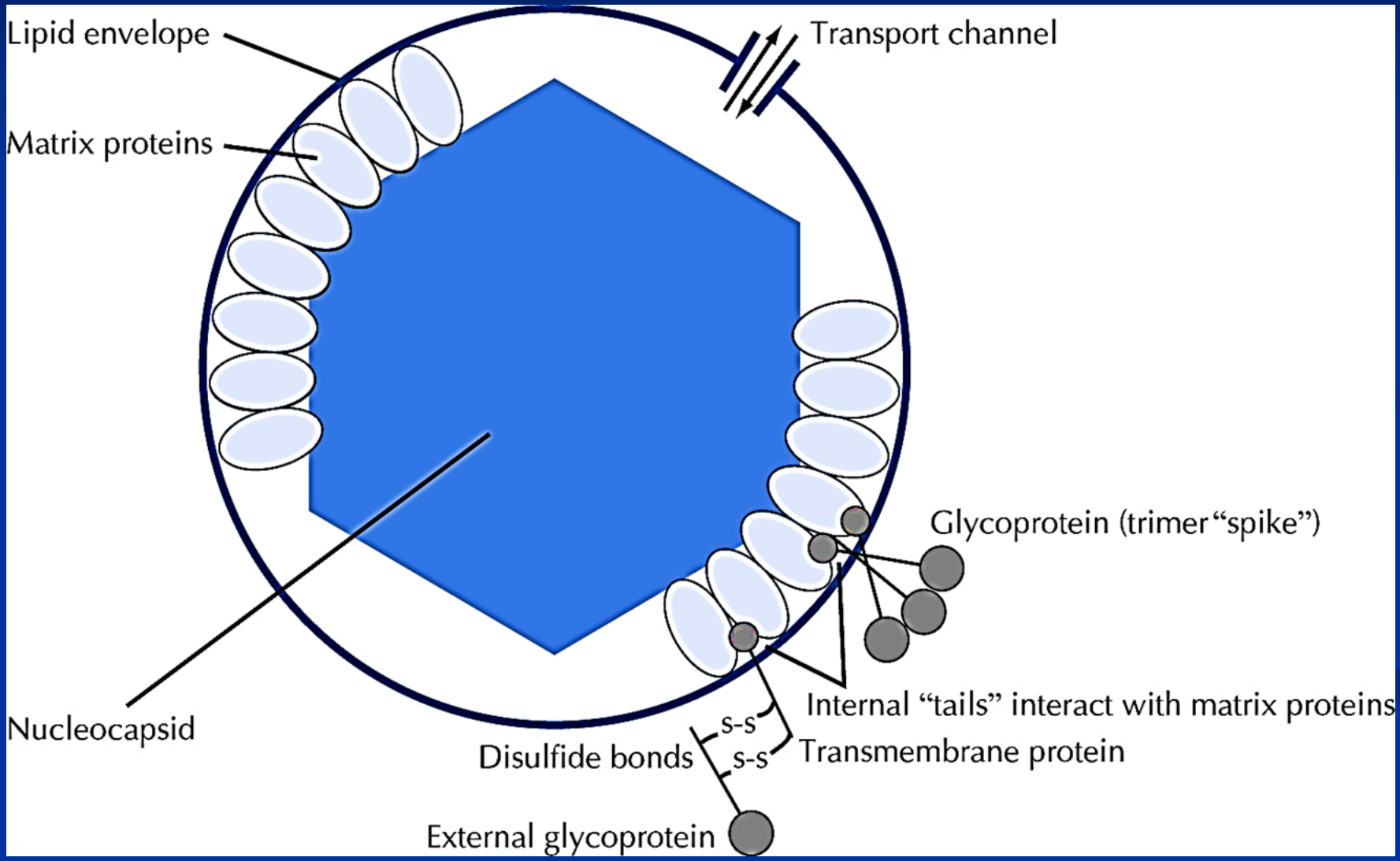
3- Envelope

Enveloped viruses are viruses which have a membrane coat surrounding the protein coat or capsid. These viruses are common in animal viruses, but are uncommon in plant viruses.

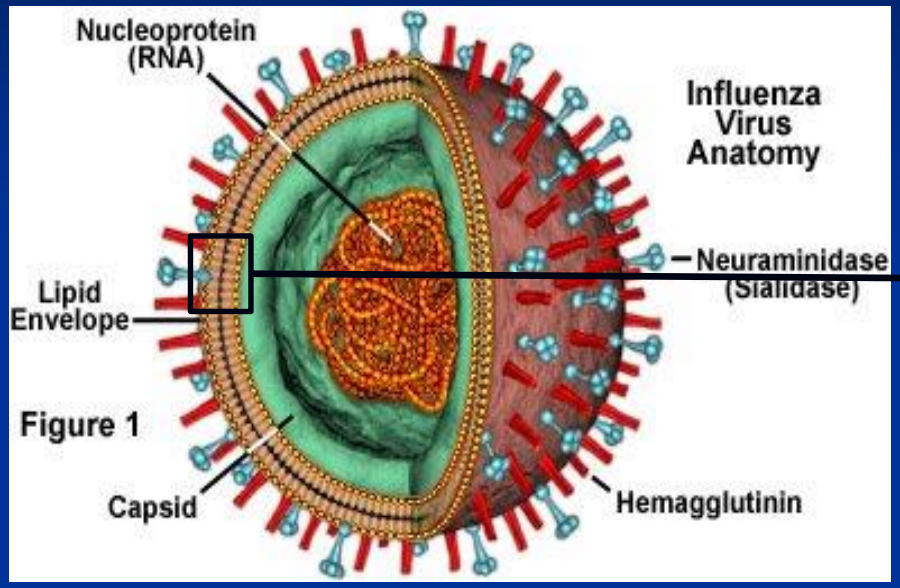


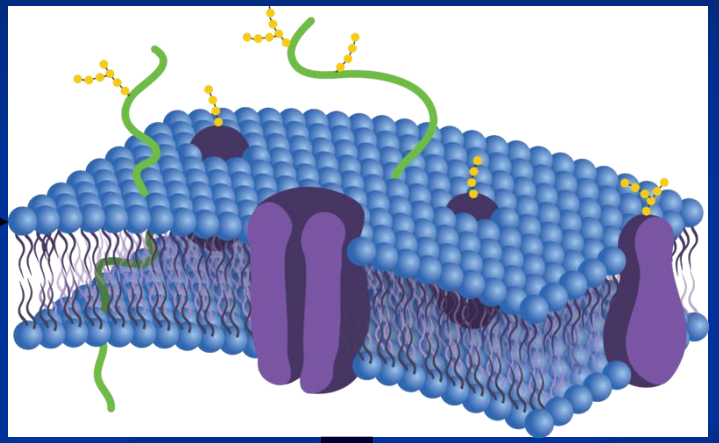


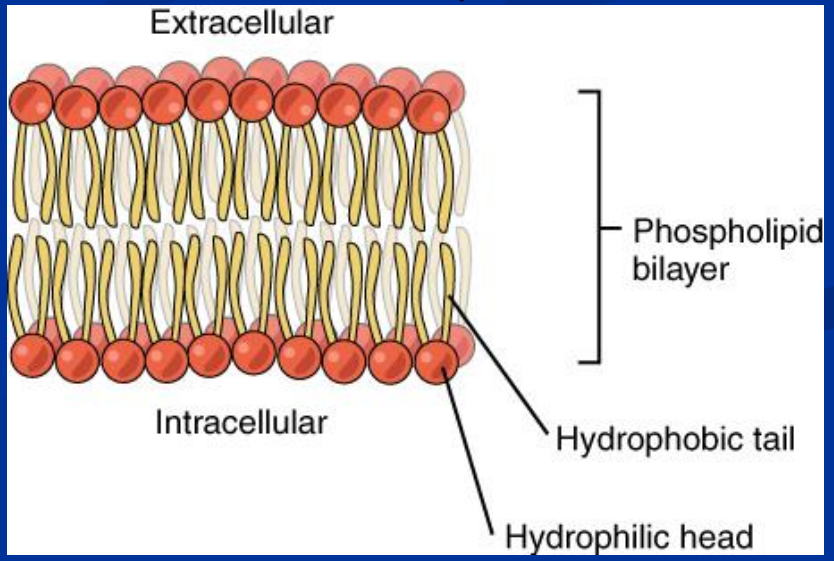
3- Envelope


Lipid envelope
Transport channel
Matrix proteins
Glycoprotein (trimer "spike")
Nucleocapsid
Internal "tails" interact with matrix proteins
s-s
Disulfide bonds
s-s
Transmembrane protein
External glycoprotein

Envelope Structure







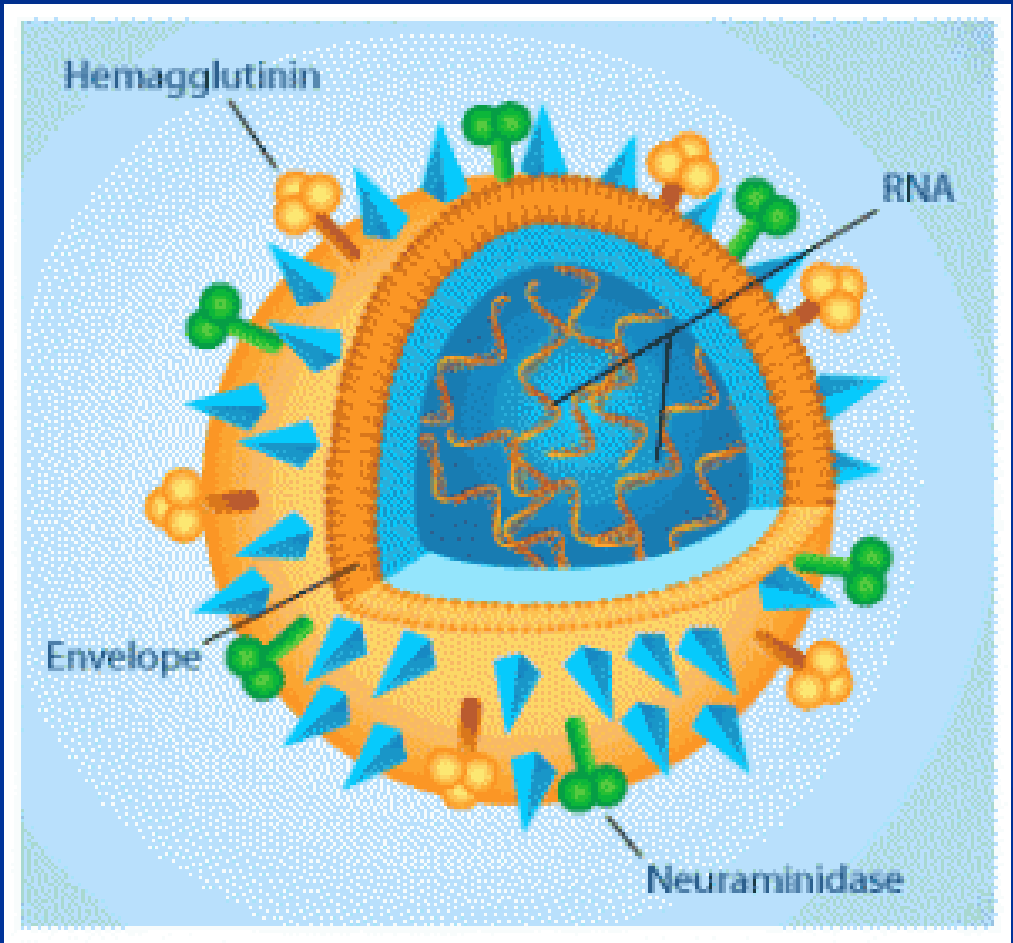
Obtained from the cell membrane through budding

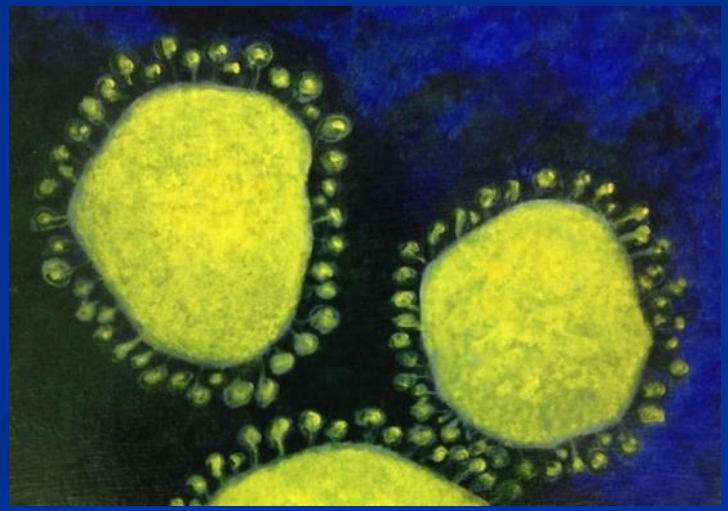
Envelope Structure

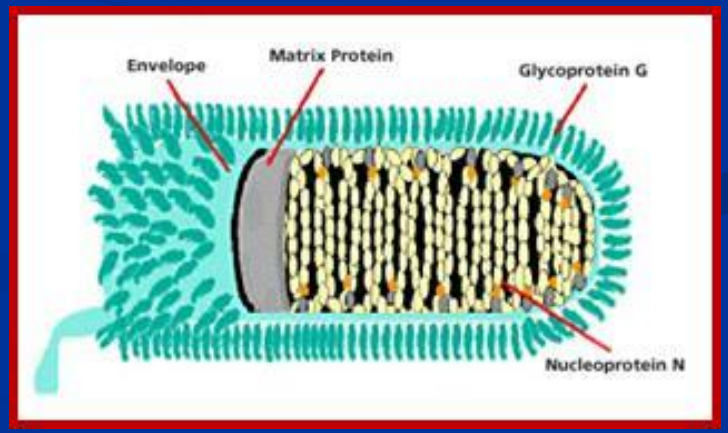
- All living cells are covered by a membrane composed of Phospholipid bilayer.
- Viruses leaving the cell usually acquire an outer coat derived from the cell membrane (i.e. envelope) through the budding process.
- The envelope of some viruses such as poxviruses, herpesviruses and coronaviruses is derived from internal cellular membranes (Nucleus – Endoplasmic reticulum – Golgi Apparatus).

Envelope-Associated Structures

1- Peplomeres (Viral Legends):







Envelope-Associated Structures

1- Peplomeres (Viral Legends):

- Glycoprotein spikes protruded from the viral envelope.
- Functions:

  1- Recognition of target cell.

  2- Attachment with cell receptor.

  3- Virus entry into the host cell.

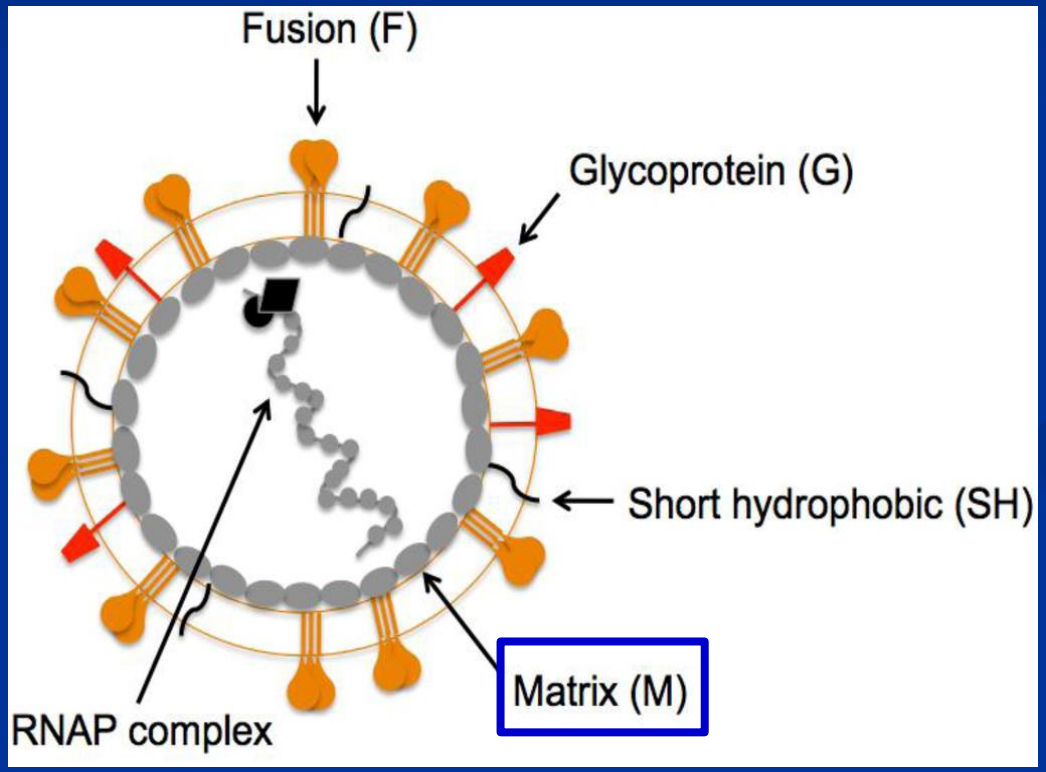
  4- Virus release from host cell.

  5- Target for immune response.

  6- Responsible for the biological properties of viruses (e.g. heamagglutination – receptor destruction).

Envelope-Associated Structures

2- Matrix protein:



Viral protein cover the envelope internally

Functions:

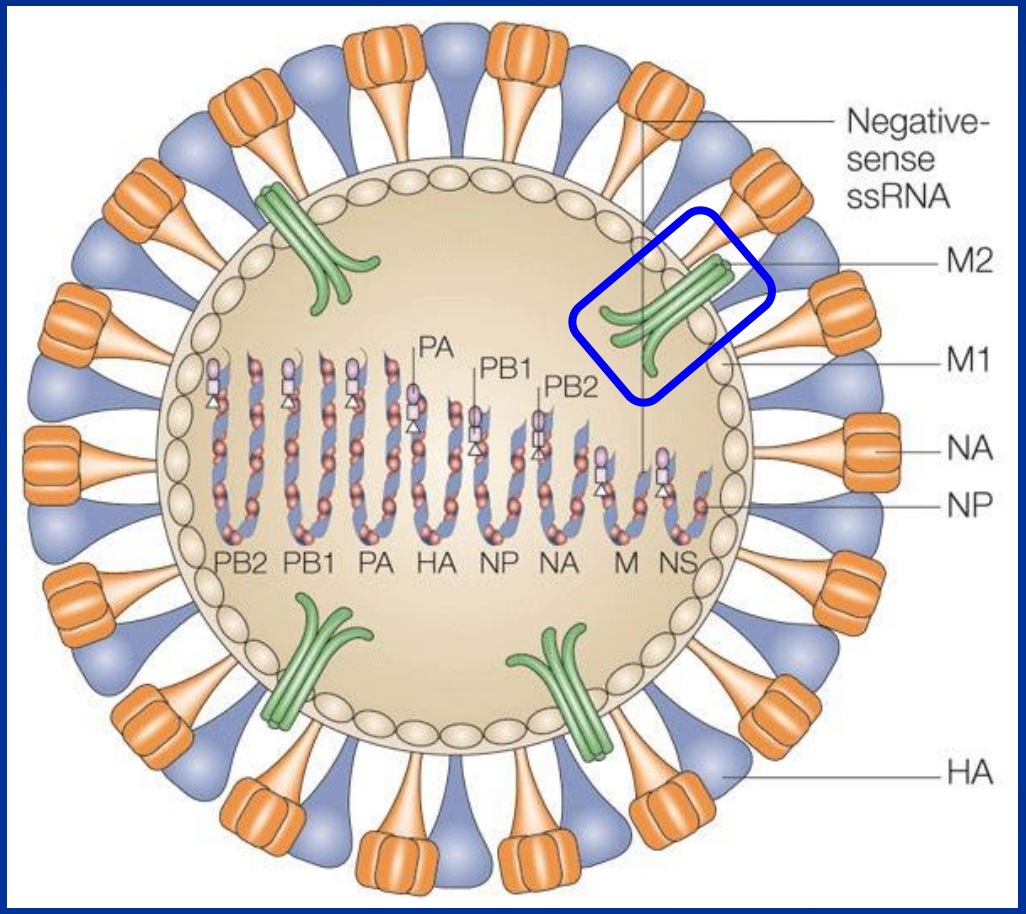
1- Protection of the loose envelope structure

2- Assembly of new viruses

Exp.: Ebola virus

Envelope-Associated Structures

3- Ion-Channel protein:



Functions:

1- Maintain pH of virus envelope.

2- Mediates uncoating of virus envelope during replication.

Exp.: Influenza

Functions of Virus Coatings

1. Protects the fragile genome from physical, chemical or enzymatic damage
2. Recognition and attachment of virus to host cell.
3. Initiation of infection by delivering the viral genome in the host cell.
4. Assembly and release of new viruses from host cell.
5. Principle targets of host immunity.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