Virus structure

Lecture Two
2nd stage

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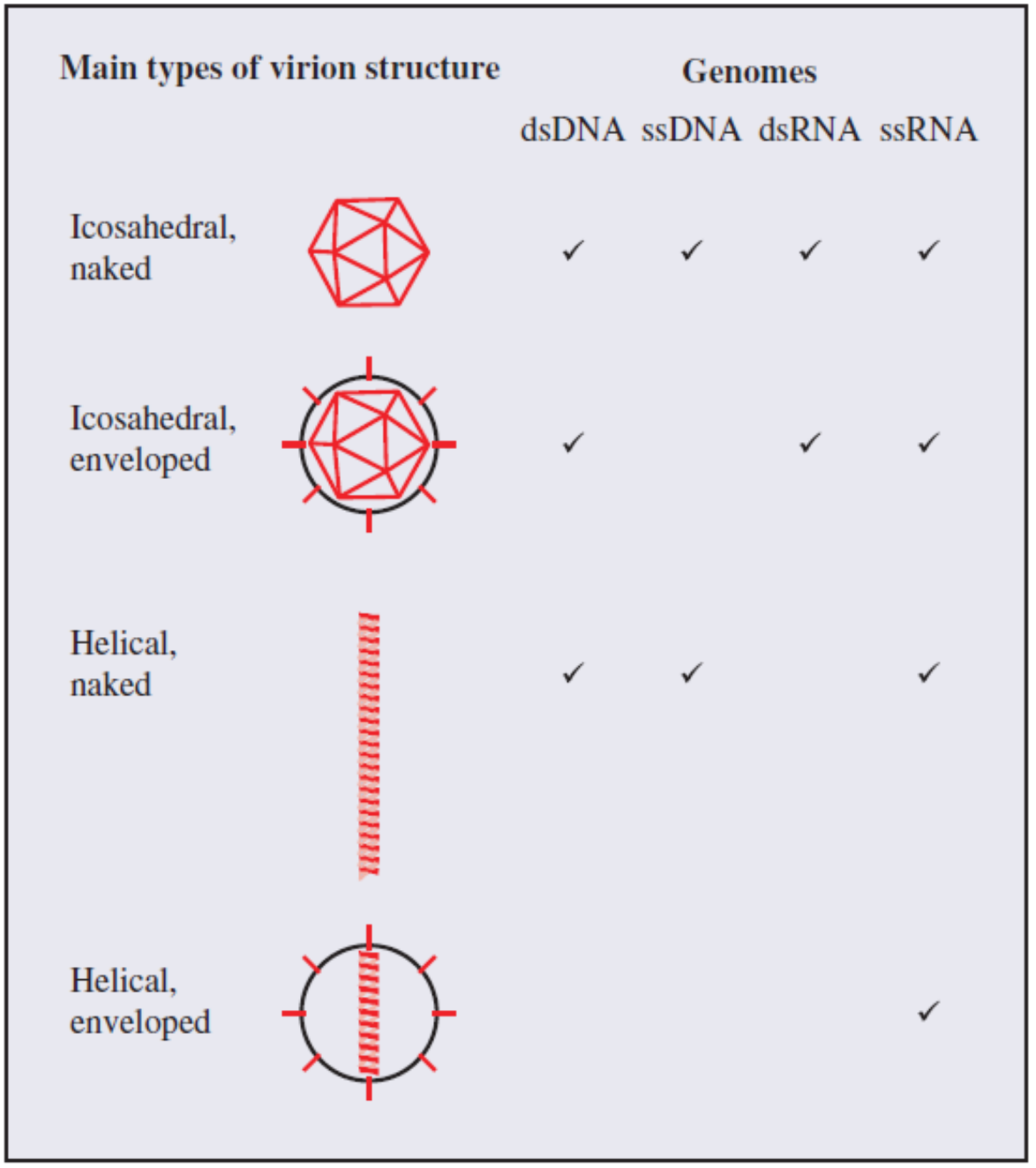
- Viruses have genome either DNA or RNA which is double-stranded (ds) or single-stranded (ss).
- Virions can be categorized into four groups according tc their structure: icosahedral (enveloped, naked) and helical (enveloped, naked).
- Naked icosahedral capsid is common in all viruses containing genomes.
- Most viruses have icosahedral enveloped capsid except for ssDNA viruses.
- There is any dsRNA viruses with naked helical symmetry.
- Helical enveloped is the only symmetry that exists in ssRNA viruses.



- In order to retain their infectivity, virus particles (**virions**) should struggle the harsh environment that could inactivate the nucleic acid genome from physical, chemical, or enzymatic damage.

- **All** virions consist of the virus **genome** which is packaged in a protein structure known as **capsid**.

- **Many** viruses also have a lipid component, present at the surface of the virion forming an **envelope** which also contains proteins that play a role in entry of virus into host cells.

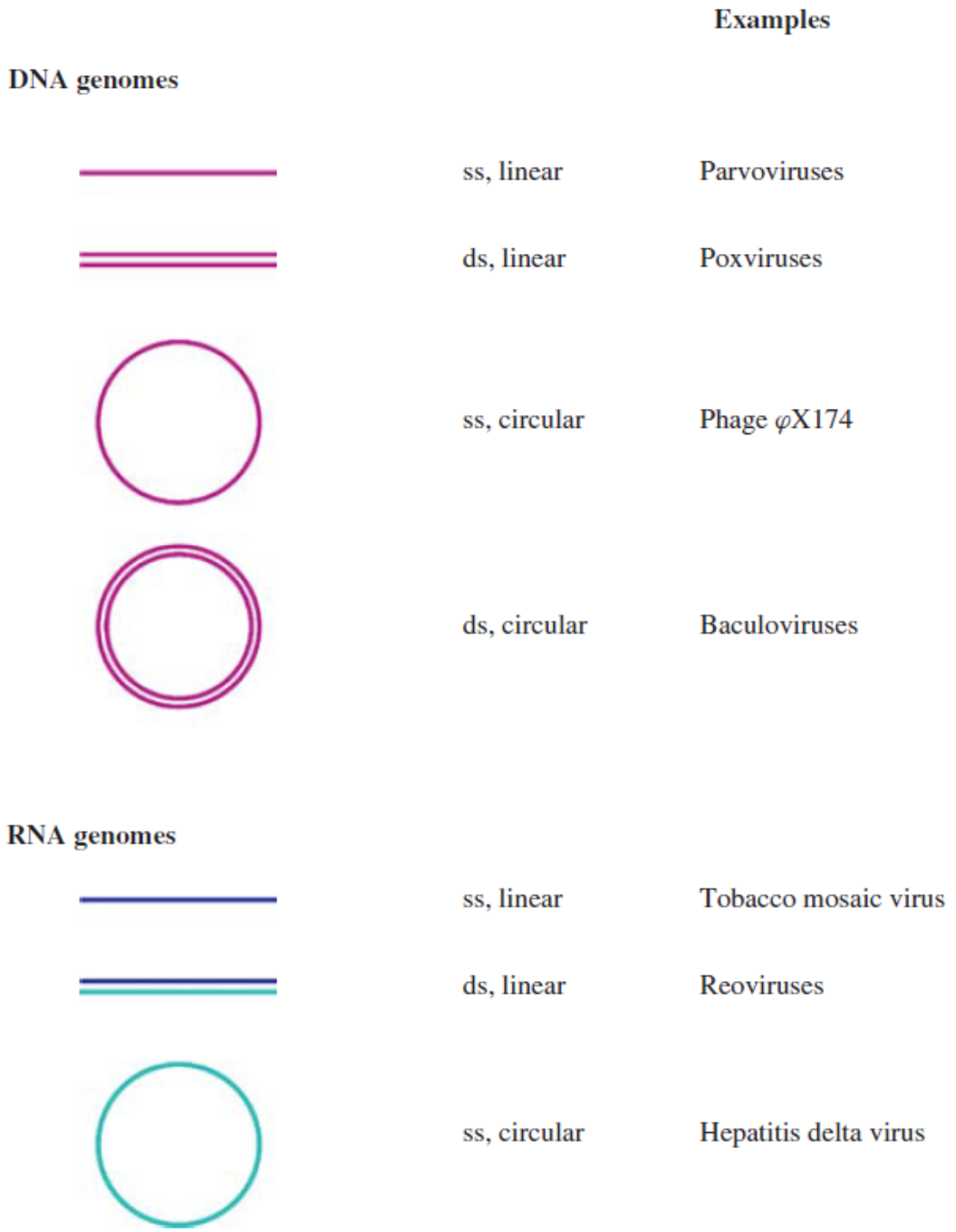
➢ Virus component and structure

1. **Virus genomes:** virus has genome which is composed of either DNA or RNA. According to the number of nucleic acid strands, viruses can be classified into dsDNA, ssDNA, dsRNA, and ssRNA.

- Virus nucleic acid is either linear with free 5’ and 3’ ends or circular as a result of the strand(s) being covalently closed as showed in the figure.

- There are no viruses known with circular dsRNA genomes.

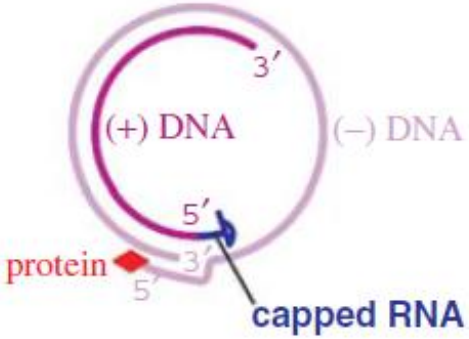
- φ = phi



Modifications at the ends of virus genomes

Genomes of some DNA viruses and many RNA viruses are modified at one or both ends. Some virus genomes have a covalently linked protein at the 5’ end which functions as a primer for initiation of genome synthesis.

DNA virus genomes with one or both ends modified.

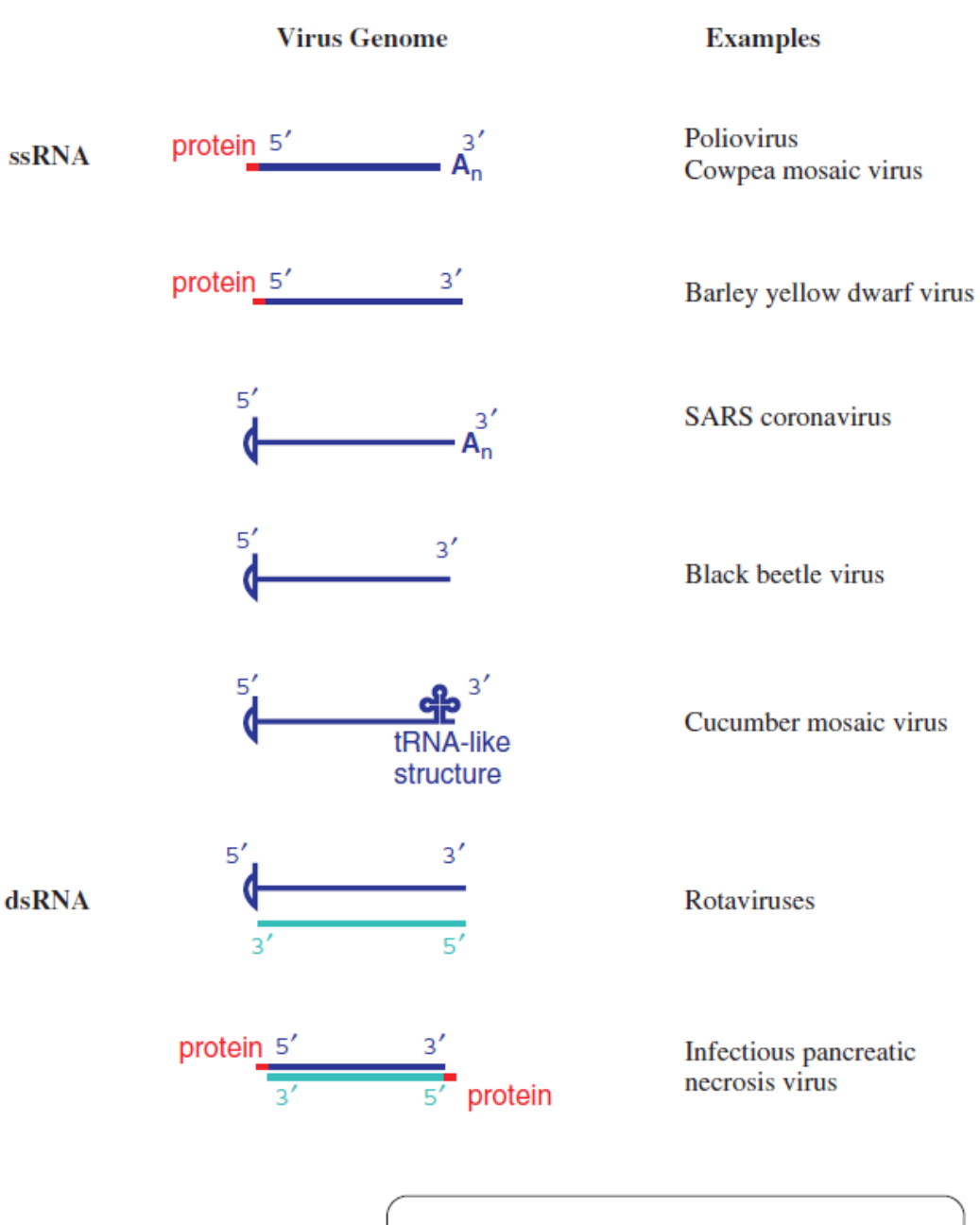
Virus Genome		Examples
dsDNA		Adenoviruses Phage PRD1 (*E. coli*)
		Hepatitis B Virus
ssDNA		Parvoviruses

Some RNA genomes are modified at one or both ends mimicking the mRNAs in eukaryotic cells which has a methylated nucleotide cap at the 5' end and a sequence of adenosine residues (a polyadenylate tail; poly (A) tail) at the 3' end. However, the cap and poly A tail structures are not necessary for translation of virus ssRNA to function as mRNA. Many virus ssRNAs can be translated albeit lacking the cap tail structures, as in the figure below.

Some ssRNA plant viruses are base paired and folded near their 3' end to form structures similar to transfer (tRNA) which promote the initiation of RNA synthesis.

- **Segmented genomes: Most virus genomes consist of a single molecule of nucleic acid, but the genes of some viruses are distributed on two or more nucleic acid molecules. The segmented genomes are more common in RNA viruses than DNA viruses. Influenza virus is a ssRNA virus with segmented genome packaged in one virion and brome mosaic virus which packages the segments in two separate virions. The segmented genome provides the virus the possibility of evolution via gene recombination. However, infection of cells with the viruses of segmented genomes packaged in separate virions requires all genome segments (i.e. virions containing the segmented genome) to enter the cell.**

RNA virus genomes with one or both ends modified. The 5’ end may be linked to a protein or a methylated nucleotide cap. The 3’ end may be polyadenylated or it may be folded like a transfer RNA.



2. Virus proteins

- **Viruses encode their own proteins which have various functions and they are classified into structural and non-structural proteins. Virion-forming proteins are known as structural proteins. Their functions are including:**

i. **Protection of the virus genome.**
ii. **Attachment of the virion to a host cell.**
iii. **Fusion of the virion envelope to a cell membrane (for enveloped viruses).**

Non-structural proteins are synthesized by the virus in an infected cell but they are not virion components. They function as:

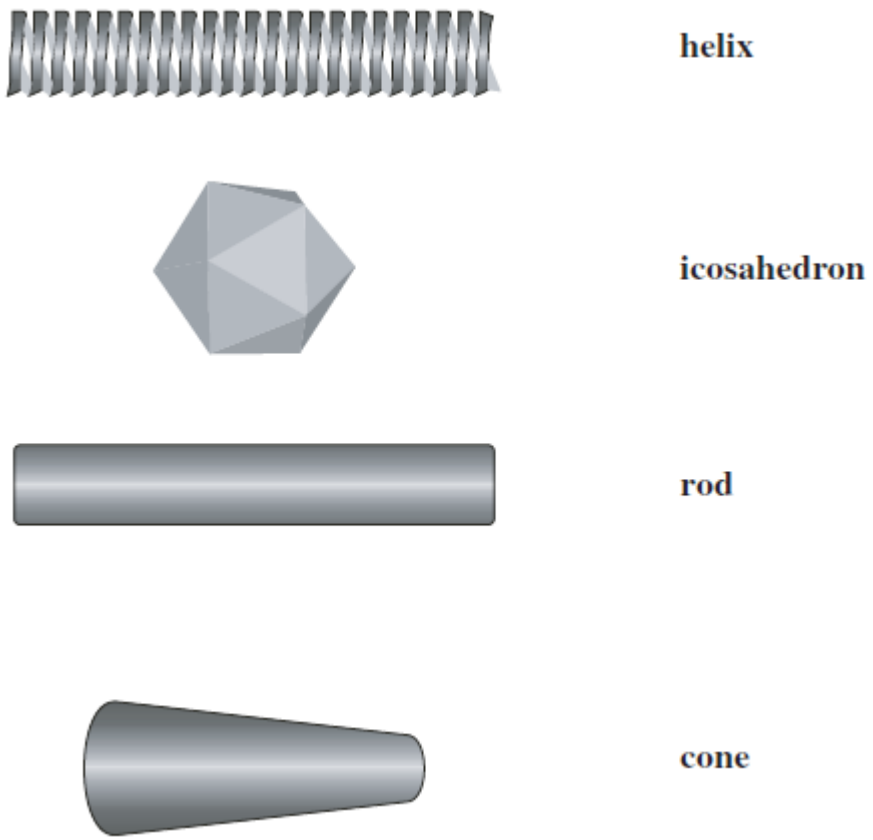
A. Enzymes, e.g. protease, reverse transcriptase
B. Transcription factors
C. Primers for nucleic acid replication
D. Interference with the immune response of the host.

- **Capsids**

Capsids are constructed from many molecules of one or a few species (type, subunit) of protein. The capsid protein subunits are asymmetrical, but they are organized to form symmetrical structures.

✓ **Various types of symmetrical structures can be seen among virus capsids. The vast majority of virus capsids have either helical or icosahedral symmetry.**

Types of symmetrical structures



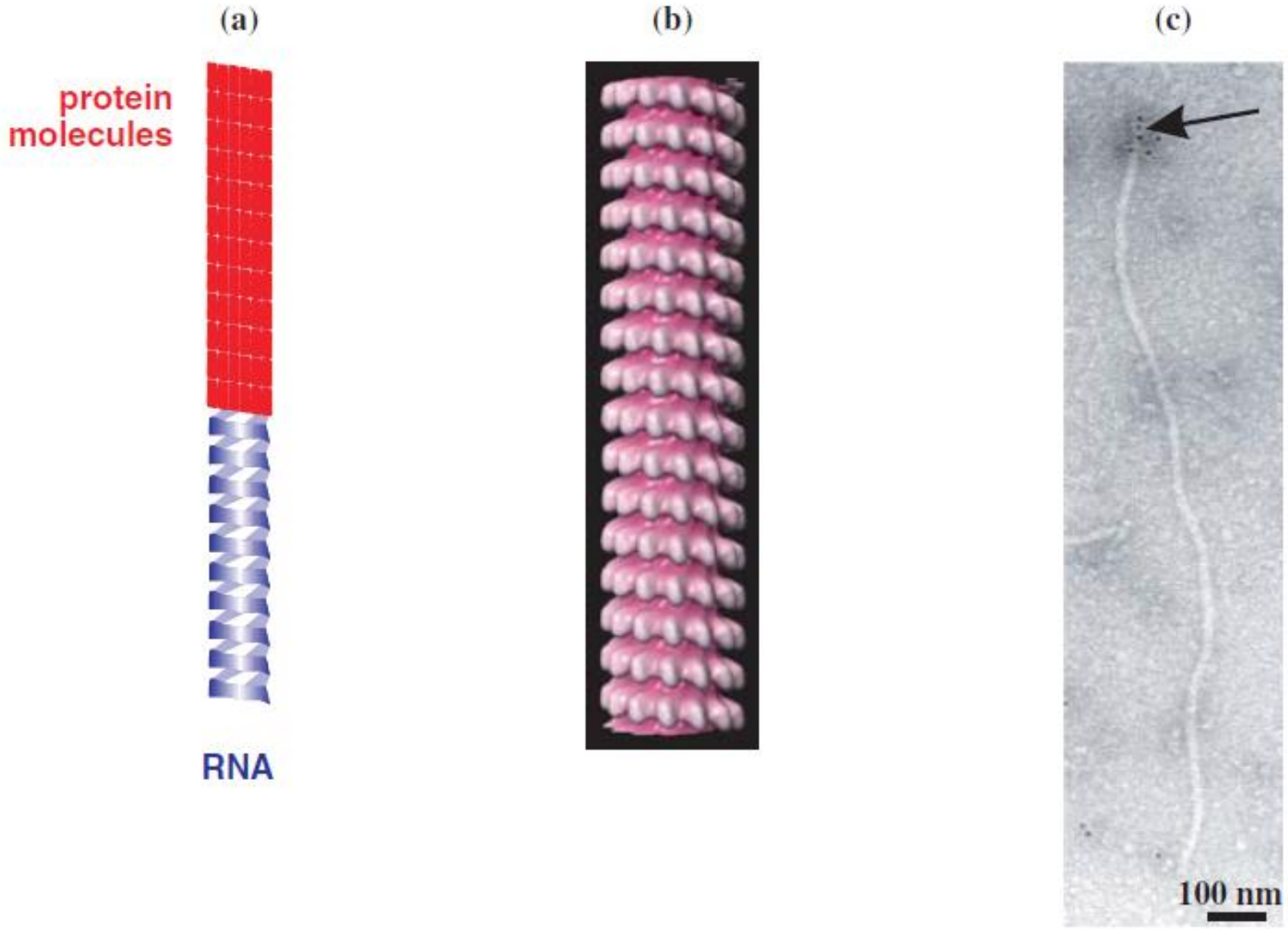
- **Capsids with helical symmetry**

Helical symmetry is very common in ssRNA viruses. The RNA is coiled in the form of a helix and many copies of the same protein species are arranged around the coil. This arrangement forms an elongated structure which may be either a rigid rod if the protein molecules are bound in strong bonds in turns of the helix, or a flexible rod if these bonds are weak. The capsid varies in length according to the length of the nucleic acid.

Influenza virus and measles virus are ssRNA viruses and have helical nucleic acids which are coated with protein to form nucleocapsid, which is inside an envelope. The nucleocapsid may be coiled or folded to form compact (complex) structure.

Tobacco rattle virus has a segmented genome with two RNA molecules of different sizes. These molecules are packaged in separate virions to yield two lengths of rod-shaped virions.

M13 bacteriophage is an example to the filamentous DNA viruses that have helical symmetry.



(a) Capsid with helical symmetry. (b) part of measles virus nucleocapsid. (c) long flexible rod virion.

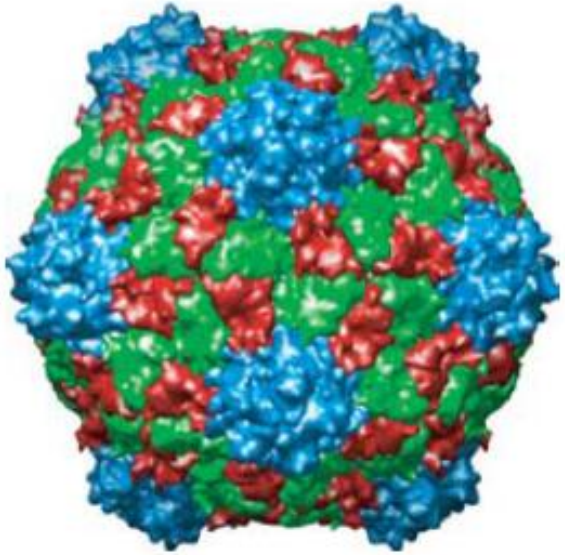
- **Capsids with icosahedral symmetry**

Icosahedron is an object with 20 faces (triangles), 12 vertices, and 30 edges.

Icosahedral capsids are built from identical protein molecules arranged in an icosahedron. The minimum number of identical protein molecules required for icosahedron construction is three molecules per one triangle, totally 60 molecules for icosahedron (3*20=60). There are many icosahedral capsids may composed of more than 60 molecules.

Also the capsids of many icosahedral viruses are constructed from more than one protein species. For instance, cowpea mosaic virus is composed of two proteins.

Cowpea mosaic virus capsid



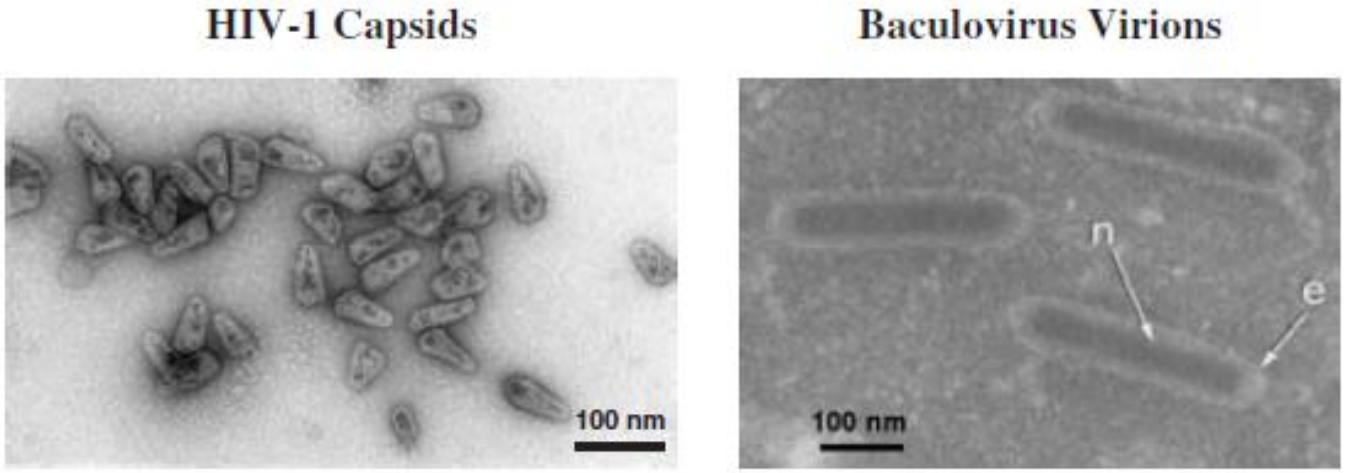
Capsid constructed from two protein species.

- **Capsid shapes (capsid surface)**

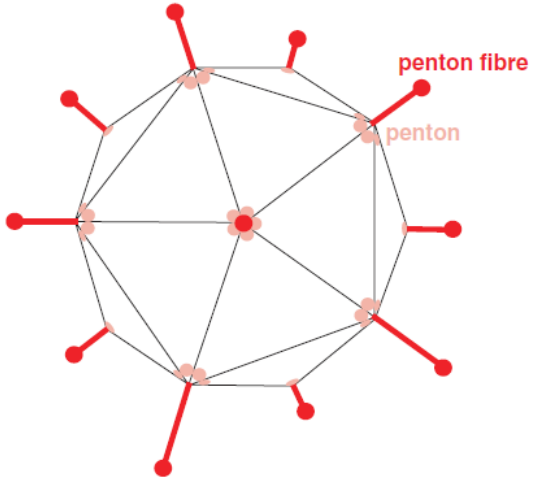
Capsid surfaces vary in their topography, in which there may be canyons, hollows, ridges, and/or spikes present.

There are also projections, knobs, and fibers at each of 12 vertices of the capsid. These structures are involved in attachment of the virion to its host cell and in delivery of the virus genome into the cell.

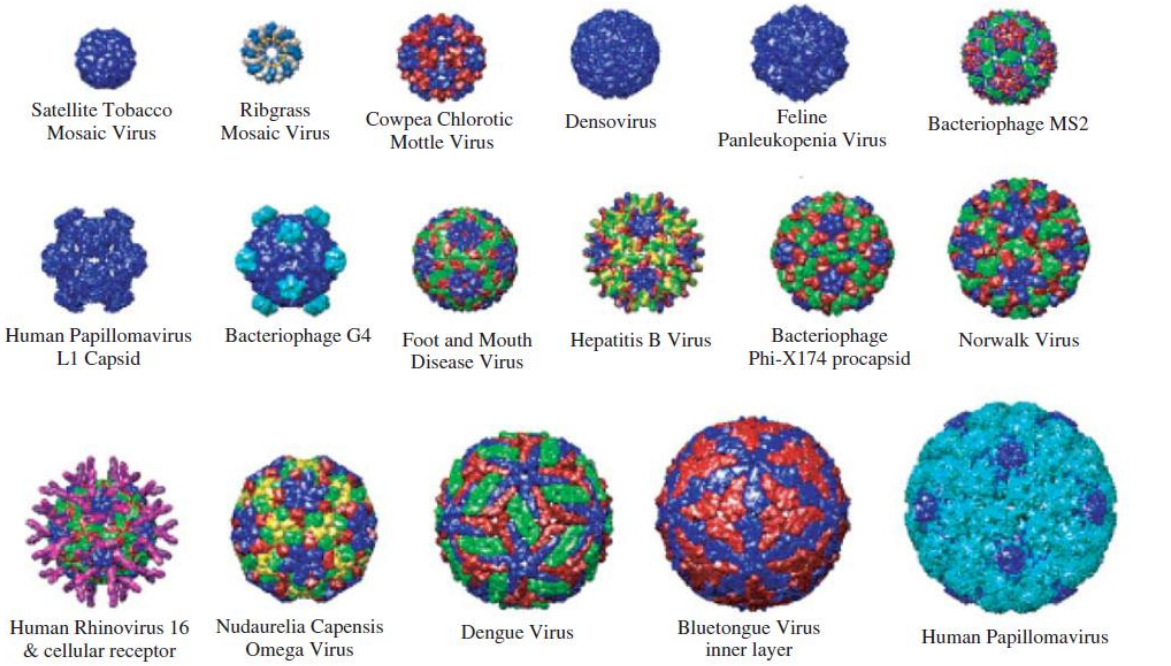
- **The football is constructed in a form of icosahedral symmetry, but the structure is spherical.**
- **Many small viruses with icosahedral capsids appear to be spherical which is known as isometric such as adenoviruses and foot and mouth disease virus.**
- **Some capsids with icosahedral symmetry are elongated like geminiviruses (Plant viruses) which are formed from two incomplete icosahedra.**
- **HIV-1 and baculoviruses have capsids that are conical and rod-shaped, respectively.**



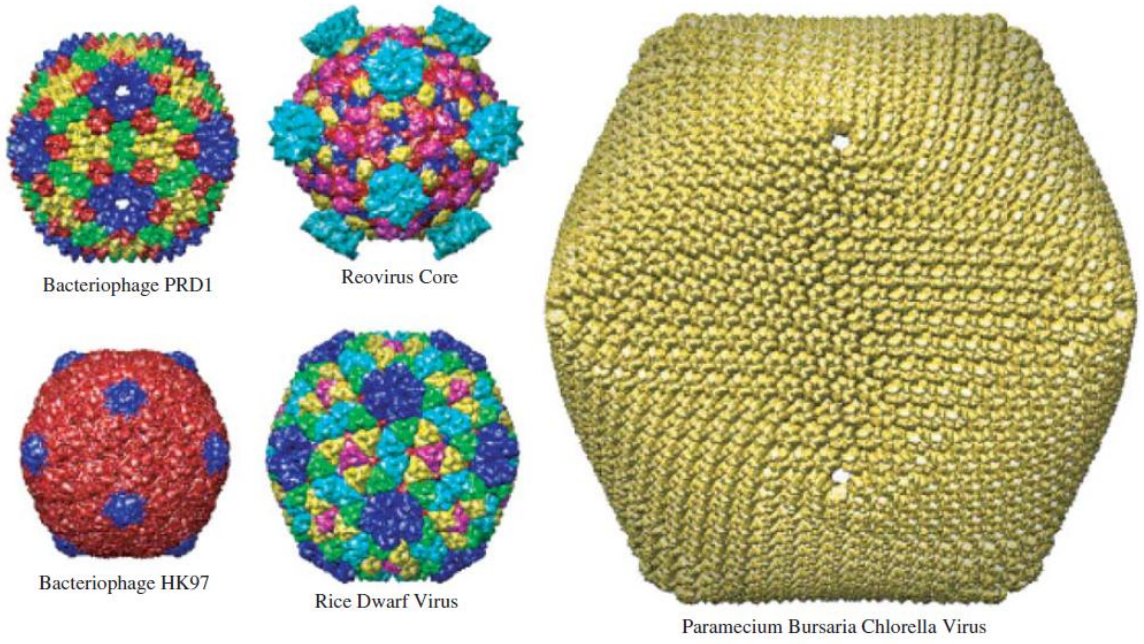
Conical and rod-shaped capsids



Adenovirus virion. fibers with the knobs at the end



Capsids with icosahedral symmetry.



- **Enveloped virions**

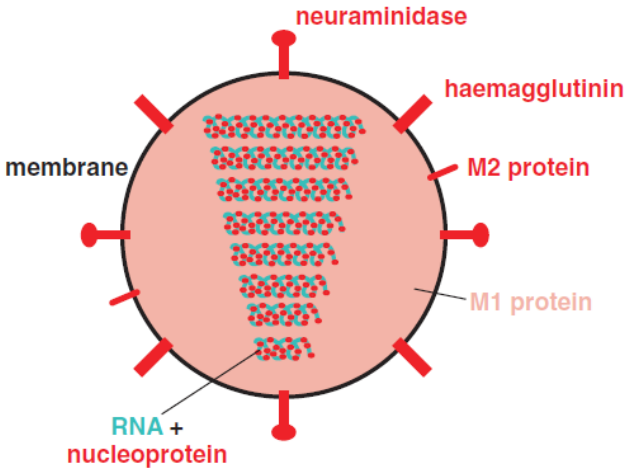
Envelope is a lipid-protein structure at the virion surface and associated with one or more of virus protein and it encloses the nucleocapsid (nucleic acid plus capsid).

Many animal viruses are enveloped including all those with helical symmetry e.g. influenza virus and those with icosahedral symmetry such as herpesviruses. Enveloped virions are much less common in plant viruses.

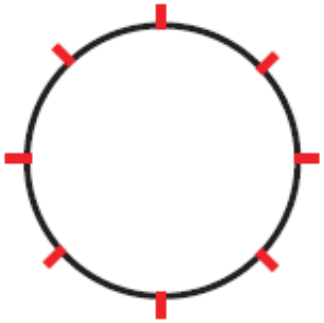
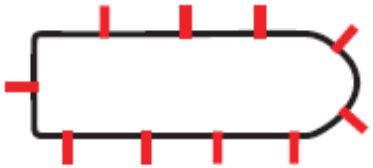
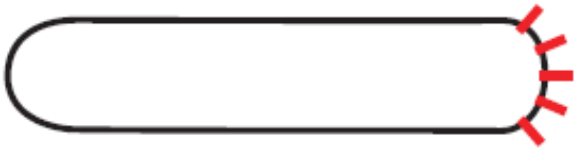
One or more species of protein associates with membranes of enveloped virus. Most of proteins are glycosylated (glycoprotein). For instance, the envelope of influenza A virus has two glycoprotein species: haemagglutinin and neuraminidase, besides the third protein species (M2) which is not glycosylated. The glycoprotein of envelope mediate the fusion of the virion to a cell membrane during the infection process.

- **Membrane lipids**

Most virion membranes are derived from host cell membranes , for example, HIV-1 envelope is derived from the plasma membrane of the host cell. Virions gain their membranes when they are released from cells.



Influenza A virus

Virion Shape		Examples
Enveloped Viruses		
Sphere		Influenza virus
Bullet		Rabies virus
Rod		Baculoviruses
Thread		Ebola virus

Virion shape