Structural Virology

Lecture 2

Pavel Plevka

NÁRODNÍ PLÁN OBNOVY

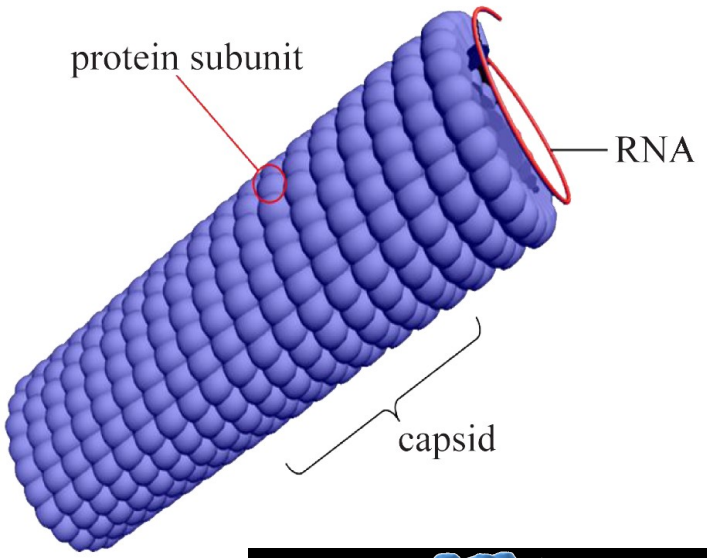
Infectious virus particle “virion”

Carrier of genetic information from cell to cell:

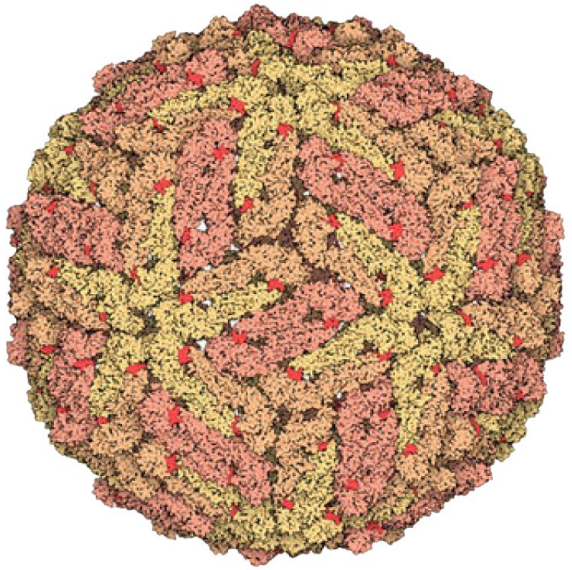
- "extracellular organelle”
- packages viral genome
- escapes from infected cell
- survives transfer from cell to cell
- attaches, penetrates, initiates replication in new host cell

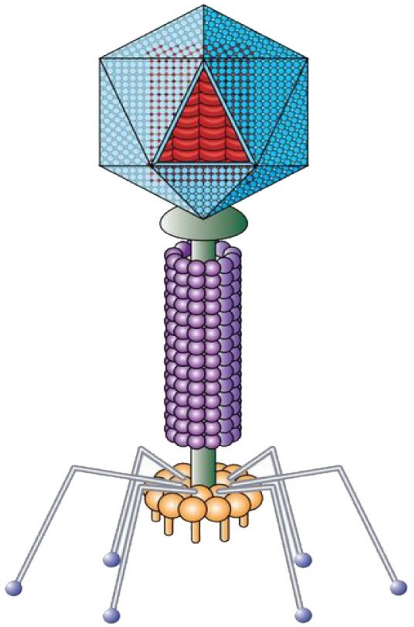
Virus structures

Helical

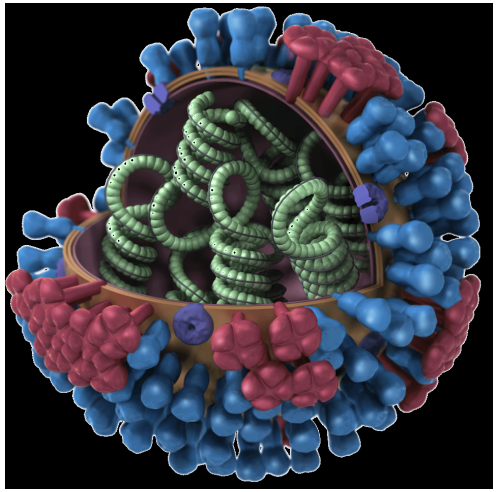


Icosahedral



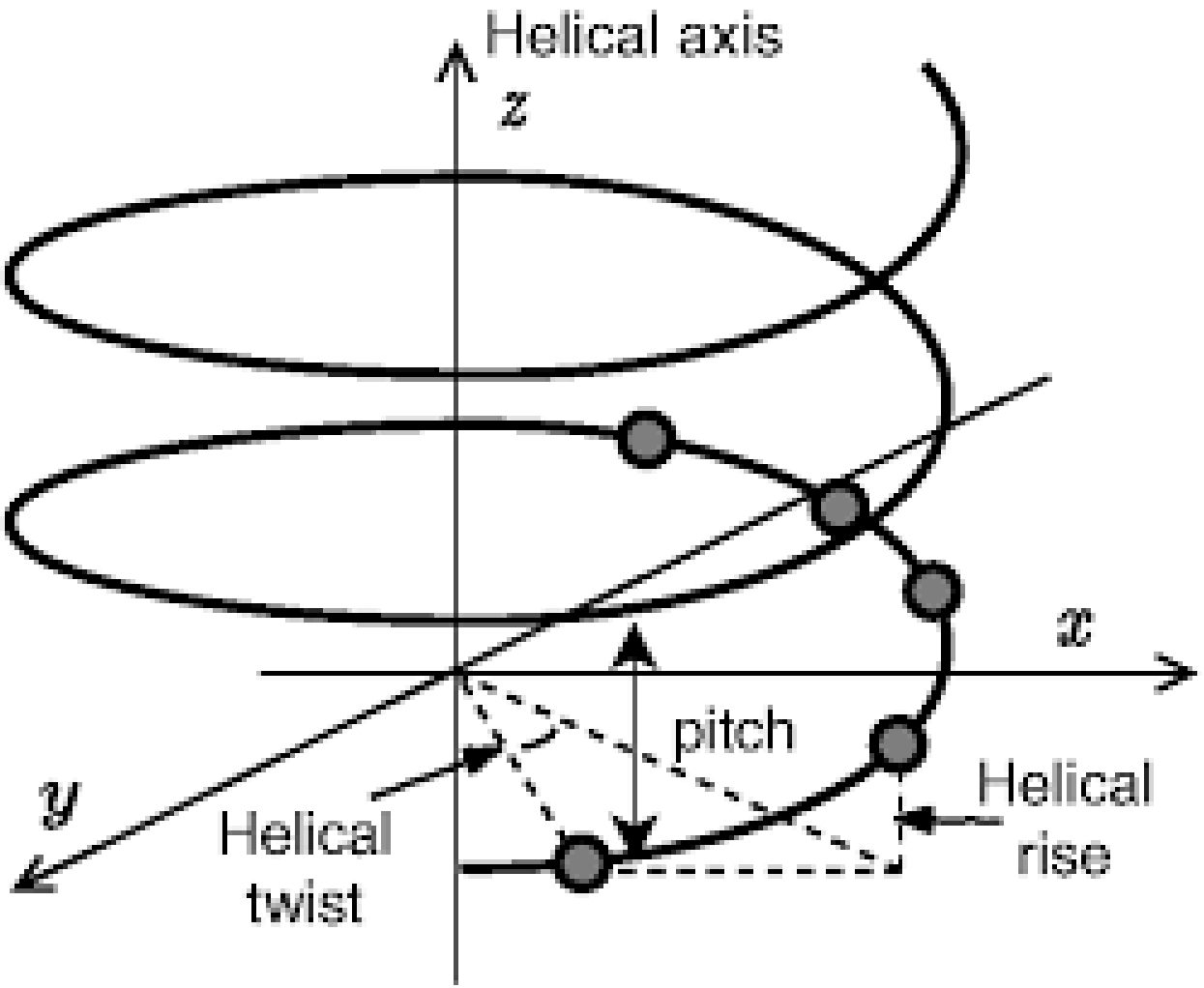


Complex



Irregular

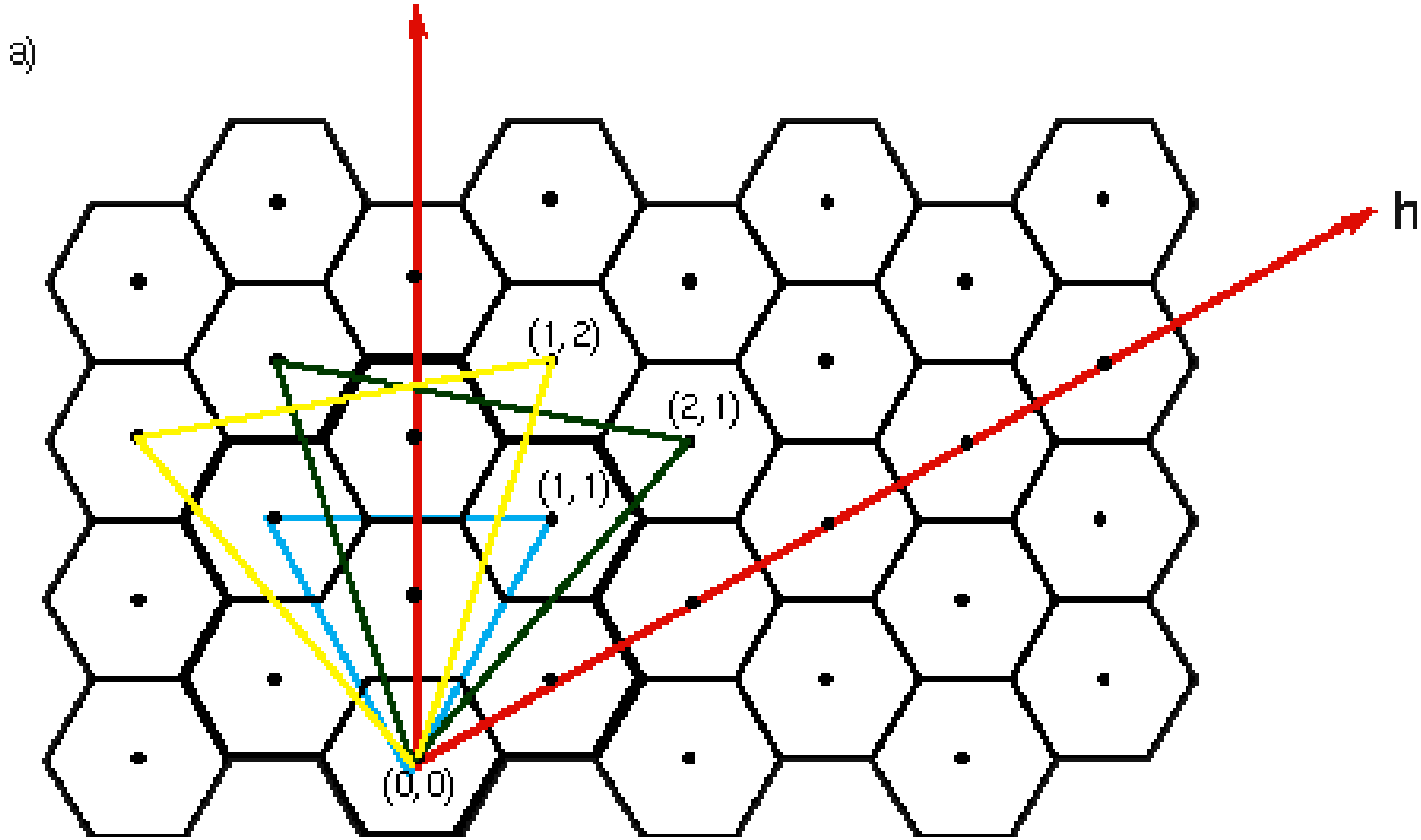
Helical symmetry



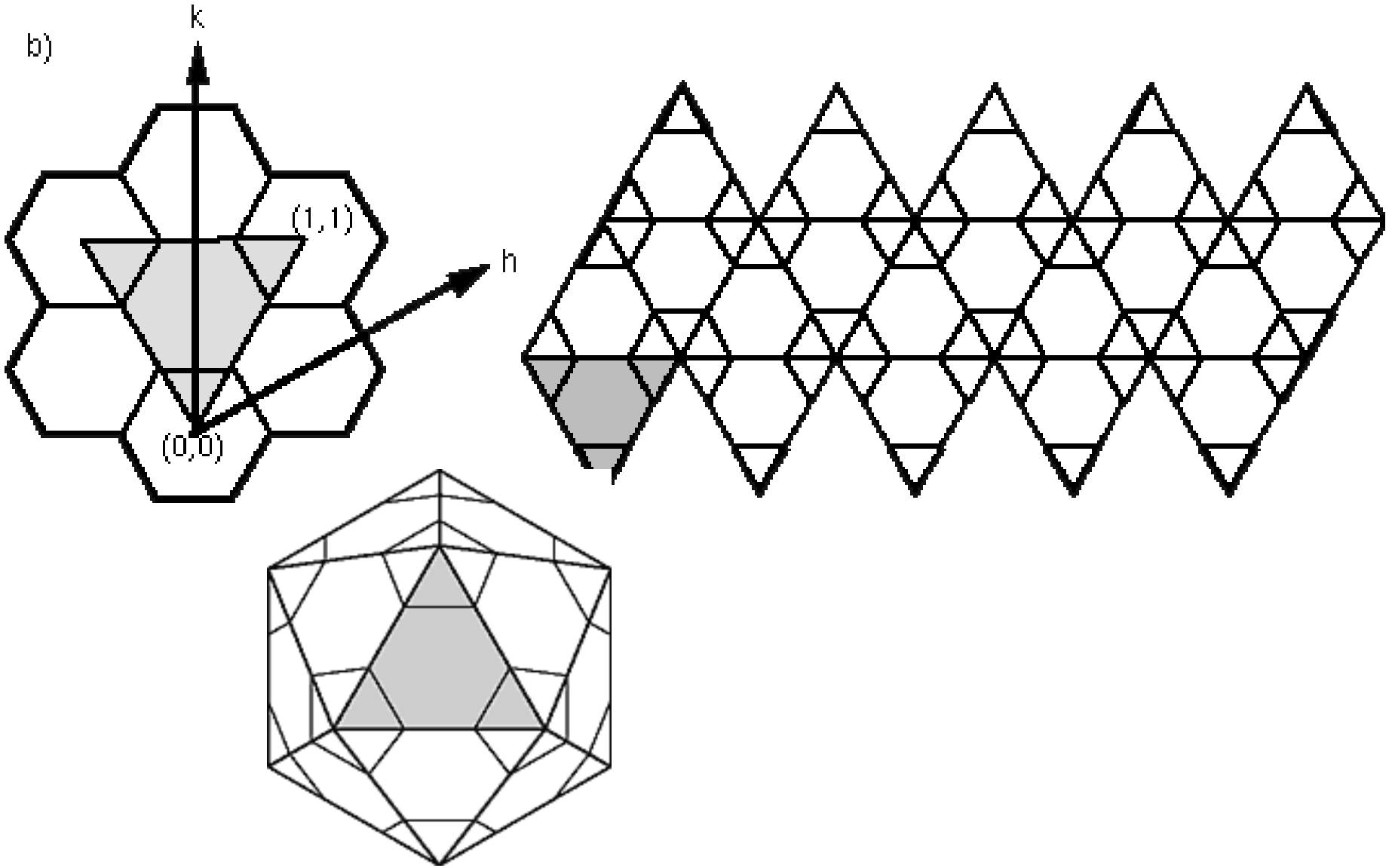
Pitch is the distance along the helix axis for one complete helix turn
Twist is the rotation between neighboring nucleotides

Quasi equivalence

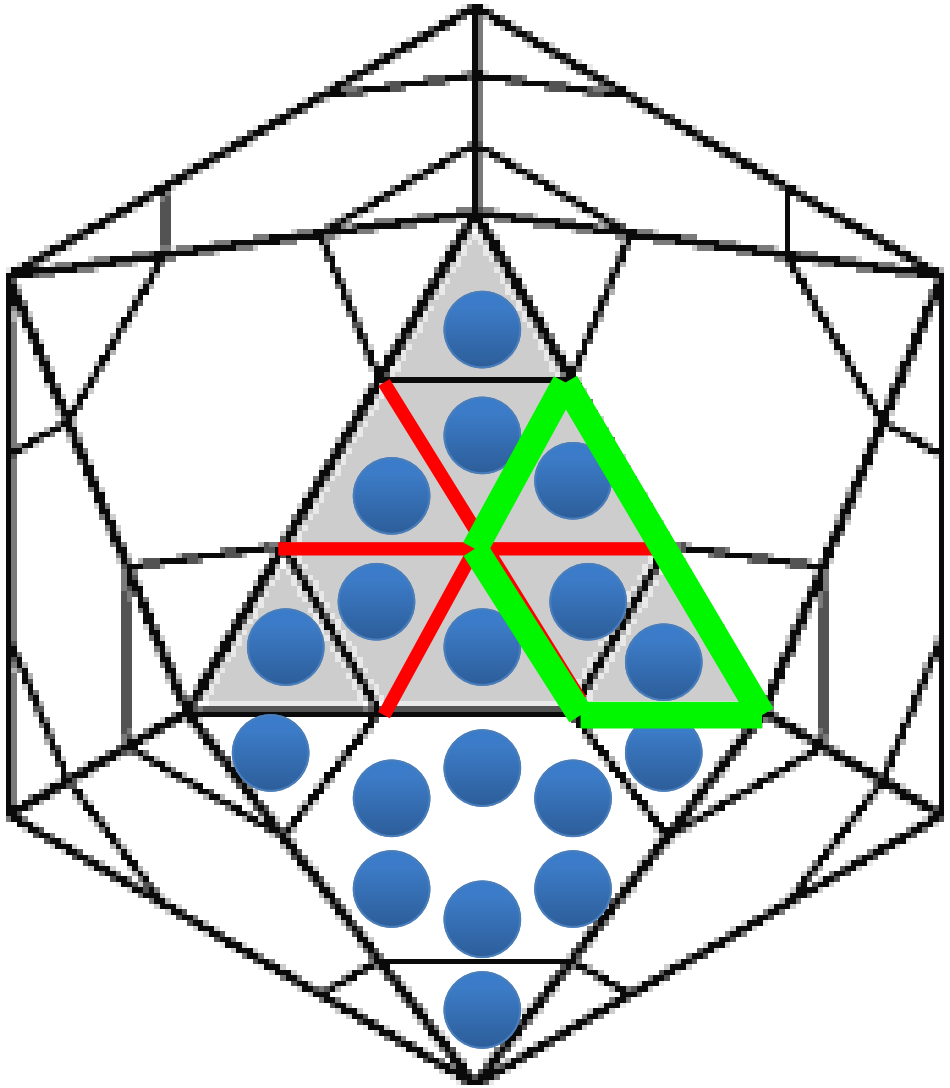
$$T = h^2 + hk + k^2$$



Quasi equivalence



Quasi-equivalence



Virus Particle Explorer db v3.0

The Hormel Institute
University of Minnesota

About | Data | Utilities | Virus World | ViBA | Help | Contact Us | Cite us | Find a Virus | PDB ID | Family List | Genus List

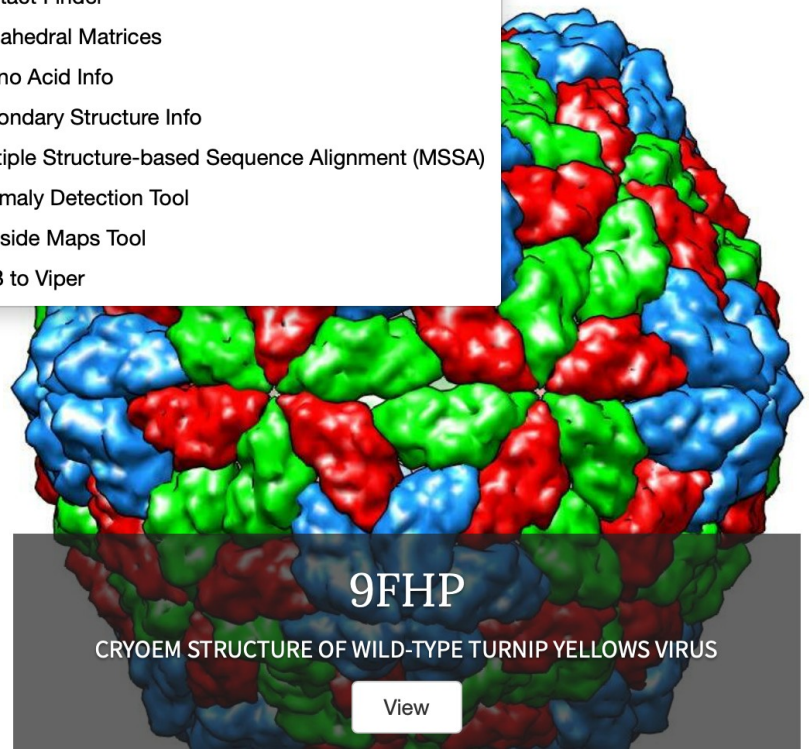
- Oligomer Generator
- Epitope Analyzer
- Viral Diseases Explorer
- Submit to VIPER
- Web API's
- Family Association Energies
- Reposition a capsid at the center of a box
- Icosahedral Server
- Gallery Maker
- Contact Finder
- Icosahedral Matrices
- Amino Acid Info
- Secondary Structure Info
- Multiple Structure-based Sequence Alignment (MSSA)
- Anomaly Detection Tool
- Capside Maps Tool
- PDB to Viper

Ne s now available @VIPERdb and @Virus World db

ent on viral diseases is now included.

75
Families
View Details

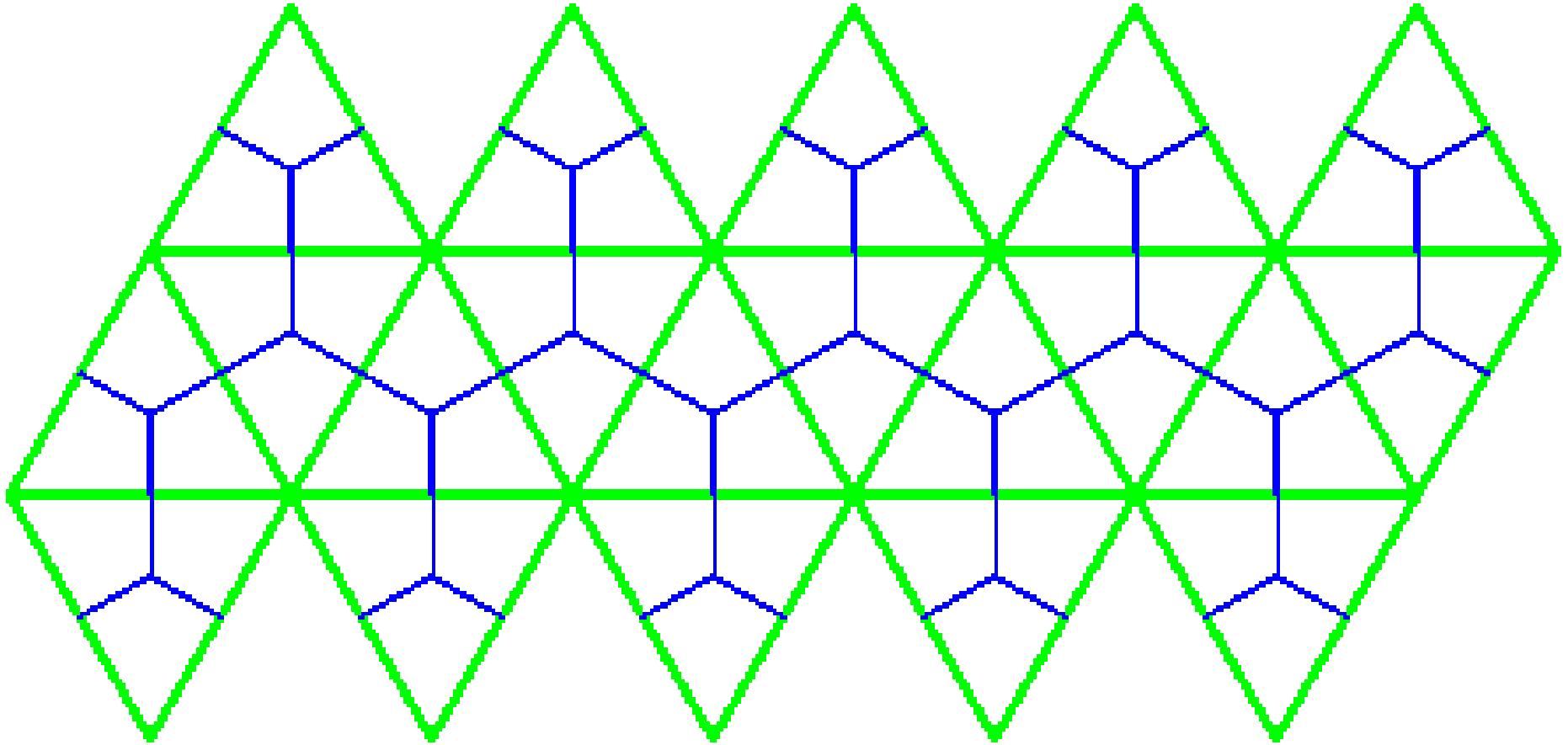
188
Genera
View Details



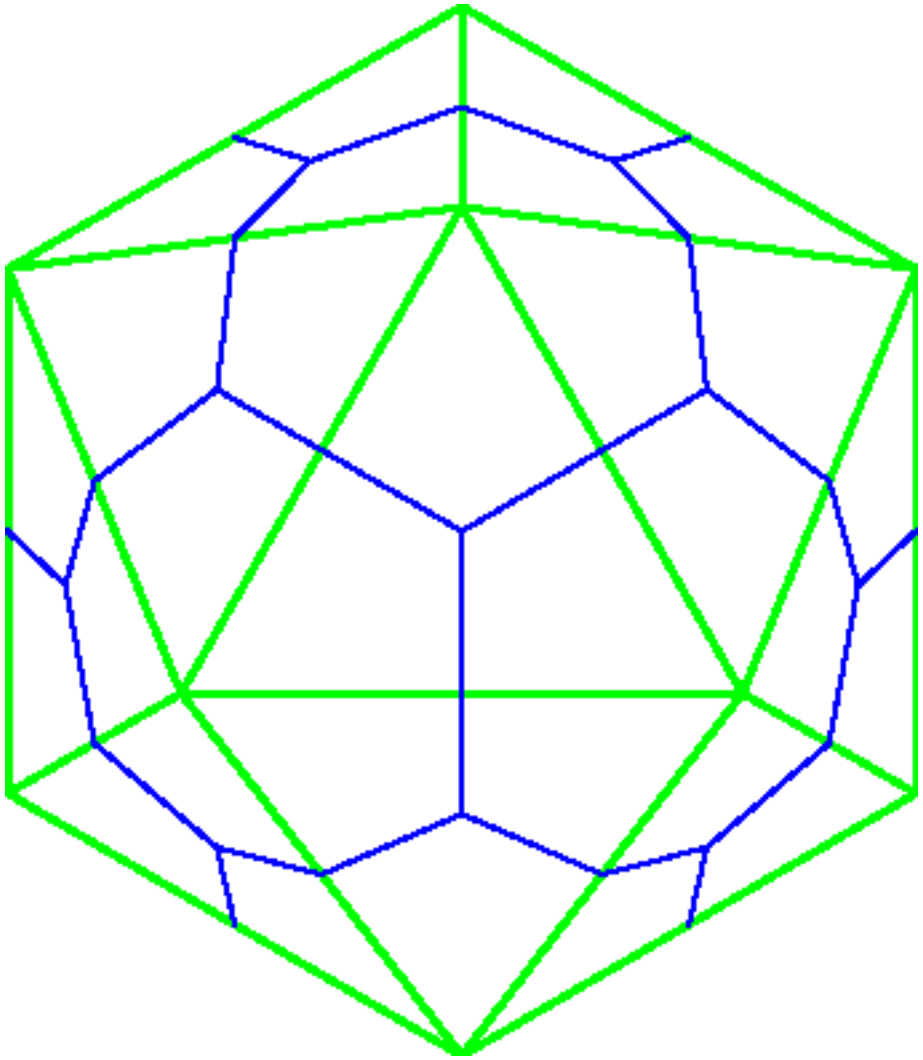
Latest Entries

9cuz	2024-07-27	Bufavirus 1 complexed with 6SLN
9g0b	2024-07-07	RHINOVIRUS A2 UNCOATING INTERMEDIATE REVEALING THE NATURAL POCKET FACTOR (PH 5.8 AND 4 DEGREES CELSIUS)
9cgm	2024-06-30	The Structure of Spiroplasma Virus 4
9fjc	2024-05-30	COMPACT CVB1-VLP (TWEEN80)
9fhp	2024-05-28	CryoEM structure of wild-type Turnip Yellows Virus
9ffg	2024-05-23	Empty capsid of Rhodobacter microvirus Ebor computed with I4 symmetry
9f5s	2024-04-30	EVA71 E096A NATIVE PARTICLE

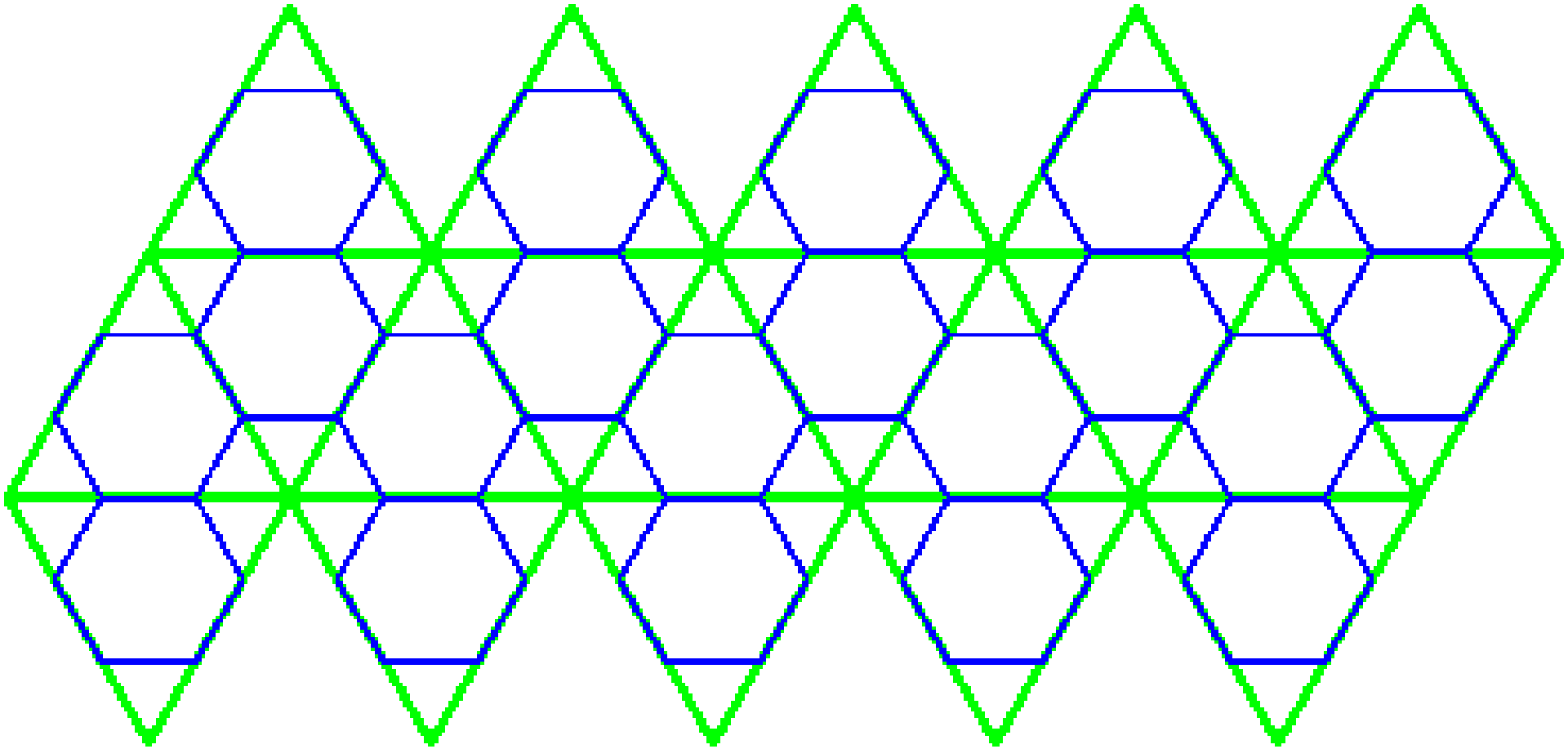
Equivalence



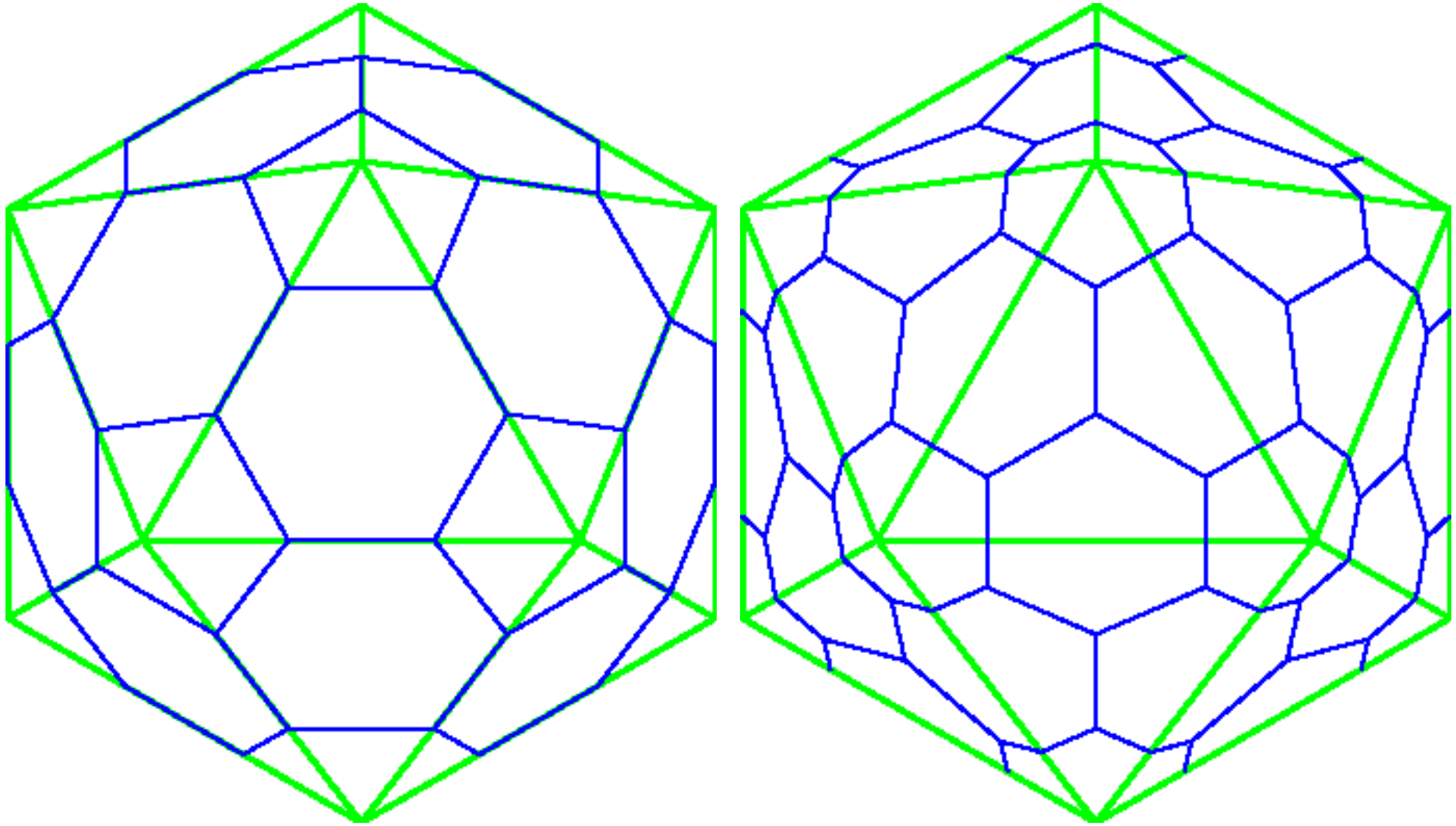
Equivalence



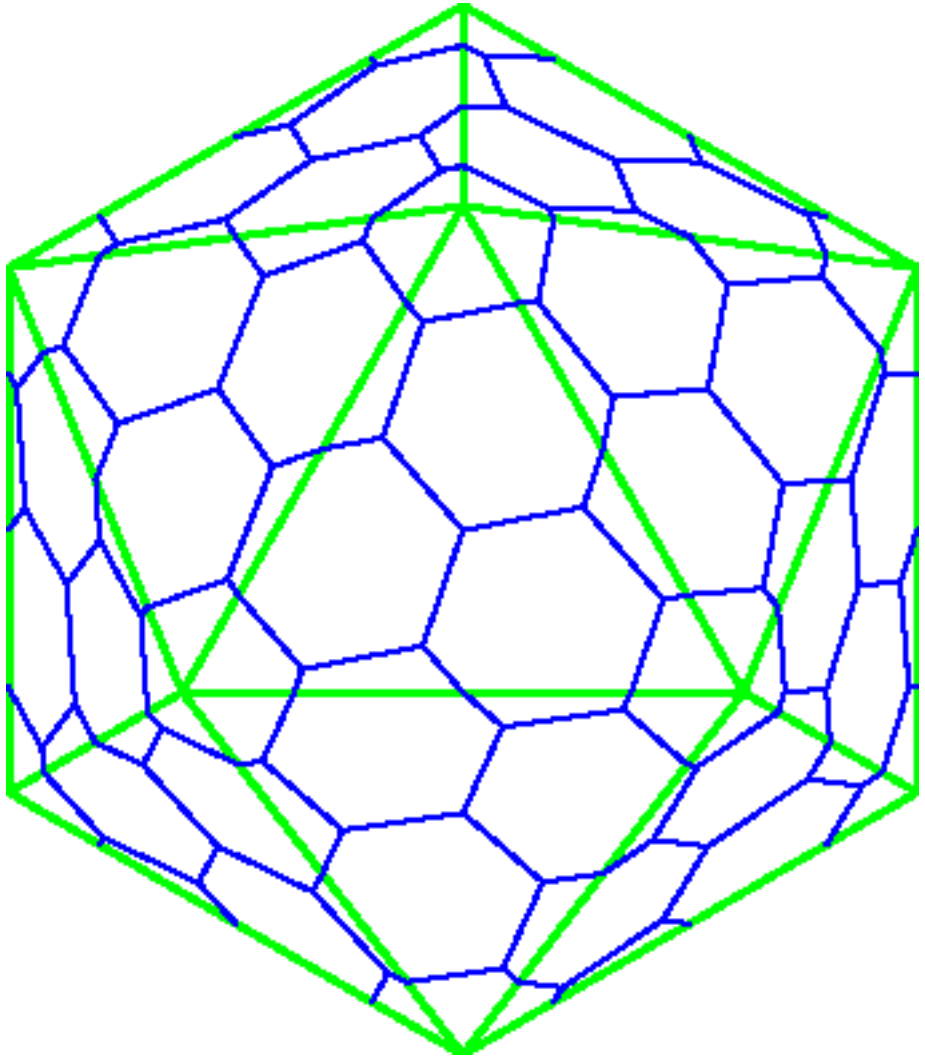
Quasi equivalence



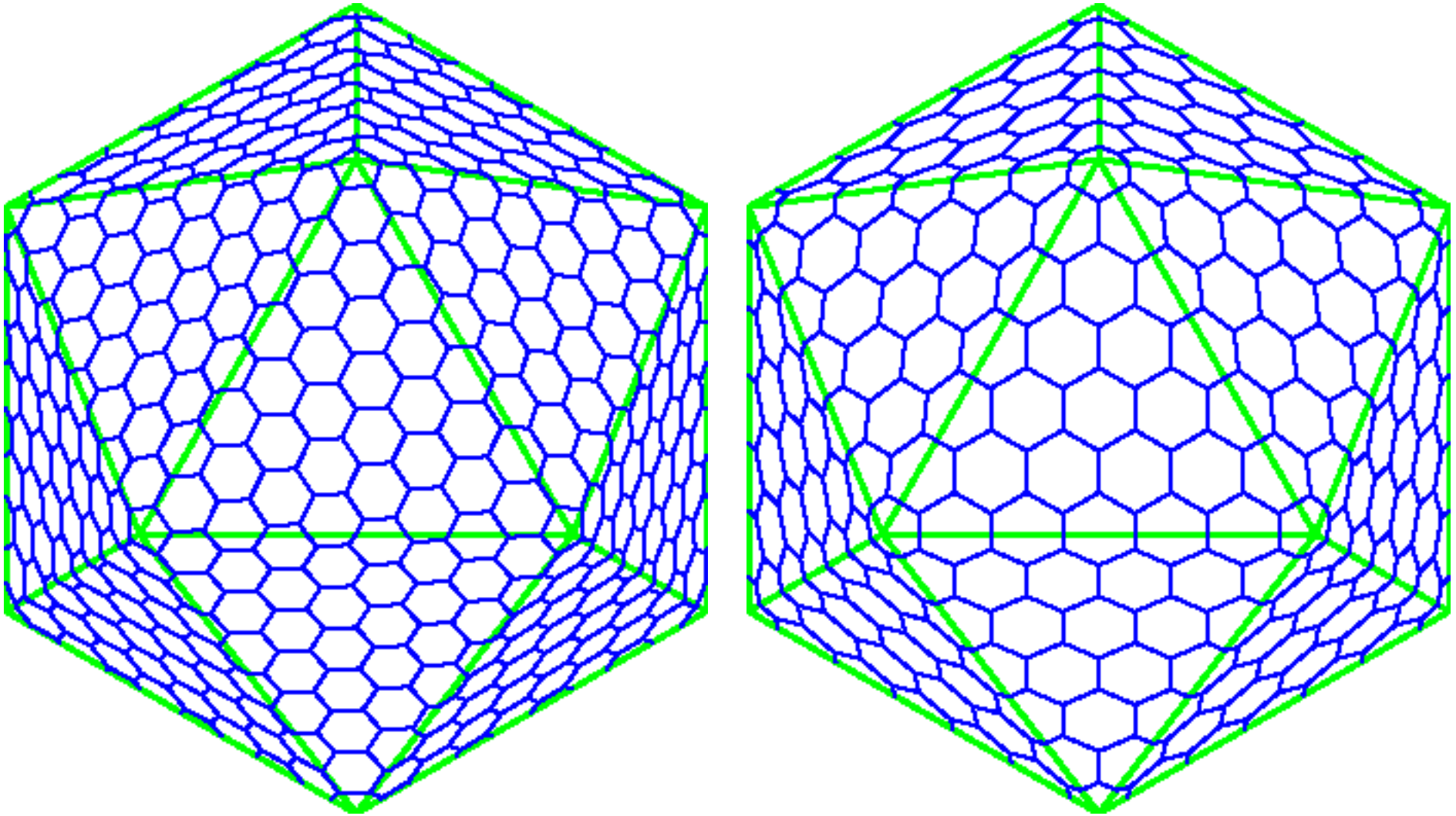
Quasi equivalence



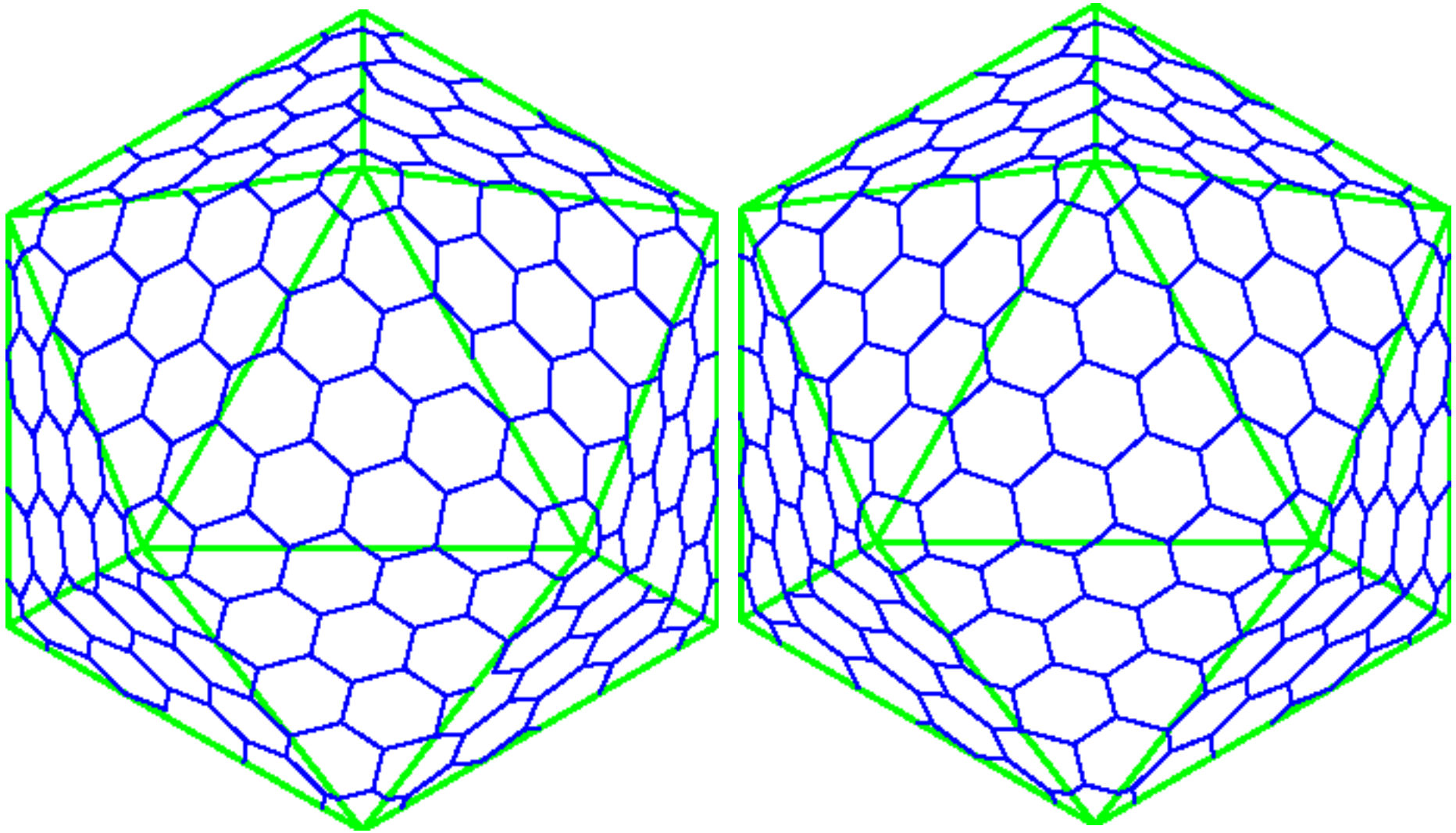
Quasi equivalence



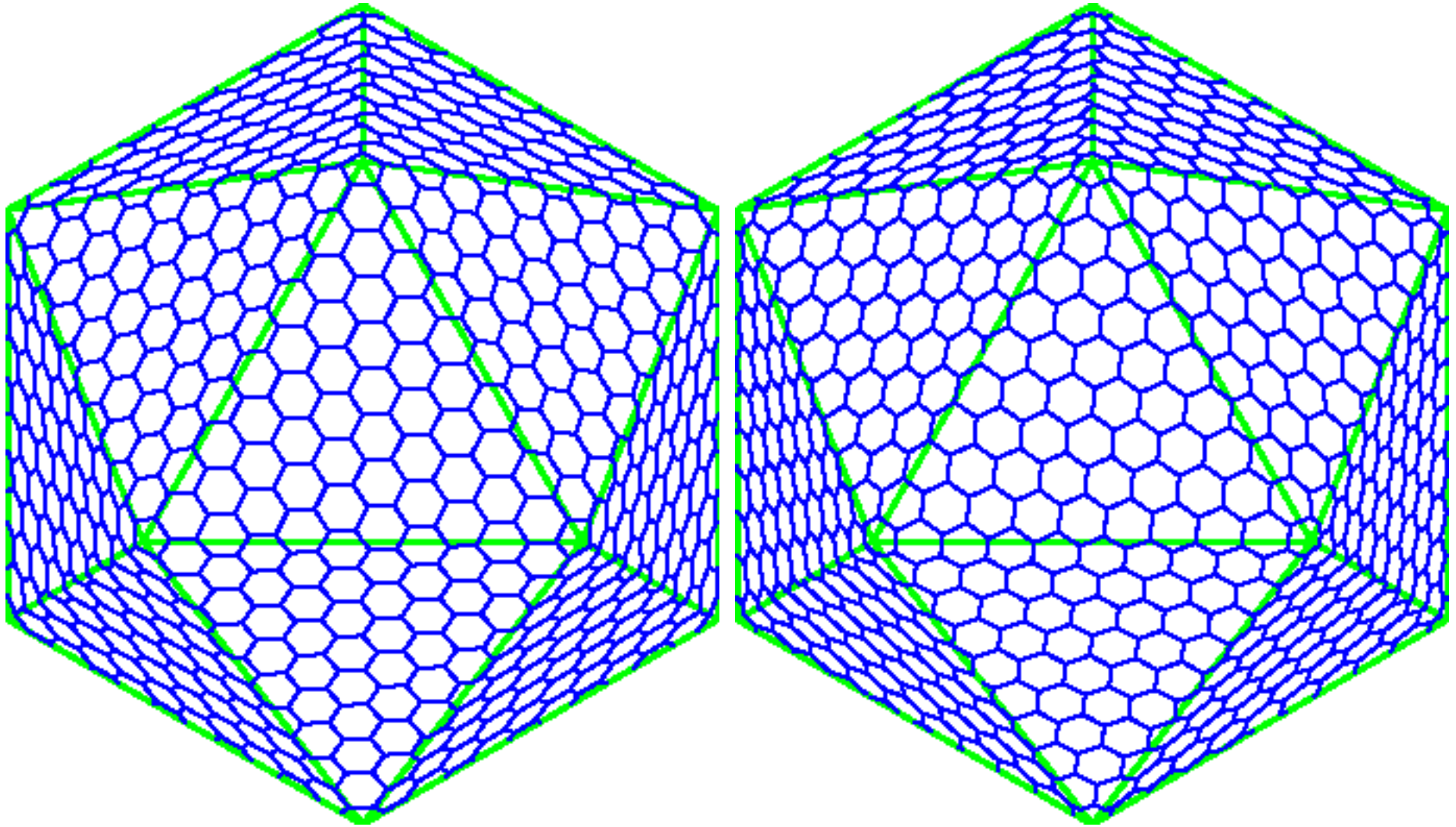
Quasi equivalence

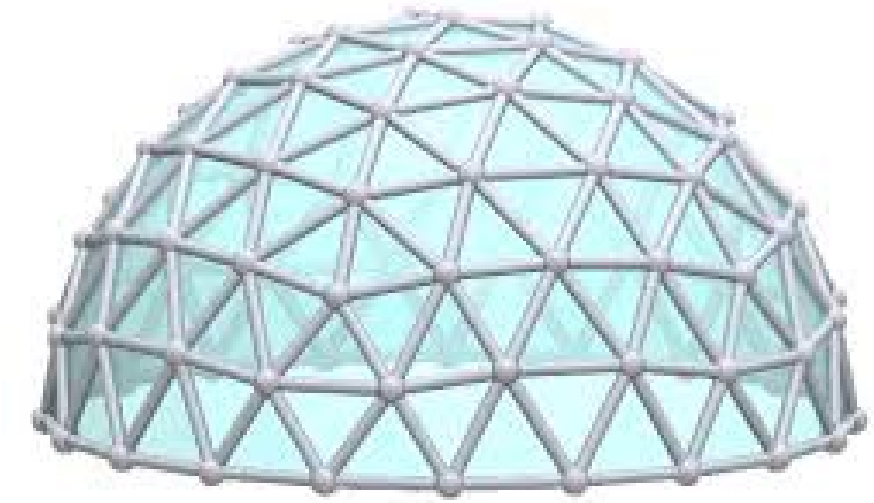


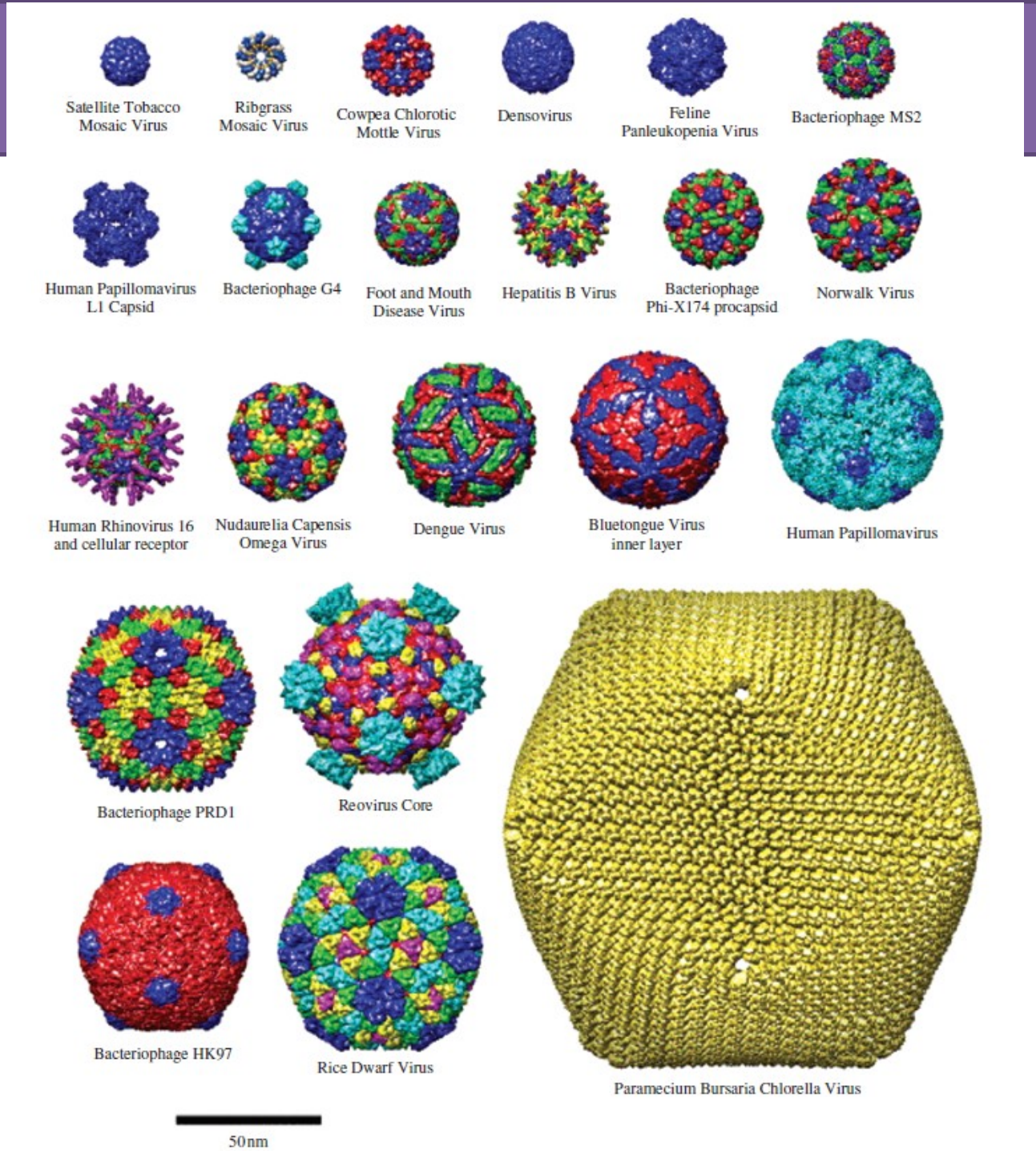
Quasi equivalence



Quasi equivalence

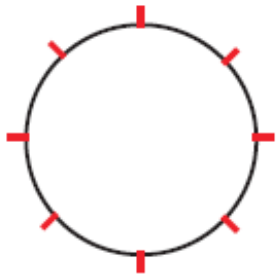





Satellite Tobacco Mosaic Virus
Ribgrass Mosaic Virus
Cowpea Chlorotic Mottle Virus
Densovirus
Feline Panleukopenia Virus
Bacteriophage MS2
Human Papillomavirus L1 Capsid
Bacteriophage G4
Foot and Mouth Disease Virus
Hepatitis B Virus
Bacteriophage Phi-X174 procapsid
Norwalk Virus
Human Rhinovirus 16 and cellular receptor
Nudaurelia Capensis Omega Virus
Dengue Virus
Bluetongue Virus inner layer
Human Papillomavirus
Bacteriophage PRD1
Reovirus Core
Bacteriophage HK97
Rice Dwarf Virus
Paramecium Bursaria Chlorella Virus
50nm

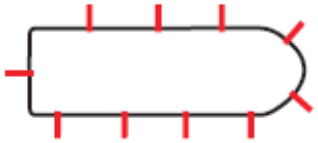
Enveloped Viruses

Sphere



Influenza virus

Bullet



Rabies virus

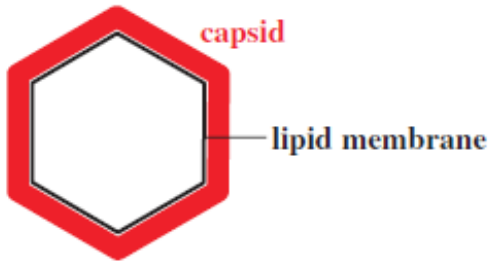
Rod

Baculoviruses

Thread

Ebola virus

Viruses with an Internal Lipid Membrane



Iridoviruses

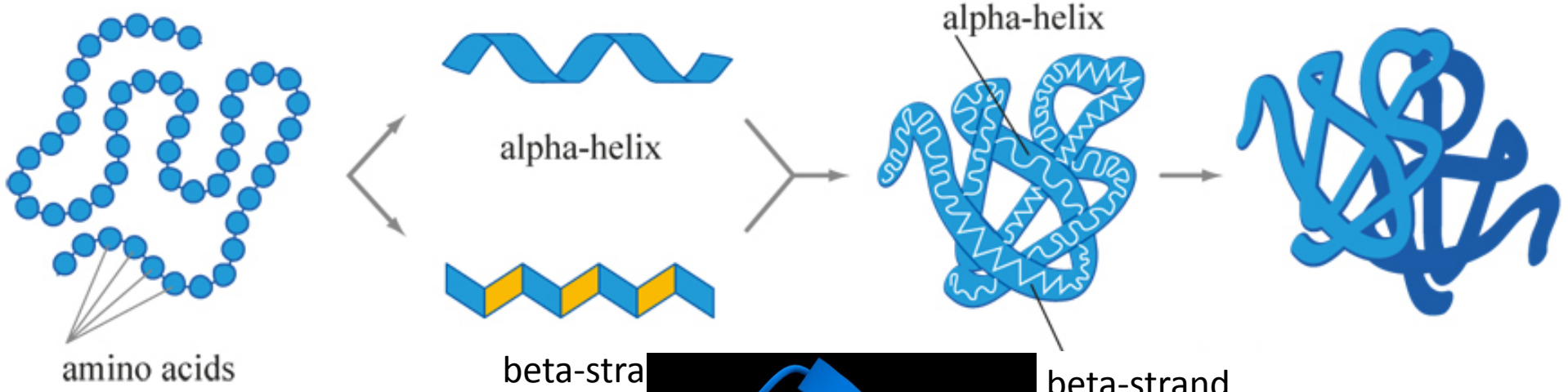
Levels of description of protein structures

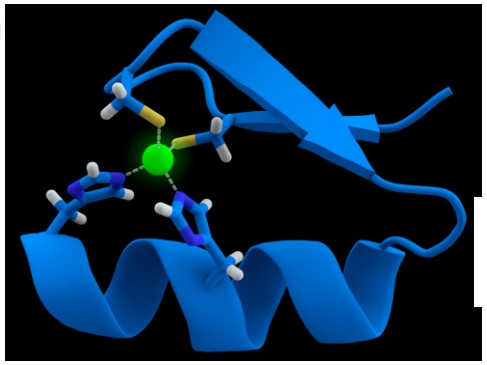
Primary structure

Secondary structure

Tertiary structure

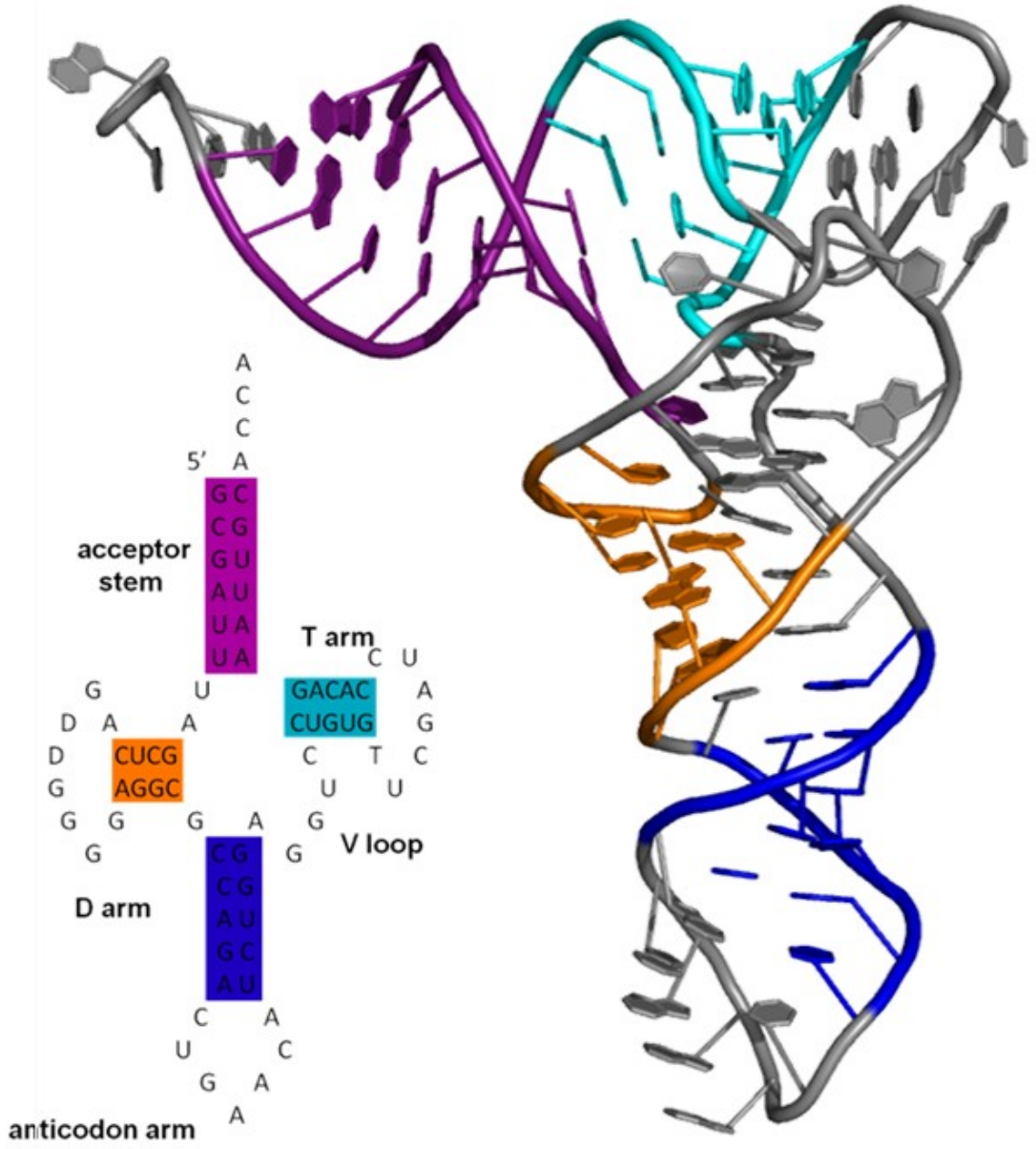
Quaternary structure



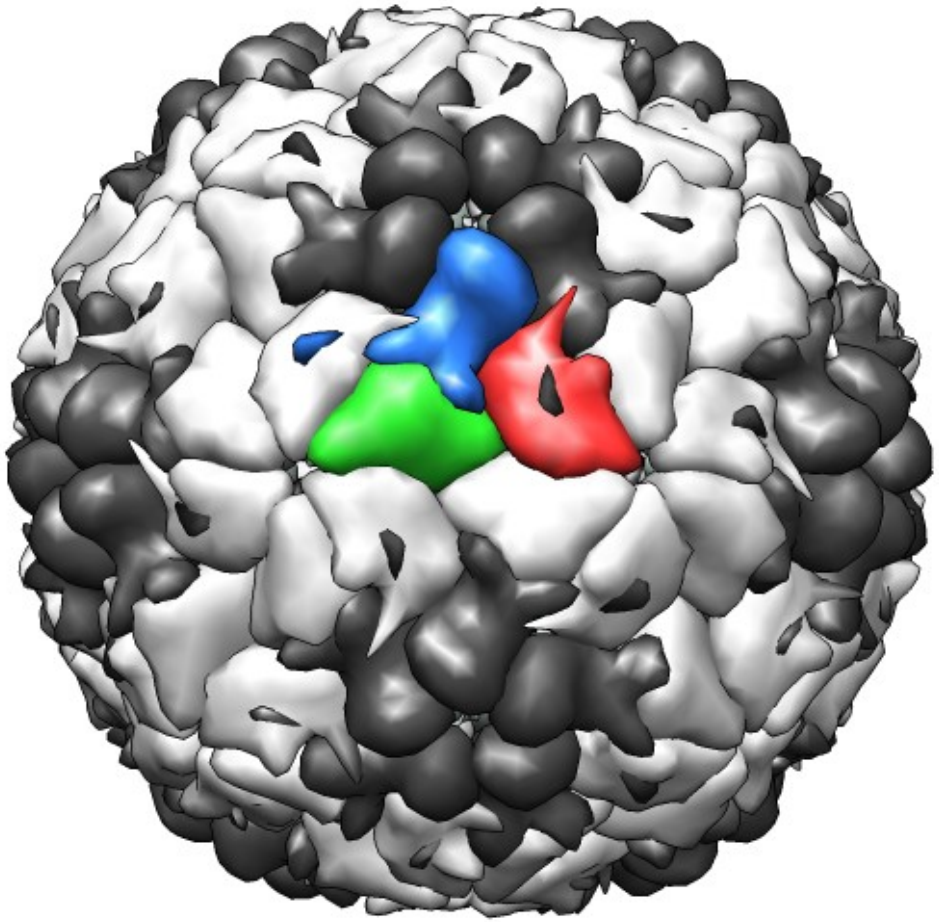


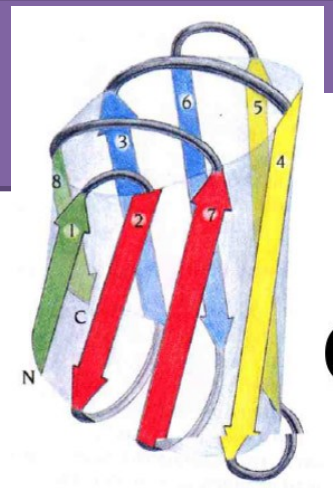
Motif

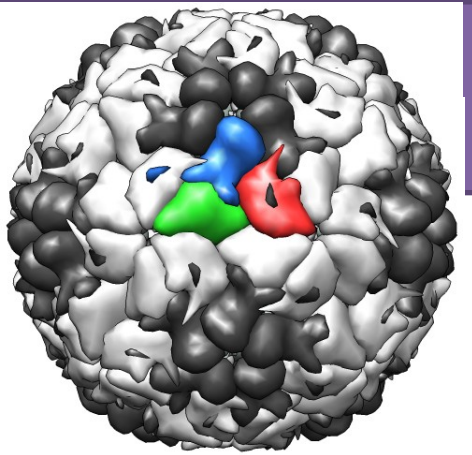
Levels of description of RNA structures



Picornavirus virion







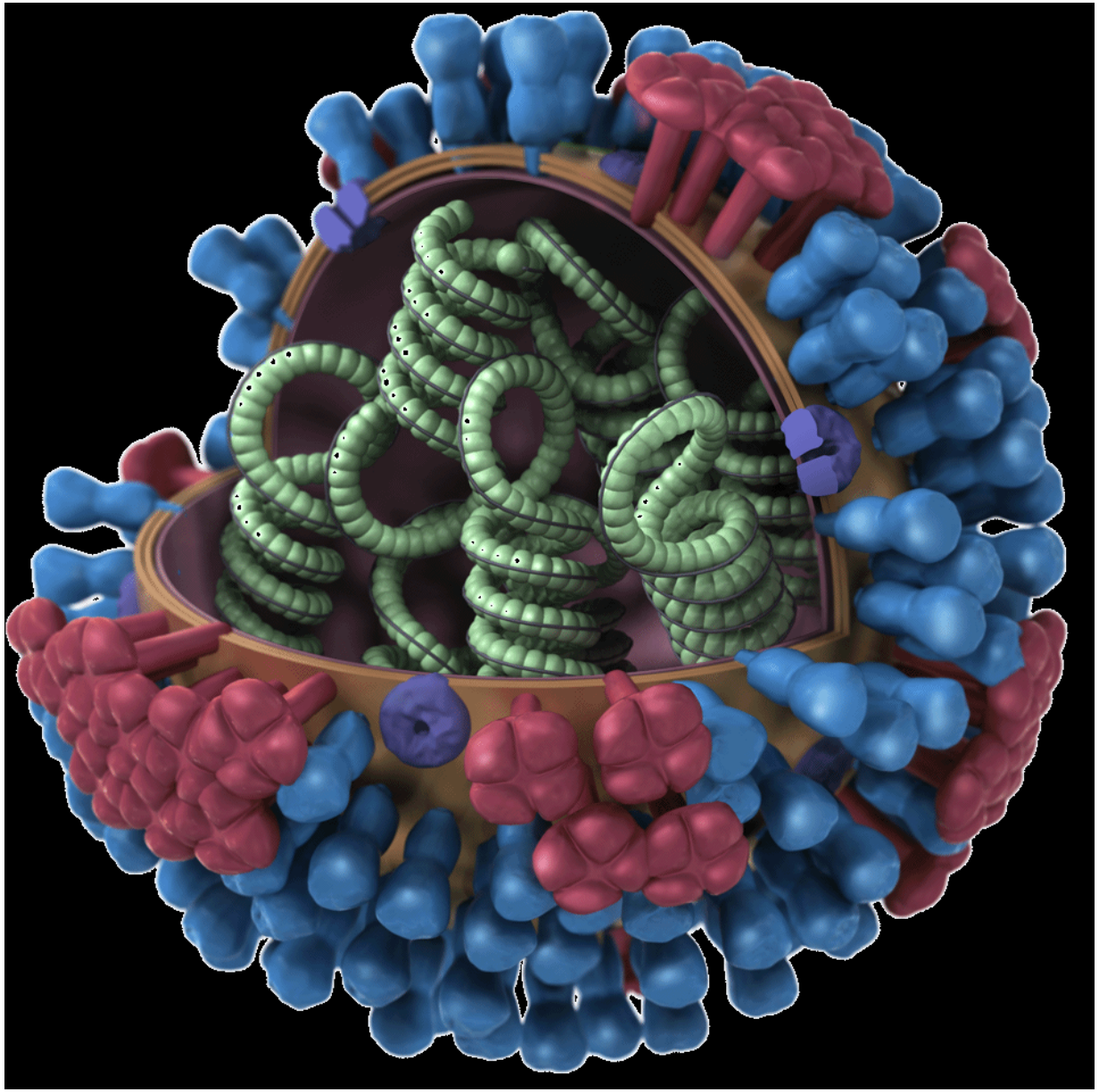
canyon

knob

puff

Plevka et al. Science 2012.

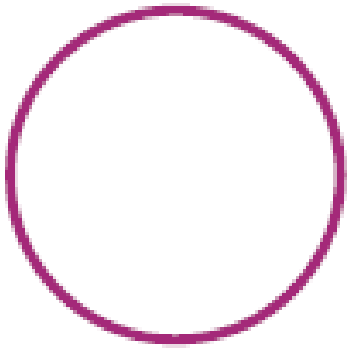
Molecular components of virions



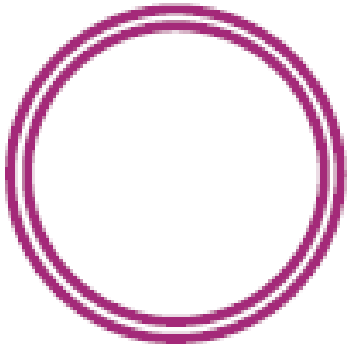
DNA genomes of viruses

ss, linear — Parvoviruses

ds, linear — Poxviruses

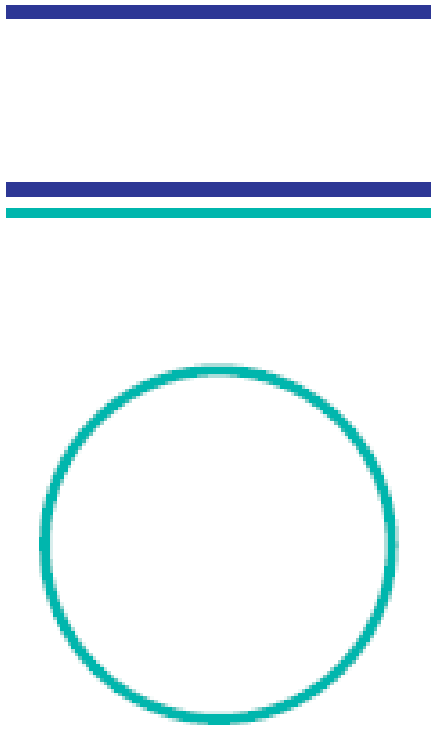


ss, circular — Phage φX174



ds, circular — Baculoviruses

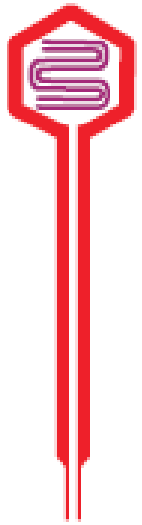
RNA genomes of viruses



ss, linear	Tobacco mosaic virus
ds, linear	Reoviruses
ss, circular	Hepatitis delta virus

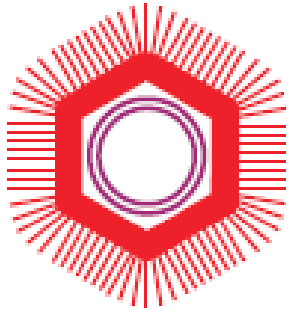
Sizes of virus genomes

Hepatitis B virus 3.2kB

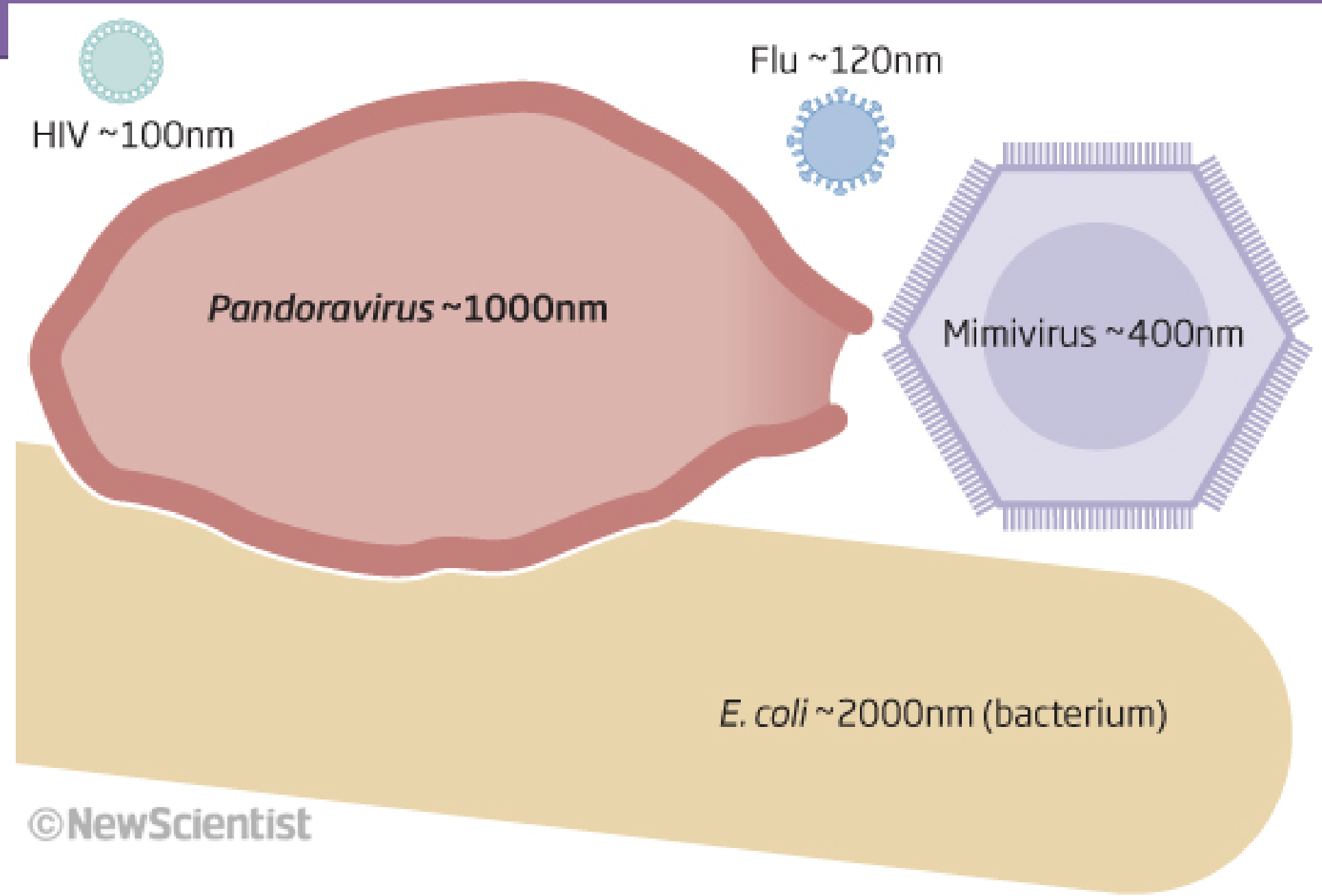


Phage lambda 48kB

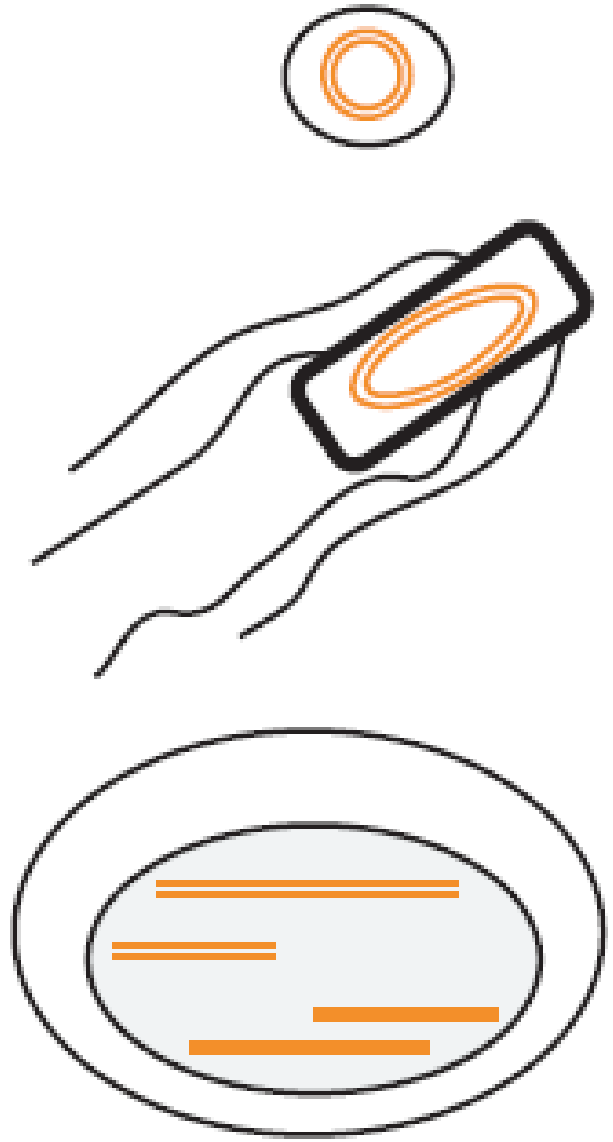
Pandoravirus	1.1-2.5MB
TNSV	1239B (RNA)
Coronaviruses	33kB (RNA)



Mimivirus 1.2MB

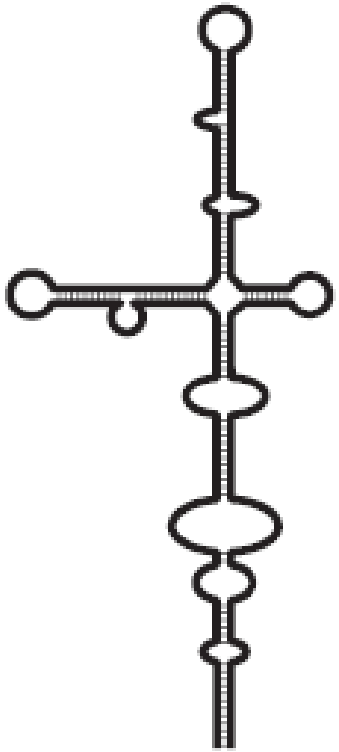

HIV ~100nm
Flu ~120nm
Pandoravirus ~1000nm
Mimivirus ~400nm
E. coli ~2000nm (bacterium)
©NewScientist

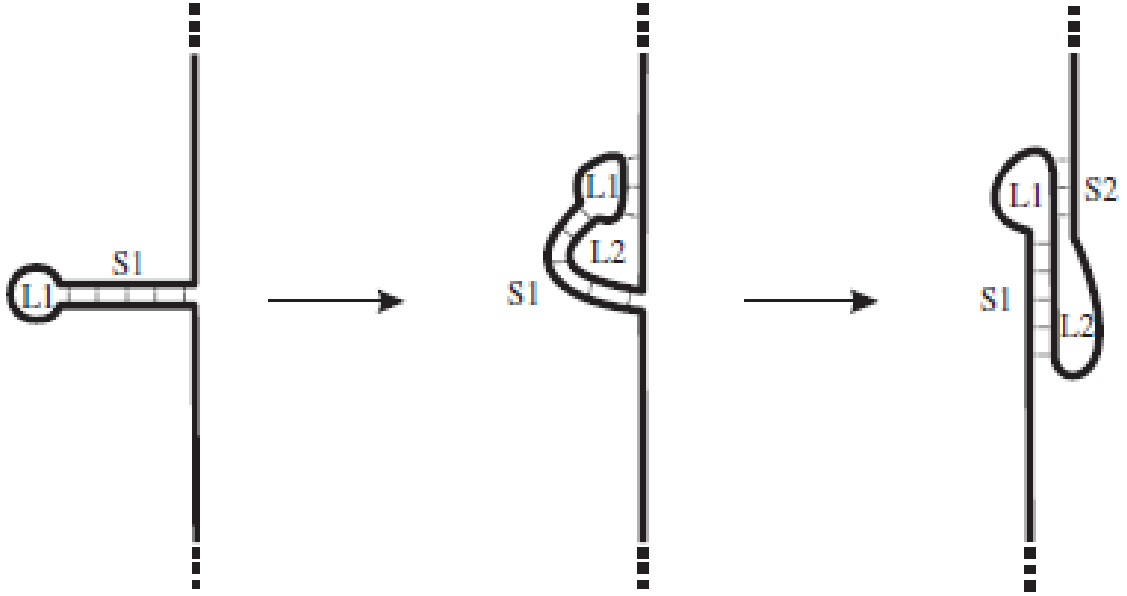
Genomes of cellular organisms (kB)



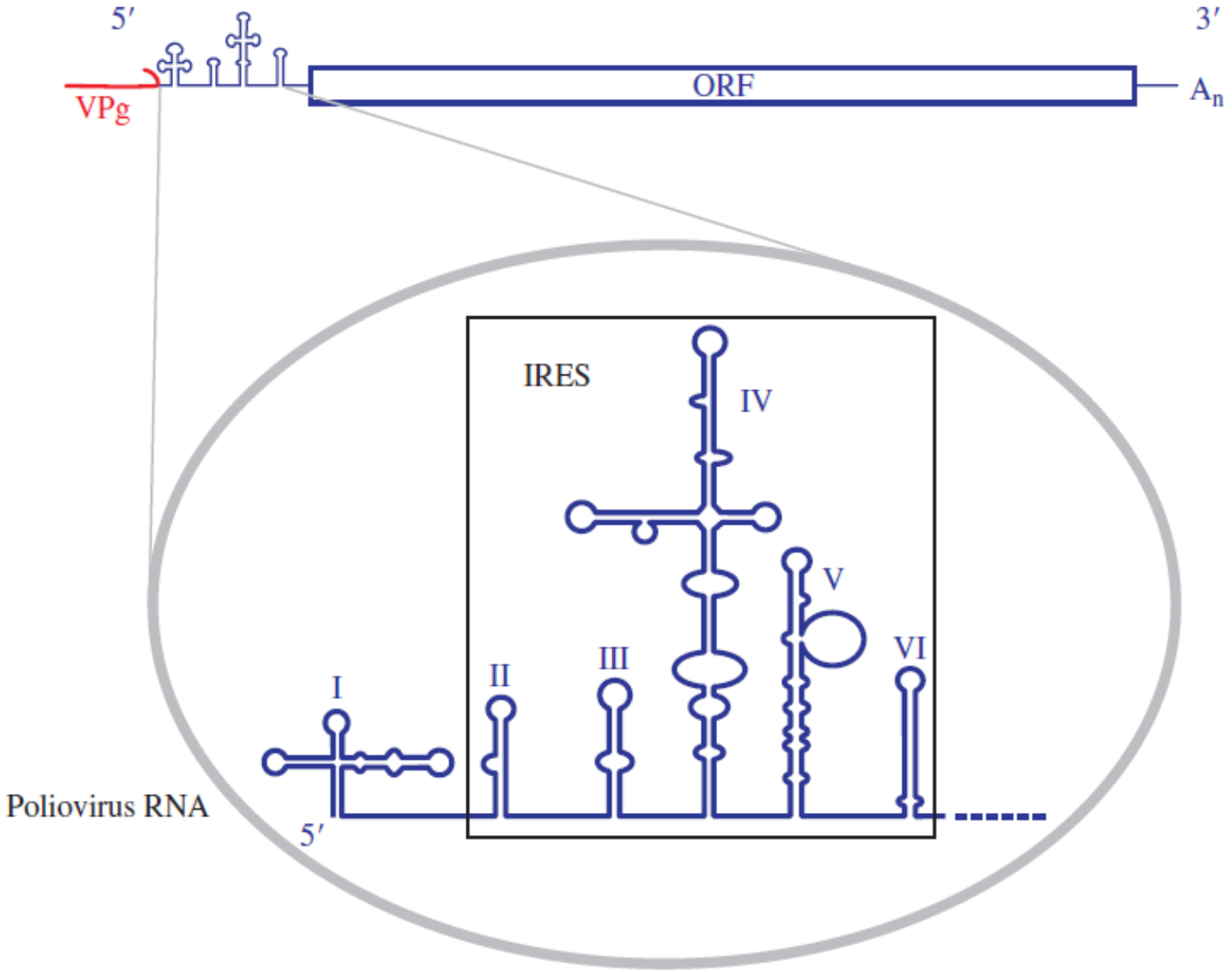
Mycoplasma genitalium	580
Escherichia coli	4700
Human	3200000

Secondary structures in ssRNA genomes





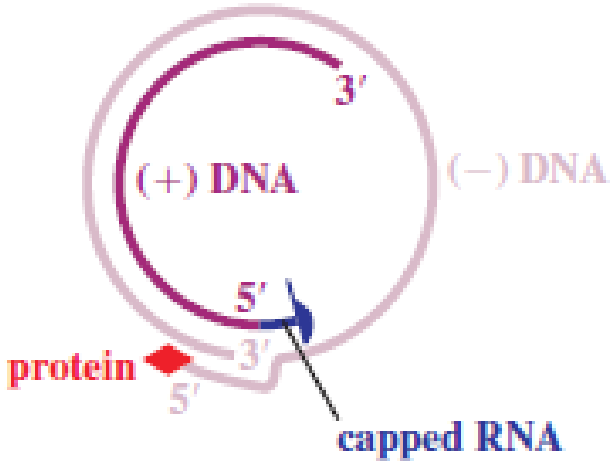
Internal Ribosome Entry Site in poliovirus



Modifications of genome ends

dsDNA

Adenoviruses
Phage PRD1 (*E. coli*)

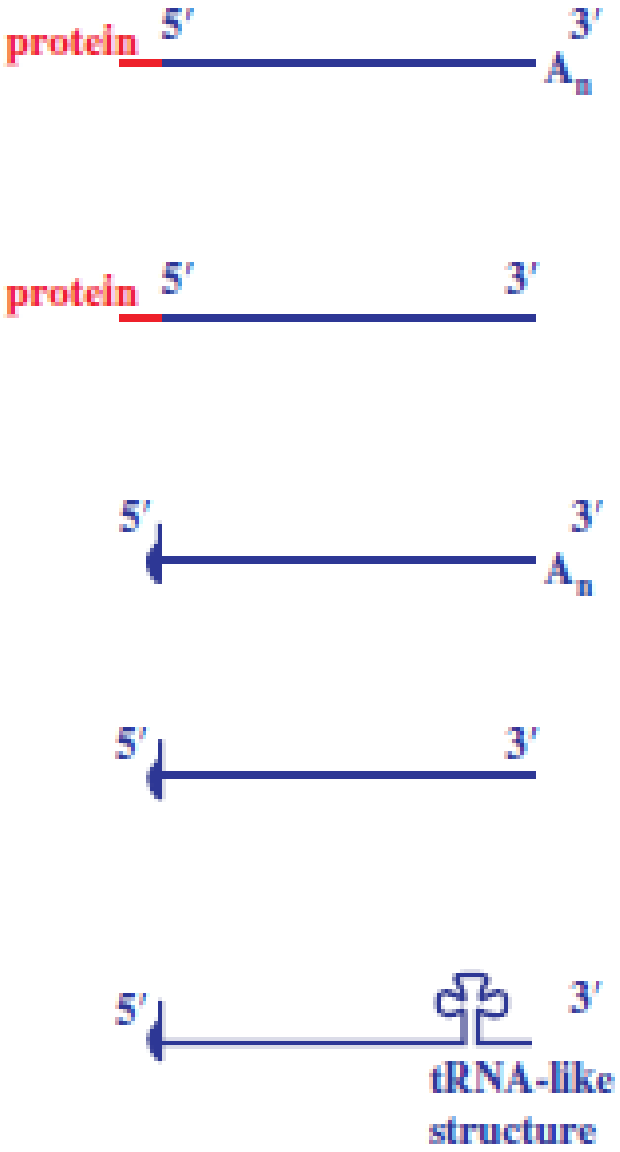


Hepatitis B virus

ssDNA

Parvoviruses

More end modifications (ssRNA)



Poliovirus
Cowpea mosaic virus

Barley yellow dwarf virus

SARS coronavirus
Retroviruses

Black beetle virus

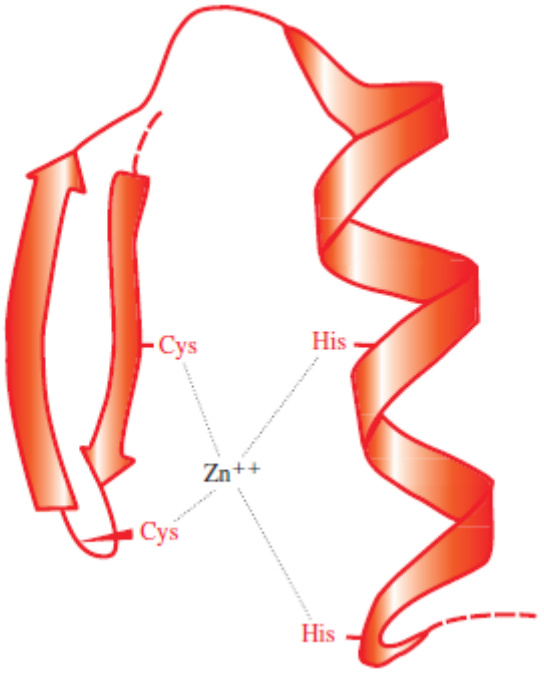
Cucumber mosaic virus

dsRNA genome modifications

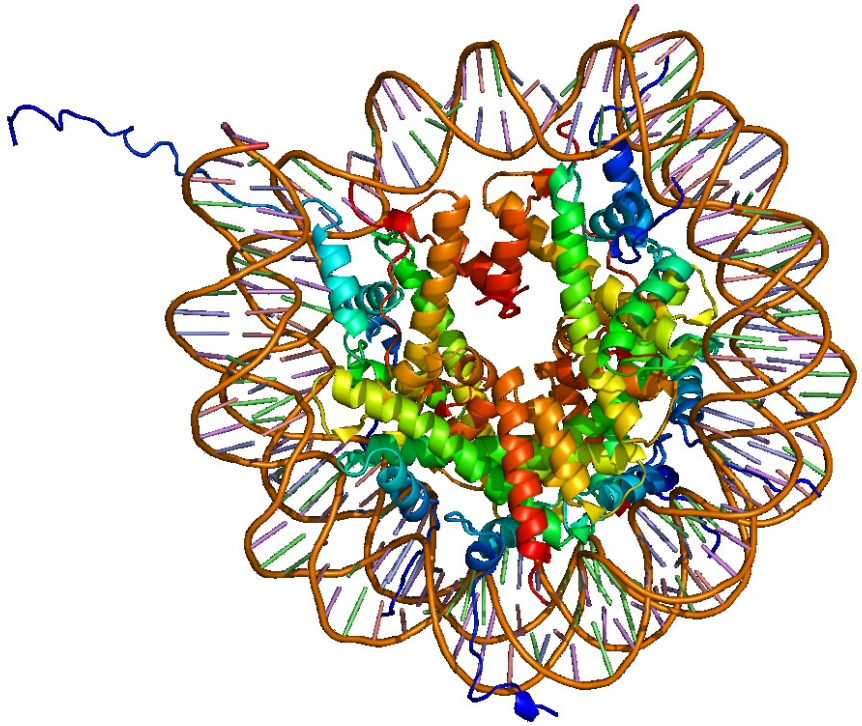
Rotaviruses

Infectious pancreatic necrosis virus

(Macro)-molecules non-covalently associated with virus genomes



Zinc finger motif

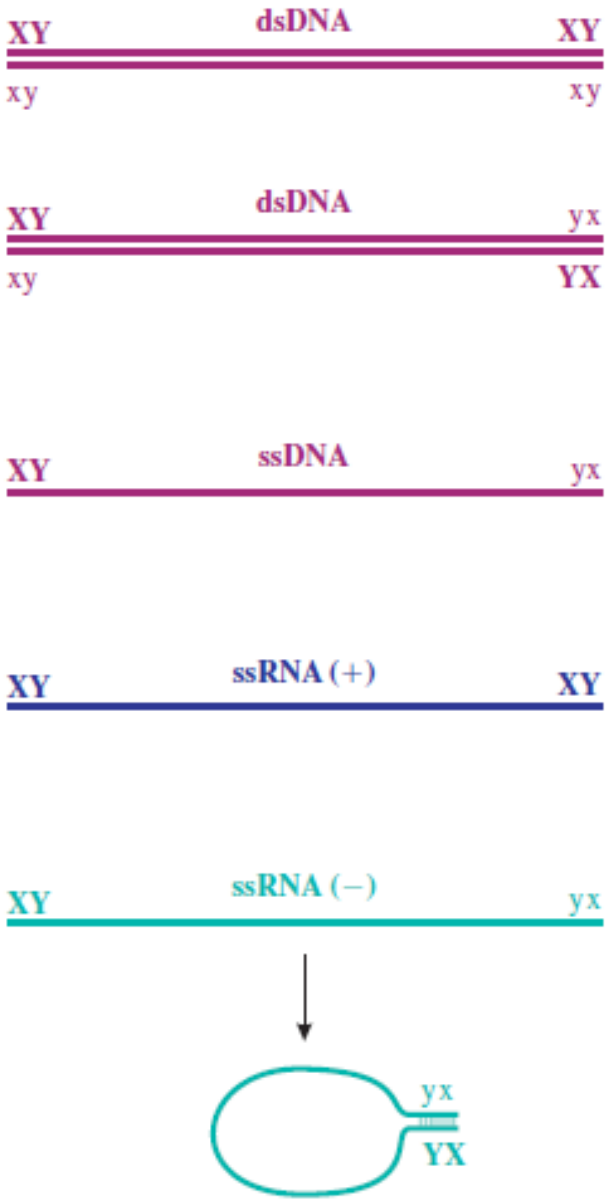


Histone core

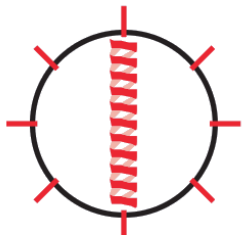
[redacted]

Poly amine - putrescine

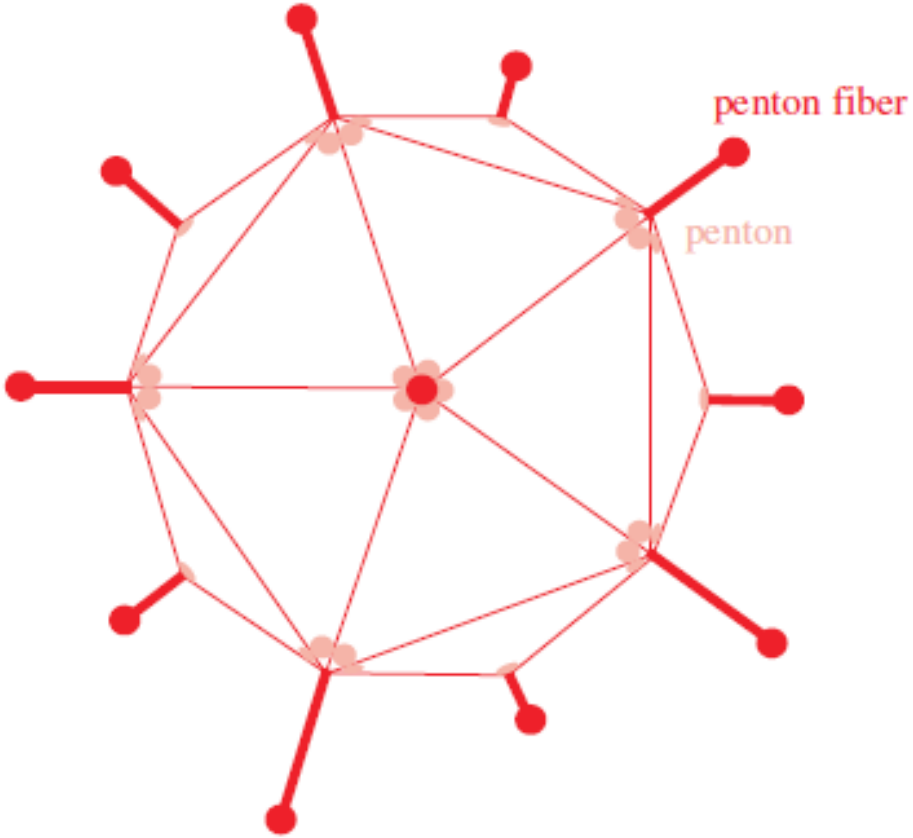
Terminal repeats in virus genomes



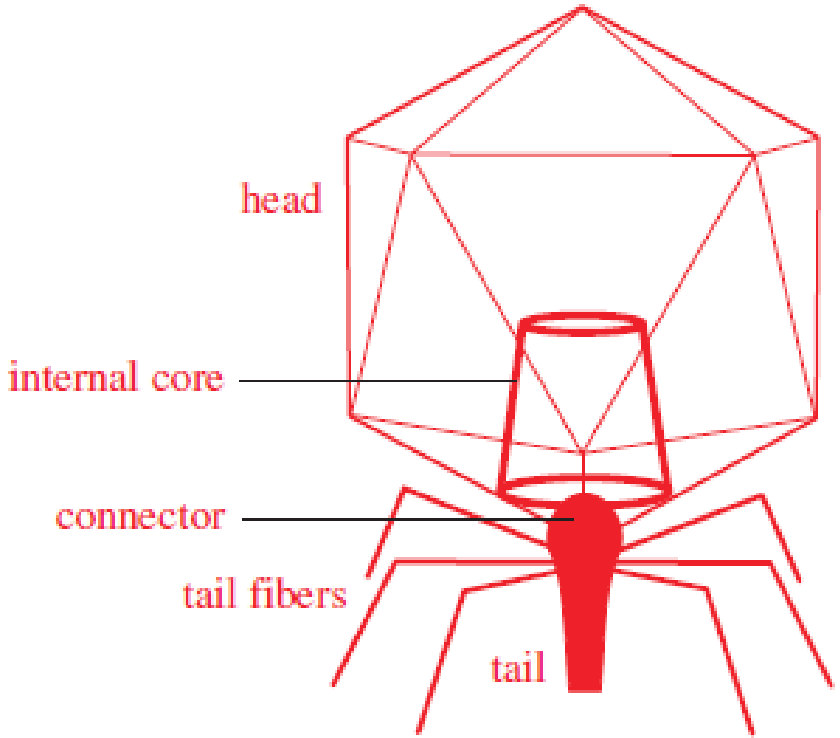
DTR	Some herpesviruses T phages
ITR	Adenoviruses Tectiviruses (phages)
ITR	Some parvoviruses
DTR	Retroviruses
ITR	Influenza viruses Bunyaviruses

Main types of virion structure		Genomes			
		dsDNA	ssDNA	dsRNA	ssRNA
Icosahedral, naked		✓	✓	✓	✓
Icosahedral, enveloped		✓		✓	✓
Helical, naked		✓	✓		✓
Helical, enveloped					✓

Adenovirus virion



Phage T7



Learning outcomes

- describe the components of virions
- illustrate the variety of virus genomes
- outline the functions of virus structural proteins
- define the terms ‘helical symmetry’ and ‘icosahedral symmetry’
- explain h and K indices and T number

Why / when / for what are structures important?

Virus transmission

Plant viruses

Vectors

- **insects**
- **mites**
- **nematodes**
- **fungi**

Human and animal viruses

- **via the air, e.g. influenza virus**
- **via food and water, e.g. rotaviruses**
- **sexually, e.g. HIV**
- **via vectors, e.g. yellow fever virus**

Insects

Potato virus Y
Cauliflower mosaic virus

Beet yellows virus
Bean yellow mosaic virus

Leafhoppers

Rice dwarf virus

Whiteflies

Tomato yellow leaf curl virus

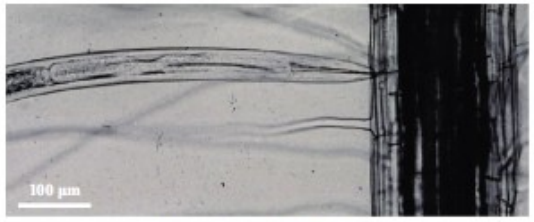
Beetles

Maize chlorotic mottle virus

Mites

Ryegrass mosaic virus

Nematodes



Grapevine fanleaf virus

Mites

Nematodes

Living Vectors

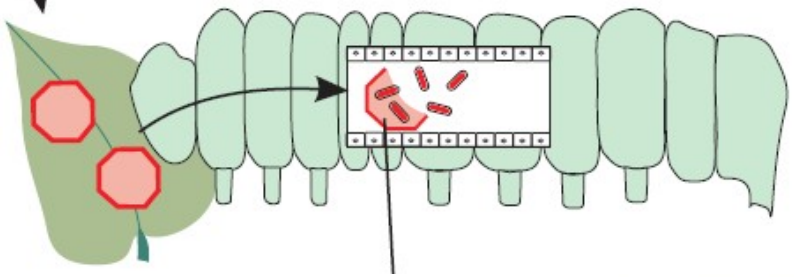
Mosquitoes		Yellow fever virus West Nile virus Chikungunya virus	Humans
Midges		Bluetongue virus	Sheep
Ticks		Louping ill virus	Sheep

Inanimate Vectors

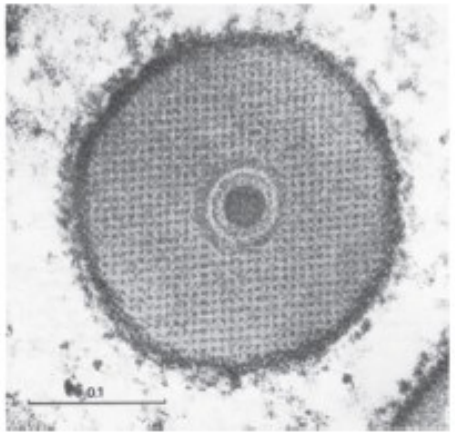
Syringes and Needles		Hepatitis B virus HIV	Humans

Baculovirus transmission

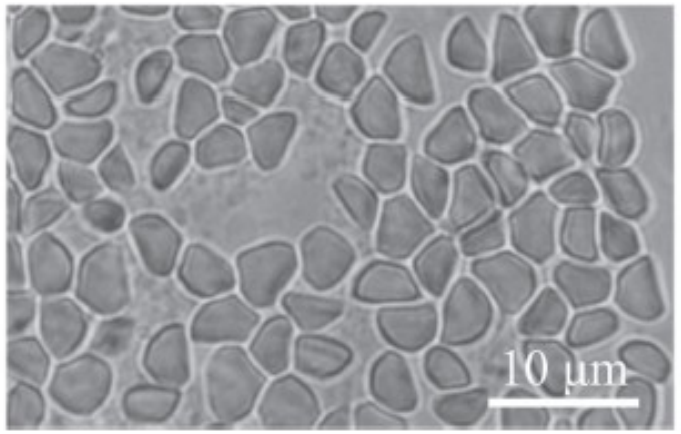
Caterpillar that has died from baculovirus infection



(a)



(b)



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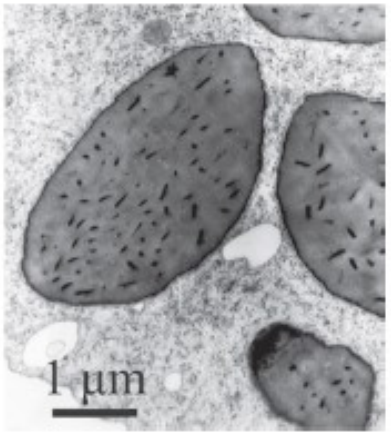
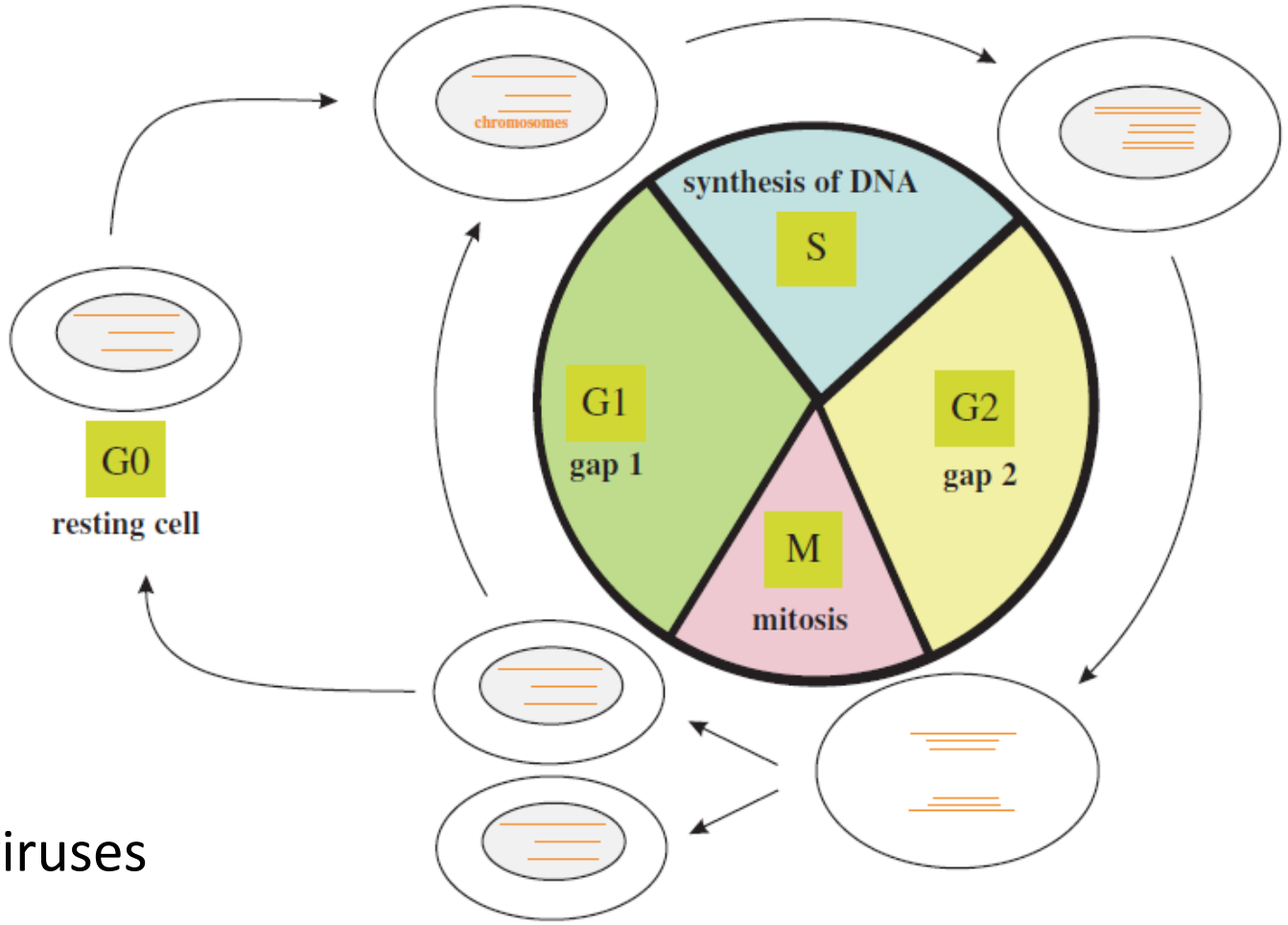


Non-vector transmission of vertebrate viruses

Transmission route	Examples of viruses transmitted
Horizontal transmission	
Respiratory tract	Influenza viruses (mammals)
	Common cold viruses
	Measles virus
Intestinal tract	Influenza viruses (birds)
	Rotaviruses
Abrasions and wounds	Papillomaviruses
	Rabies virus
Genital tract	HIV
	Papillomaviruses
Vertical transmission	
Mother to foetus via the placenta	Rubella virus
Mother to baby via milk	HIV

Virus infection X cell cycle



Retroviruses
Polyomaviruses, papillomaviruses

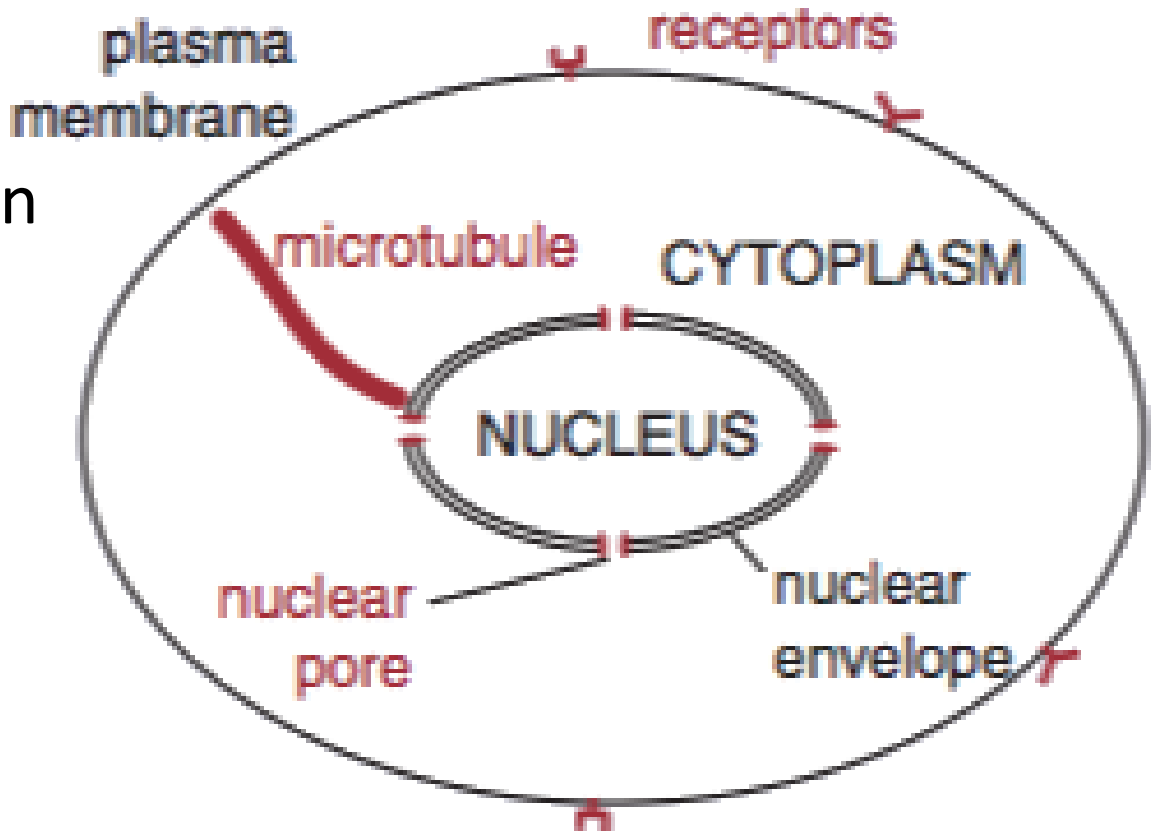
Restriction endonucleases
RNAi response, CRISPR / Cas, antibodies, NK cells

Learning outcomes

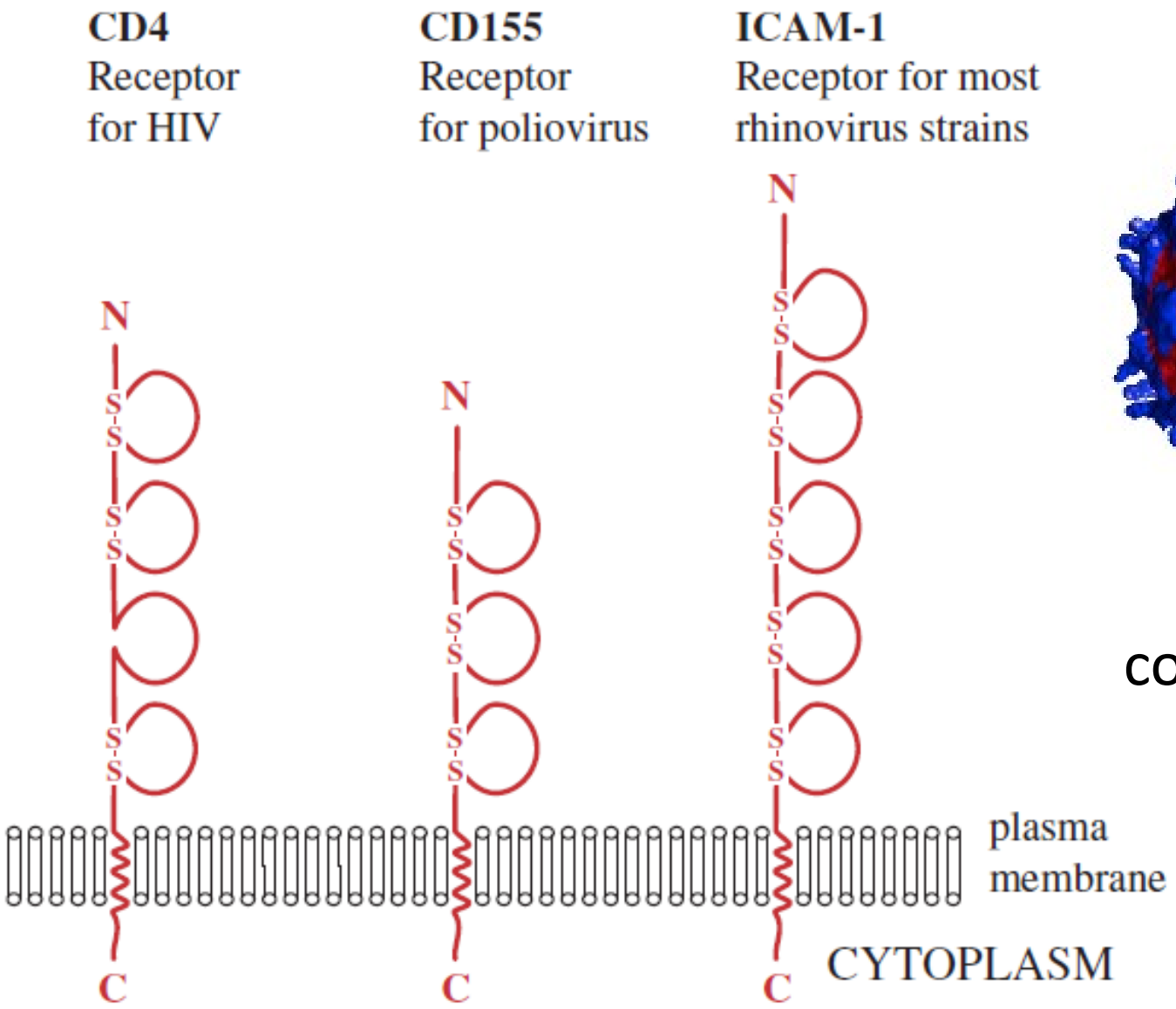
- describe the modes of transmission of plant viruses and animal viruses
- describe the roles of vectors in virus transmission

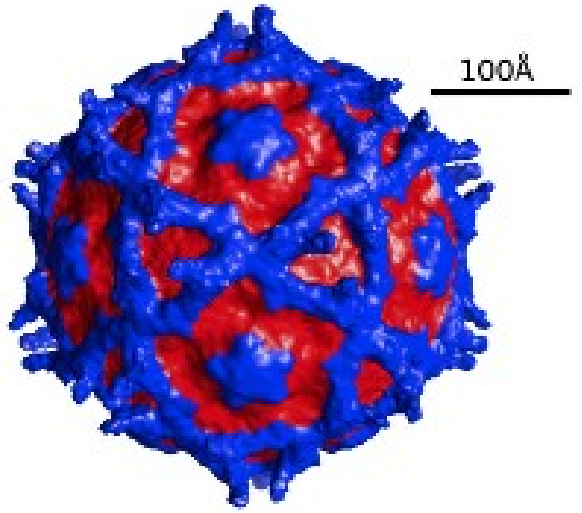
Attachment and entry of viruses into cells

1. **A**ttachment
2. **E**ntry
3. **T**ranscription
4. **T**ranslation
5. **G**enome replication
6. **A**ssembly
7. **E**xit



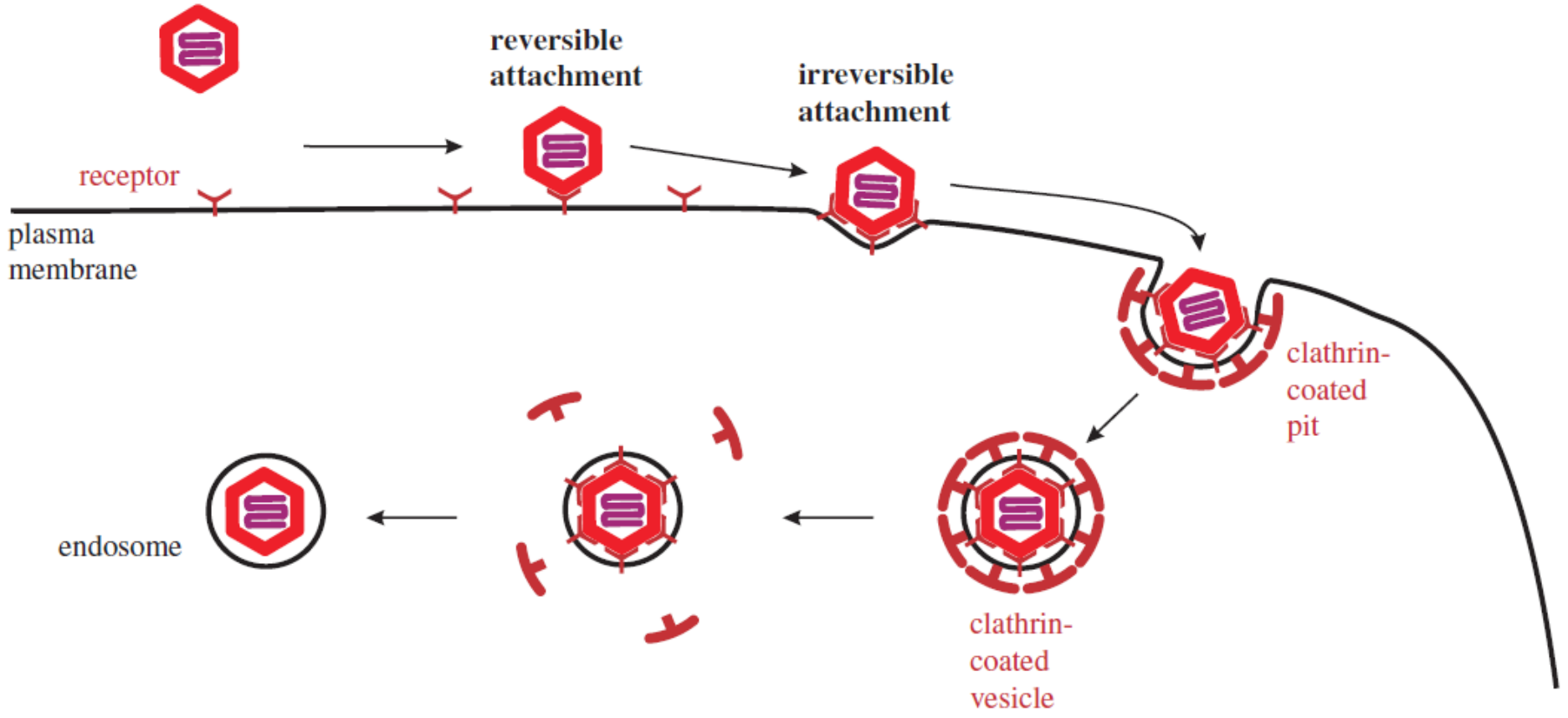
Virus receptors



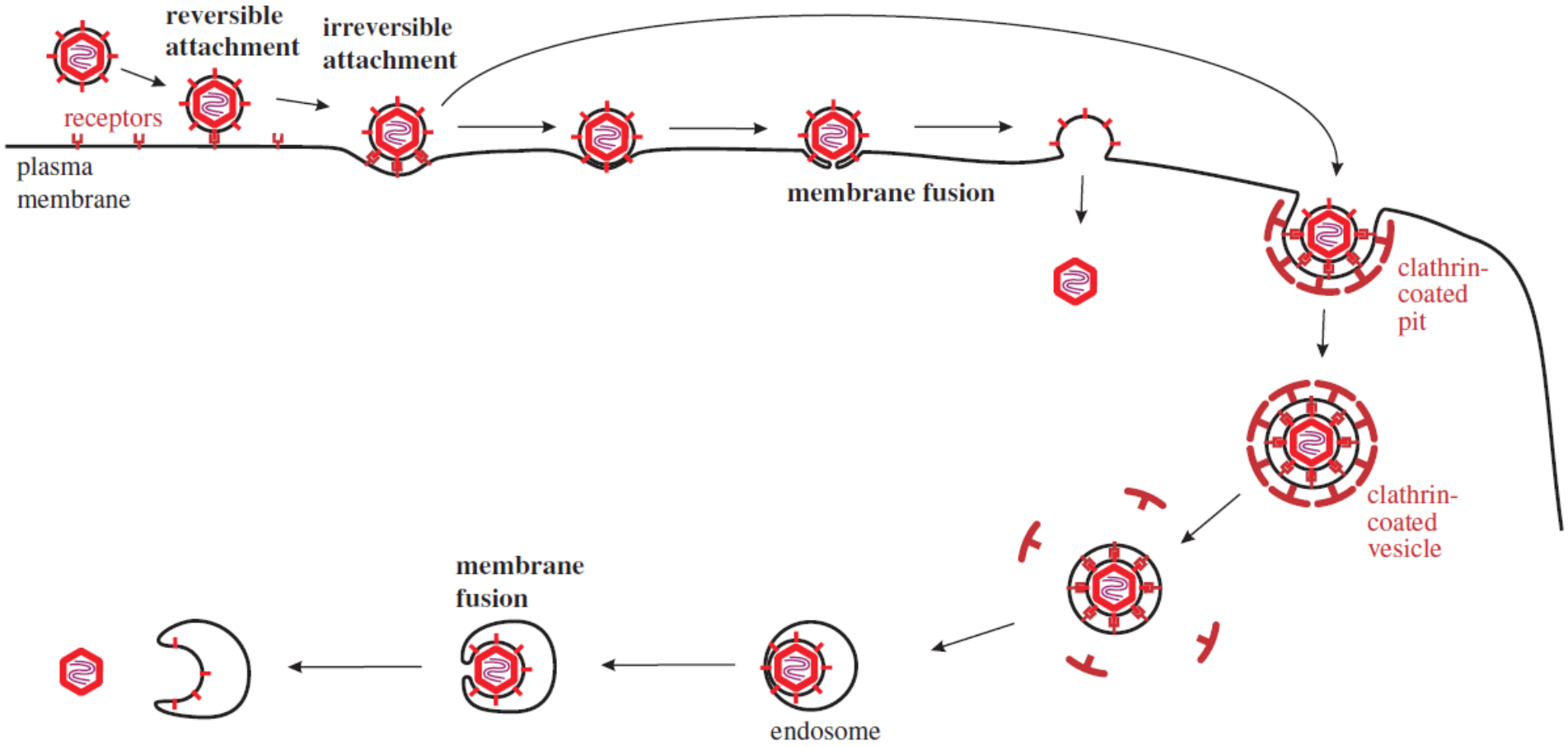


Echovirus 7 in complex with DAF

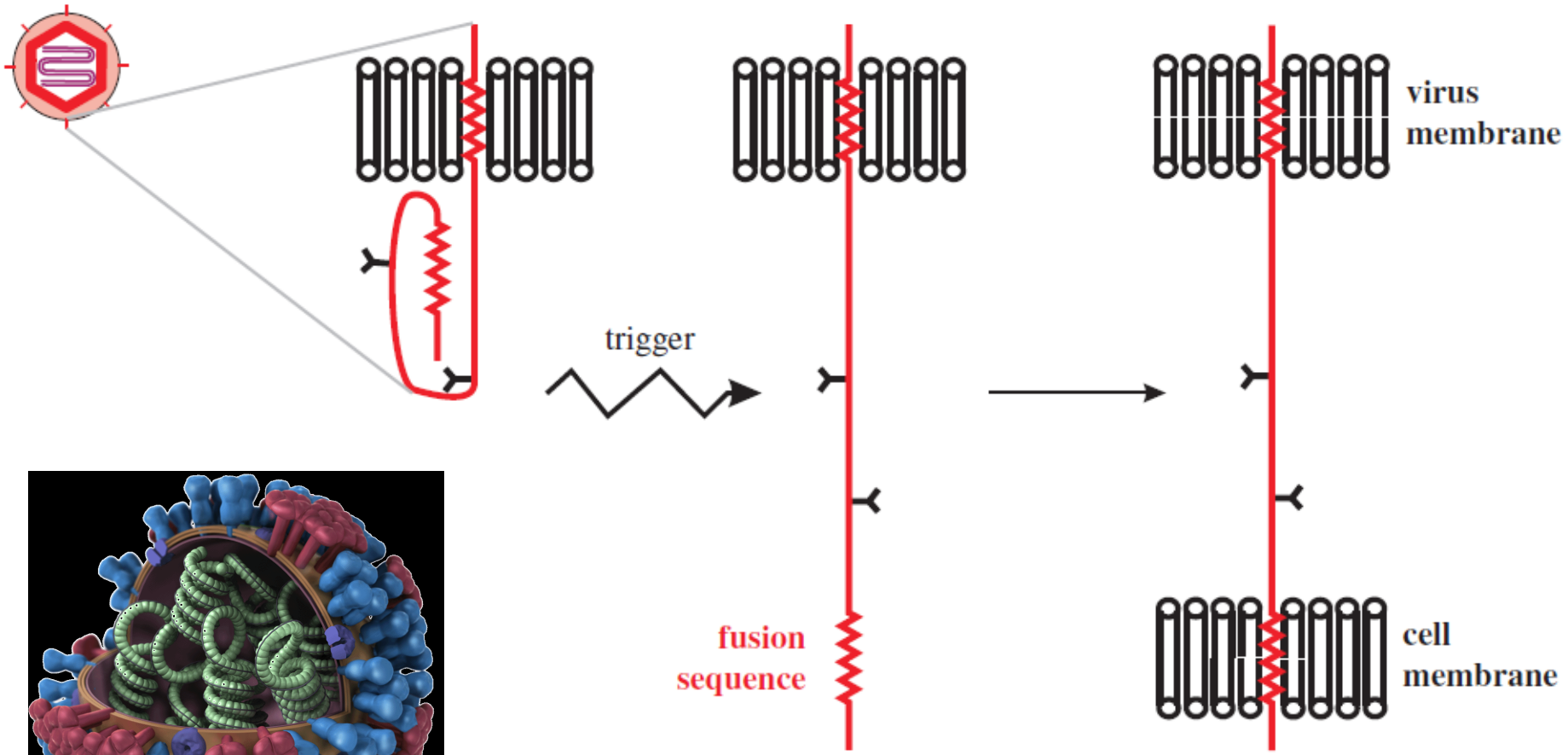
Attachment and entry of a naked virion



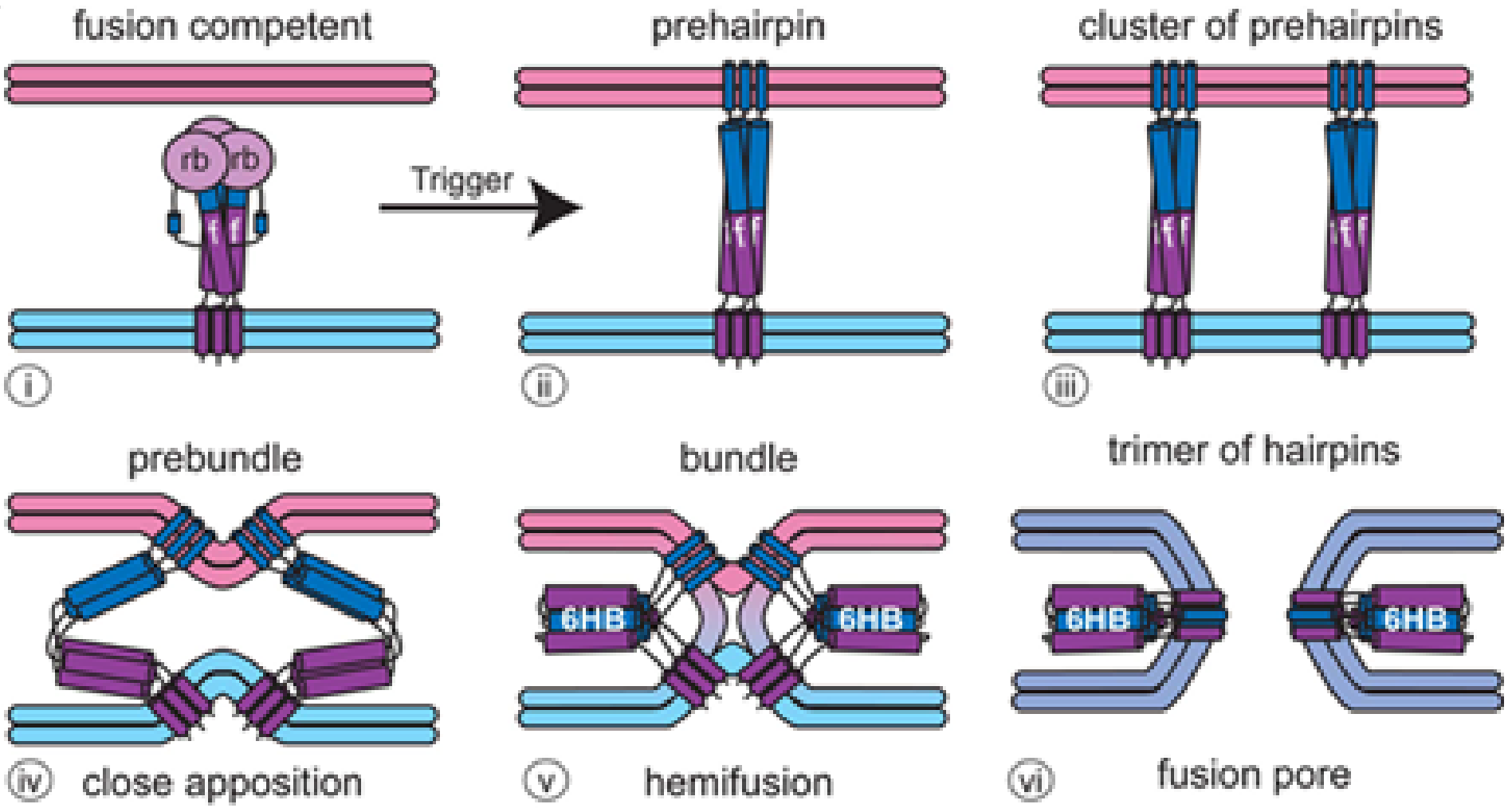
Attachment and entry of an enveloped virion



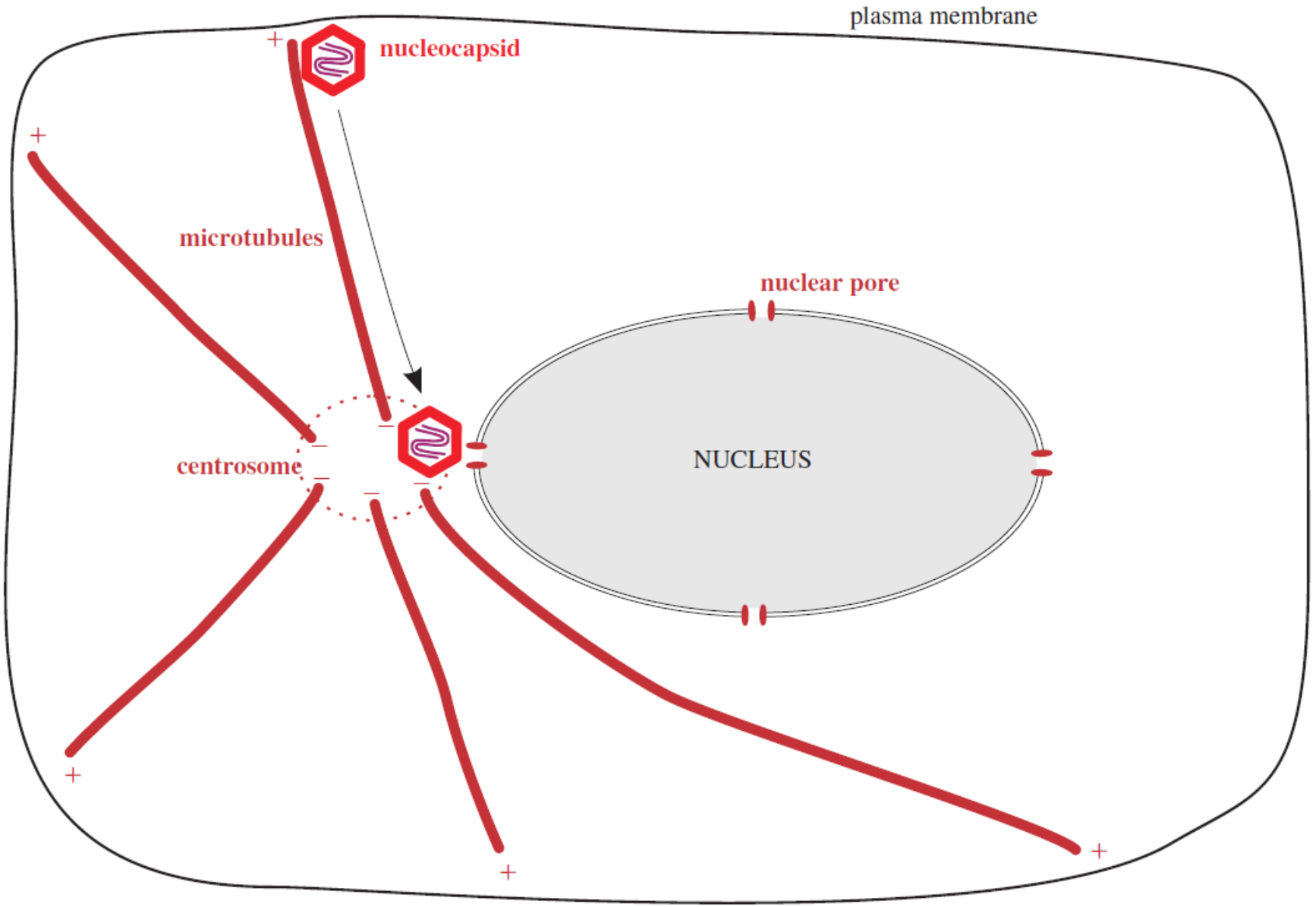
Virus membrane fusion



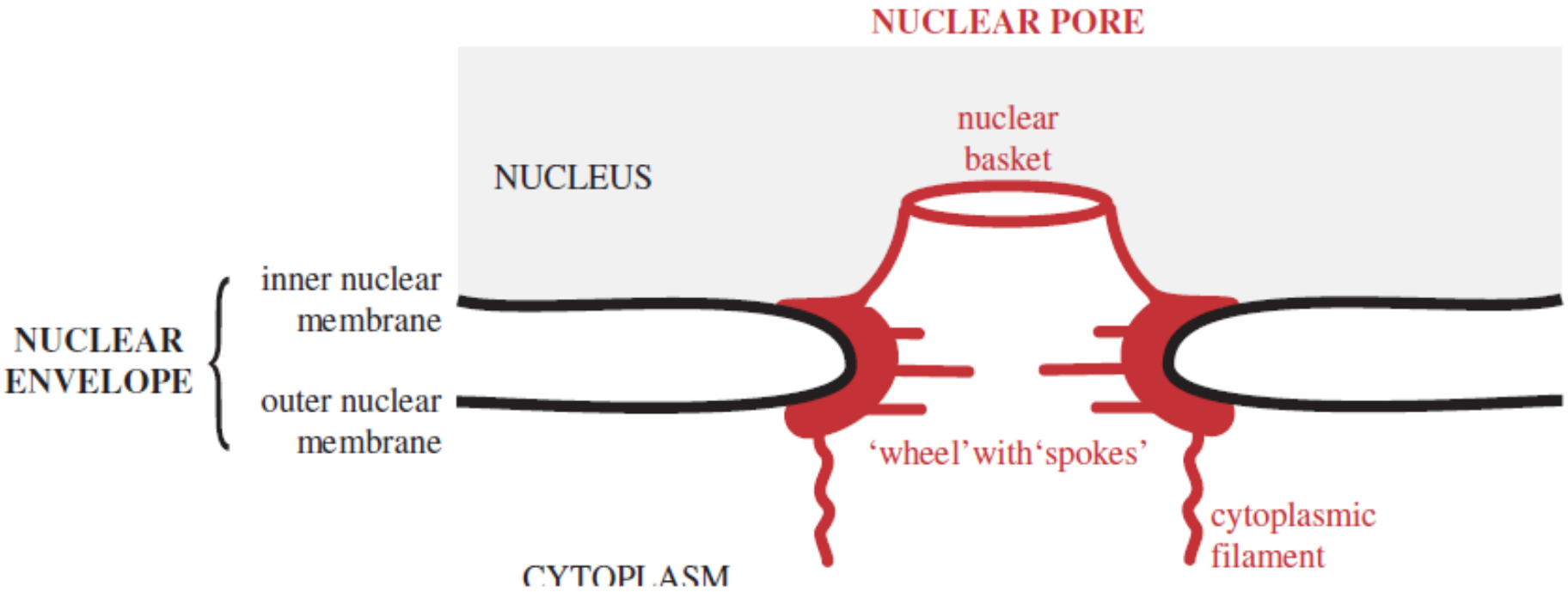
Virus membrane fusion



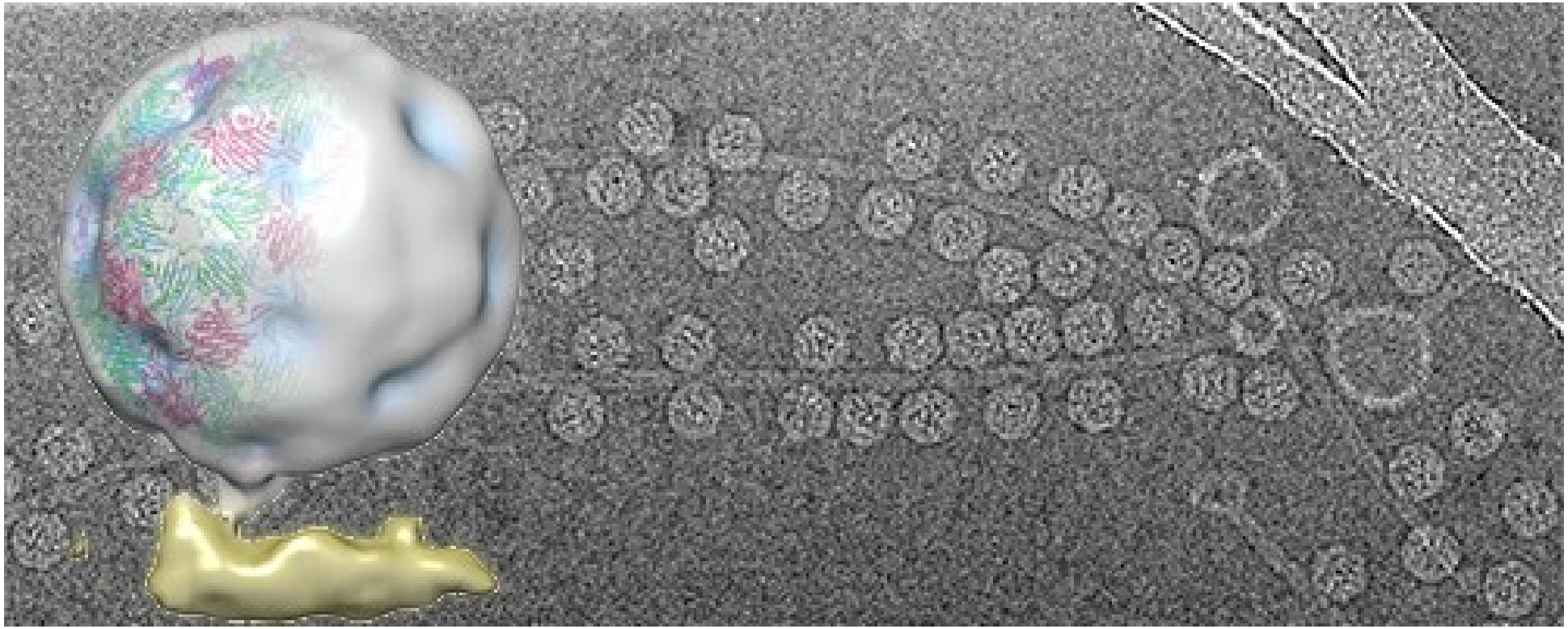
Intracellular transport of viruses



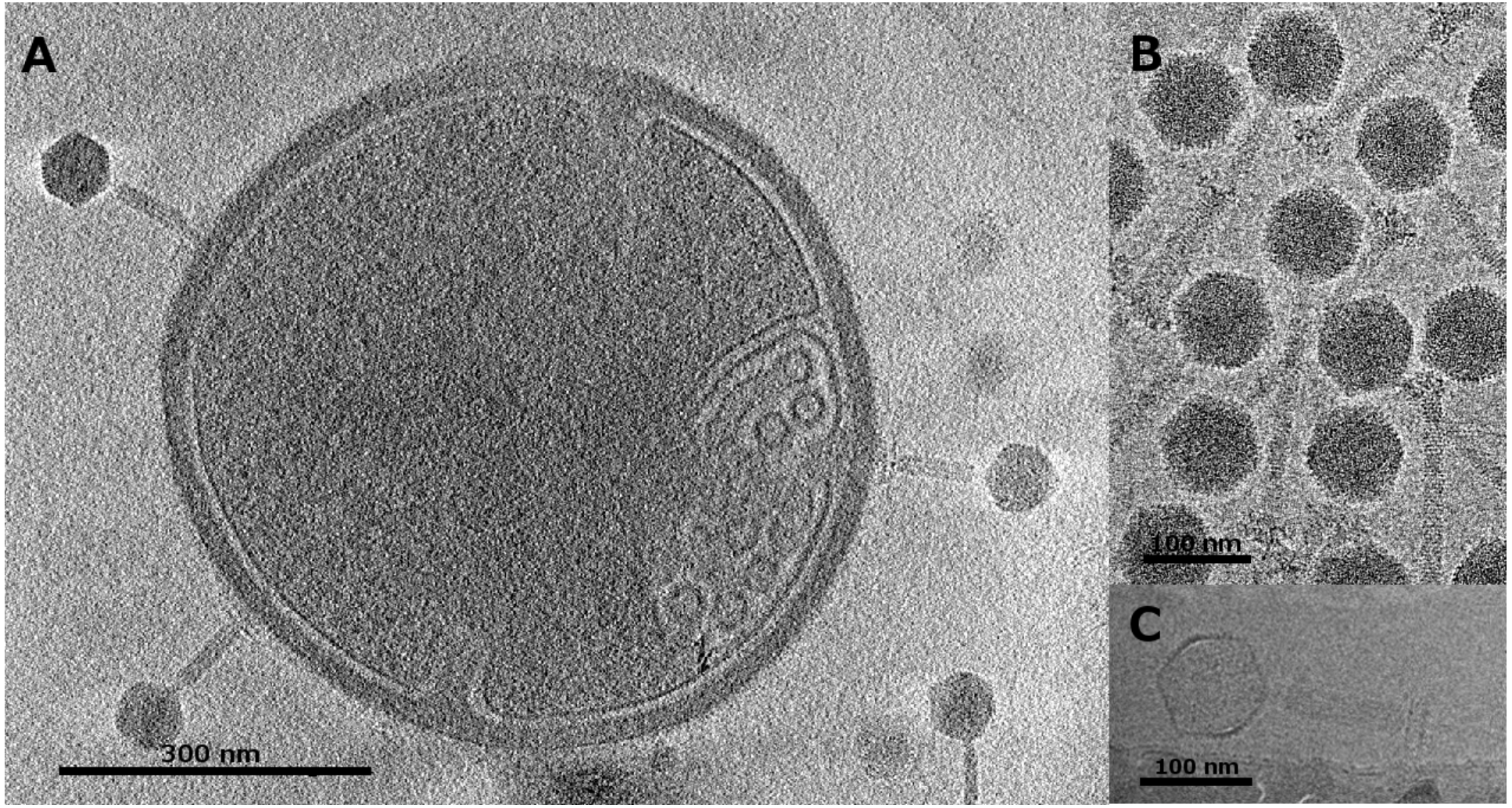
Intracellular transport of viruses



Phage MS2 infection



Phage phi812 genome injection



Learning outcomes

- outline a generalized scheme of virus replication involving seven steps
- describe how animal viruses attach to and enter their host cells
- differentiate between the entry mechanisms of naked and enveloped animal viruses
- describe the roles of cell components in the delivery of viral genomes to the nucleus
- outline the infection mechanisms of phages