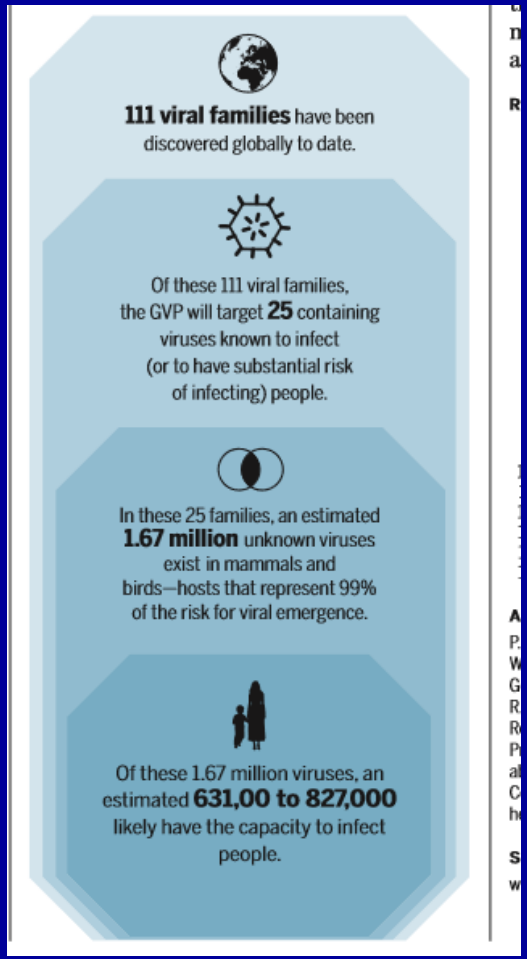
VIROLOGY

Virus Diversity

- There is much more biological diversity among viruses then all other life put together.
- Viruses are parasites to all other life.
- They are also drivers of evolution

The Global Virome Project



Viruses are distinct from living organisms

- Viruses are submicroscopic, obligate cellular parasites. But
- Bacteria can be intracellular too.
- While viruses are so small they cannot be seen with an optical microscope (80 to 300 nm), the biggest viruses are bigger than the smallest bacteria.
- So what makes a virus unique?

Virus Definition:

- Viruses are produced from the assembly of pre-formed components. Other agents grow and reproduce by division.
- Virus particles (virions) do not grow or undergo division.
- Viruses have the genetic info to reproduce themselves, but only by hijacking cell machinery and energy.
- Think of a virus as information that has an annoying way of reproducing itself inside of you. It's not trying to kill you, it just doesn't care (like McDonald's)

Viruses are energy parasites

- No virus has the ability to generate the energy necessary to drive biological processes.

- They are absolutely dependent on the host cell for energy.

Are viruses alive?

- One view is that inside the host cell, viruses are alive, but outside it they are complex assemblages of inert chemicals.

- Chemical changes occur in extracellular virus particles, (like HIV) but these are not the 'growth' of a living organism.

The History of Virology

- First record of virus infection:
  - poliovirus in ancient Egypt (3700 BC).
  - Hieroglyphs from Memphis
- Pharaoh Ramses V died from smallpox in 1196 BC.
- Smallpox was endemic in China by 1000 BC.
- The Chinese invented “variolation”.
  - Inhaled the dried crust from smallpox lesions
- Edward Jenner: Smallpox vaccination.
  - 1796 used cowpox infected material

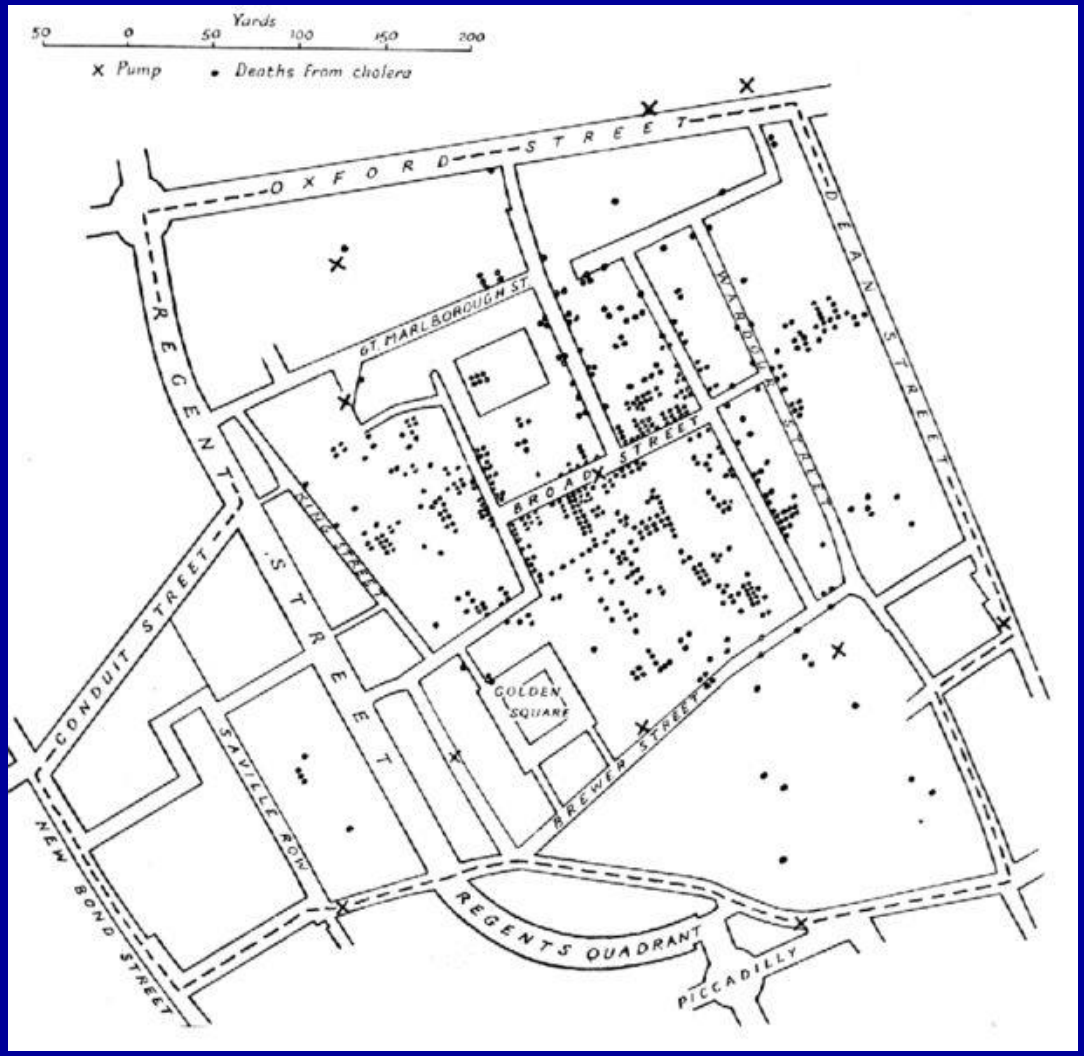
- Antony van Leeuwenhoek (1632-1723) constructed his own microscopes and saw bacteria (aminalcules)

- Robert Koch and Louis Pasteur (1880s) jointly proposed the 'germ theory' of disease.

- This overturned the prevailing “Miasma” hypothesis that illness was caused by “bad air”.

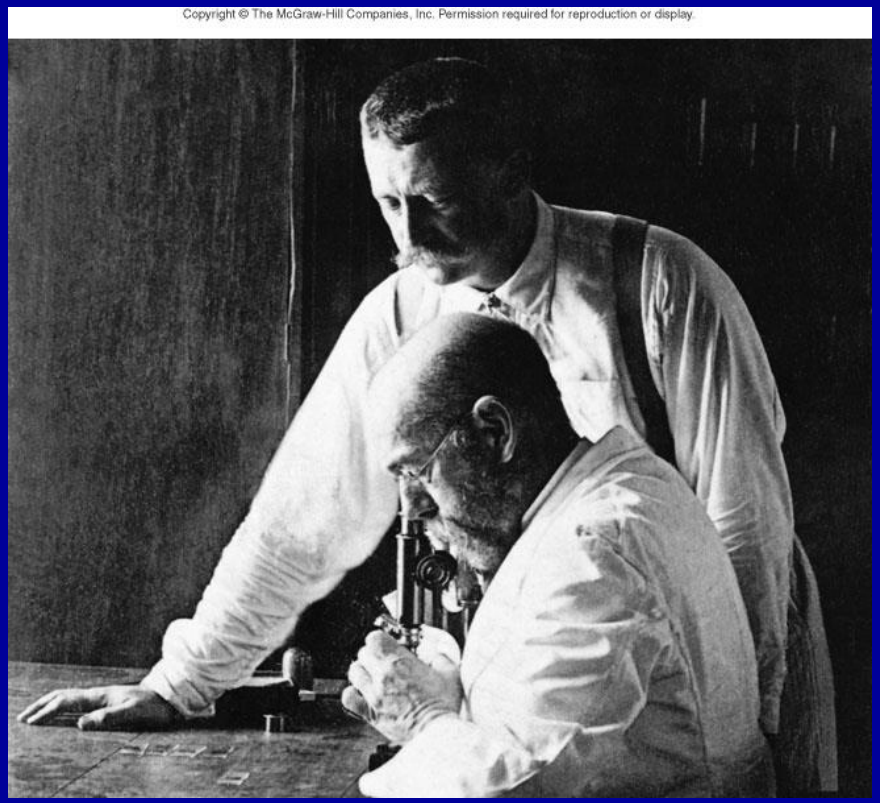
- Dr John Snow was also a strong proponent of germ theory, tracing a cholera epidemic in London to a single street pump contaminated with feces from a cellar ten feet away from it.

The ghost map



Flu season is coming...

Robert Koch



- **Established a sequence of experimental steps to show that a specific germ causes a particular disease.**
- **Identified cause of anthrax, TB, & cholera.**

(1843-1910)

KOCH'S POSTULATES

1. The organism must be regularly found in the lesions of the disease

2. The organism must be isolated in pure culture

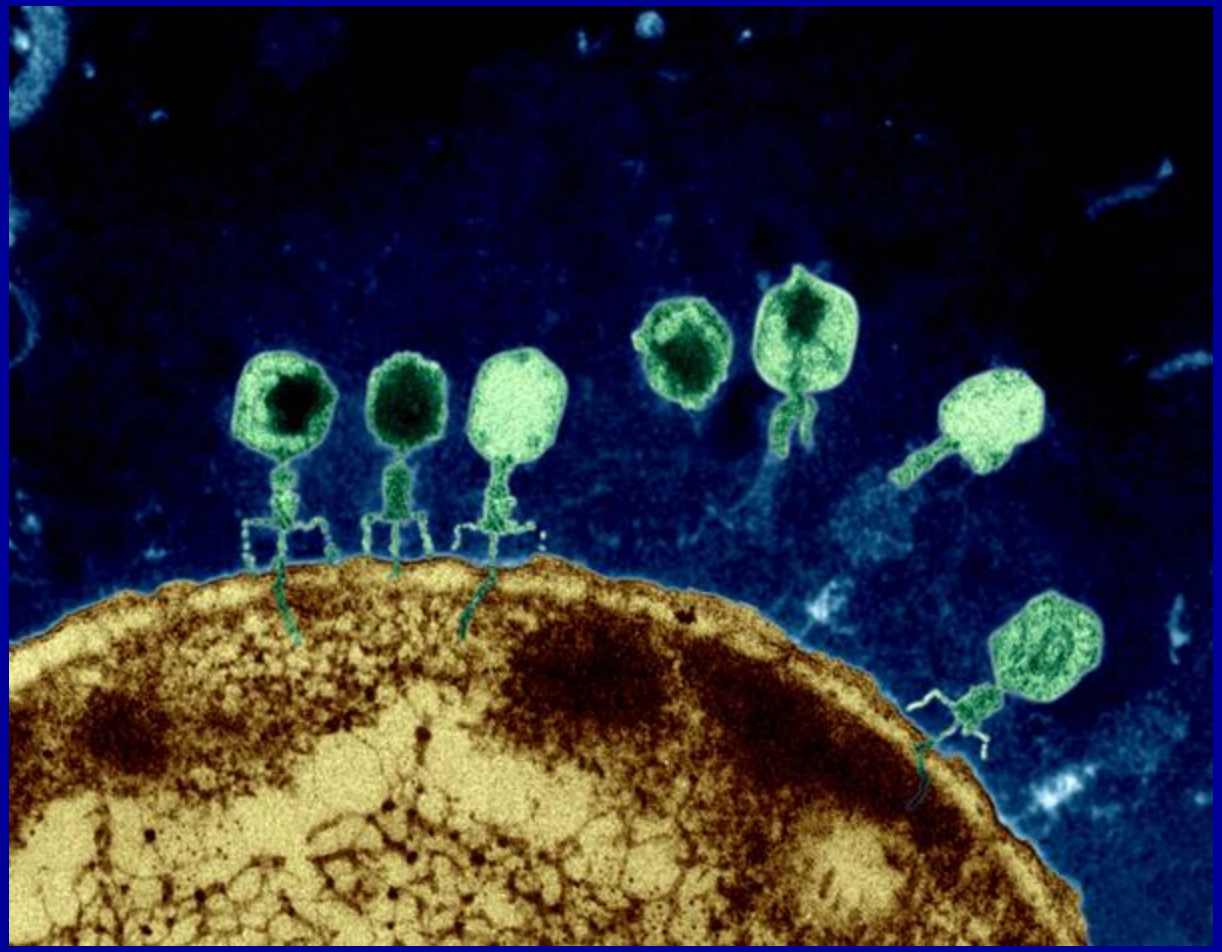
3. Inoculation of such a pure culture of organisms into a host should initiate the disease

4. The organism must be recovered once again from the lesions of the host

History

- 1881: Louis Pasteur, attenuation of rabies.
  - Vaccine from drying the spinal cords or rabbits
- 1915 bacteriophages ("eaters of bacteria").
- We use bacteriophages in our mouths to destroy bacteria we don’t like!
- The history of virology is the development of experimental tools like the electron microscope, and later, sequencing.

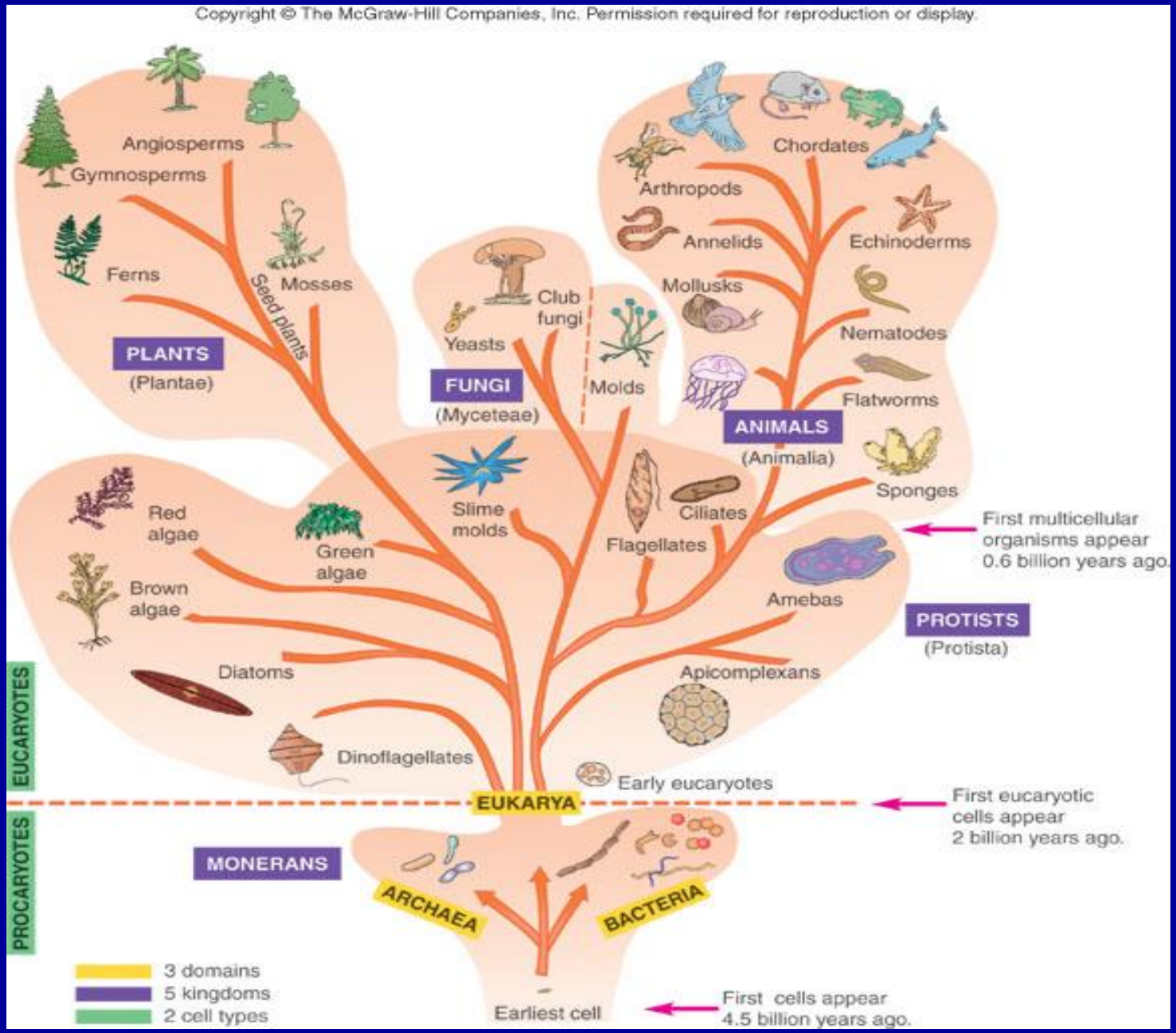
Bacteriophage



History

- Spanish American war: More death from yellow fever than bullets.
- 1900: Walter Reed demonstrated that yellow fever was caused by a virus and spread by mosquitoes. He died of yellow fever.
- 1950s: development of vaccines.
- We grow vaccines in eggs. (Hence some allergies)

VIRUS TAXONOMY



No viruses on the tree of life

- They are not considered alive.
- Cellular chauvinism!
- They predate the eukaryotes (modern cell)
- By transporting genes horizontally they are a major driver of evolution. (Bush of life)
- We have viral DNA which helps us live.
- Viral DNA can also be lethal (oncogenes.)
- Marijuana has THC due to an ancient viral infection. Thank you viruses!

VIRUS TAXONOMY

- **The earliest efforts to classify viruses were based on**
  - **common pathogenic properties**
  - **Common organ changes**
  - **Common ecological and transmission characteristics**
- **E.g. viruses that attack the liver would have been brought together as "the hepatitis viruses"**
  - **Hepatitis A, Hepatitis B, Hepatitis C, Yellow fever virus**
  - You may as well classify birds, squirrels, humans and ants together because we all eat fruit!
- **It was not until 1930 that evidence of the structure and composition of virions started to emerge**

TABLE 131-1 Classification and Structure of Herpesviridae That Infect Humans

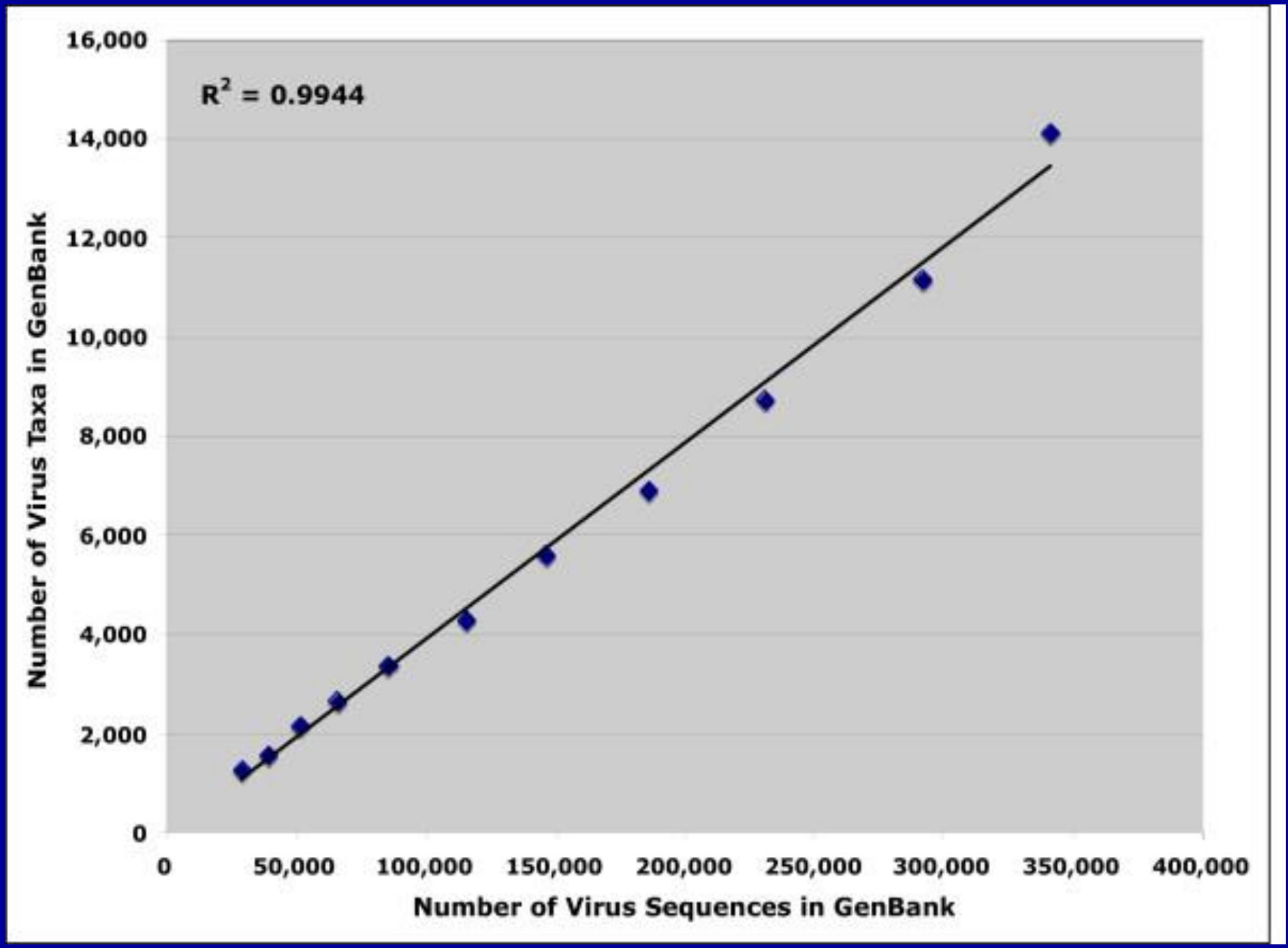
Common Name	*Other Designation*	*Subfamily*	*Genome Size (Kbp × 10^6)*	*Genome Isomers (No.)*	*Genome Type*	*Receptor(s)*
Human Virus						
Herpes simplex virus type 1	Human herpesvirus 1	α	152	4	1	TNFRSF14; nectin 1; nectin 2; 3-O-S-heparin sulfate
Herpes simplex virus type 2	Human herpesvirus 2	α	152	4	1	TNFRSF14;nectin 1; nectin 2; 3-O-S-heparin sulfate
Varicella-zoster virus	Human herpesvirus 3	α	125	2	2	?
Epstein-Barr virus	Human herpesvirus 4	γ	172	1	3	CD21; MHC class II (co-receptor)
Cytomegalovirus	Human herpesvirus 5	β	229	1	1	?
Human herpesvirus 6	—	β	165	1	4	CD46
Human herpesvirus 7	—	β	145	1	4	CD4
Human herpesvirus 8	Kaposi's sarcoma herpesvirus	γ	165	1	5	Integrin $\alpha_3\beta_1$
Simian Virus						
Herpes B virus	Herpesvirus simiae; cercopithecine herpesvirus 1	α	150	4	1	?

Kbp, kilobase pairs; MHC, major histocompatibility complex; TNFRSF14, tumor necrosis factor receptor superfamily, member 14; ?, not known.

- ~1950 it was proposed for the first time that viruses be grouped on the basis of shared virion properties
- The first taxonomic groups constructed on this basis were herpesvirus group (1954), myxovirus group (1955) and poxvirus group (1957)
- 1950's and 1960's explosion in the discovery of new viruses
- With growing mass of data , several individuals and committees independently advanced classification system
- Result was confusion over competing and conflicting schemes

INTERNATIONAL COMMITTEE ON TAXONOMY OF VIRUSES (ICTV)

- **ORDER, FAMILY, (subfamily), GENUS and SPECIES**
- **Artificial viruses don’t count**
- **ICTV now has the responsibility to sort this whole thing out.**

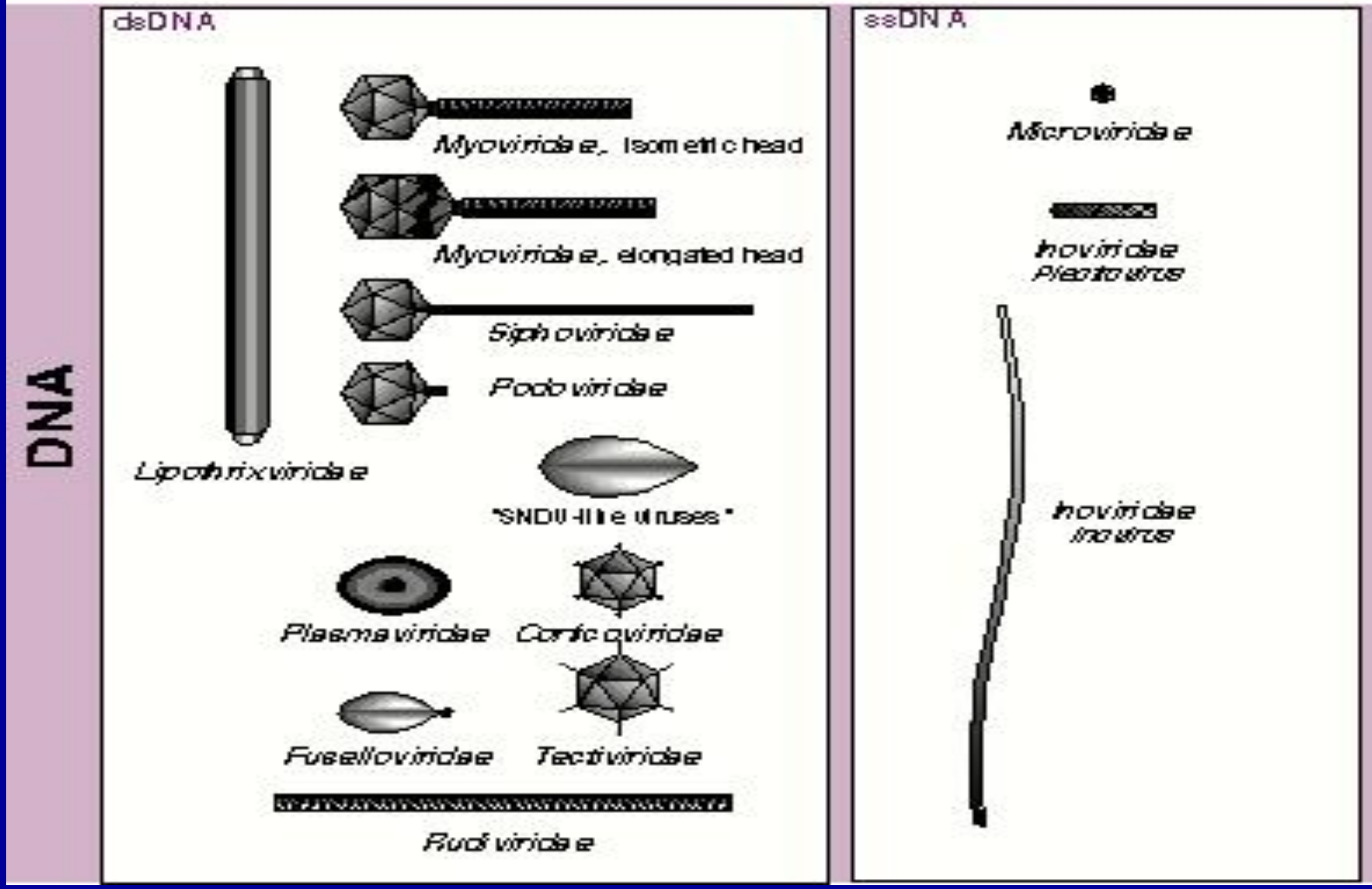

R^2 = 0.9944
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Number of Virus Taxa in GenBank
0
50,000
100,000
150,000
200,000
250,000
300,000
350,000
400,000
Number of Virus Sequences in GenBank

VIRUS TAXONOMY

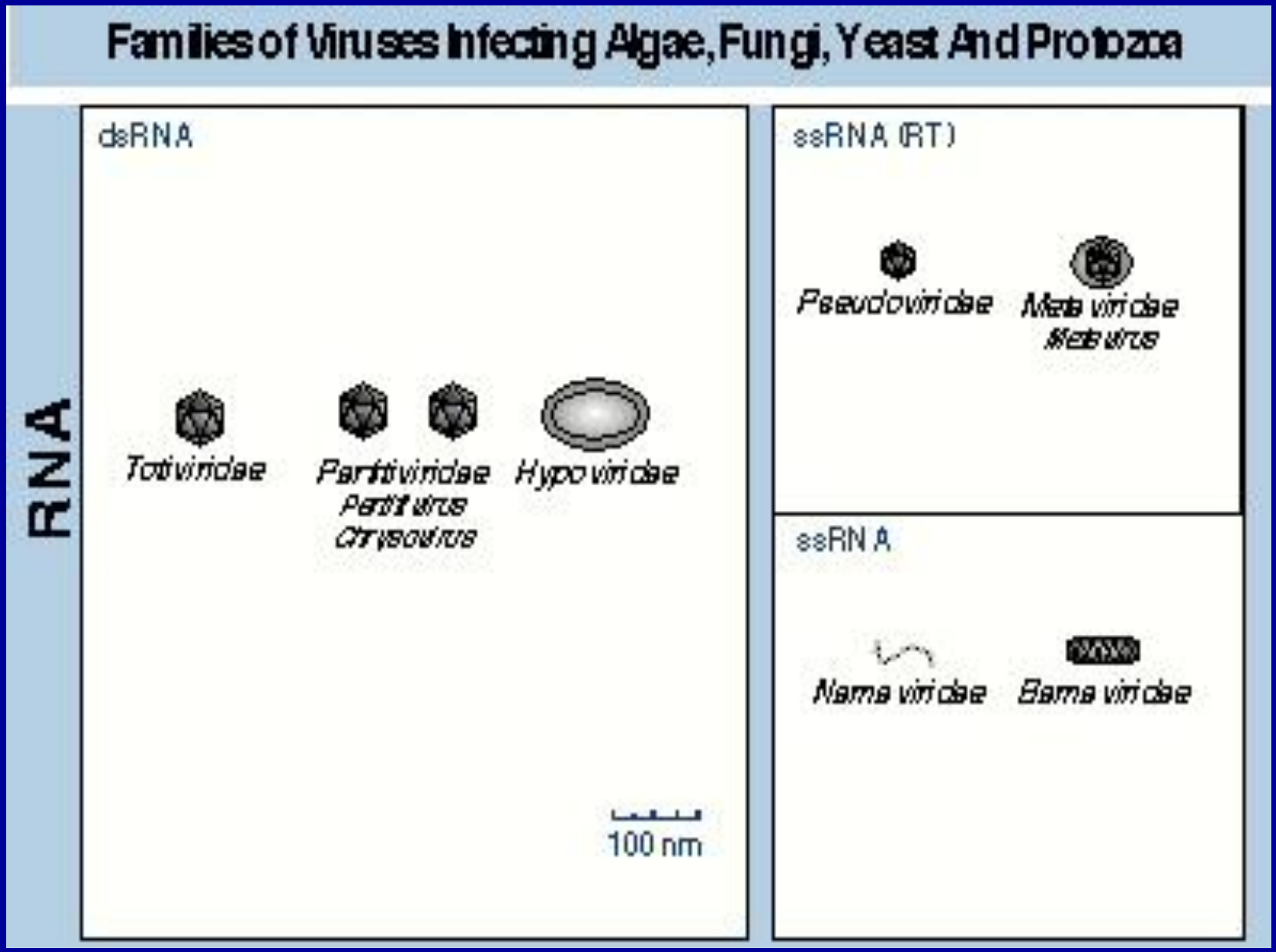
- Bacterial viruses
- Fungal viruses
- Plant viruses
- Invertebrate viruses
- Vertebrate viruses

- All viruses are classified together irrespective of their host.

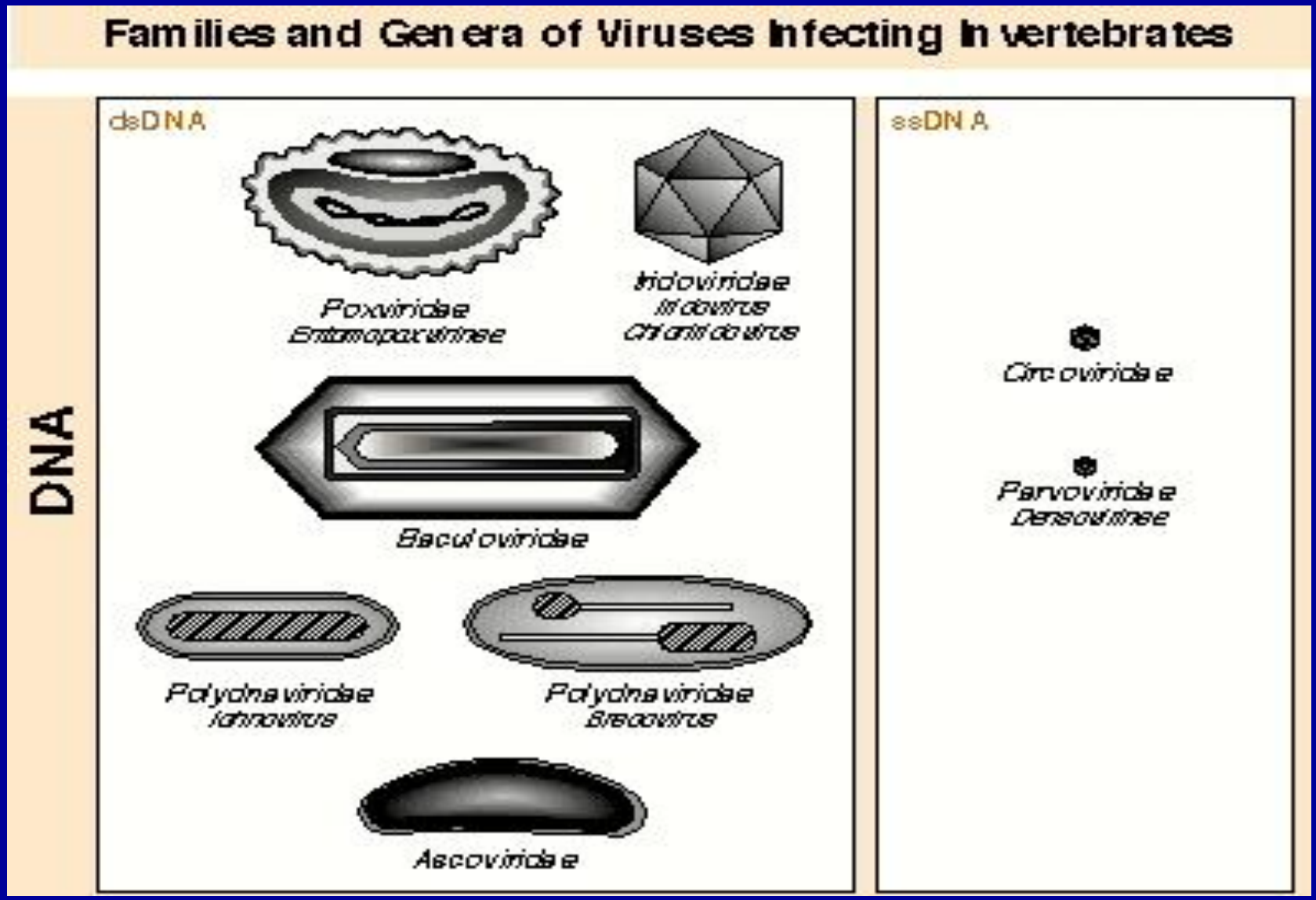
Families and Genera of Viruses Infecting Bacteria



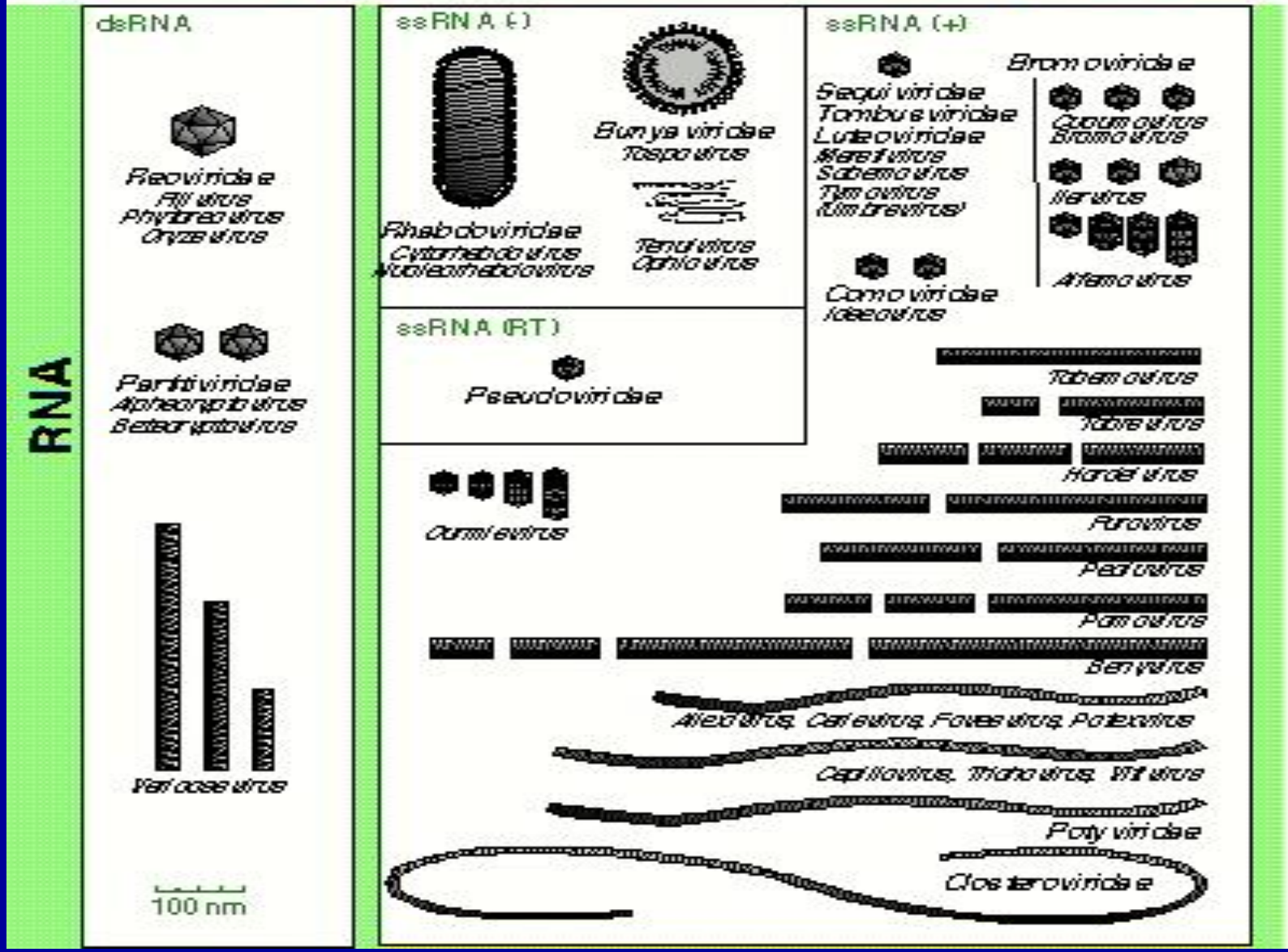
Families of Viruses Infecting Algae, Fungi, Yeast And Protozoa



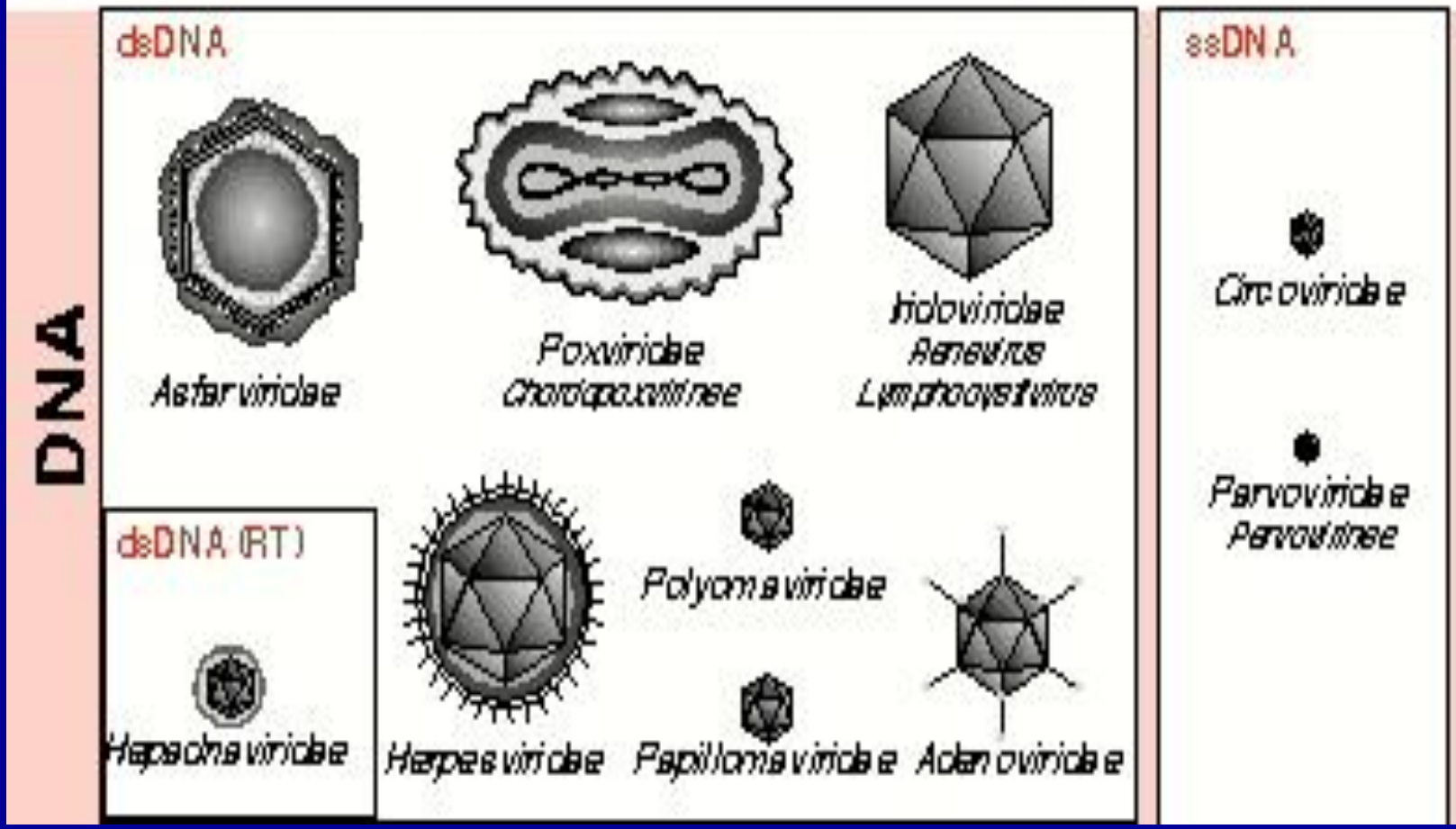
Families and Genera of Viruses Infecting Invertebrates



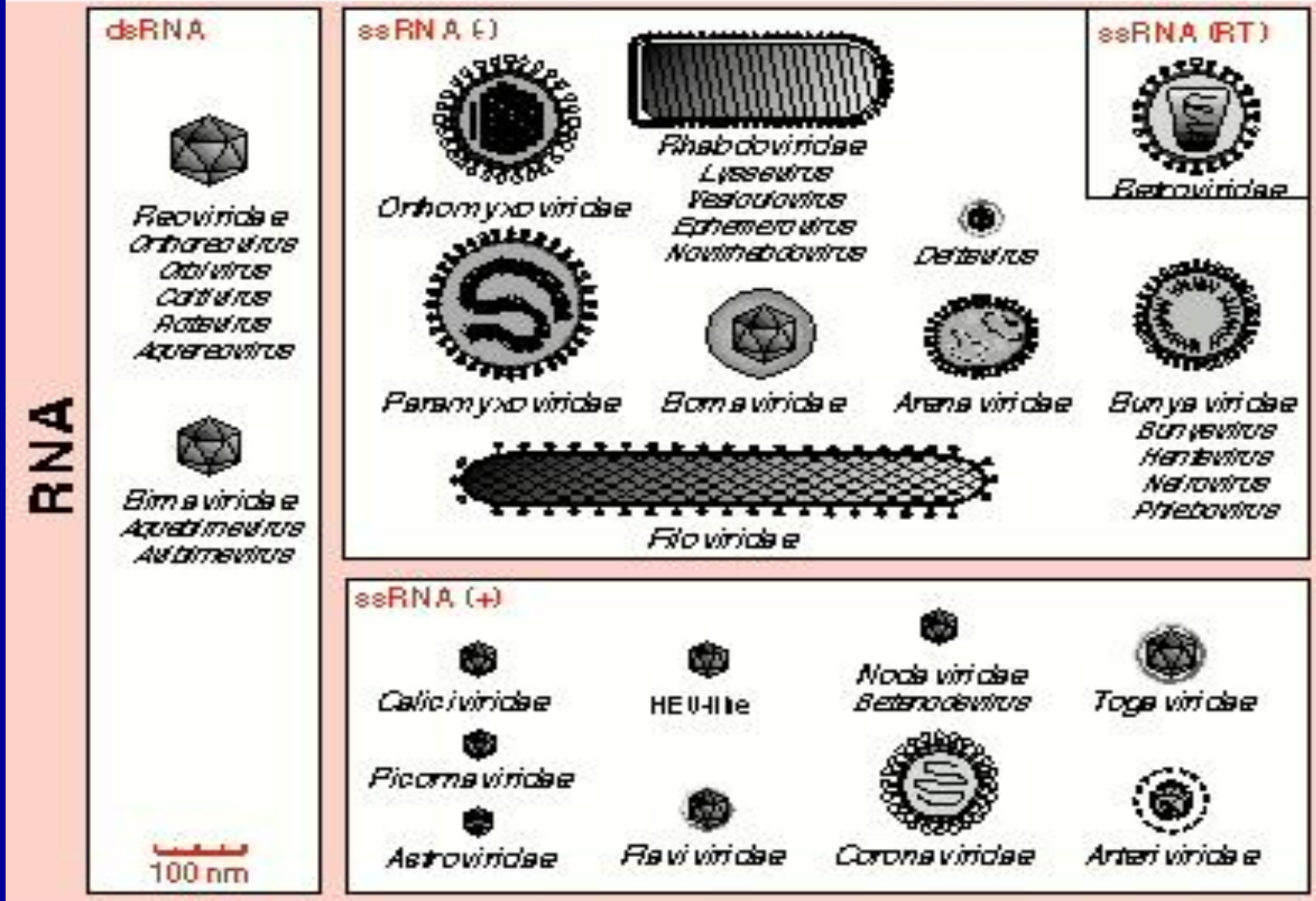
Families and Genera of Viruses Infecting Plants



Families and Genera of Viruses Infecting Vertebrates



Families and Genera of Viruses Infecting Vertebrates



VIRUSES INFECTING HUMANS

DNA VIRUSES
dsDNA & ssDNA

- ***Poxviridae***
  - **Vaccinia, Orf virus, Molluscum contagiosum virus**
- ***Herpesviridae***
  - **HSV-1, -2, VZV, CMV, HSV-6, -7, EBV, KSHV**
- ***Adenoviridae***
  - **Human adenoviruses**
- ***Polyomaviridae***
  - **JC virus**
- ***Papillomaviridae***
  - **Human papillomaviruses**
- ***Parvoviridae***
  - **B19 and adeno-associated virus-2**

DNA AND RNA RT VIRUSES

- ***Hepadnaviruses***
  - **Hepatitis B virus**

- ***Retroviridae***
  - **HTLV-1, HTLV-2, HIV-1, HIV-2, Spumavirus**

RNA VIRUSES
dsRNA, ssRNA(-)

- ***Reoviridae***
  - Reovirus type 3, Kemerovo virus, human rotavirus, Colorado tick fever virus
- ***Paramyxoviridae***
  - Parainfluenca viruses, Measles, Mumps, Nipah, RSV
- ***Rhabdoviridae***
  - Vesicular stomatitis virus, Rabies virus
- ***Filoviridae***
  - Ebola and Marburg viruses
- ***Orthomyxoviridae***
  - Influenza virus A, B, C
- ***Bunyaviridae***
  - LaCrosse virus, Hantaan virus, Rift Valley fever virus
- ***Arenaviridae***
  - Lymphocytic choriomeningitis virus (LCMV)

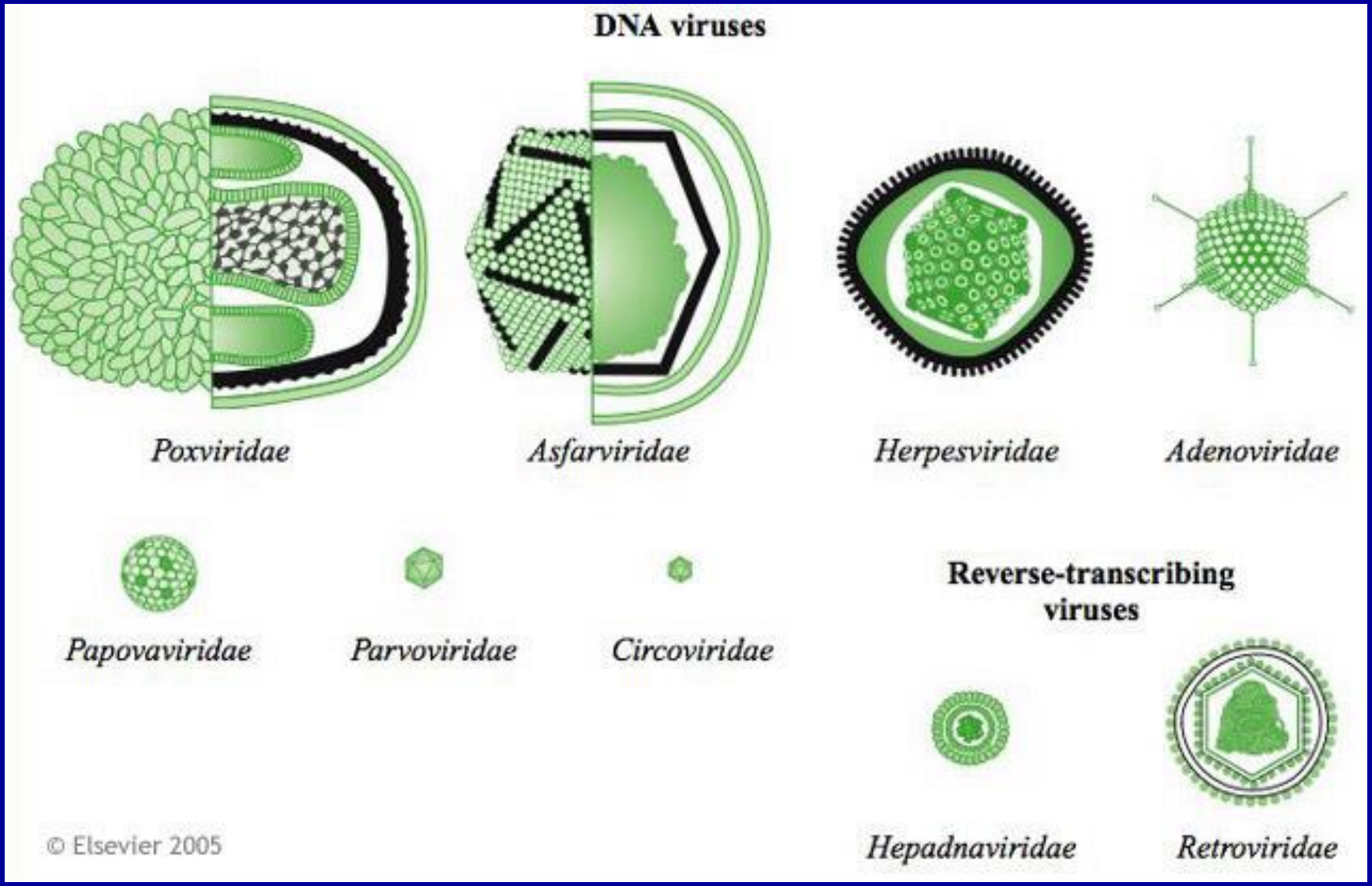
RNA VIRUSES
ssRNA(+)

- ***Picornaviridae***
  - **Polioviruses, rhinovirus, hepatitis A virus**
- ***Caliciviridae***
  - **Norovirus, Hepatitis E virus**
- ***Astroviridae***
  - **Human astrovirus 1**
- ***Coronaviridae***
  - **Human corona virus**
- ***Flaviviridae***
  - **Yellow fever virus, hepatitis C virus**
- ***Togaviridae***
  - **Western equine encephalitis virus, rubella virus**

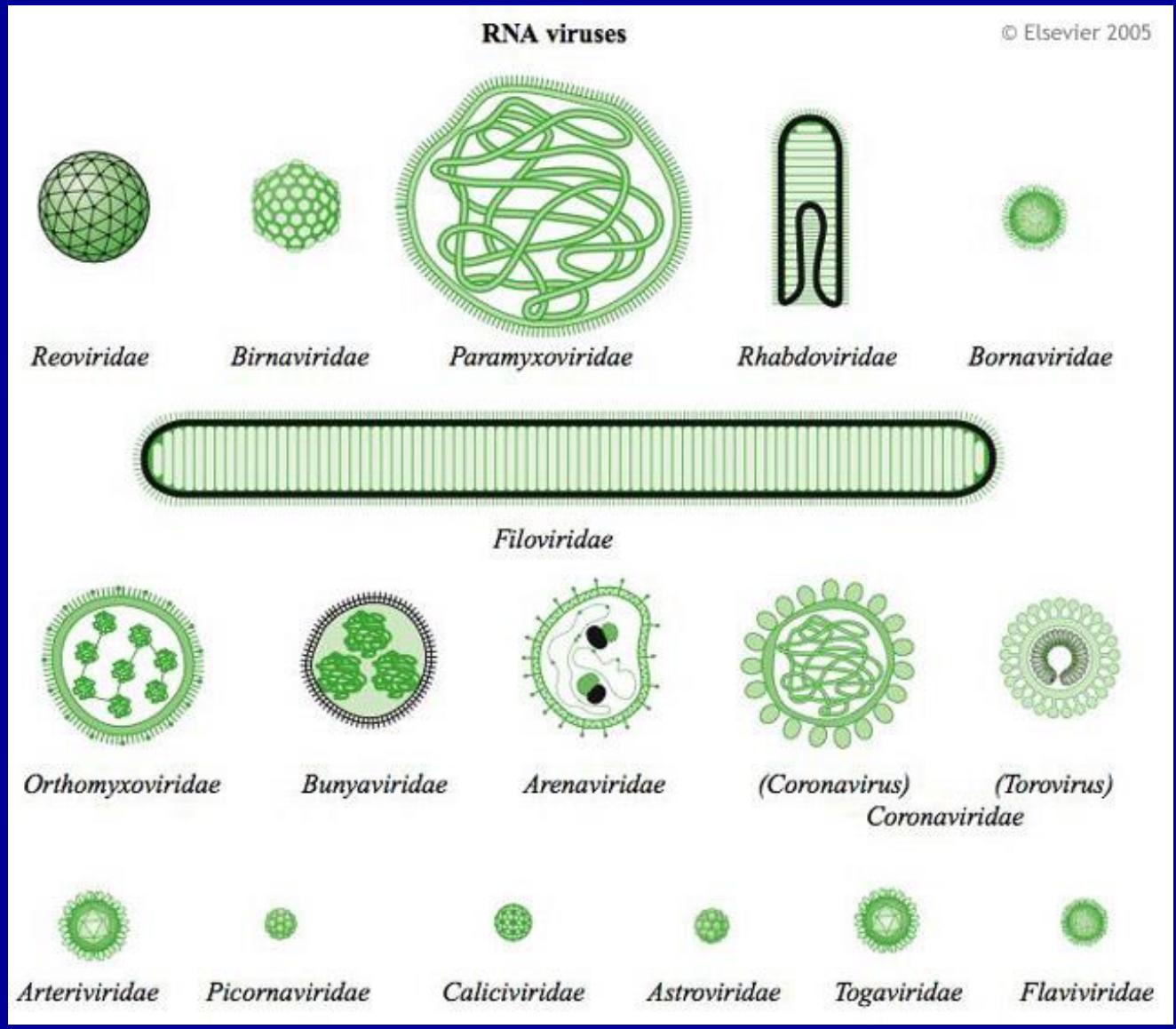
1. STRUCTURE

2. VIRUS LIFE CYCLE

Virus Particles



Virus Particles



Virus Particles

- One of the functions of a virus particle is to protect the viral genome from damage
- On leaving the host cell, the virus enters a hostile environment.
- The environment is heavily laden with nucleases, enzymes which dissolve RNA and DNA .

Virus Particles

- The outer surface of the virus is responsible for recognition of and interaction with the host cell.
- This takes the form of binding of a specific virus-attachment protein to a cellular receptor molecule.
- The capsid also initiates infection by delivering the genome into the the host cell.

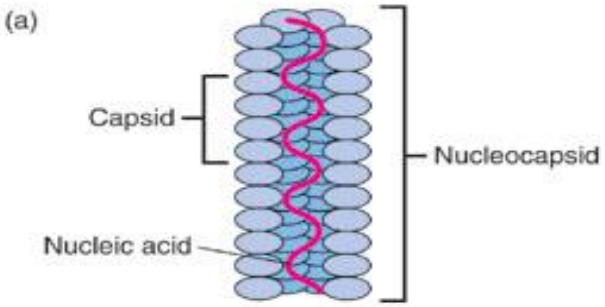
STRUCTURES

CAPSID VIRIONS:

- Helical capsid
- Icosahedral capsid

ENVELOPED VIRIONS:

- Helical capsid enveloped
- Icosahedral capsid enveloped



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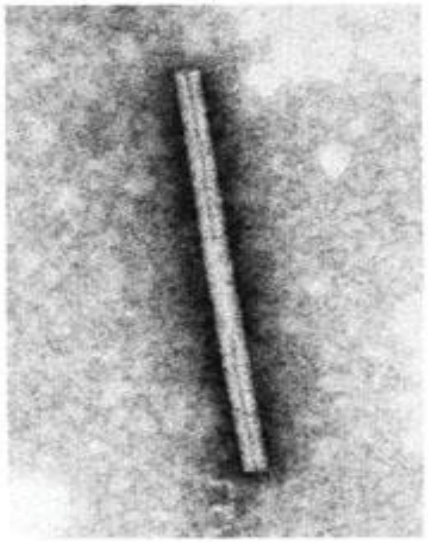
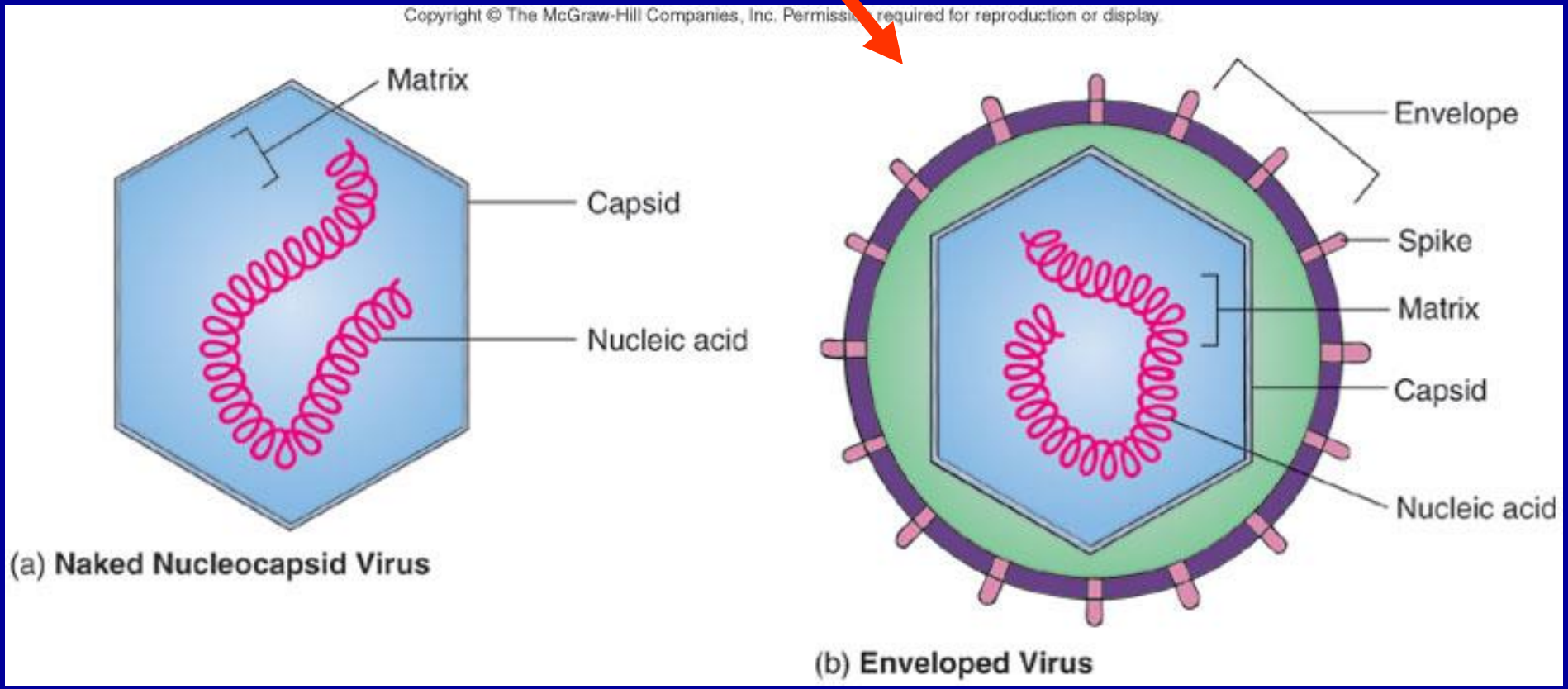


HELICAL CAPSID

NON-ENVELOPED ICOSAHEDRAL STRUCTURE

ENVELOPED ICOSAHEDRAL CAPSID



Formation of virus particles

To form infectious particles, viruses must overcome two fundamental problems:

- **They must assemble the particle utilizing the information from the viral genome (often hijacking host proteins as well).**

- **Virus particles form regular geometric shapes, even though the proteins from which they are made are irregularly shaped.**

Formation of virus particles

- **1957: When mixtures of purified *Tobacco mosaic virus* RNA and coat protein were incubated together, without anything else, virus particles formed.**

- **This indicates that the particle is in the free energy minimum state and thus favoured structure. (It comes together by itself due to electromagnetic attraction)**

Formation of virus particles

- Assembly of virus particles includes hydrophobic and electrostatic interactions.
- Some viruses are fragile and become non viable after one second outside the host (HIV). Many are quite stable and can last for years, even frozen (norovirus).

Helical capsids

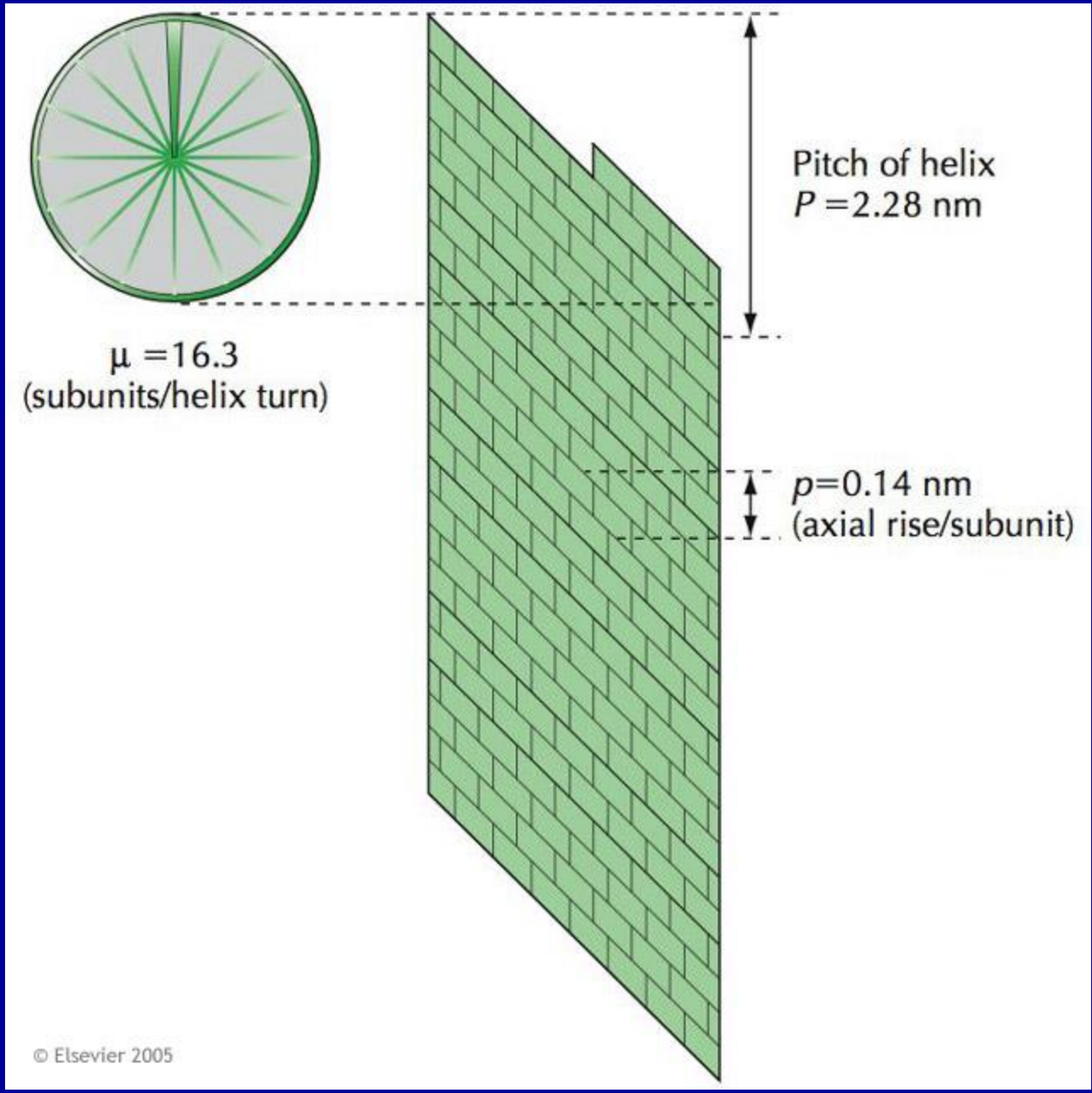
helical symmetry

- **The simplest way to arrange multiple, identical protein subunits is to link them together in a line and wrap the line around and around like a slinky. A slinky is a helix.**
- **The RNA or DNA resides inside the cylinder thus formed**

Helical capsids

- **The great advantage is one gene can code for one capsid protein which is used over and over again.**
- **For a small genome this is a very efficient use of coding space.**
- **Helices are simple structures formed by winding repeated components with a constant relationship (amplitude and pitch) to one another.**

TMV


Pitch of helix
P =2.28 nm
μ =16.3
(subunits/helix turn)
p=0.14 nm
(axial rise/subunit)
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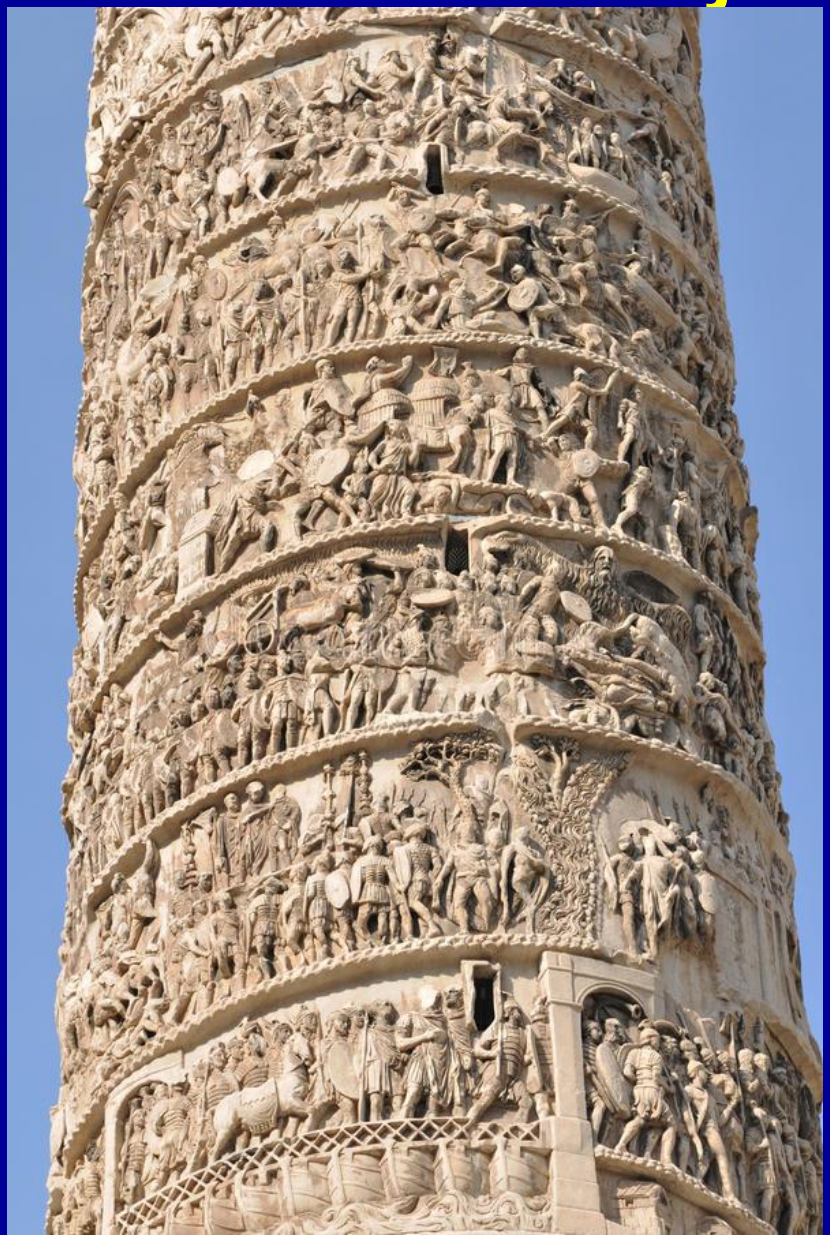
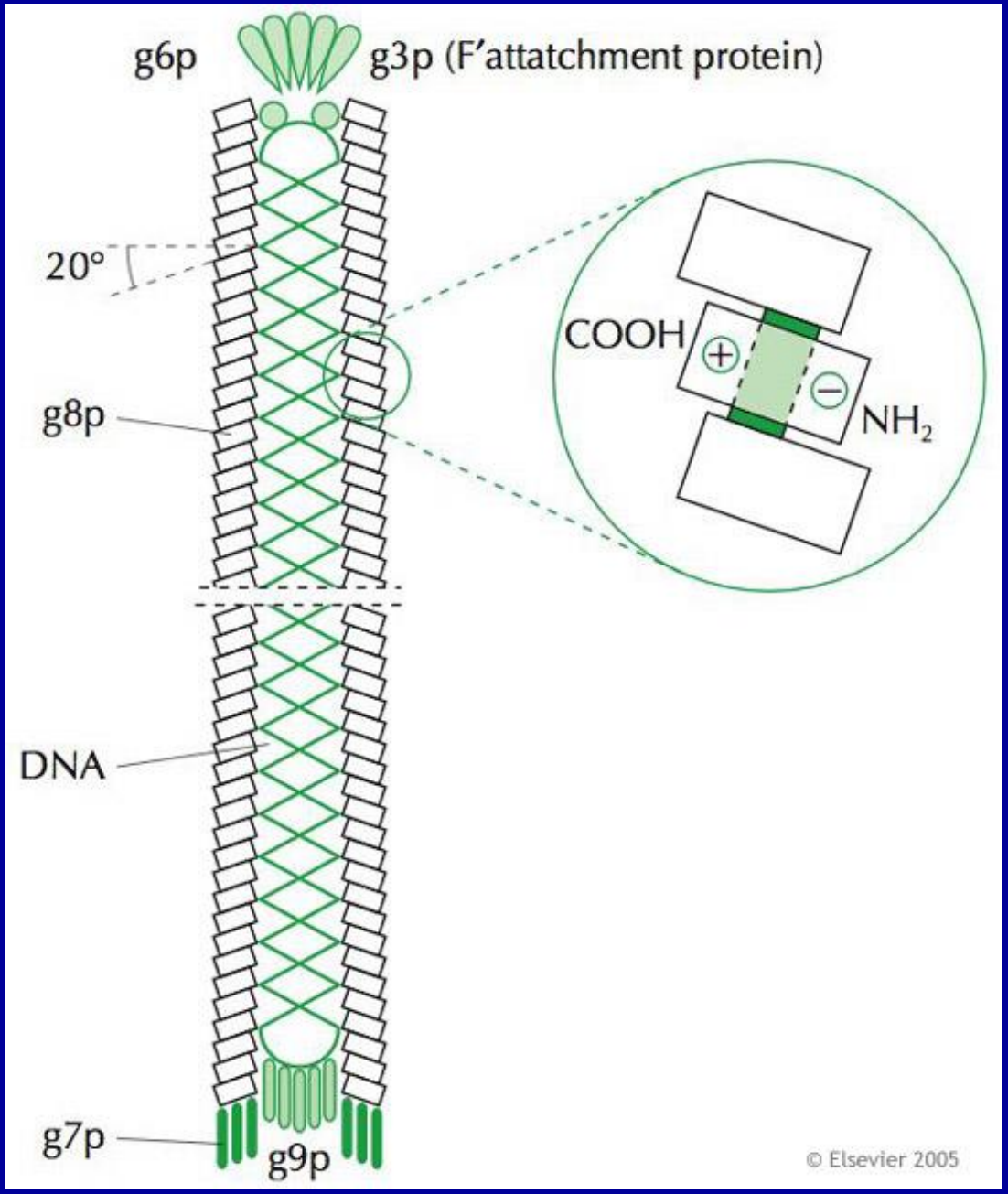
Column of Trajan



Bacteriophage M13



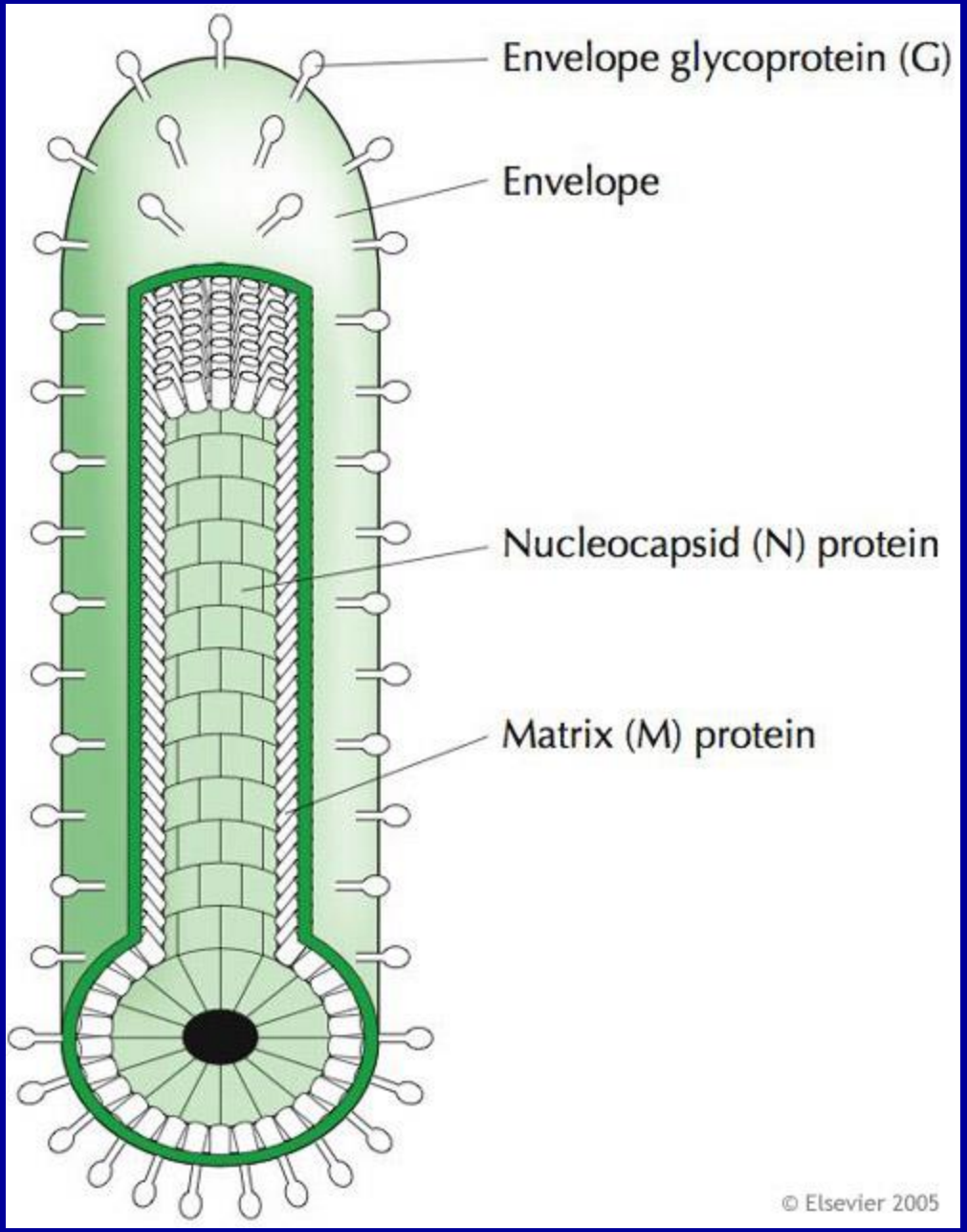
Helical animal viruses

- There are a large number of animal viruses with helical symmetry, but all have a lipid envelope with some extra bells and whistles
- These include many of the best known human pathogens, e.g. influenza virus, mumps and measles viruses, and Rabies virus.

Helical Symmetry - Summary

- Many different groups of viruses have evolved with helical symmetry.
- Simple viruses are helical to protect their genome without the need to encode multiple capsid proteins.
- More complex virus particles have a basic helical structure but elaborate on it with additional layers of protein and lipid.

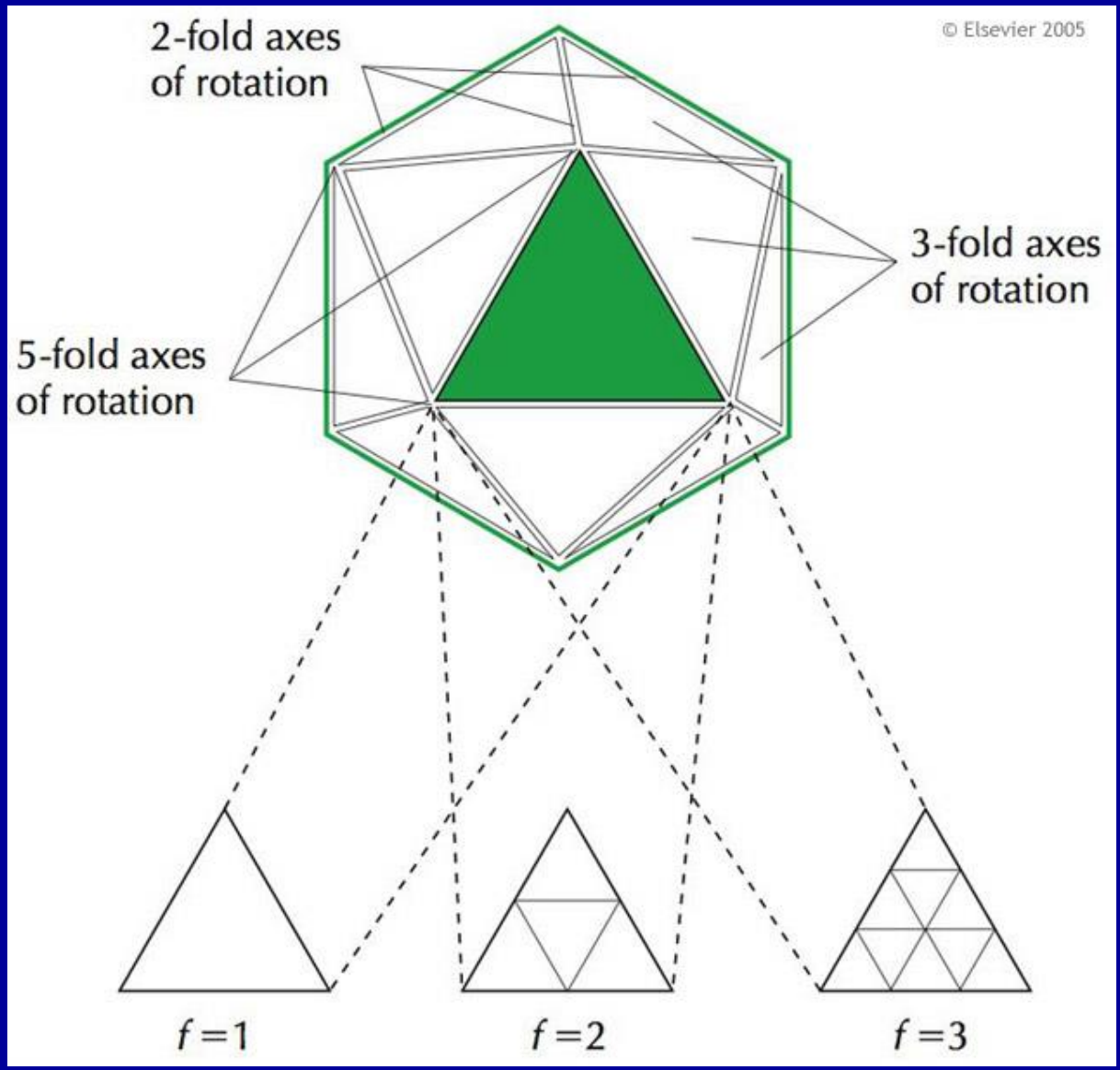
Rhabdovirus particle - rabies



Icosahedral Symmetry

- Icosahedral symmetry is based on the rotation, known as 2-3-5 symmetry:
  - An axis of twofold rotational symmetry through the centre of each edge
  - An axis of threefold rotational symmetry through the centre of each face
  - An axis of fivefold rotational symmetry through the centre of each corner (vertex)

Icosahedral Symmetry



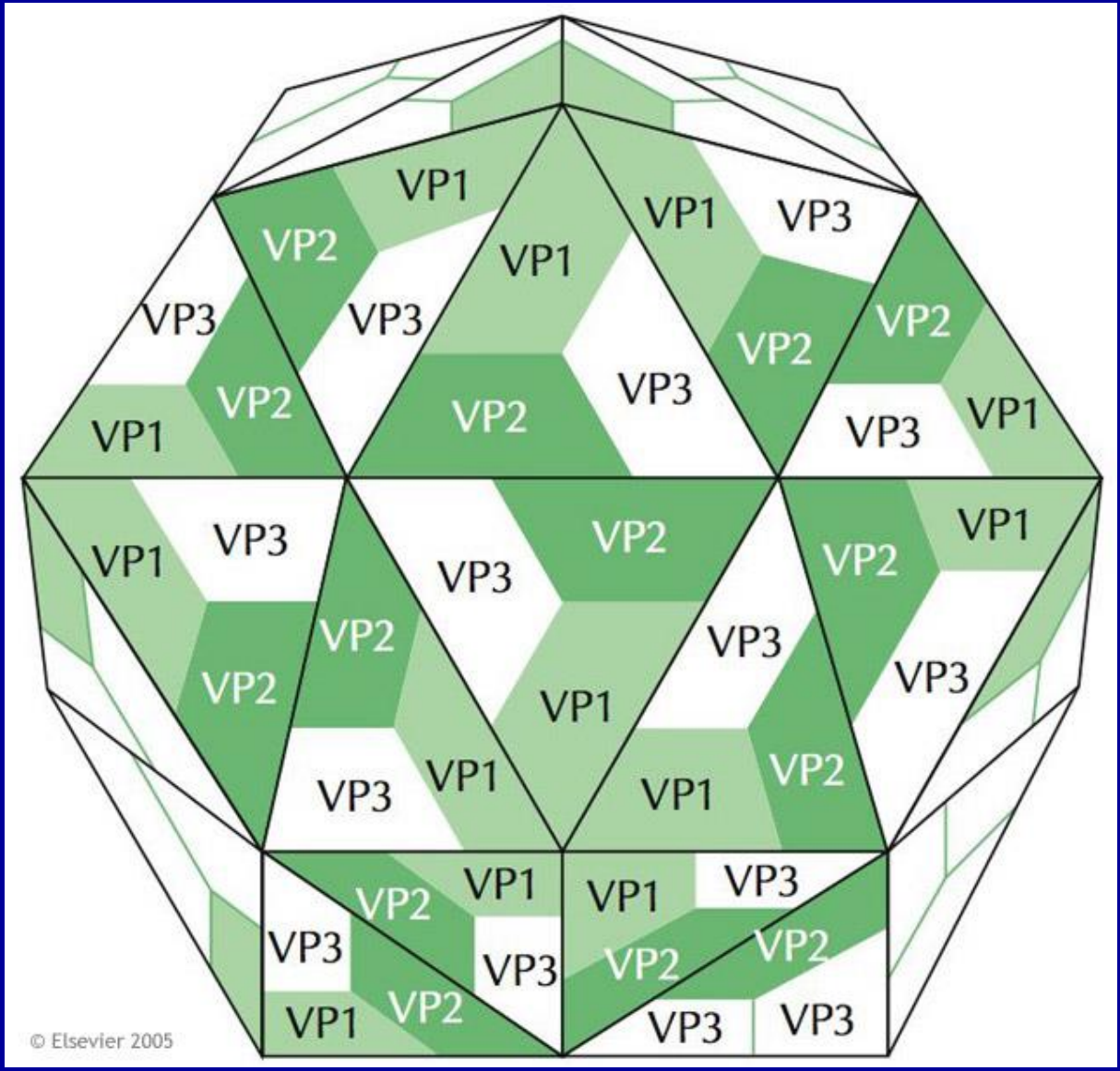
NON-ENVELOPED ICOSAHEDRAL STRUCTURE

Icosahedral Symmetry

- Protein molecules are irregularly shaped, not regular equilateral triangles, so the simplest icosahedral capsids are built up by using three identical subunits to form each triangular face.

- 60 identical subunits are required to form a complete capsid. A few simple virus particles are constructed in this way.

Picornavirus capsids



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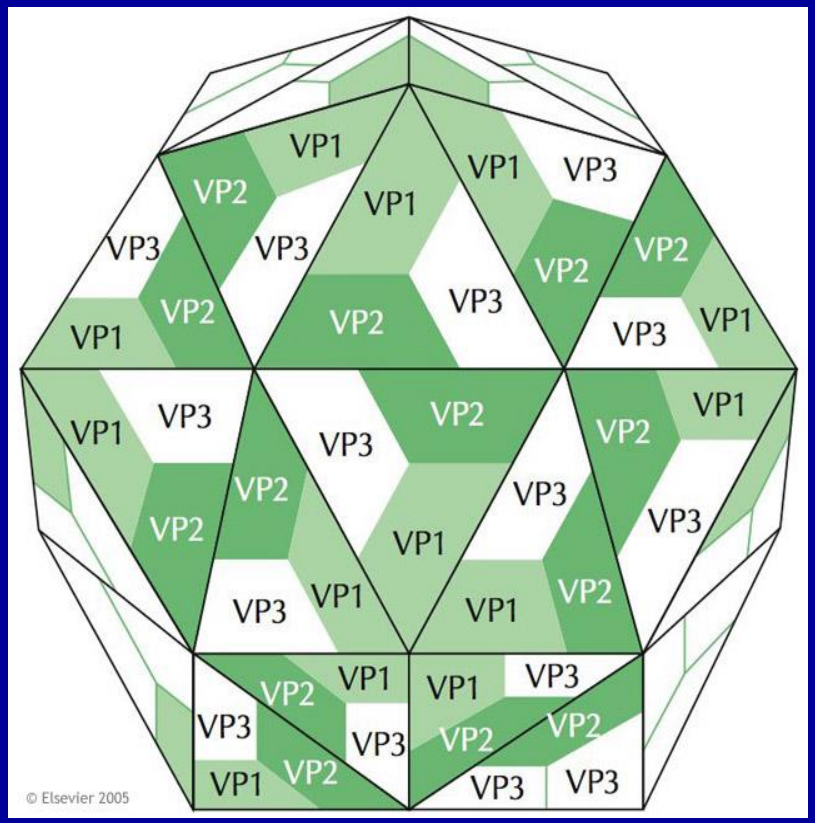
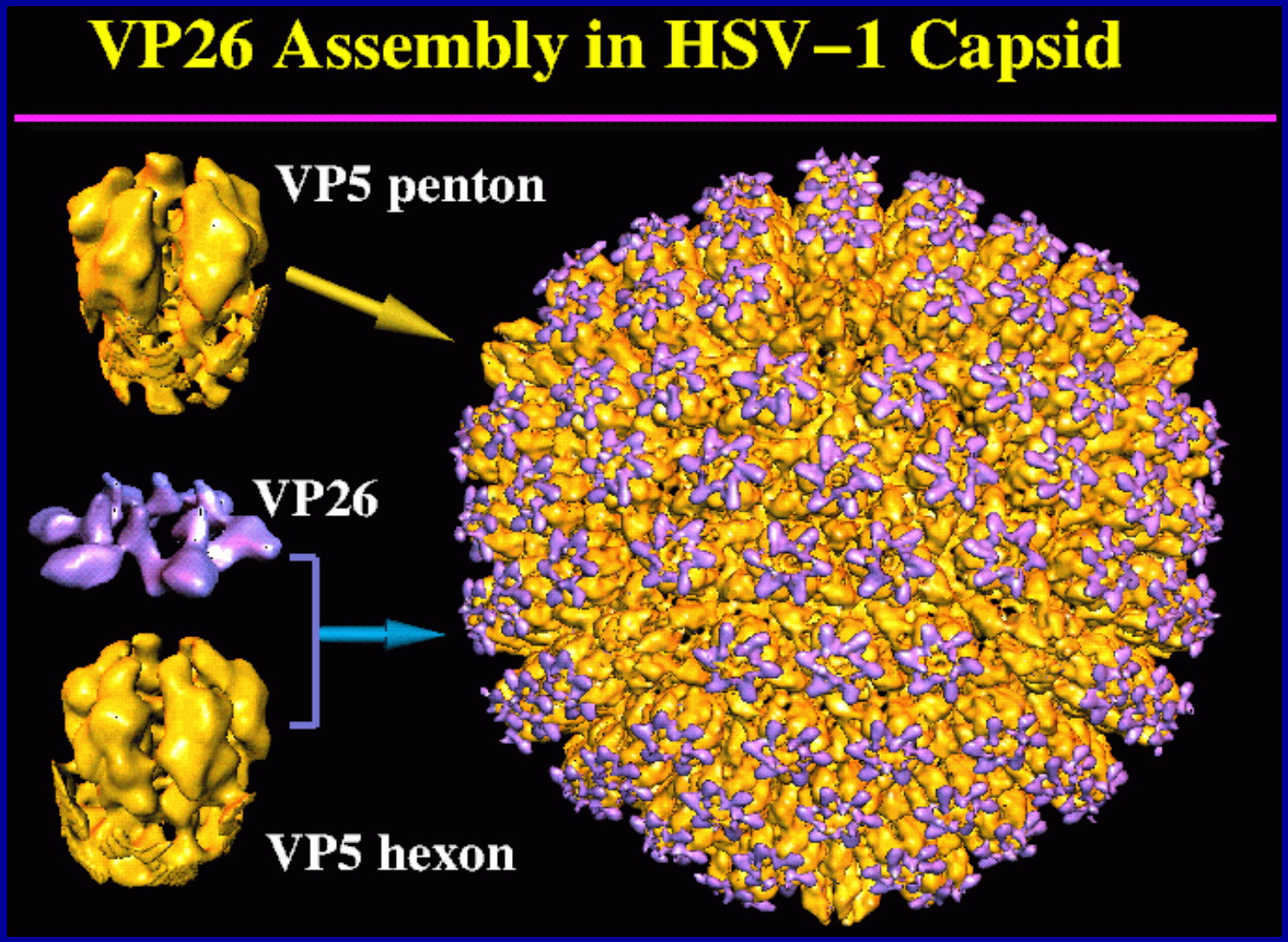
PICORNAVIRUS





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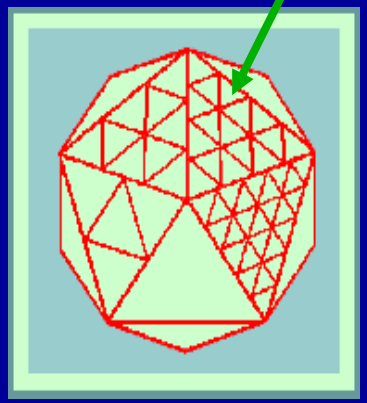
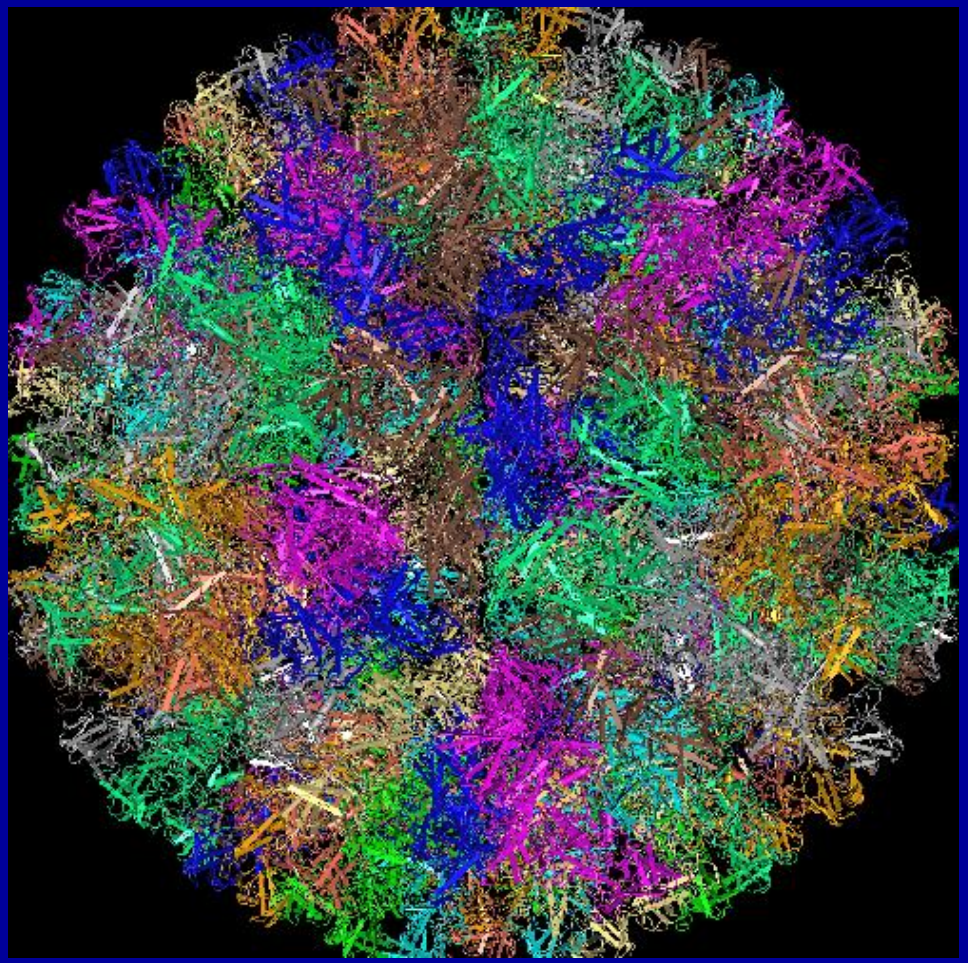
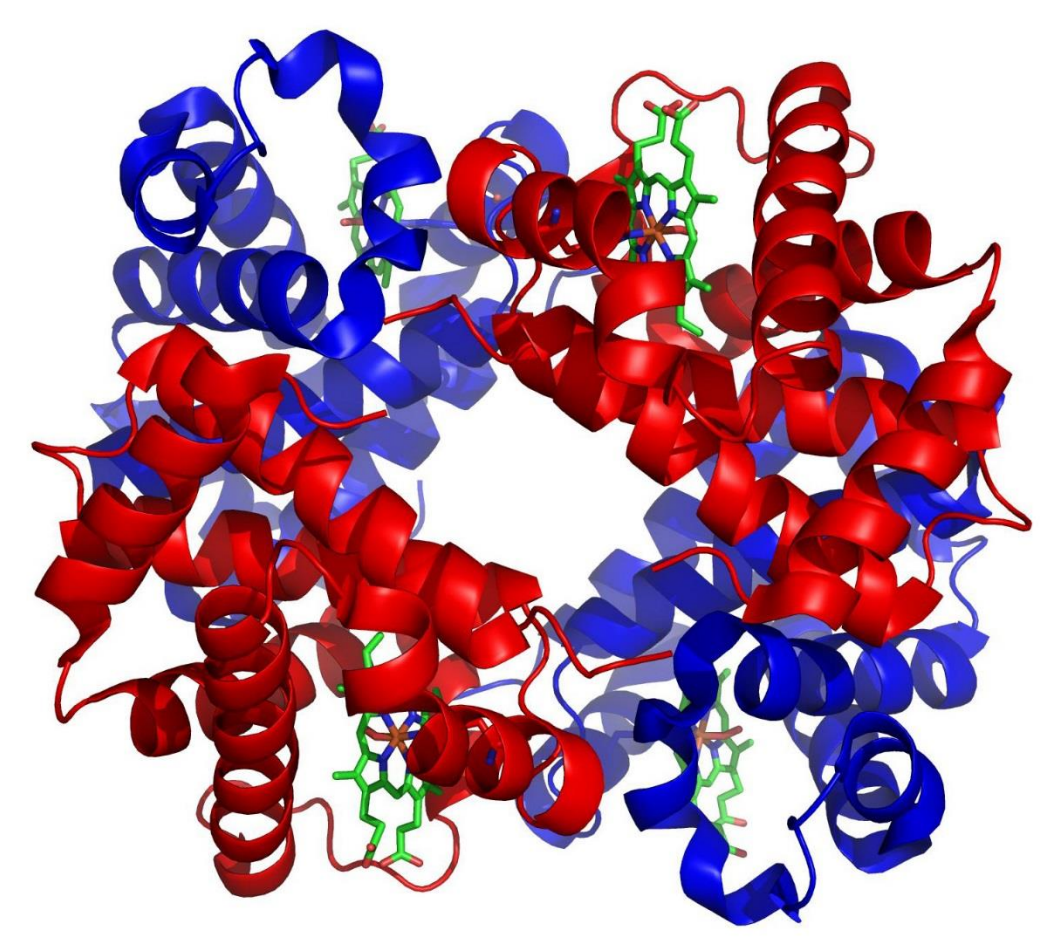


“viral zone”

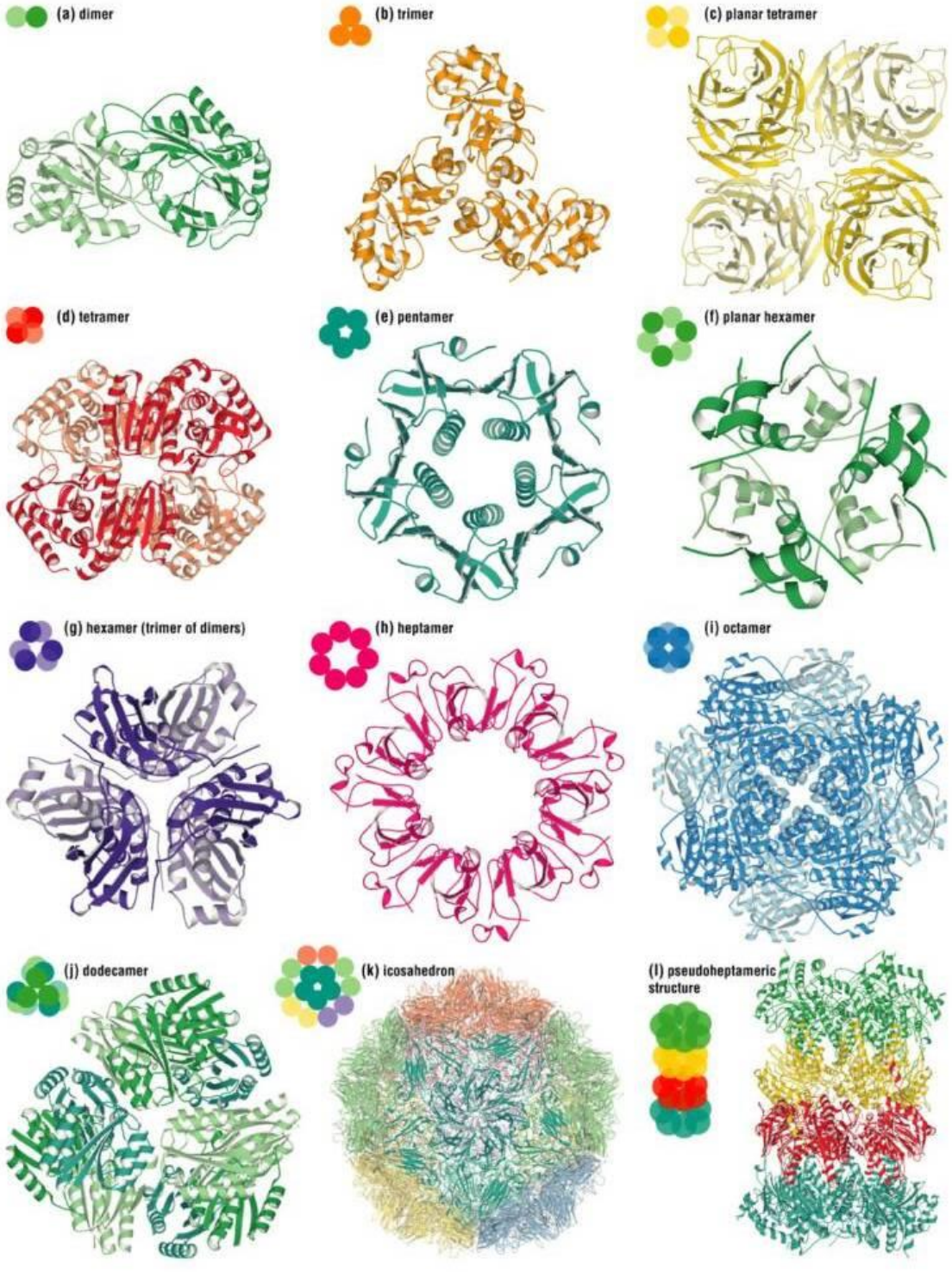
Norovirus



Hemoglobin



From **Protein Structure and Function** by Gregory A Petsko and Dagmar Ringe

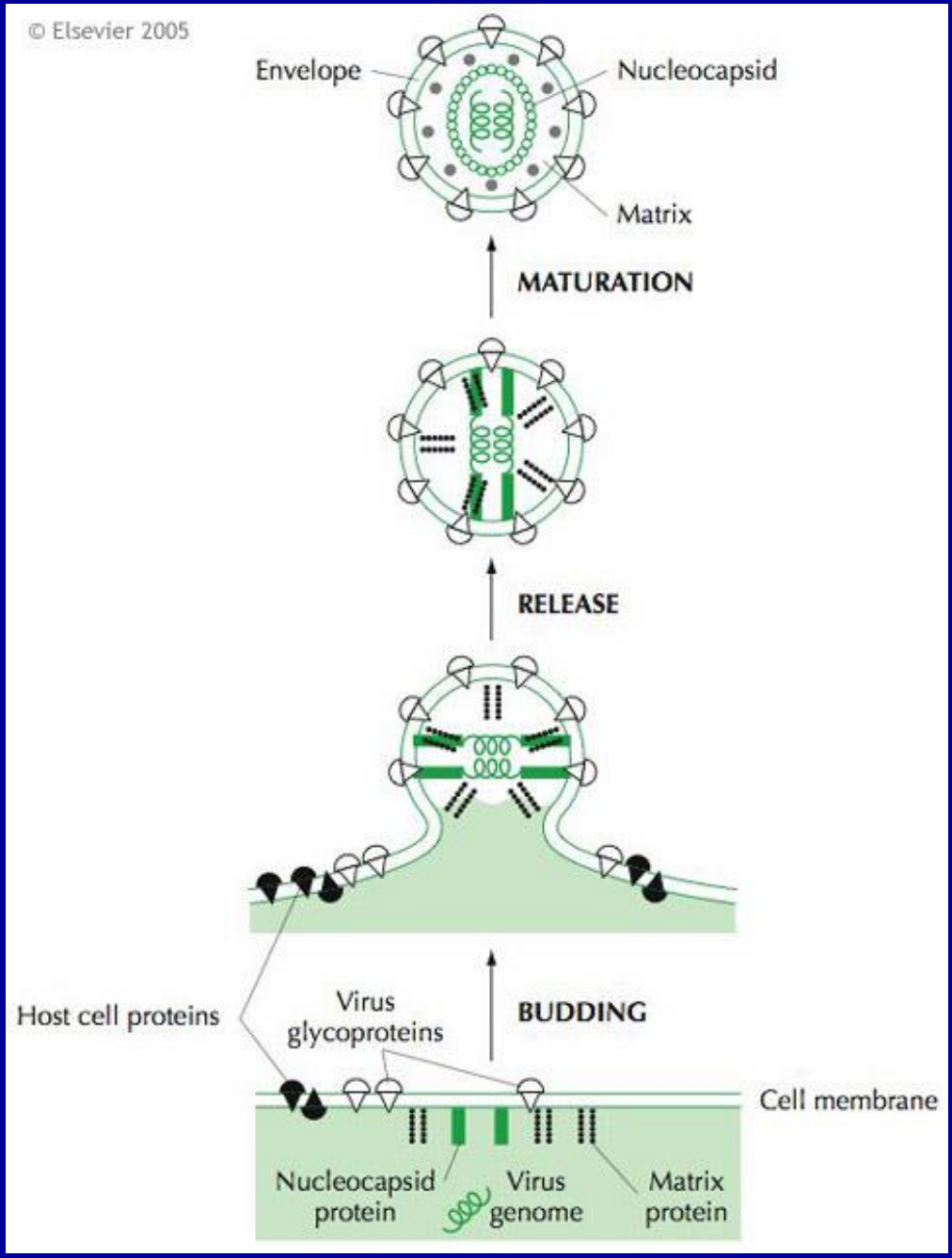


ENVELOPED VIRUSES

Enveloped Viruses

- 'Naked' virus particles, i.e. those in which the capsid proteins are exposed to the external environment, are released by lysis, killing the cell. Since the cell is a viral factory it would be better to leave it alive.
- Many viruses have devised strategies to exit from the infected cell without its total destruction.
- All living cells are covered by a membrane composed of a lipid bilayer. Viruses leaving the cell must, therefore, allow this membrane to remain intact.
- This is achieved by extrusion (budding) of the particle through the membrane.

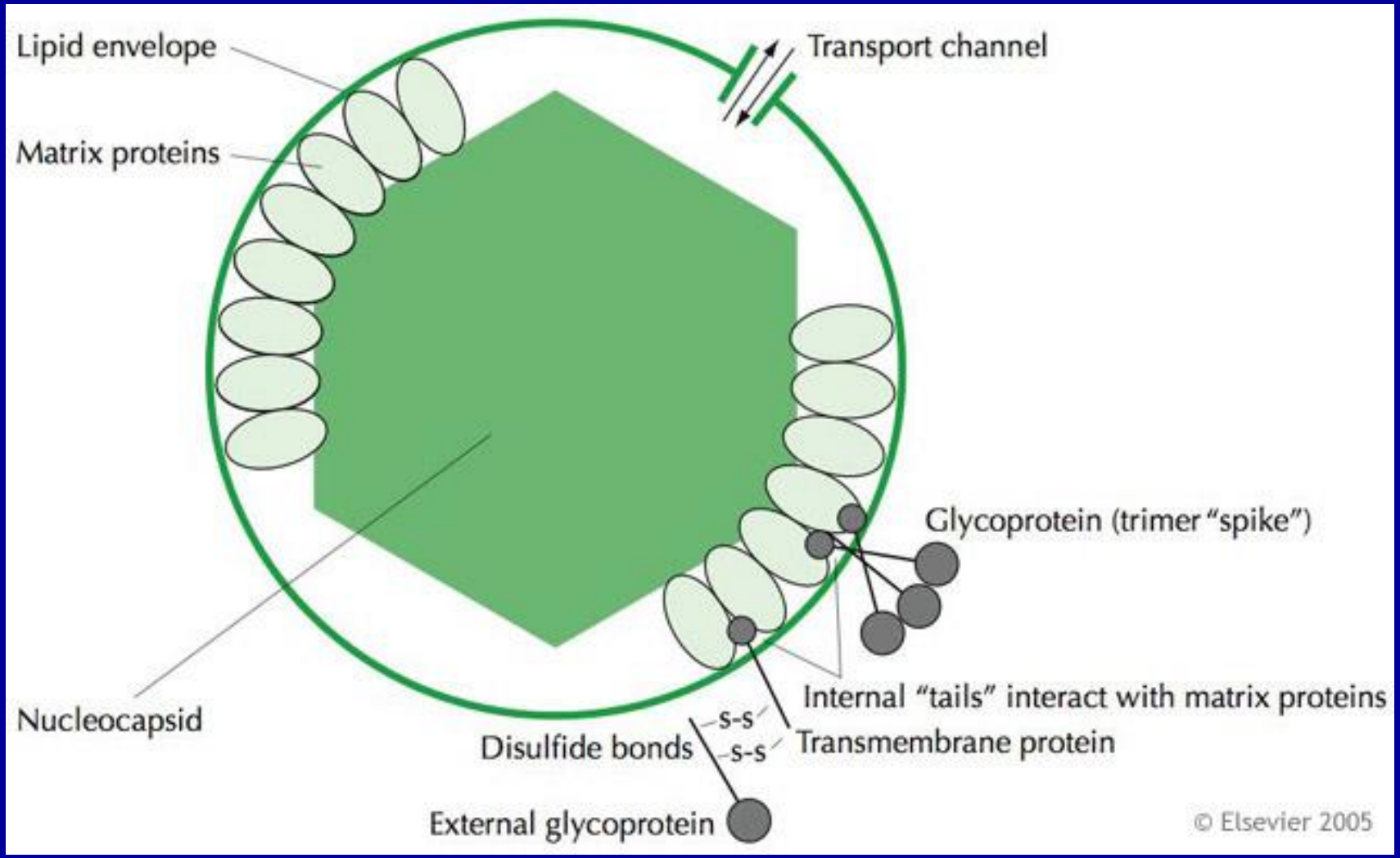
Budding


© Elsevier 2005
Envelope
Nucleocapsid
Matrix
MATURATION
RELEASE
Host cell proteins
Virus glycoproteins
BUDDING
Cell membrane
Nucleocapsid protein
Virus genome
Matrix protein

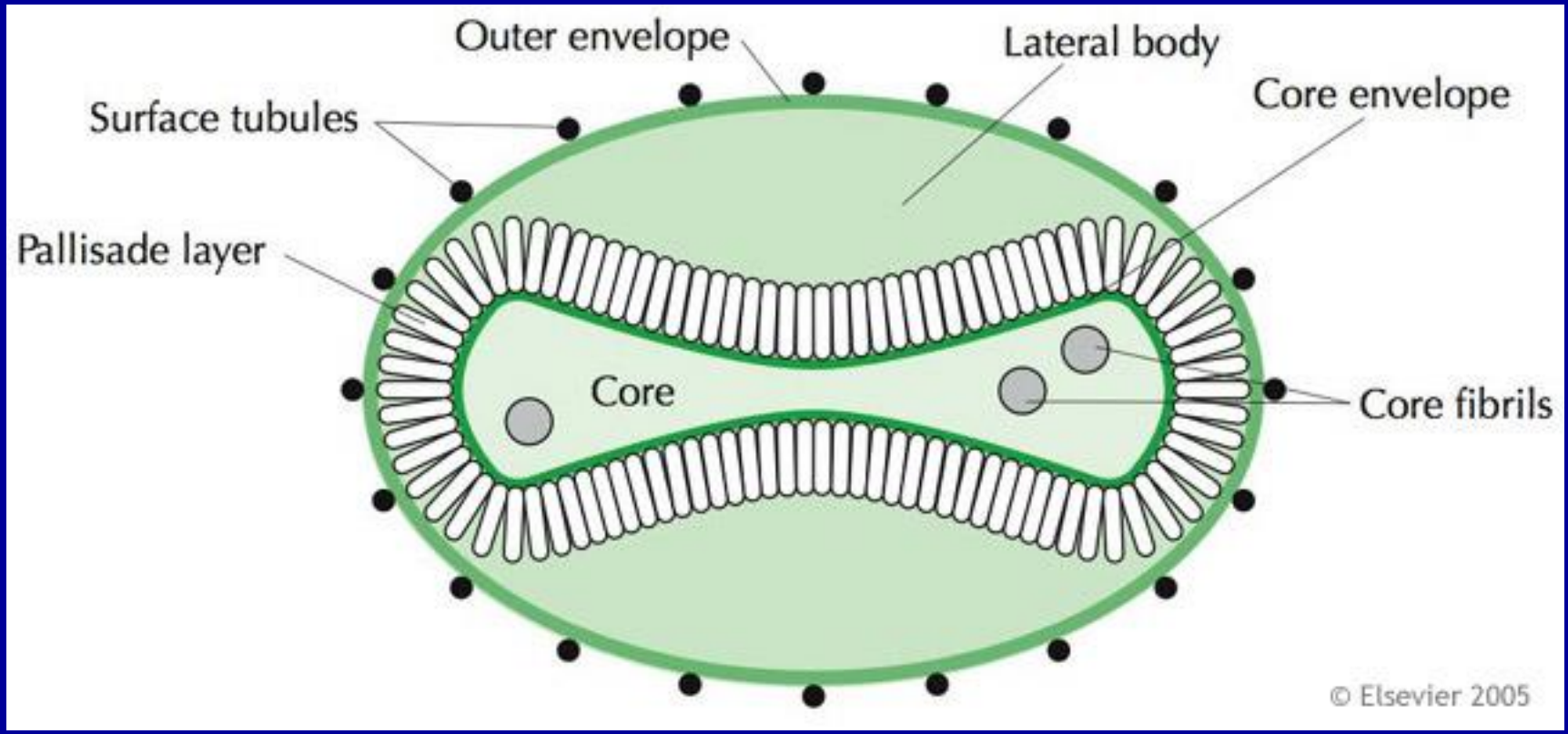
Formation of enveloped virus particles

- Most enveloped viruses use cellular membranes as sites of assembly.
- The formation of the particle inside the cell, maturation and release are in many cases a continuous process.
- Different viruses will use different membranes – some use the cell surface membrane; many use cytoplasmic membranes such as the Golgi apparatus, others, such as herpesviruses, which replicate in the nucleus may utilize the nuclear membrane.

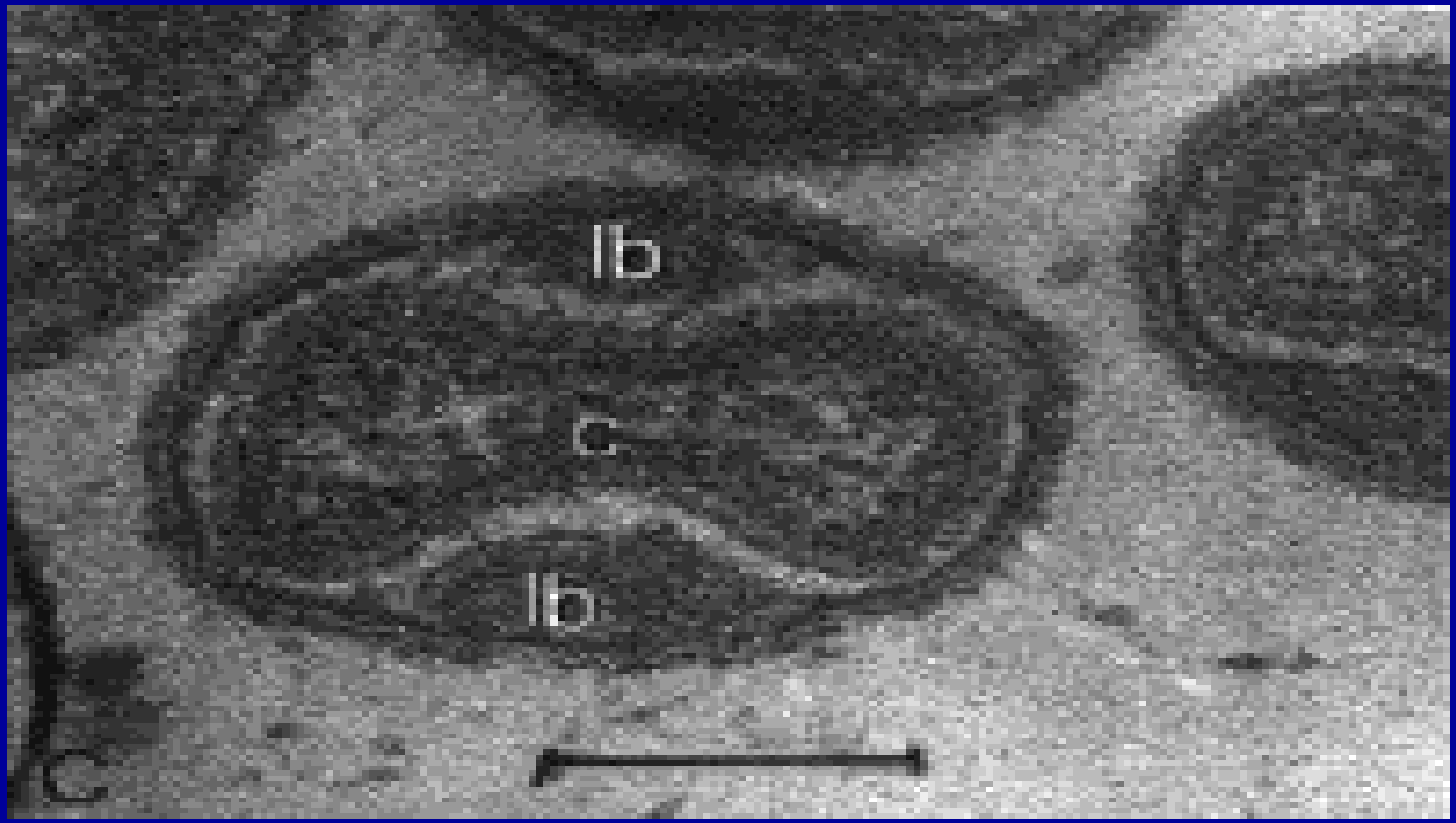
Envelope proteins



Poxvirus Particle



FOWLPOX VIRUS



Electron microscopic image with thin sectioning of Fowlpox virus. From F. Fenner.

Virus Receptors - Recognition and Binding

- Cellular receptor molecules used by many viruses have now been identified.
- This binding event activates inert virus particles and initiates the replication cycle.
- The immune system makes antibodies to attach to viral surface proteins to PREVENT binding.

VIRUS LIFE CYCLE / REPLICATION CYCLE

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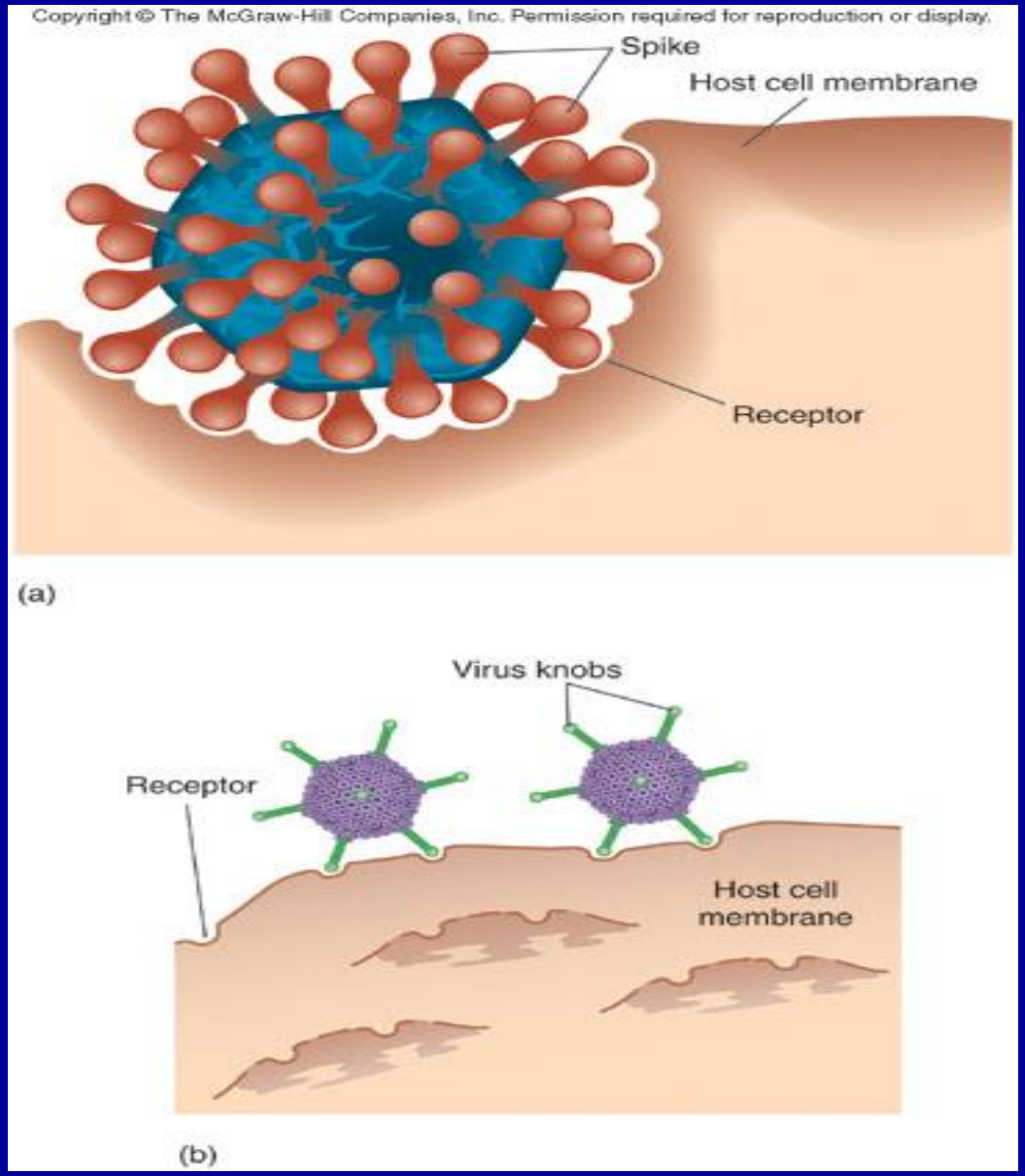
ATTACHMENT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Spike
Host cell membrane
Receptor
(a)
Virus knobs
Receptor
Host cell membrane
(b)

Countermeasures

- The host makes antibodies to attach to and block the action of binding molecules.
- Vaccines stimulate the host to do that before you are infected.
- Fusion inhibitors prevent the virus from fusing its envelope to the cell membrane.
- (The virus attaches but it can’t get in.)

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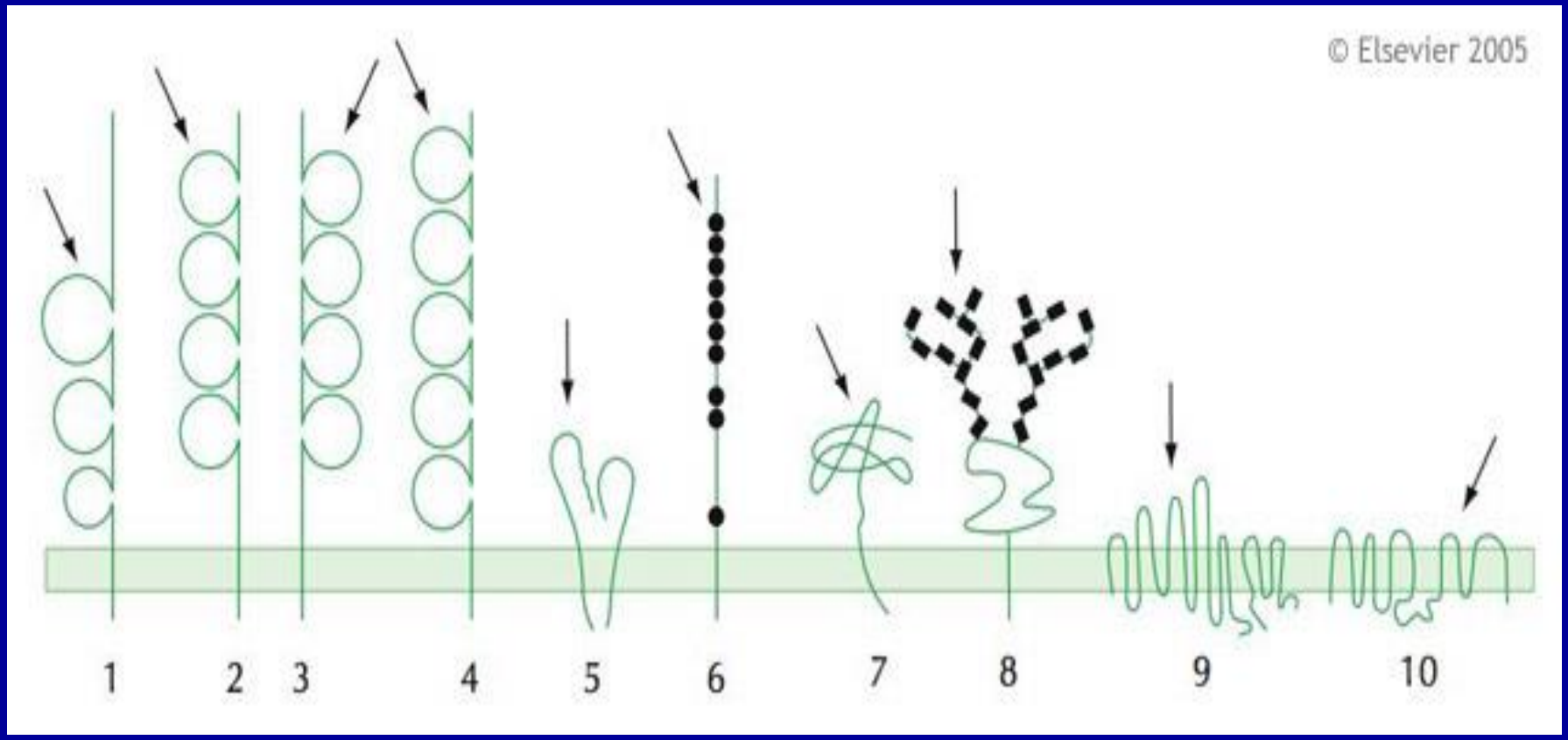
Virus Receptors



2. CD4 for HIV-1

4. ICAM-1 for most rhinovirus

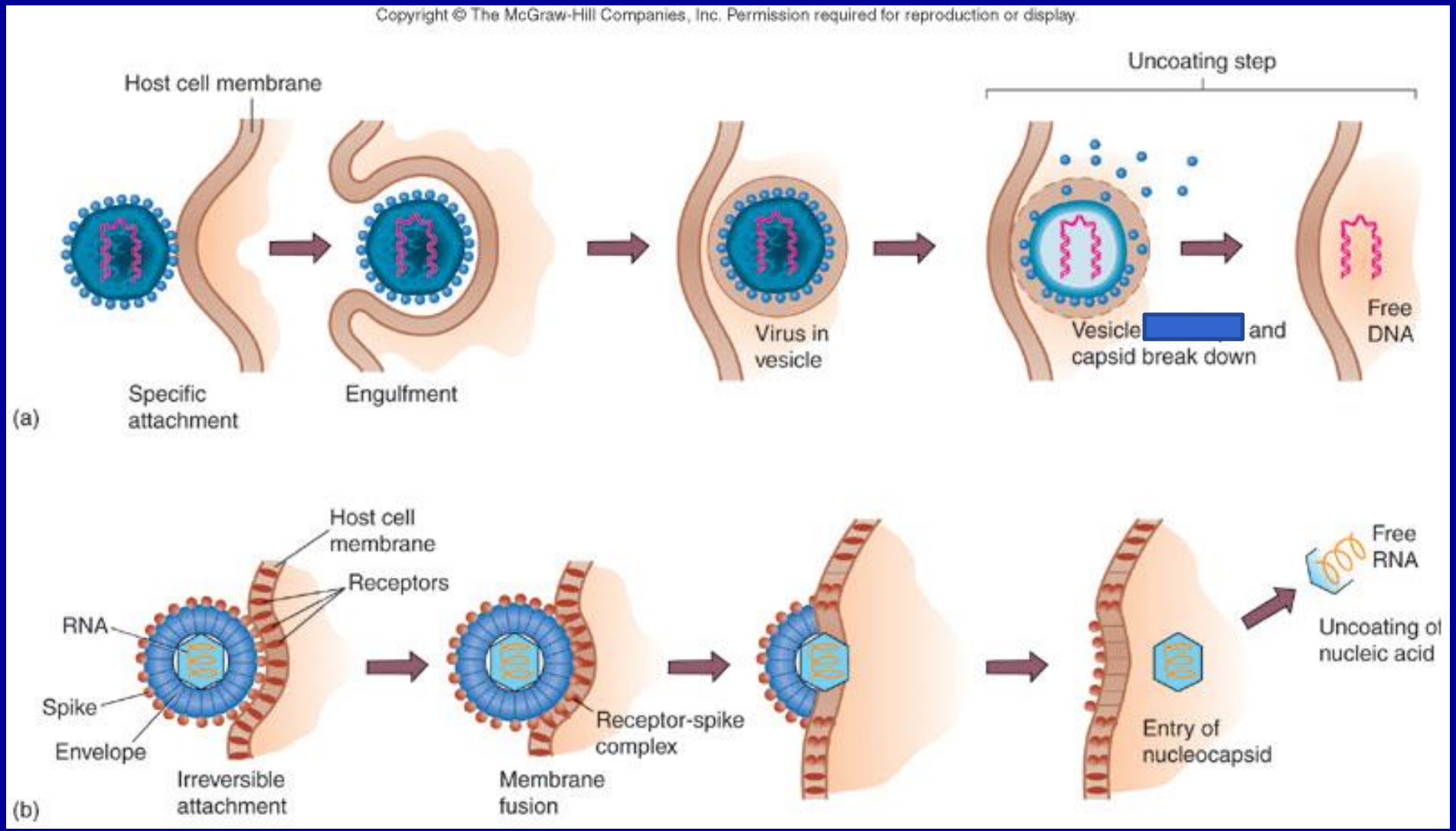
5. VLA-2 integrin for ECHO virus

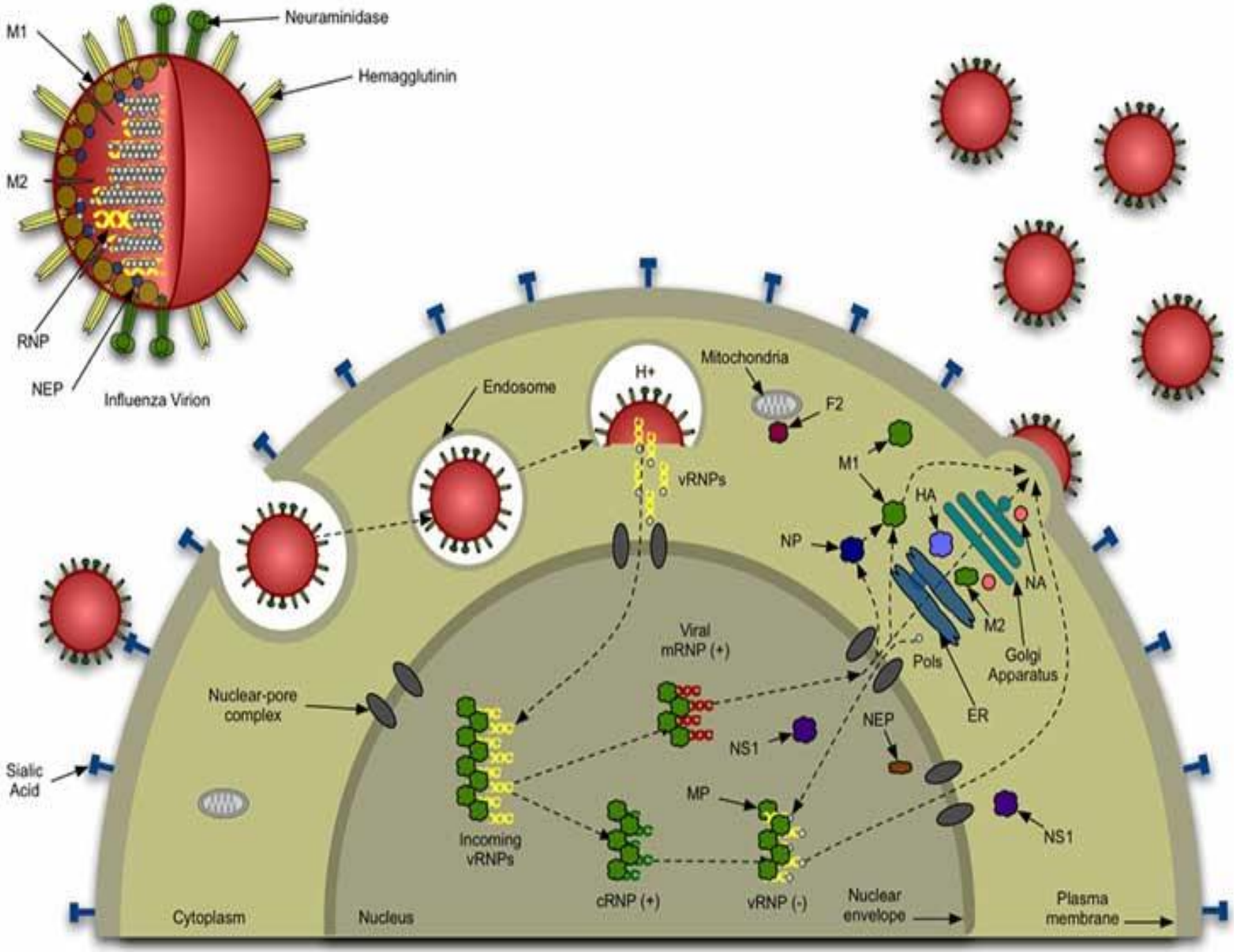
6. LDL receptor for some rhinoviruses

7. Aminopeptidase N for coronaviruses

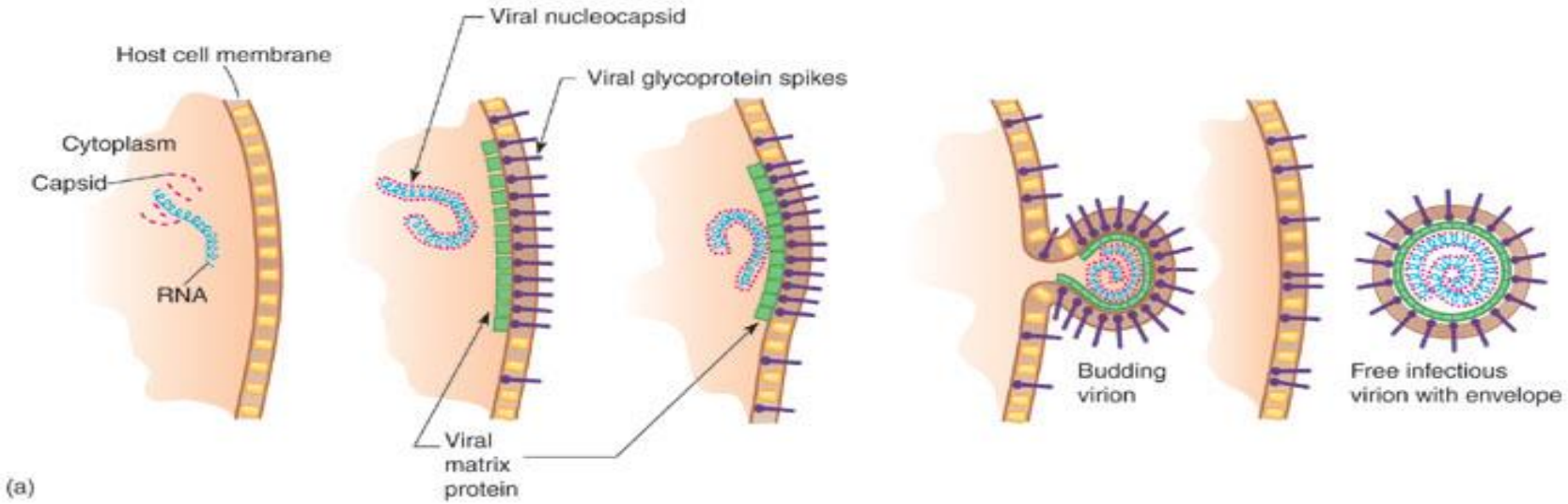
8. Sialic acid on glycoprotein for influenza

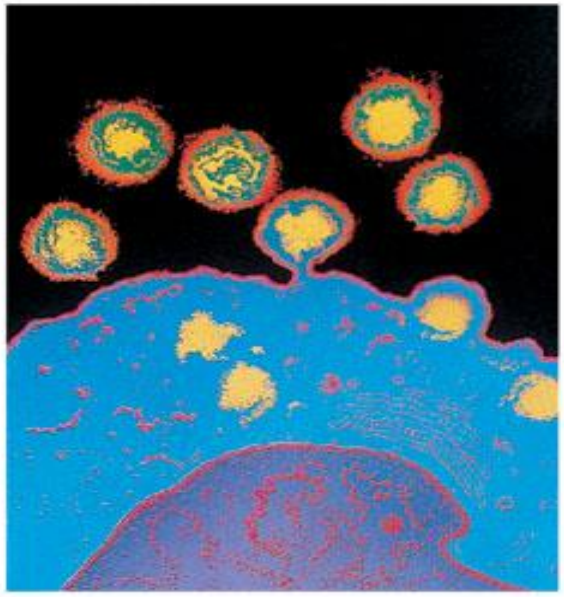
PENETRATION AND DISASSEMBLY



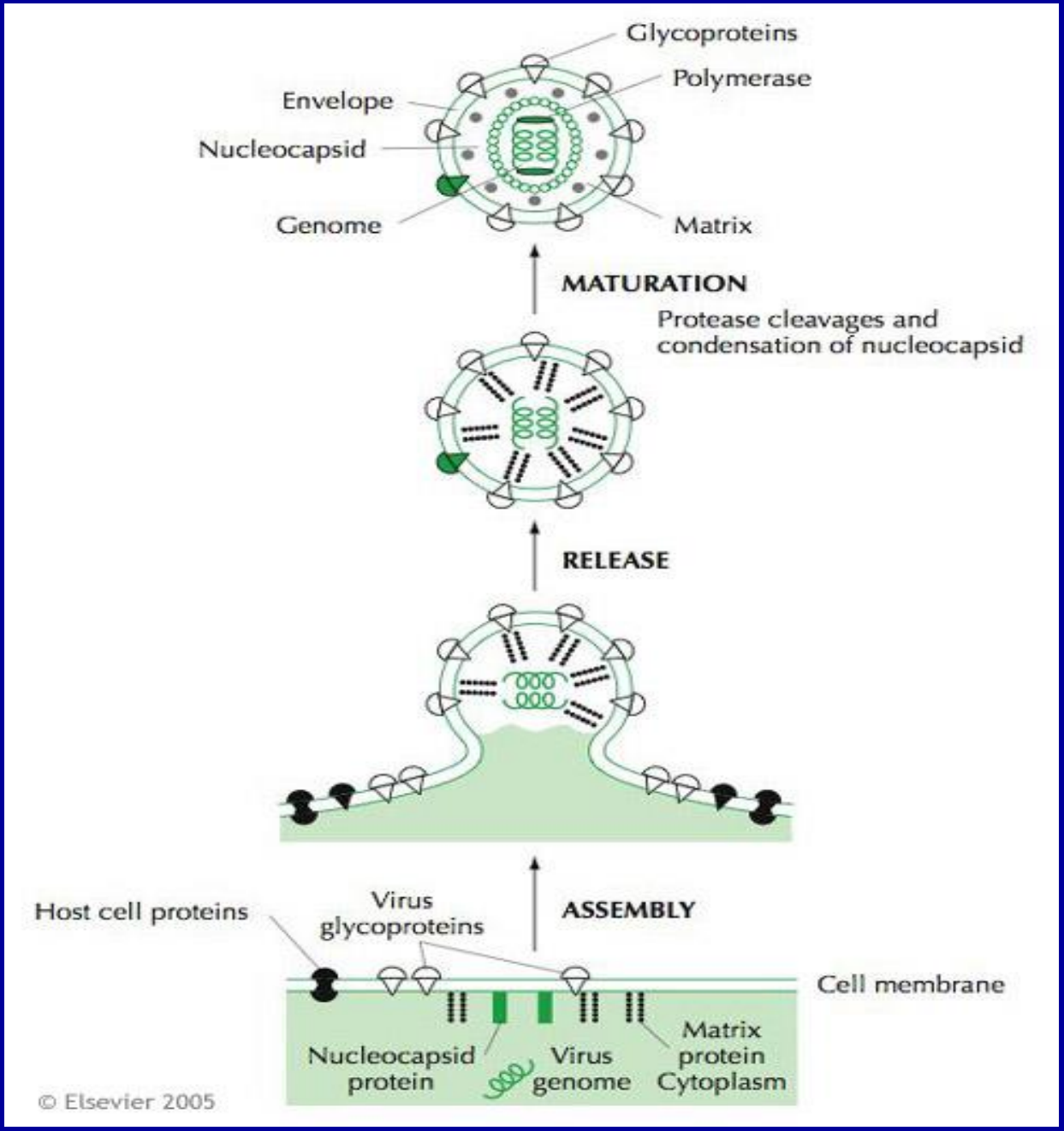

M1
Neuraminidase
Hemagglutinin
M2
RNP
NEP
Influenza Virion
Endosome
H+
Mitochondria
F2
vRNPs
M1
HA
NP
NA
M2
Pols
Golgi Apparatus
ER
Viral mRNP (+)
Nuclear-pore complex
NS1
NEP
Sialic Acid
MP
Incoming vRNPs
cRNP (+)
vRNP (-)
NS1
Cytoplasm
Nucleus
Nuclear envelope
Plasma membrane

ASSEMBLY & RELEASE





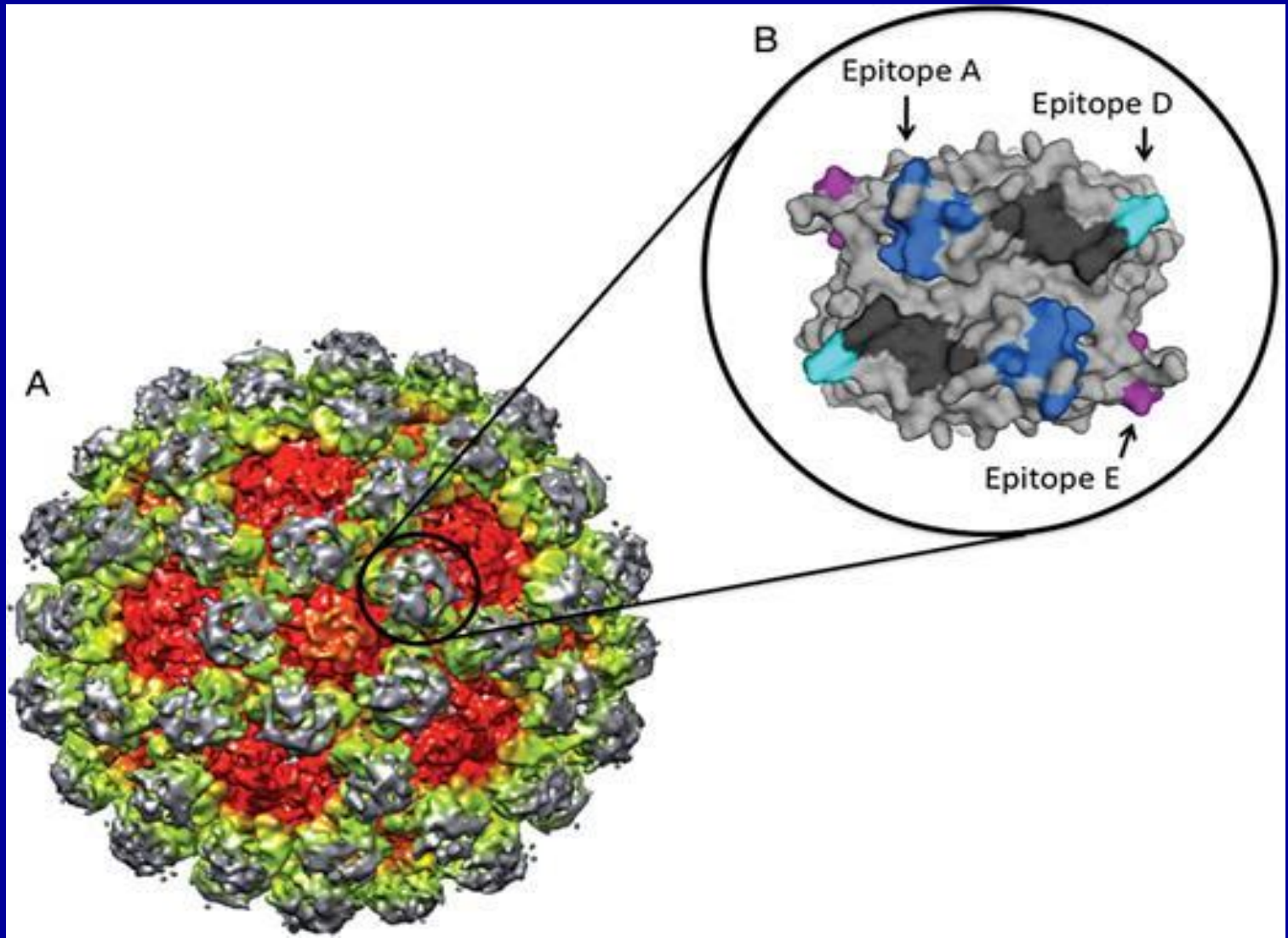
Budding


Glycoproteins
Polymerase
Envelope
Nucleocapsid
Genome
Matrix
MATURATION
Protease cleavages and condensation of nucleocapsid
RELEASE
Host cell proteins
Virus glycoproteins
ASSEMBLY
Cell membrane
Nucleocapsid protein
Virus genome
Matrix protein
Cytoplasm
© Elsevier 2005

Host cell lysis

Budding

Defenses



Antibiotics vs antivirals

- Antibiotics damage the cell wall of bacteria which kills it. Your cells don't have a cell wall. This makes antibiotics a "magic bullet" that kills bacteria and leaves your body cells alone.
- Antivirals target some part of the viral life cycle. Your cells do the same chemical processes so they are affected. The trick is to make effective antivirals that are not too toxic.

Vaccines

- Vaccines do not confer immunity. They stimulate the body to generate immunity as if you had been infected with the real pathogen. You make antibodies.
- Infection also causes the generation of antibodies which attach to and cover the surface proteins of antigens, preventing them from entering the cell. Imagine a key covered with bubblegum. It won't fit the lock.

- Many symptoms of illness are actually caused by the immune system.

  These include headache, fever, achiness, stuffiness and swelling.

  By stimulating the immune system, vaccines can trigger these same signs and symptoms, usually to a lesser extent.

  People think the vaccine is causing it, but it is really the Immune system.

  Some vaccines DO cause allergic reactions.

Types of Vaccines

- Attenuated Vaccines are made of a weakened version of the real pathogen. It cannot reproduce very much in the body.
- A very small percentage of people will get sick – and some have died.
- Often this was from an unknown vulnerability in their own immune systems.
- There are no childhood vaccines like this anymore.

Subunit vaccines

- These are vaccines prepared from parts of the virus, surface proteins for example.
- They have no genetic material and no chance of reproducing in the body.
- The only possible problem would be a rare and unusual immune response. (an allergy for example)
- They have a good track record.

- Subunit vaccines are safer but not all vaccines can be made that way.
- Attenuated vaccines are often more effective.
- Polio V. is available in both forms. The attenuated is more effective (and oral) and has been used to reduce polio by 99.9%.
- It can (rarely) give a person polio.
- Once polio is gone the plan is to switch to subunit for a few years until we are sure it is gone for good.

mRNA - Pfizer, Moderna

- mRNA is injected into a muscle.
- Muscle makes Covid spikes
- Immune system antibodies and memory cells to deal with the spikes

Keeping you out of the hospital

- Moderna 95%
- Pfizer 80%
- J and J 60%
- This is only with 2 shots for Moderna and Pfizer
- In all cases, medically frail people made up most of those who did have to be hospitalized.
- Being out in public probably serves as a booster shot

CDC Advisory Committee on Immunization Practices

- Evaluates safety and sets policy. The website lists the side effects of every vaccine.
- The Vaccine Adverse Event Reporting System (VAERS) tracks illness cases to see if they are related to the vaccine. (Run by FDA and CDC)
- Some vaccines have been pulled or replaced due to safety concerns. (i.e. mercury)
- No vaccine is totally safe but catching the disease itself is much more dangerous.

- There have been famous problems with vaccines in the past.
- 1975 Swine flu vaccine was rushed into production because a pandemic was feared. 48,000,000 vaccinated.
- A contaminant in the vaccine caused over 1000 people to contract Guillaume Barr, an autoimmune disease. 25 people died.
- The pandemic never came…
- Problems like this are rare, but new vaccines always introduce a novel risk. We don't know about it for sure until millions have been inoculated.

- The antivax movement
- In 1998 a British MD claimed that the preservative in the MMR vaccine, thimerosol, was causing autism.
- He based this on his own study and a big increase in reported autism cases in school at the same time as the MMR vaccine was introduced.
- The paper did not attract much interest so he had a press conference (which most researchers don’t do.)

- There was a media frensy, so a lot of researchers looked at the paper.
- They saw problems:
- - there were only 12 people in the study
- - there were no controls
- - Closer scrutiny found that several of the children had autism BEFORE the vaccine
- - It was later found that the medical files had been changed.

- This caused Lancet to retract the paper
- Much later it was found that a law firm that was planning a major lawsuit against the vaccine manufacturer paid him about 1 million dollars to do this study.
- They needed evidence to sue, so they bought some.
- His medical license was revoked for fraud.
- But the damage was already done.

- There is no evidence at all that MMR caused autism in anybody.
- The increase in *reported* autism cases coincided with a change in the education law.
- Schools were given more money to help autistic children in their population.
- For the first time they had an incentive to test everybody. The more autism spectrum they found, the more money they got.

- Former Doctor Wakefield, completely discredited, moved to Texas where there are still plenty of people who will believe him (and in UFO's)
- From there he sued the journalists who exposed him for libel.
- A Texas judge dismissed the case and ordered him to pay everyone's legal fees.
- He still appears at antivax rallies, where he is well paid (so he can pay back all his legal fees)

- It doesn’t help that the Kremlin got involved.
- Since at least 2016 the Russians have been using trolls and bots to sow discord and distrust in American society and institutions.
- Tweets with polarizing language on race, vaccines, and economic instability have been traced to companies set up by Russia. An example is the Internet Research Agency, which has been indicted for interfering in the election. A typical tweet:
- “Clean vaccines are reserved only for elites.”
- For Russia it’s a win/win. We are more vulnerable to disease and faith in our institutions is eroded.

- Anti vaccine ads popular as clickbait.
- Click on the link and you get malware.
- If you don’t trust vaccines, not only are you more likely to get a virus, so is your computer.
- Between purposeful misinformation and the tendency of many to look at issues as black and white, it is easy for things to be blown out of proportion, especially something as complicated as health.

- Wakefield targeted Thimerosal as the agent in the MMR vaccine that caused autism.
- As a precaution, Thimerosal has been removed from all childhood vaccines since 2001. Autism levels have continued to increase anyway.
- There is no evidence the preservatives are a problem, but it is impossible to say that no one on the planet will ever have an adverse reaction to a vaccine. (Worldwide 2-6% get allergic reactions (contact dermatitis) to Thimerosal.)

Thimerosal is still used in cosmetics, processed foods, (eye drops), and some flu shots. It is a different kind of mercury than you find in fish (methylmercury), and **much more quickly removed from the body.**

Toxic substances per se are not a problem. Many toxic substances are found in small amounts in you body and in the food we eat.

Formalin, a 37% solution of formaldehyde is used to kill some pathogens to make subunit vaccines. Formaldehyde is found naturally in fruits and vegetables. One pear has more formaldhyde in it then a vaccine.

The media (to make headlines) and the internet (because it is the internet) often overreact to the government and big pharma.

On the other hand, distrust in big pharma is well placed. I try to wait five years before I use any new drug or vaccine. But with a Pandemic, you can’t wait.

While a vaccine is safe for millions, not everyone has the same immune system and some individuals have gotten get sick and a few have died. Many more die from the diseases.

From a public health perspective (CDC) everyone should be vaccinated because many lives will be saved. The flu alone kills between 3000 and 50,000 Americans a year. Covid is 2000/day right now.

Anti vaxers make a lot of money by driving traffic to their websites and selling advertising, vitamins, supplements, and alternative treatments that they make. It’s getting people killed.

- Even before Covid many parents have stopped having their children vaccinated at all.
- In 2015 measles resurfaced due to this. (Disneyland and Ohio outbreaks – imported.)
- Hundreds of cases. One death.
- 2018: 372 cases
- Jan 2019: 101 cases

- In NYS there are school required vaccines against twelve pathogens.
- The long and successful record of vaccinations indicates that the great majority of the population has no trouble with this.
- I did have my children vaccinated, after much hand wringing.

- Diphtheria and Tetanus and Pertussis vaccine (Dtap/DTP/Tdap)
- Hepatitis B vaccine
- Measles, Mumps and Rubella vaccine (MMR)
- Polio vaccine (IPV/OPV)
- Varicella (Chickenpox) vaccine
- Meningococcal conjugate vaccine (MenACWY)
- Haemophilus influenzae type b conjugate vaccine (HiB)
- Pneumococcal Conjugate vaccine (PCV)

In this course we will study:

- Viral Structure
- Viral life cycle
- Pathogenesis – What it does to cells and people
- Epidemiology – How it spreads. Who gets it.
- Treatment – Vaccines? Antivirals? Prayer?