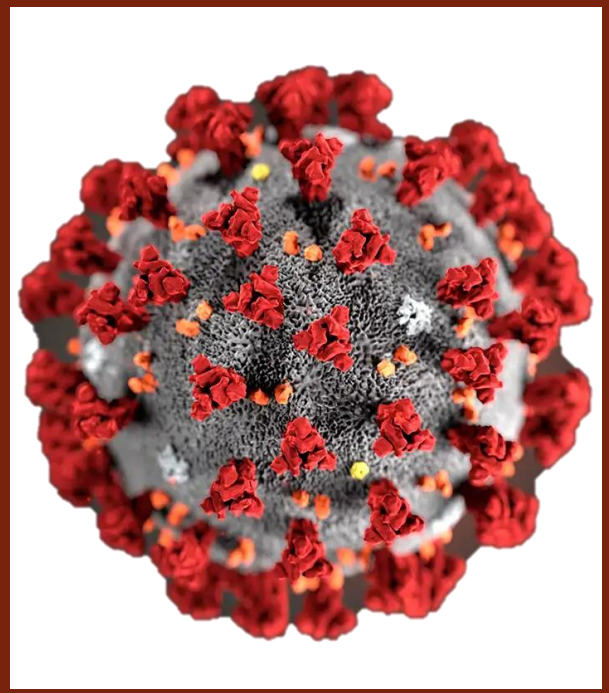


INTRODUCTION TO VIRUSES

15.06.2021

NM

CONTENT

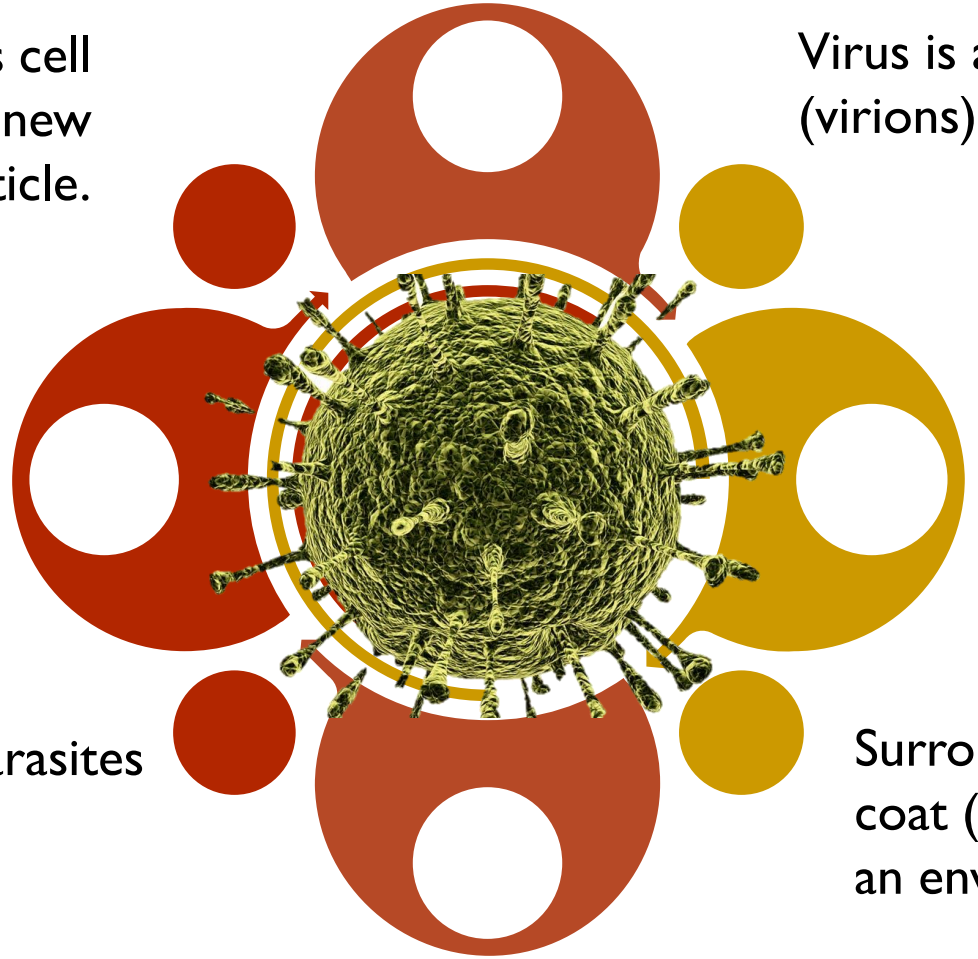
- Definition of virus
- Structure of virus
- Taxonomy and classification
- DNA and RNA viruses
- Viral multiplication
- Bacteriophage T4 and Bacteriophage lambda
- Transmission of virus

What is a VIRUS?

Virus uses their host's cell machinery to produce a new generation of viral particle.

Not considered as living entities - It can only multiply inside living cells.

Obligate intracellular parasites



Virus is a small infectious particle (virions) that contain genetic materials.

The genetic materials are either RNA or DNA (single- or double-stranded).

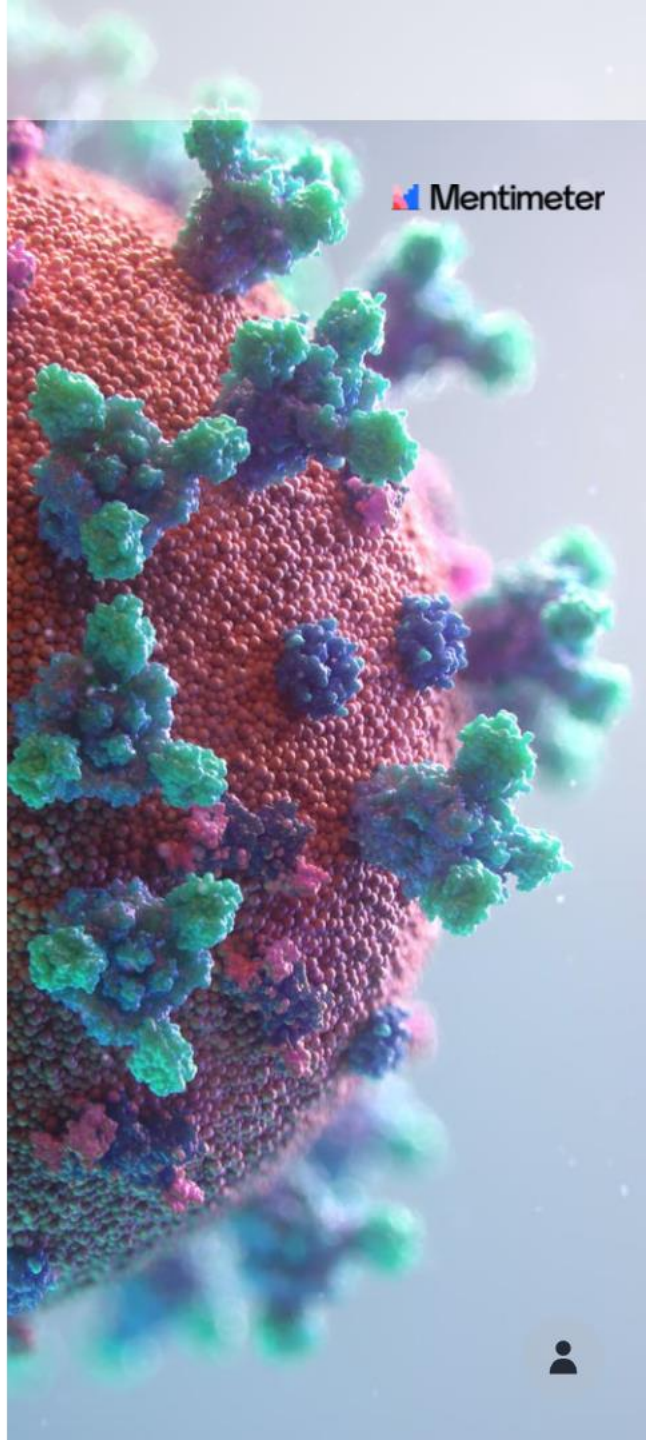
Surrounded by a protein coat (capsid) and sometimes an envelope.

TABLE 6.1 Properties of Viruses

- Are obligate intracellular parasites of bacteria, protozoa, fungi, algae, plants, and animals.
- Ultramicroscopic size, ranging from 20 nm up to 450 nm (diameter).
- Are not cells; structure is very compact and economical.
- Do not independently fulfill the characteristics of life.
- Are inactive macromolecules outside the host cell and active only inside host cells.
- Basic structure consists of protein shell (capsid) surrounding nucleic acid core.
- Nucleic acid can be either DNA or RNA but not both.
- Nucleic acid can be double-stranded DNA, single-stranded DNA, single-stranded RNA, or double-stranded RNA.
- Molecules on virus surface impart high specificity for attachment to host cell.
- Multiply by taking control of host cell's genetic material and regulating the synthesis and assembly of new viruses.
- Lack enzymes for most metabolic processes.
- Lack machinery for synthesizing proteins.

Go to **www.menti.com** and use the code **40 39 06 2**

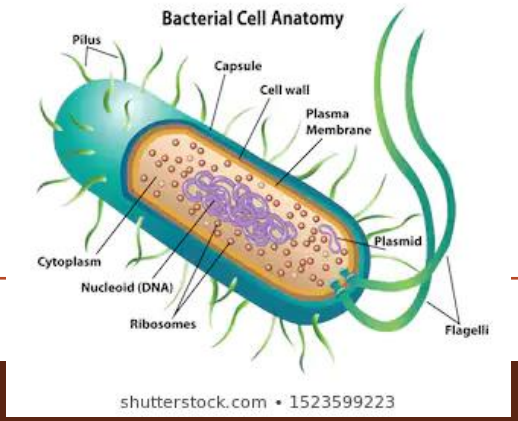
What are the differences between virus and bacteria?



Bacteria vs Viruses

Bacteria

- Living organism
- Single-cell organism
- Bigger size (~1000 nm)
- Can be seen under light microscope
- Genetic material is DNA
- Has metabolic machinery
- Does not need host cells to reproduce
- Respond to antibiotic
- Maybe beneficial/harmful

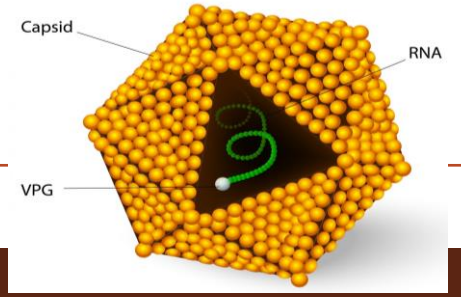


Similarities

Both can be a pathogens and cause disease to human/animal/plants

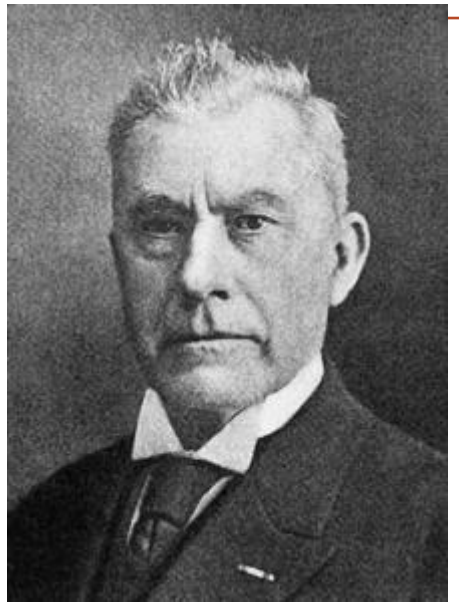
Viruses

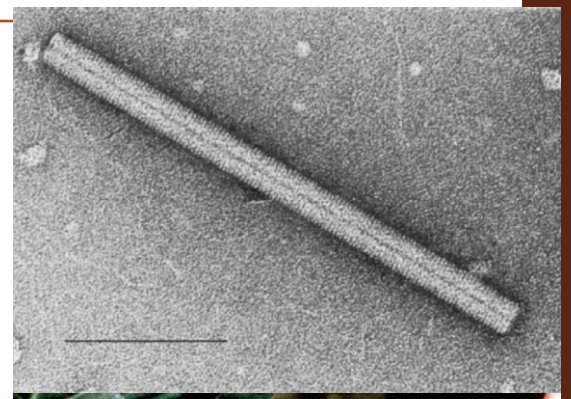
- Intermediate between living and non-living.
- Acellular, just a particle
- Smaller size (20-400 nm): need an electron microscope
- Genetic material can be DNA/RNA
- No metabolic machinery
- Need a host cell to reproduce
- Need antiviral drug
- Always harmful

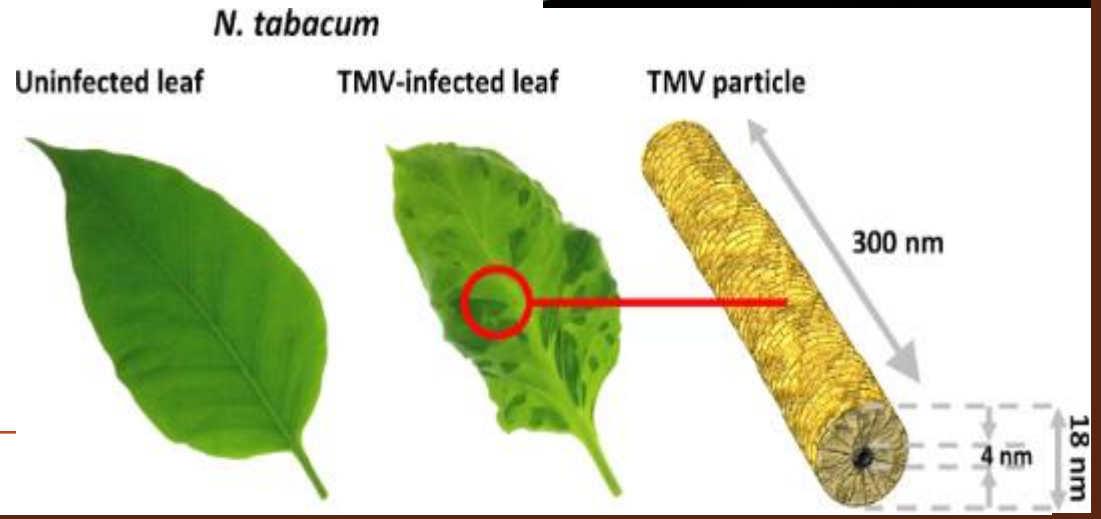


History of virology

- Viruses were too small to be seen with the first microscopes
- The cause of viral infections was unknown for years
- Ivanovski and Beijerinck showed that a disease in tobacco was caused by a virus

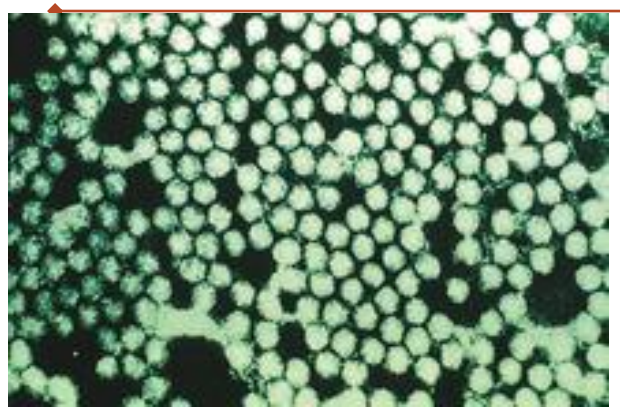




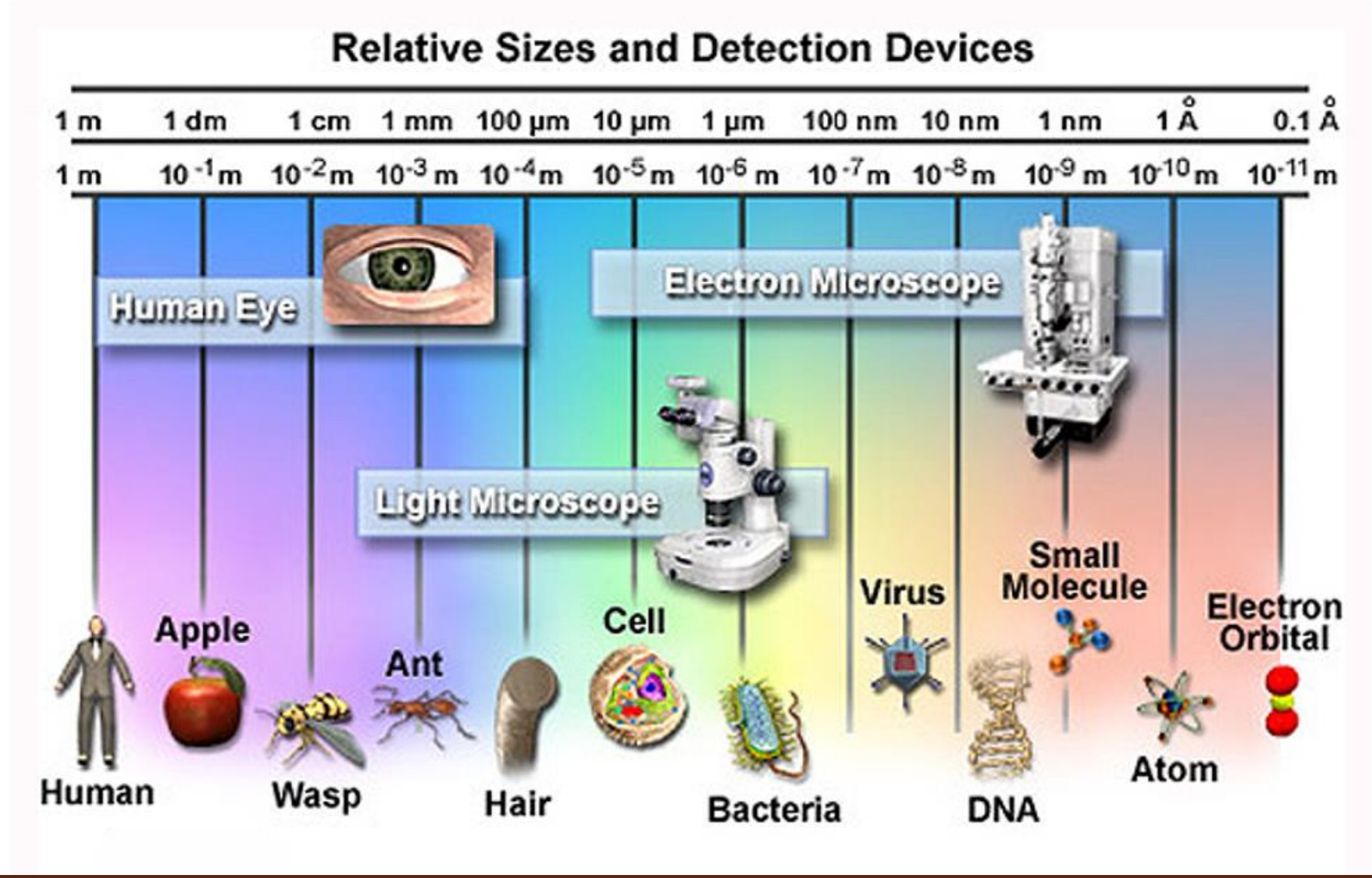


History of virology

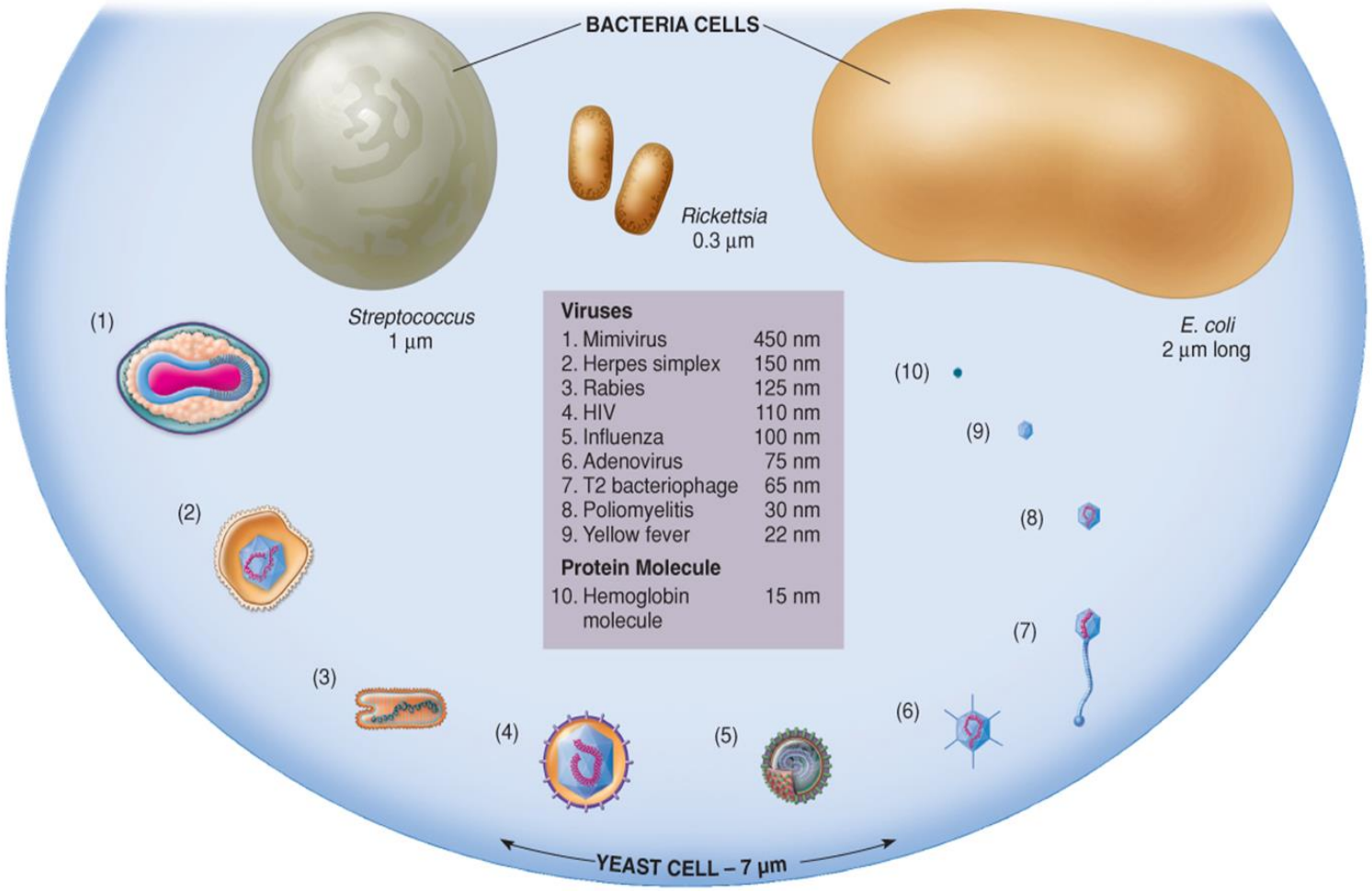
- Loeffler and Frosch discovered an animal virus that causes foot –and-mouth disease in cattle



Size of a virus



Size of a virus



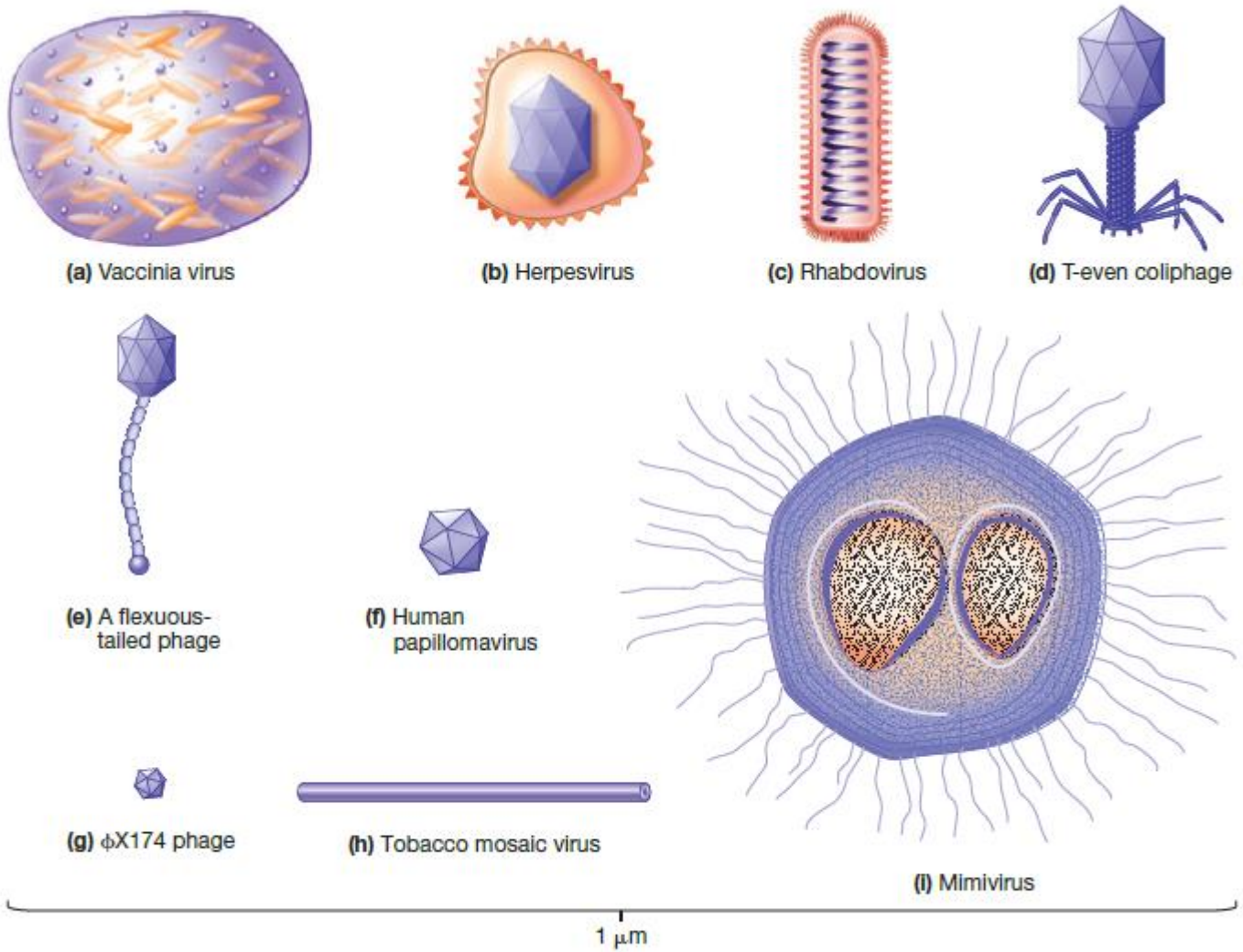
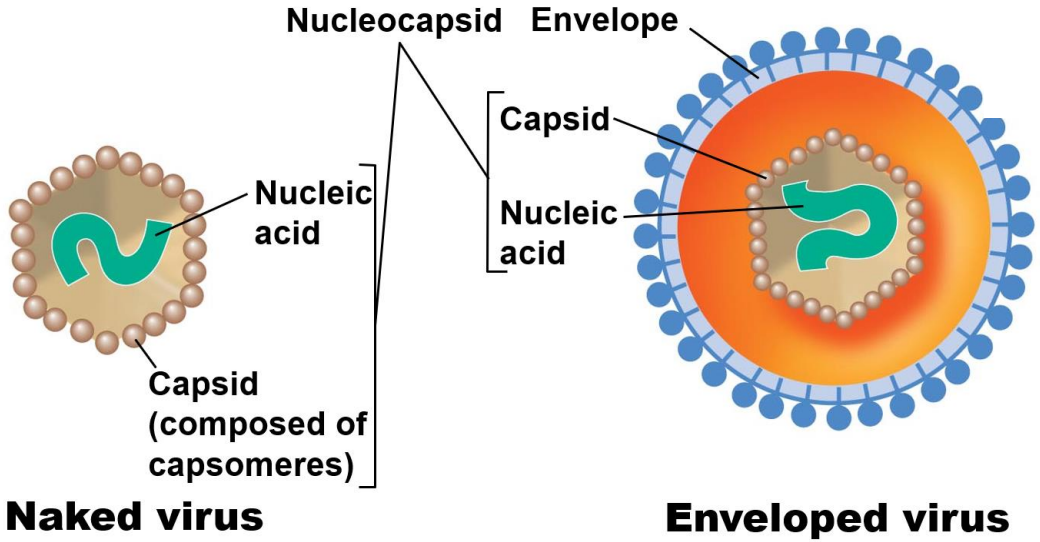
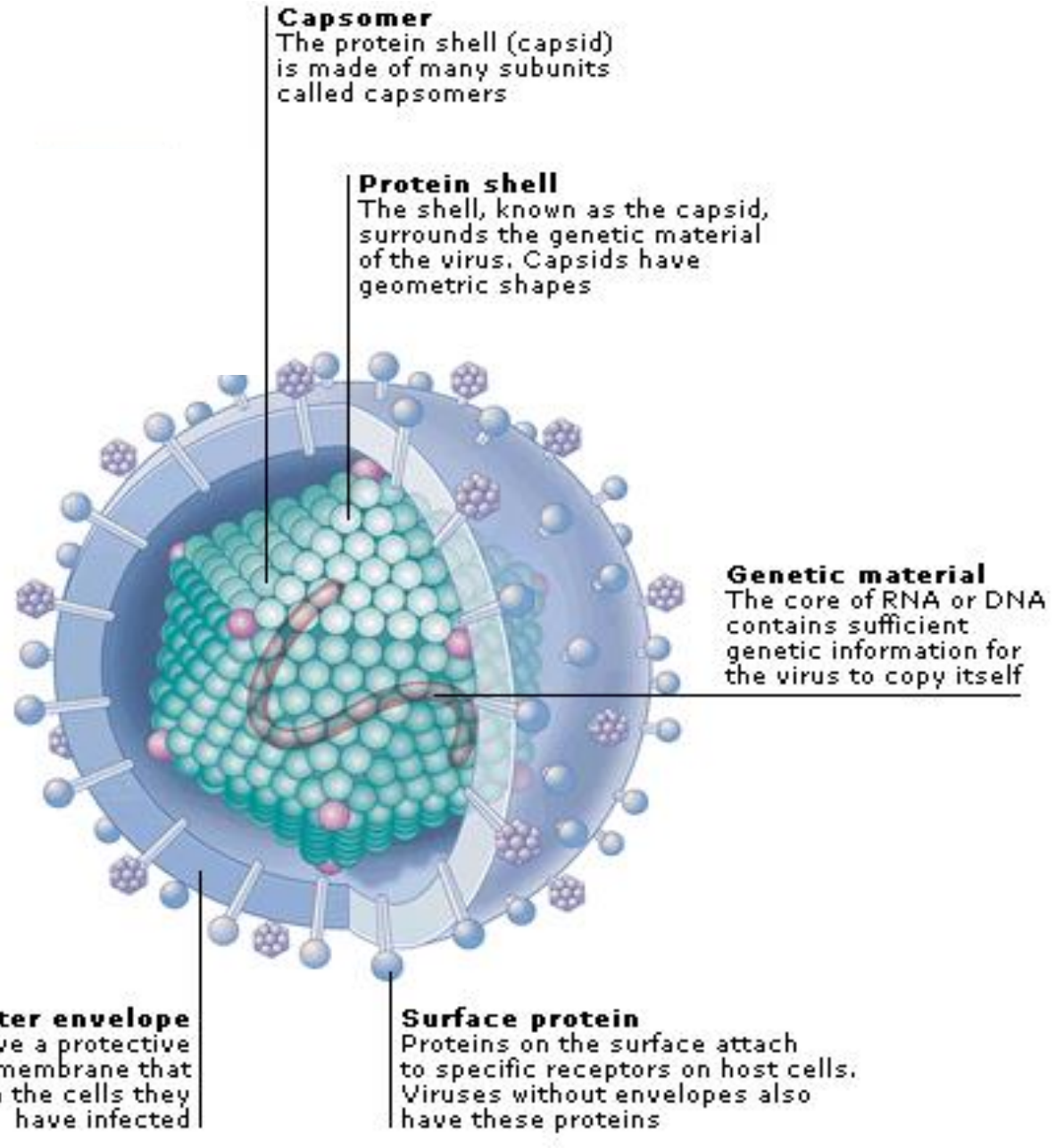


Figure 6.1 The Size and Virion Morphology of Selected Viruses. The virions are drawn to scale.

Viral structure



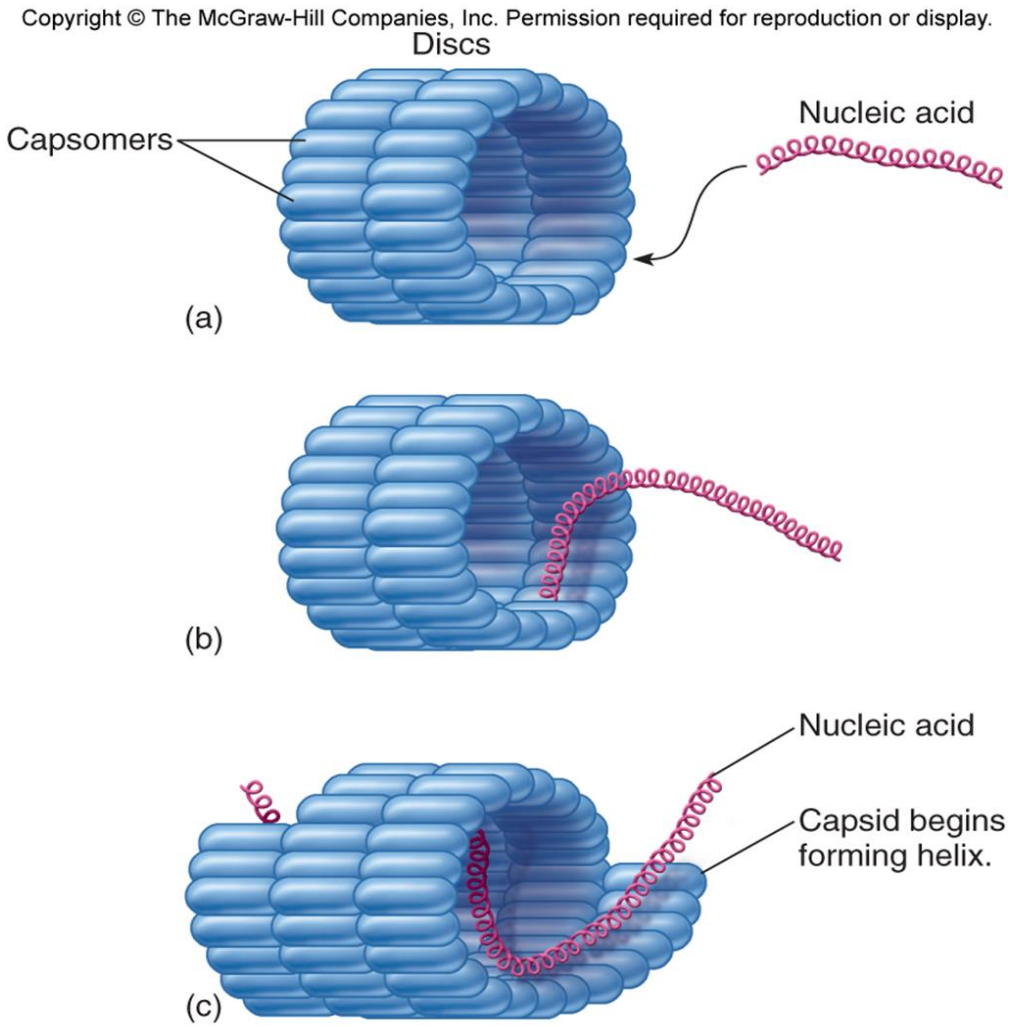


YouTube:Viruses - Part 1: Enveloped and Non-Enveloped Viruses (Naked)
https://youtu.be/miOPtXTeHYE

The Viral Capsid: The Protective Outer Shell

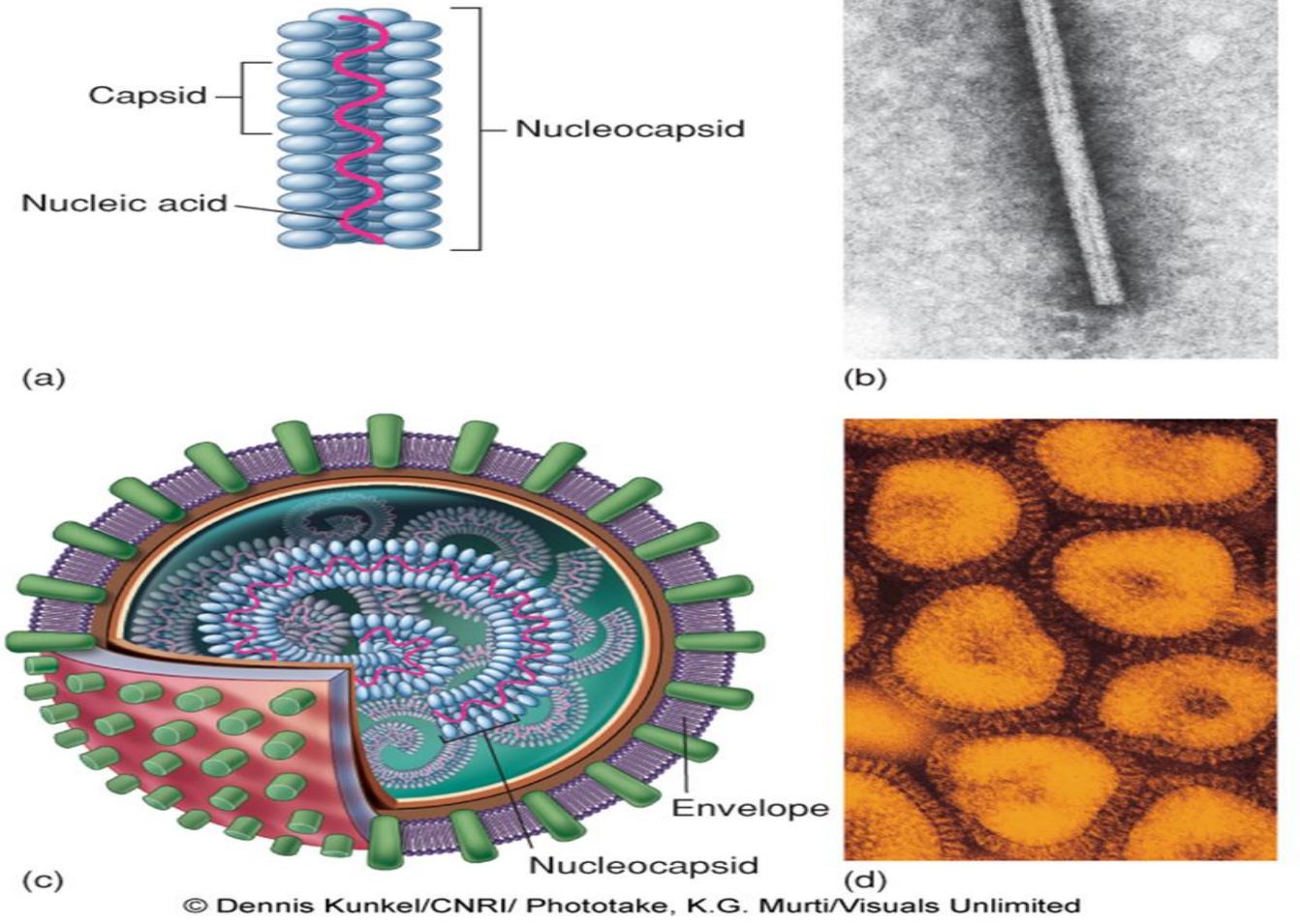
- Constructed from identical subunits called capsomers

- Made up of protein molecules
- Two different types:
  1. Helical
  2. Icosahedral



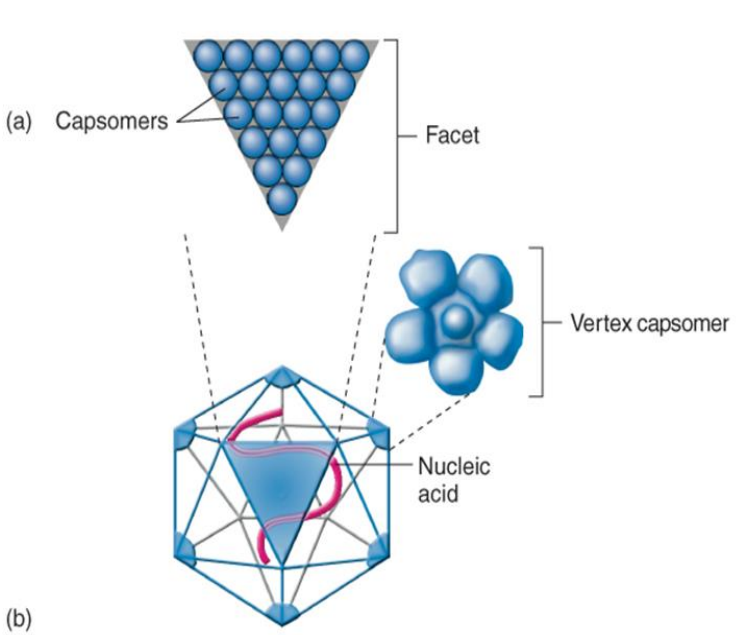
Capsid Structure

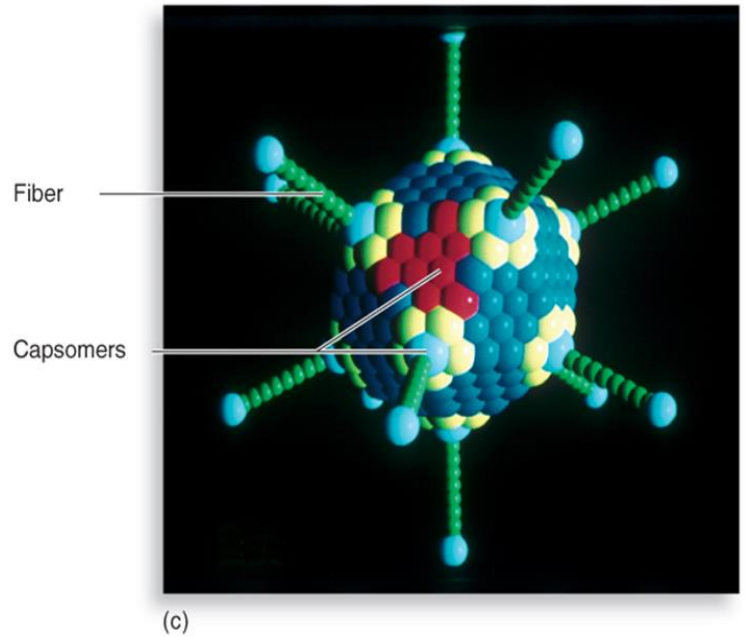
- **Helical capsid**
  - Rod-shaped capsomers
  - Assemble in to helical nucleocapsid



Capsid Structure

- **Icosahedral capsid**
  - Three-dimensional, 20-sided figure with 12 evenly spaced corners
  - Although they all display this symmetry, there are wide variations





The Viral Envelope

- **Enveloped viruses** take a bit of the host cell membrane in the form of an envelope
- In the envelope, some or all of the regular membrane proteins are replaced with viral proteins
- Some proteins form a binding layer between the envelope and the capsid
- Glycoproteins remain exposed as **spikes** (peplomers)- essential for attachment

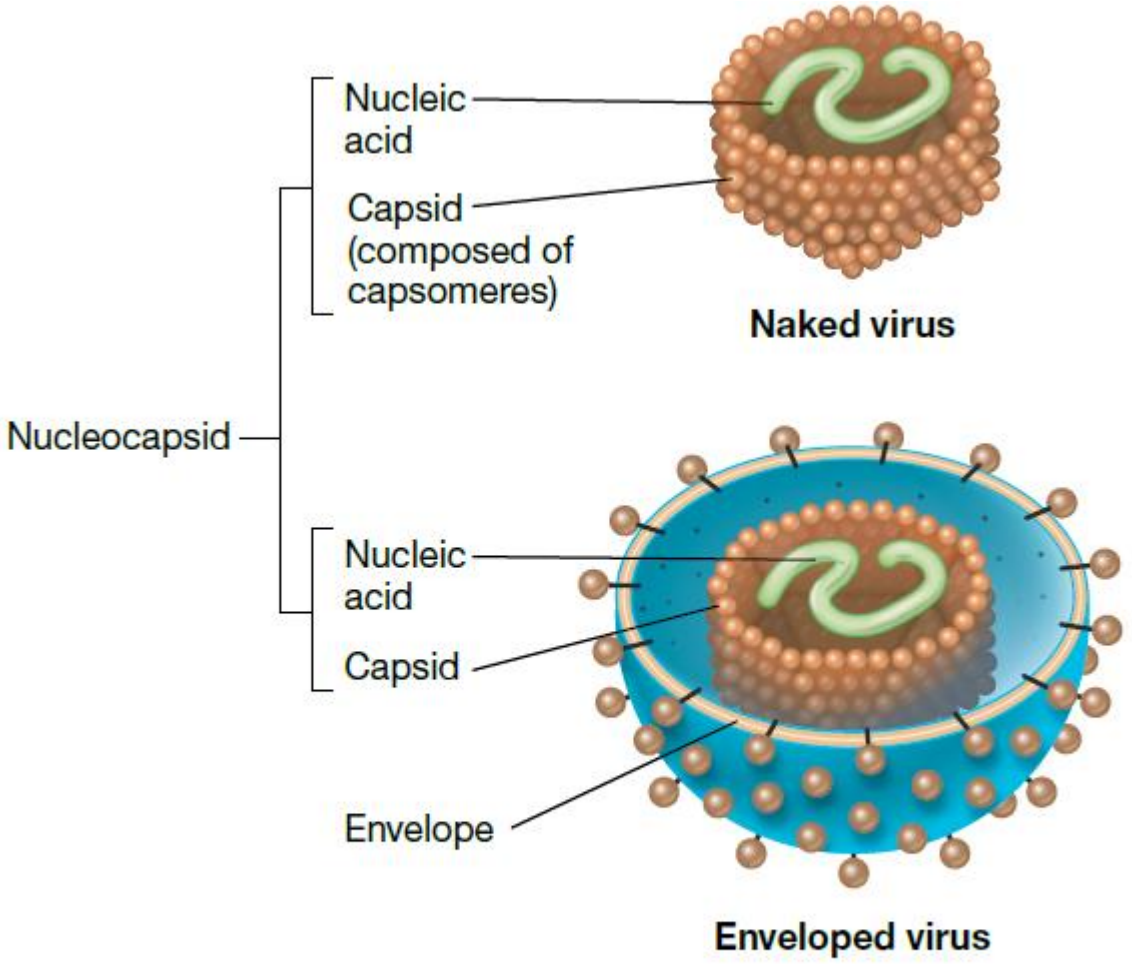


Figure 8.1 Comparison of naked and enveloped virus particles. The envelope originates from host cytoplasmic membrane.

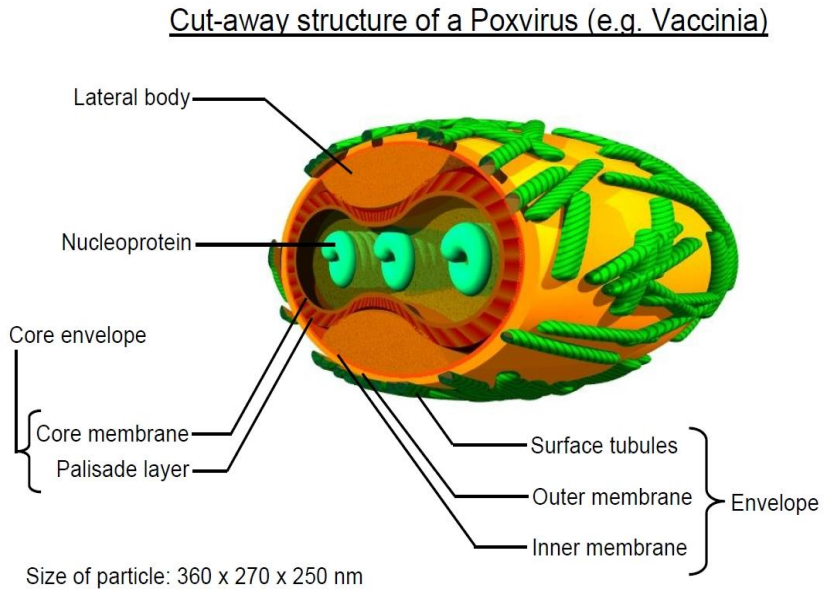
The Viral Envelope

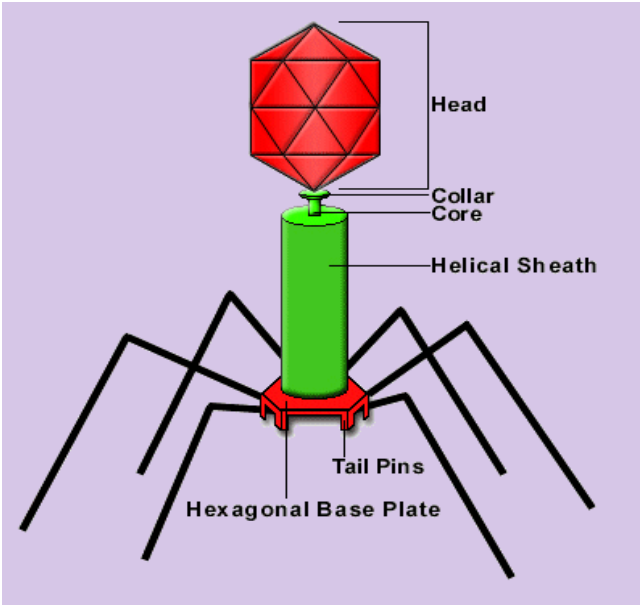
- Protects capsid & nucleic acids
- Help introduce the viral DNA or RNA into a suitable host cell
- It can stimulate the immune system to produce antibodies that can protect the host cells against future infections

Complex viruses

- Poxvirus
  - ➢Very large DNA viruses that lack a typical capsid and covered by dense layer of lipoproteins and coarse fibrils on their outer surface

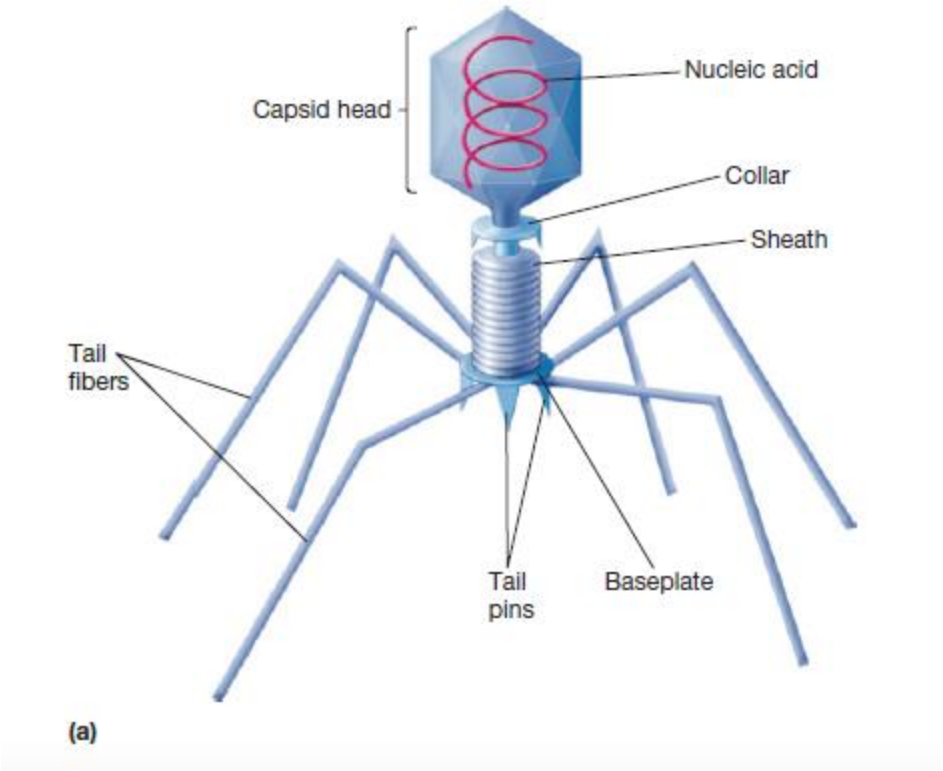
- Bacteriophage
  - ➢Polyhedral capsid head as well as a helical tail and fibers for attachment to the host cell





Complex viruses

- Detailed structure of complex viruses:
  a) Section through the vaccinia virus, a poxvirus.
  b) Bacteriophage from cyanobacteria
  c) T4 Bacteriophage from *E. coli*.



DNA & RNA viruses

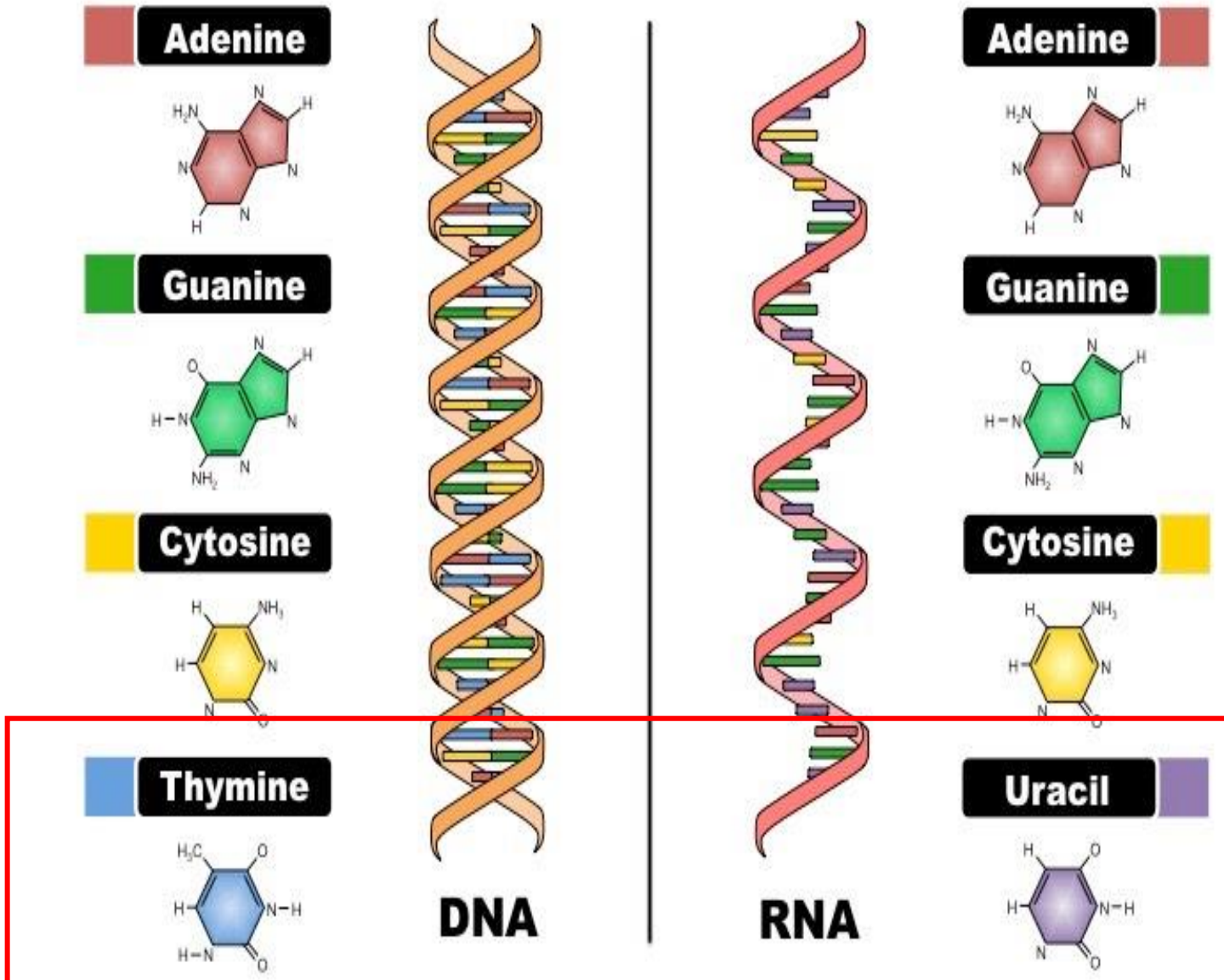
DNA viruses

- ssDNA
- dsDNA
  - linear
  - Circular

RNA viruses

- Mostly single-stranded
  - Positive-sense RNA: genomes that are ready for immediate translation into proteins
  - Negative-sense RNA: genomes have to be converted into the proper form to be made into proteins
- Segmented- individual genes exist on separate pieces of RNA

YouTube: Viruses - Part 2: DNA vs. RNA Viruses
https://youtu.be/IvMnnvv5NBA

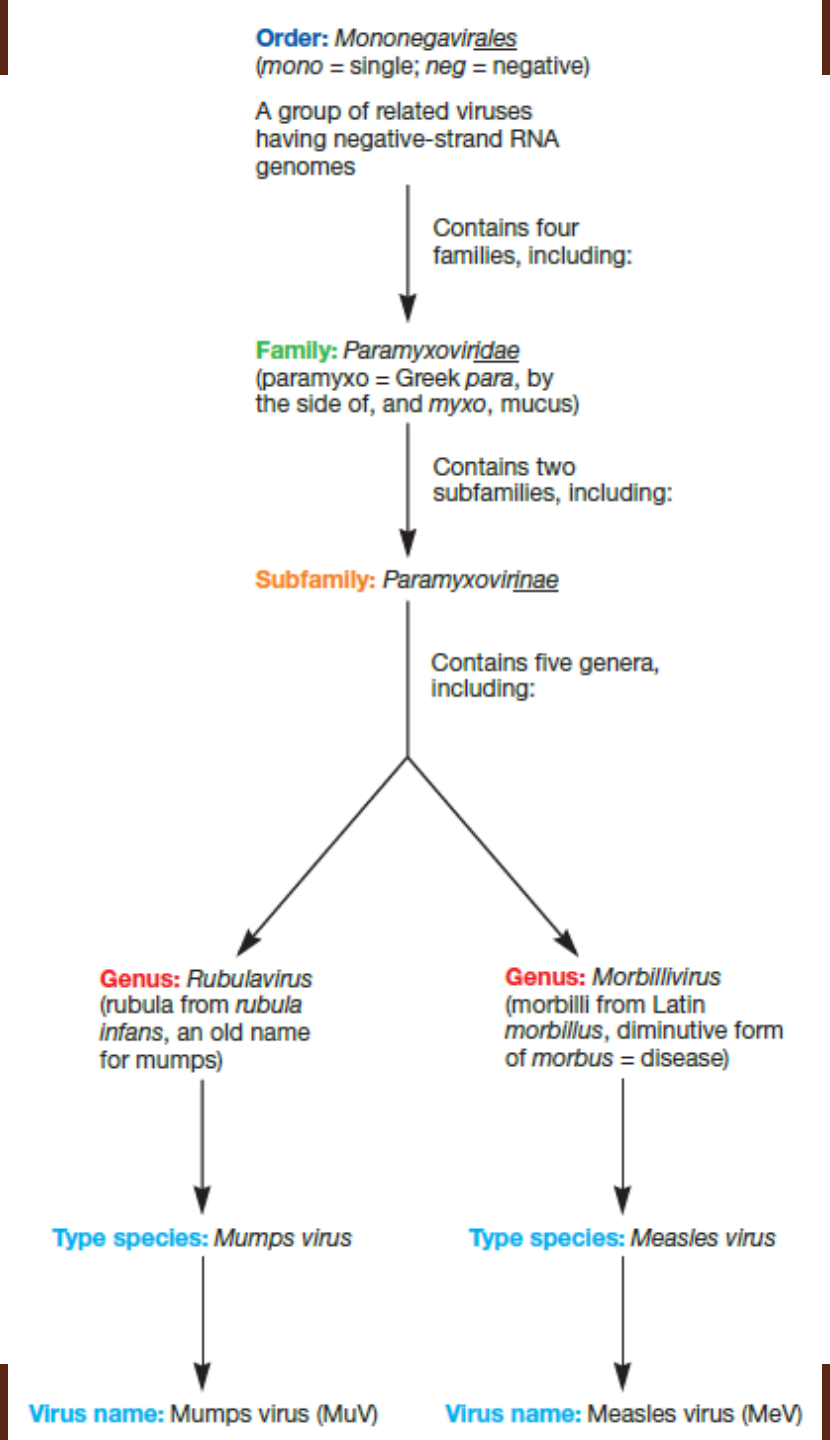

Adenine
Guanine
Cytosine
Thymine
DNA
RNA
Adenine
Guanine
Cytosine
Uracil

Virus taxonomy

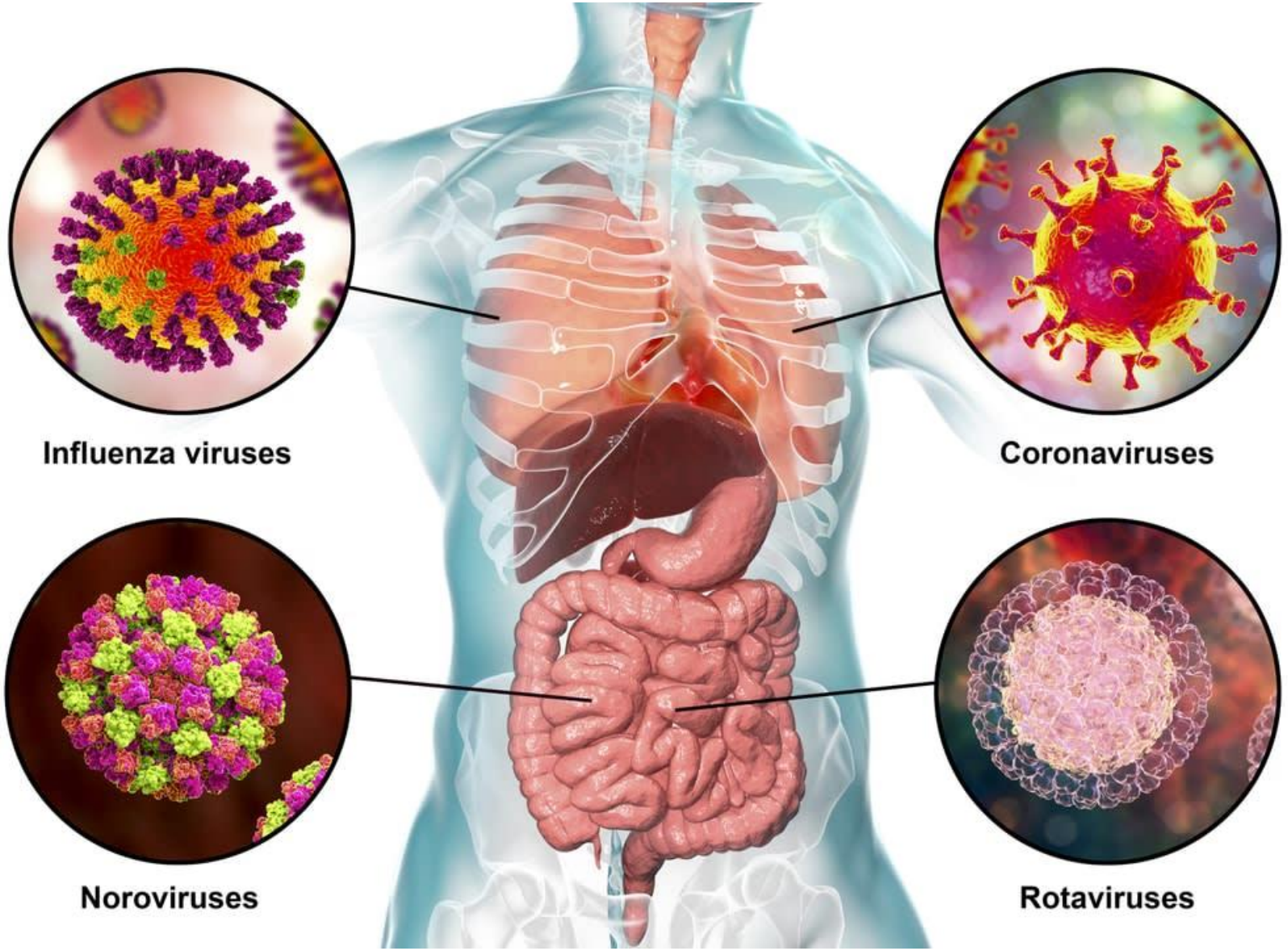
- International Committee on Taxonomy of Viruses (ICTV) developed a uniform classification system for viruses - official authority on viral taxonomy,
- The goal of taxonomy is to classify organisms based on their evolutionary history.
- > 2,000 virus species and places them in
  - 6 **orders**
    - Virus order names end in -*virales*
  - 87 **families**
    - nucleic acid type, presence or absence of an envelope, symmetry of the capsid, and dimensions of the virion and capsid.
    - Family names end in in -*viridae*
  - 19 **subfamilies**
    - subfamily names end in in -*virinae*
  - 349 **genus**
    - Genus names end in in -*virus.*

Mumps is caused by Rubula virus

- Symptoms: fever, swelling of salivary glands
- Highly contagious
- Transmitted by respiratory droplets

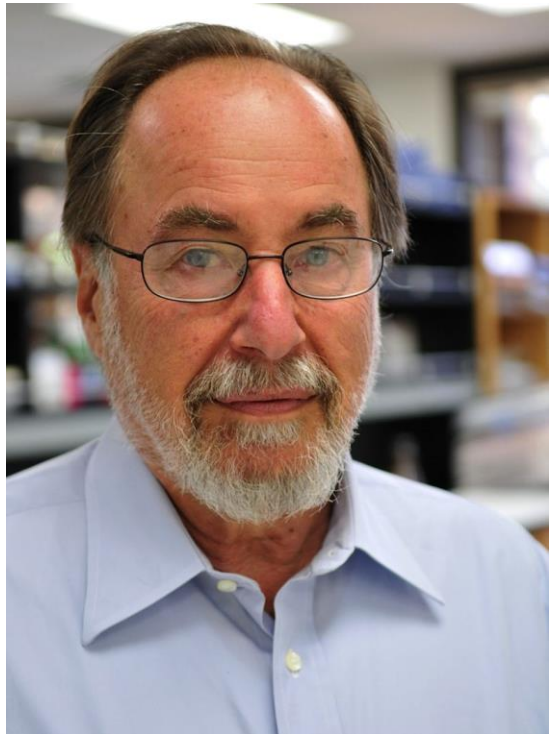


- Measles is caused by infection with the rubeola virus
- The **virus** lives in the mucus of the nose and throat
- Rashes after 3-5 days

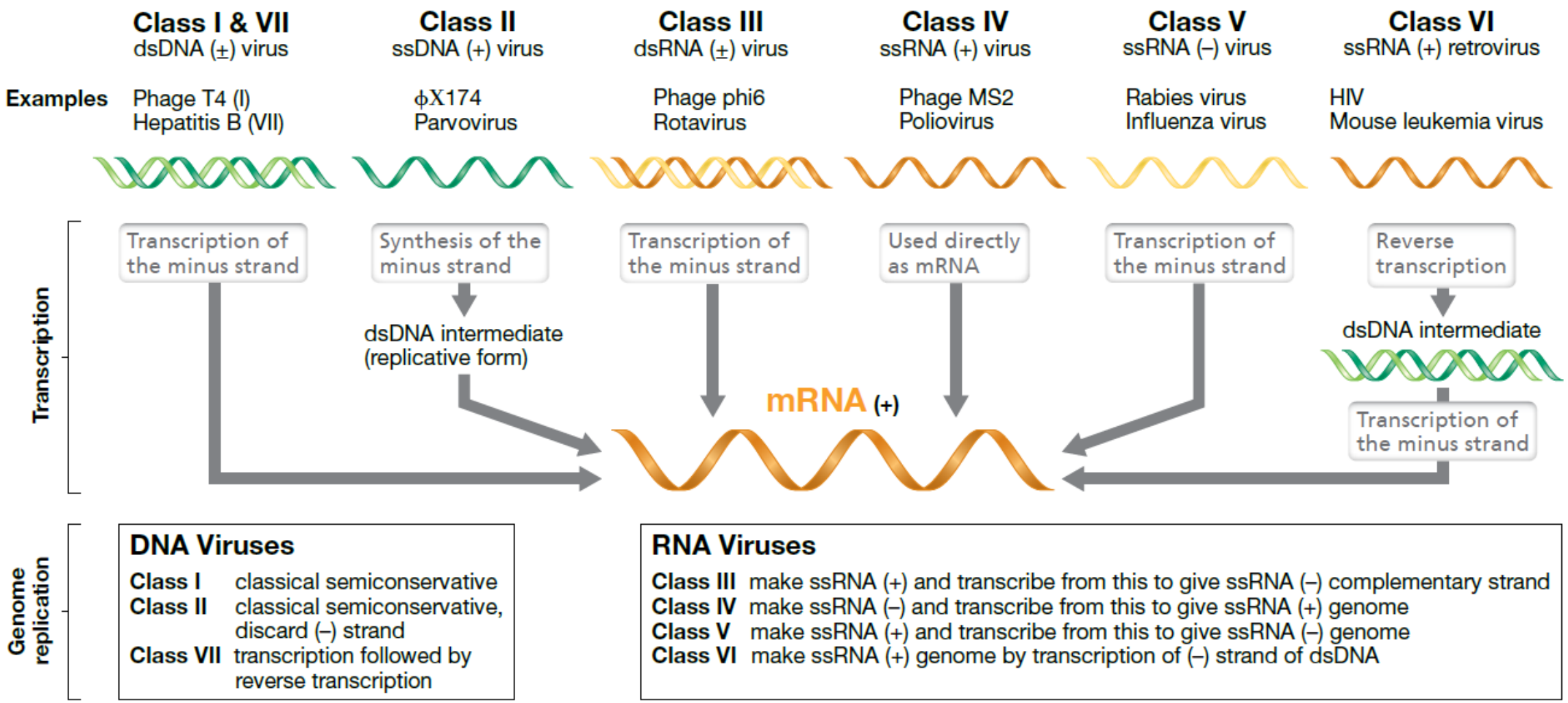

Influenza viruses
Coronaviruses
Noroviruses
Rotaviruses

Baltimore classification of viral genome

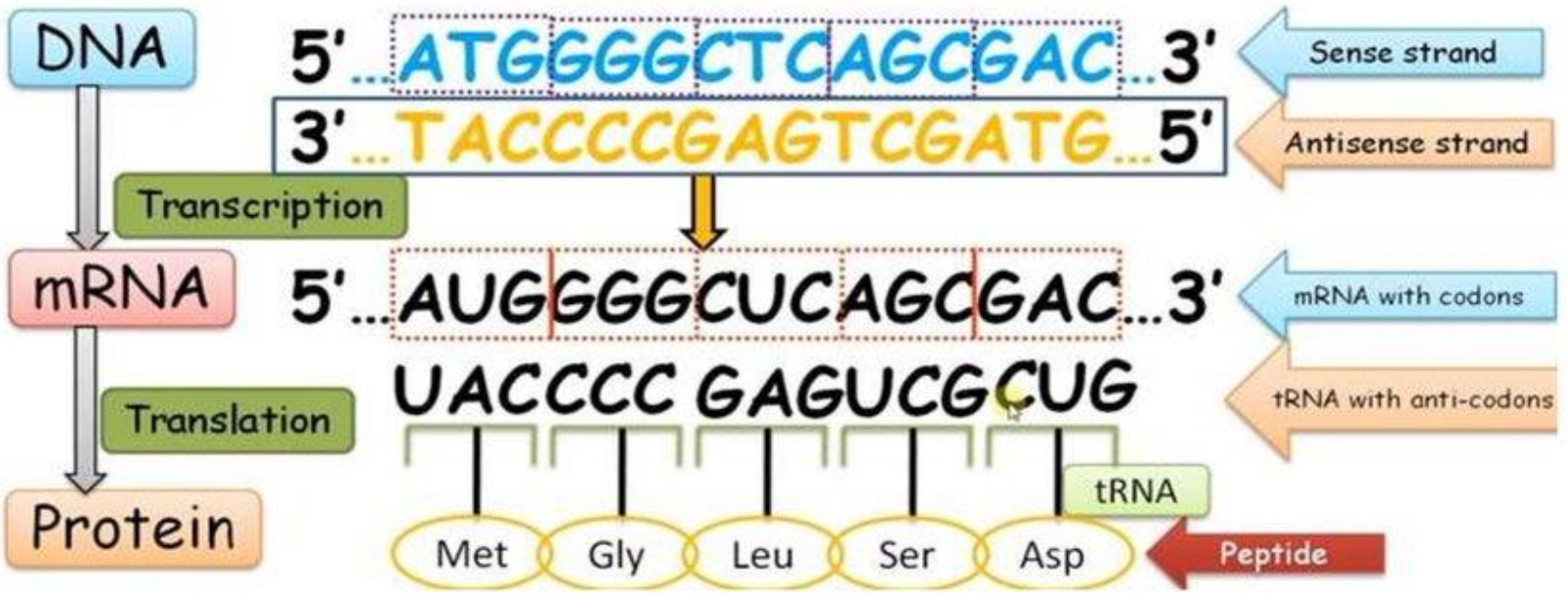
- The Baltimore system complements the ICTV system but focuses on the viral genome and the process used to synthesize viral mRNA.
- David Baltimore, an American virologist discovered the retroviruses and their key enzymes (reverse transcriptase) & developed the virus classification.
- The classification is based on the relationship of the viral genome to its mRNA – 7 classes of viruses
  - Viral mRNA is always considered to be the *plus strand* configuration
  - Thus, one must know the nature of viral genome and steps to produce complementary mRNA



Baltimore classification of viral genome



5’ to 3’Sense, coding, non-template - 3’ to 5’ Antisense, non-coding, template

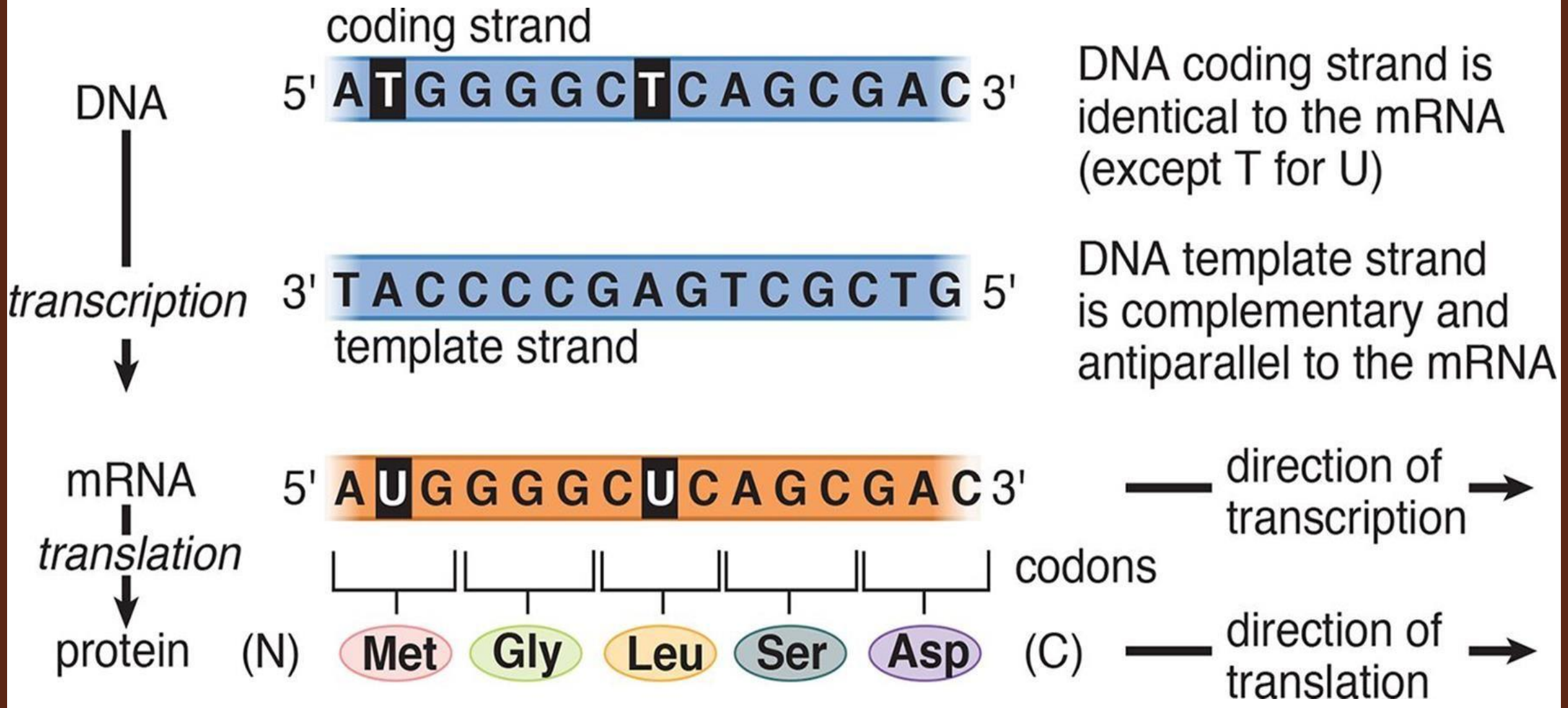


Sense Strand 5’ → 3’

1. Is also called the coding strand or non-template strand.
2. Is the same as mRNA except that thymine in DNA is replaced by Uracil in RNA.
3. The sense strand contains the information for codons via mRNA.

Antisense 3’ → 5’

1. Is also called the non-coding strand or template strand.
2. Is a template for the synthesis of mRNA – antisense is complementary to sense strand.
3. Antisense contains the code for anticodons – except T in DNA is U in RNA


coding strand
DNA
5' ATGGGGCTCAGCGAC 3'
DNA coding strand is identical to the mRNA (except T for U)
transcription
3' TACCCCGAGTCGCTG 5'
template strand
DNA template strand is complementary and antiparallel to the mRNA
mRNA
5' AUGGGGCUCAGCGAC 3'
direction of transcription
translation
codons
protein
(N)
Met
Gly
Leu
Ser
Asp
(C)
direction of translation

The Baltimore scheme: DNA viruses

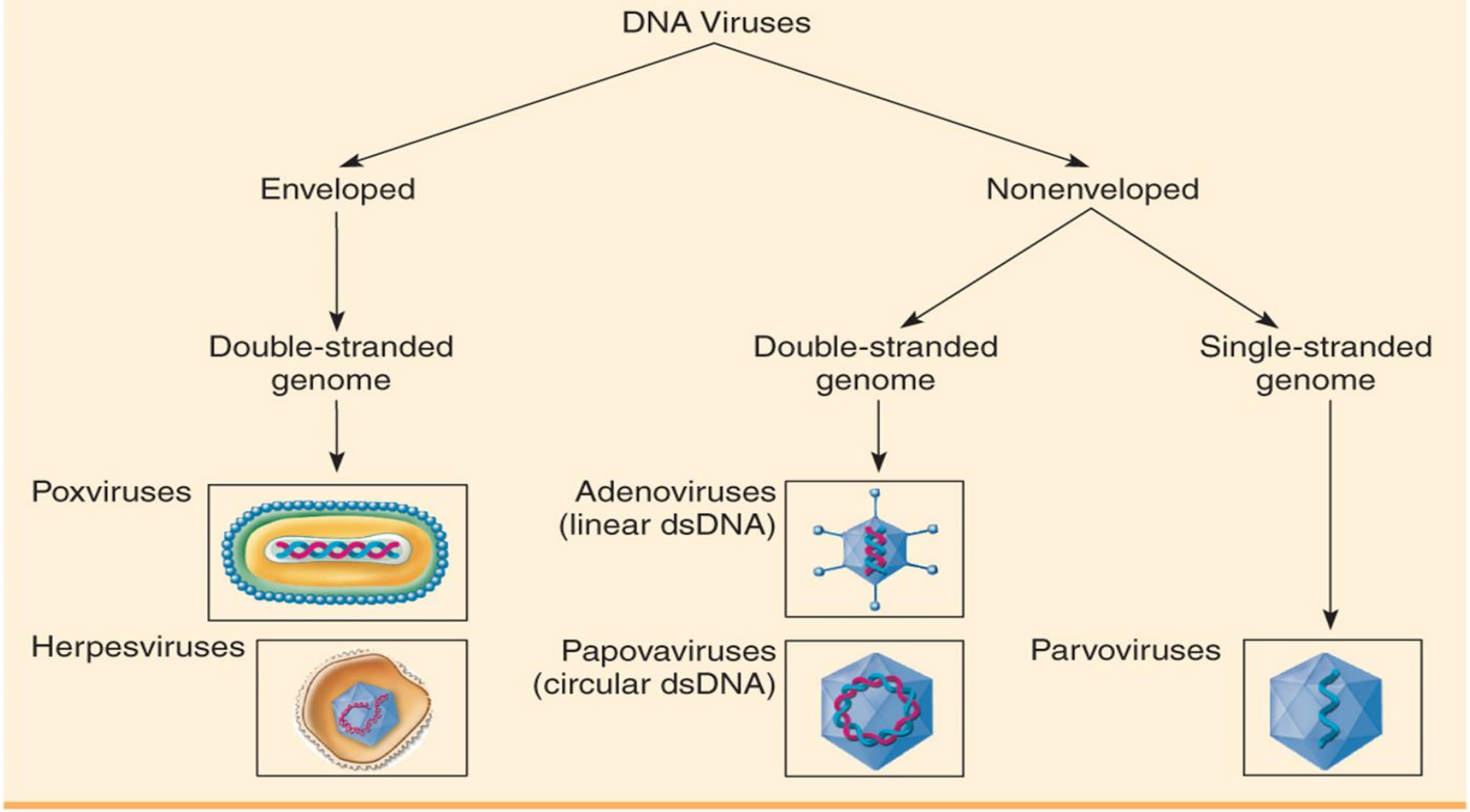
- Class I – **Double stranded DNA viruses** ("plus & minus strand" DNA)
  - Transcription of the "minus strand" DNA - e.g. Bacteriophage T4
  - Virus infecting prokaryotes & eukaryotes (animals cells)

- Class II – **Single stranded "plus-strand" DNA viruses**
  - Complementary DNA strand ("minus strand") must first be synthesis to form double stranded
  - The "minus strand" is used for transcription and source of new genome copies
  - Virus infecting eukaryotes (plant cells)

- Class VII – **Double stranded DNA viruses**
  - But replicate through an RNA intermediate
  - Need *reverse transcriptase* enzyme
  - E.g. Hepadnaviruses (Hepatitis B virus)

DNA viruses

TABLE 6.2 Medically Relevant DNA Virus Groups



Source: Adapted from: *Poxviridae* from Buller et al., National Institute of Allergy & Infectious Disease, Department of Health & Human Services.

The Baltimore scheme: RNA viruses

- Class III – **Double stranded RNA viruses** ("plus & minus strand" RNA)
  - Transcription from the "minus strand"
  - Cellular RNA polymerase (in host cell) require DNA template to to form mRNA
  - RNA viruses must carry *RNA replicase* in their virion or encode it in their genome
  - E.g. Rotaviruses

- Class IV – **Single stranded RNA viruses ("plus strand" RNA)**
  - The genome is also mRNA
  - Virus infecting eukaryotic cells
  - E.g. Coronaviruses

- Class V - **Single stranded RNA viruses ("minus strand" RNA)**
  - RNA replicase must synthesize a "plus strand" RNA – used as mRNA and template to make negative strand genome – need *RNA replicase*
  - Virus infecting eukaryotes (animals)
  - E.g. Influenza viruses

The Baltimore scheme: RNA viruses

- Class VI – **Single stranded RNA viruses ("plus strand")**
  - ➢But replicate through a reverse transcription process
  - ➢Require *reverse transcriptase* enzyme
  - ➢RNA is converted to DNA and integrated into the host genome
  - ➢Transcription of the "minus strand" DNA to form mRNA
  - ➢Human pathogens
  - ➢E.g. Retrovirus (HIV virus)

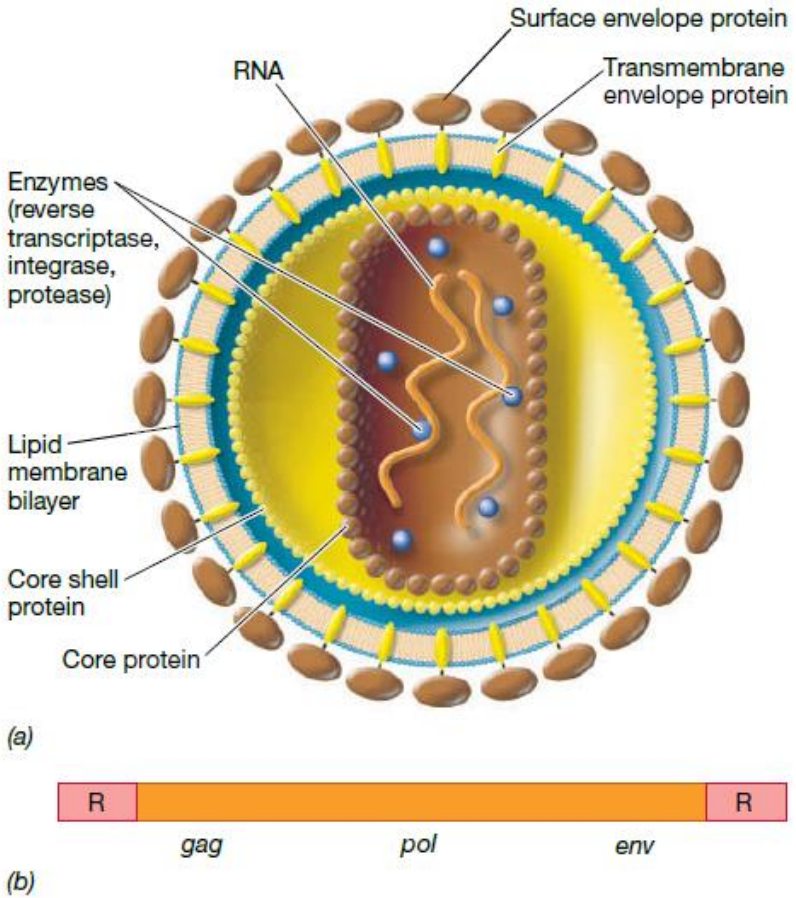


Figure 8.21 Retrovirus structure and function. *(a)* Structure of a retrovirus. *(b)* Genetic map of a typical retrovirus genome. Each end of the genomic RNA contains direct repeats (R).

Proviral state

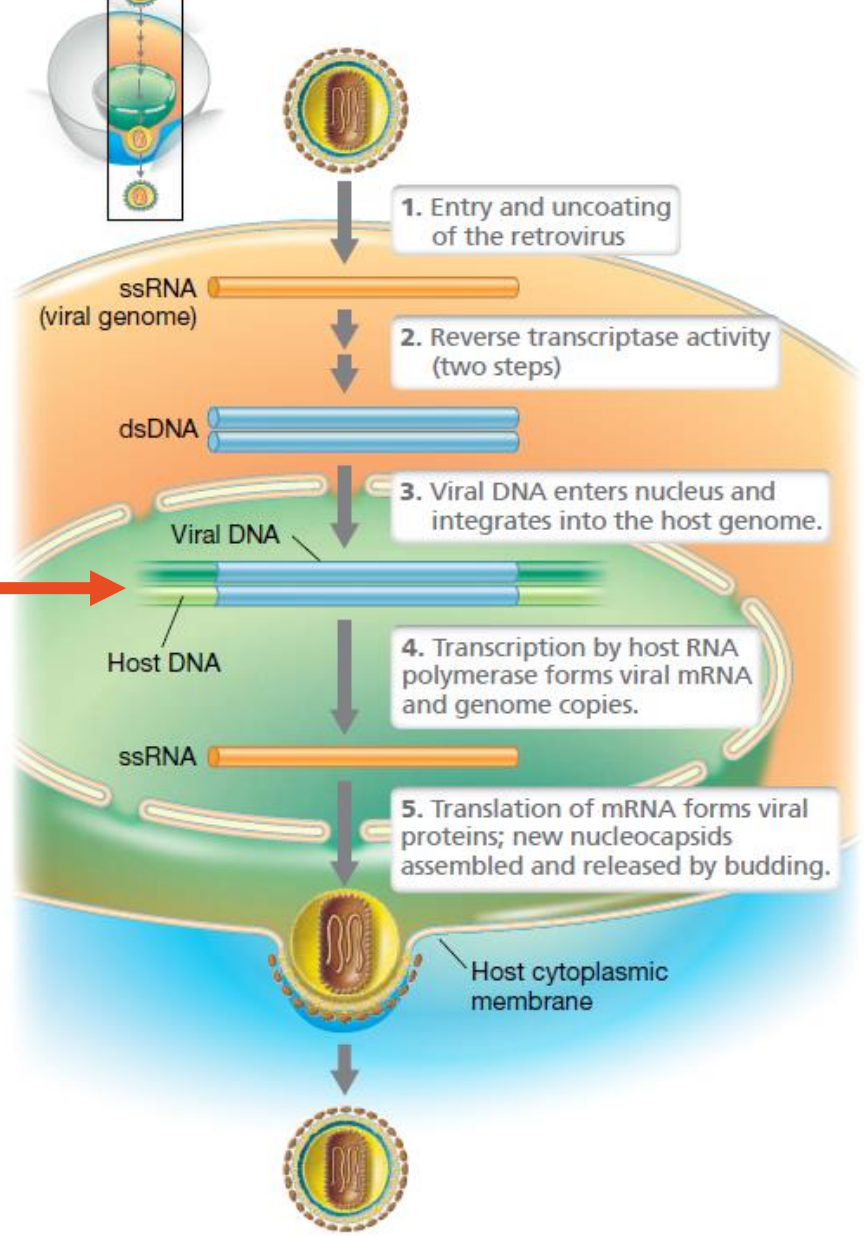
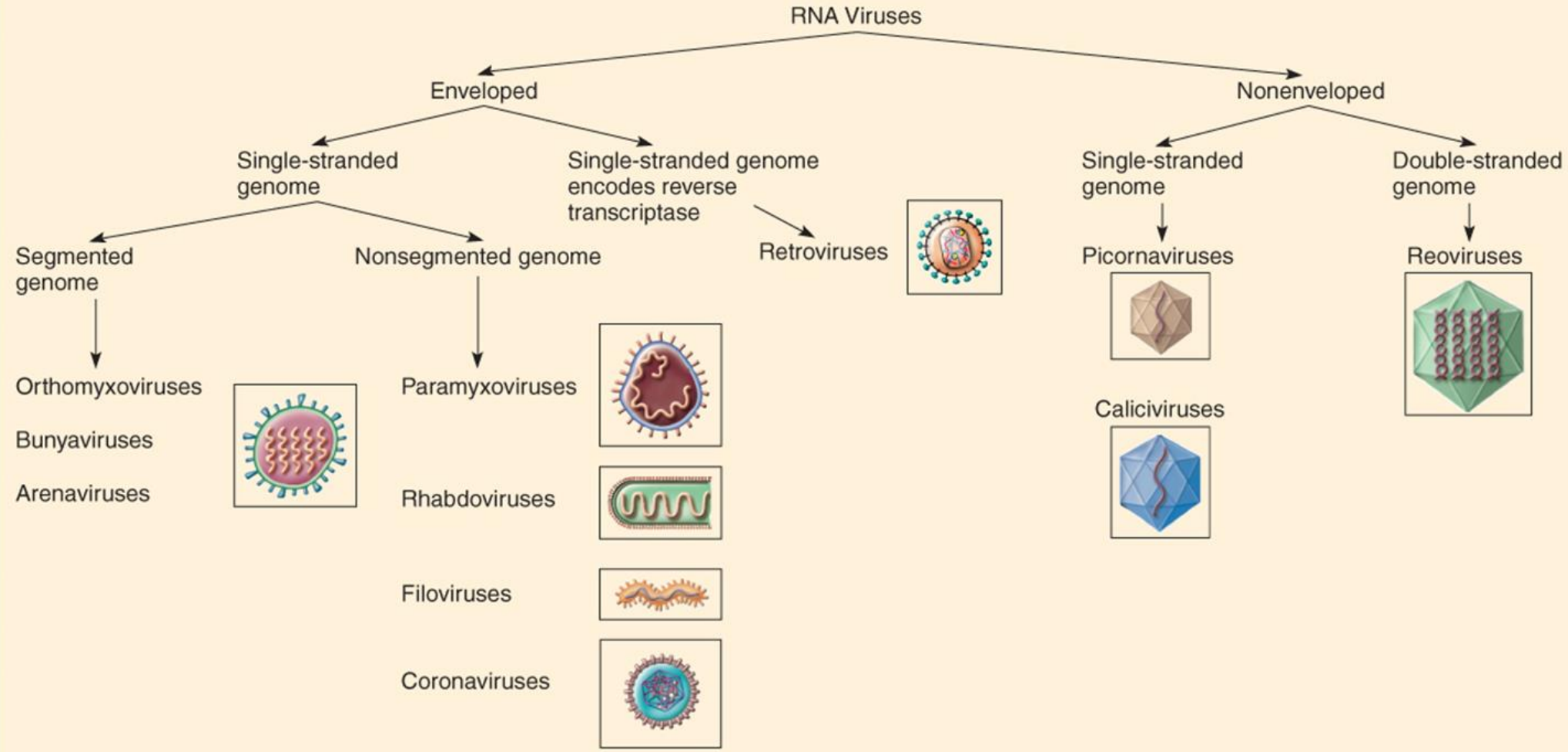


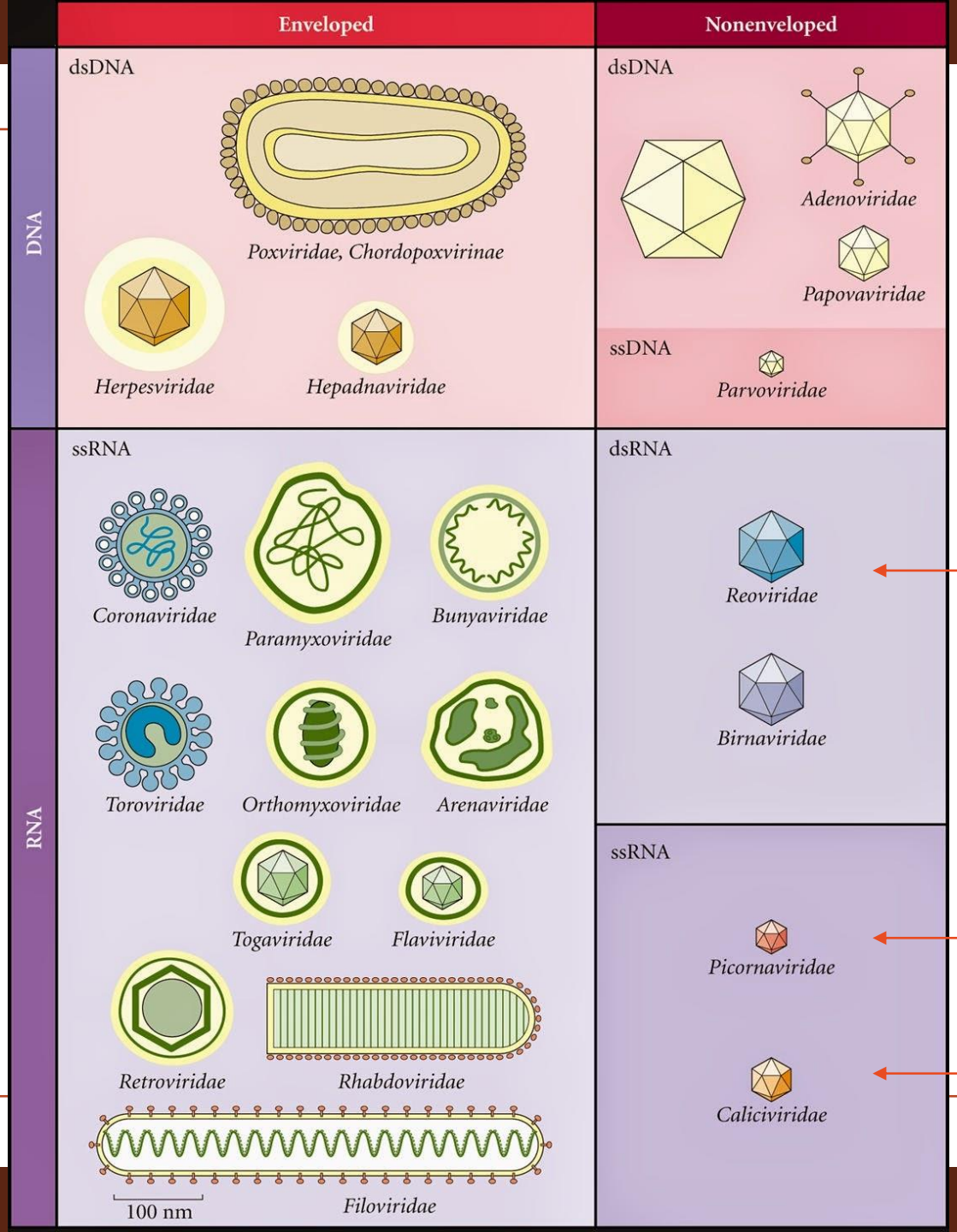
Figure 8.22 Replication of a retrovirus. The virion carries two identical copies of the RNA genome (orange). Reverse transcriptase, carried in the virion, makes single-stranded DNA from viral RNA and then double-stranded DNA that integrates into the host genome as a provirus. Transcription and translation of proviral genes leads to the production of new virions that are then released by budding.

One of the challenges of HIV vaccine design is determining ways to effectively eradicate HIV in its latent, proviral state.

RNA viruses

TABLE 6.3 Medically Relevant RNA Viruses





Foodborne viruses

Rotavirus

Hepatitis A virus

Norovirus

Growth curve of virus replication

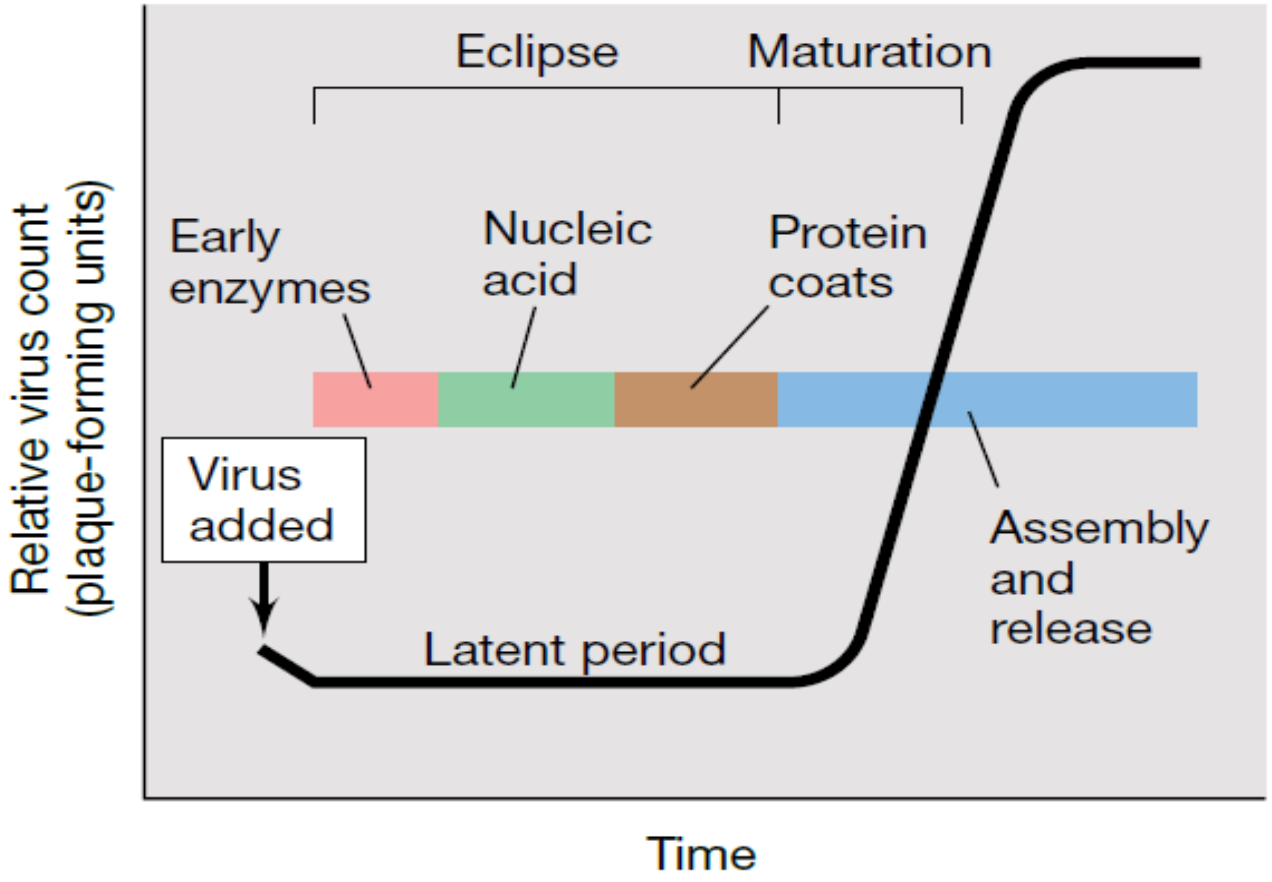


Figure 8.8 One-step growth curve of virus replication. Following adsorption, infectious virions cannot be detected in the growth medium, a phenomenon called *eclipse*. During the latent period, which includes the eclipse and early maturation phases, viral nucleic acid replicates and protein synthesis occurs. During the maturation period, virus nucleic acid and protein are assembled into mature virions and then released.

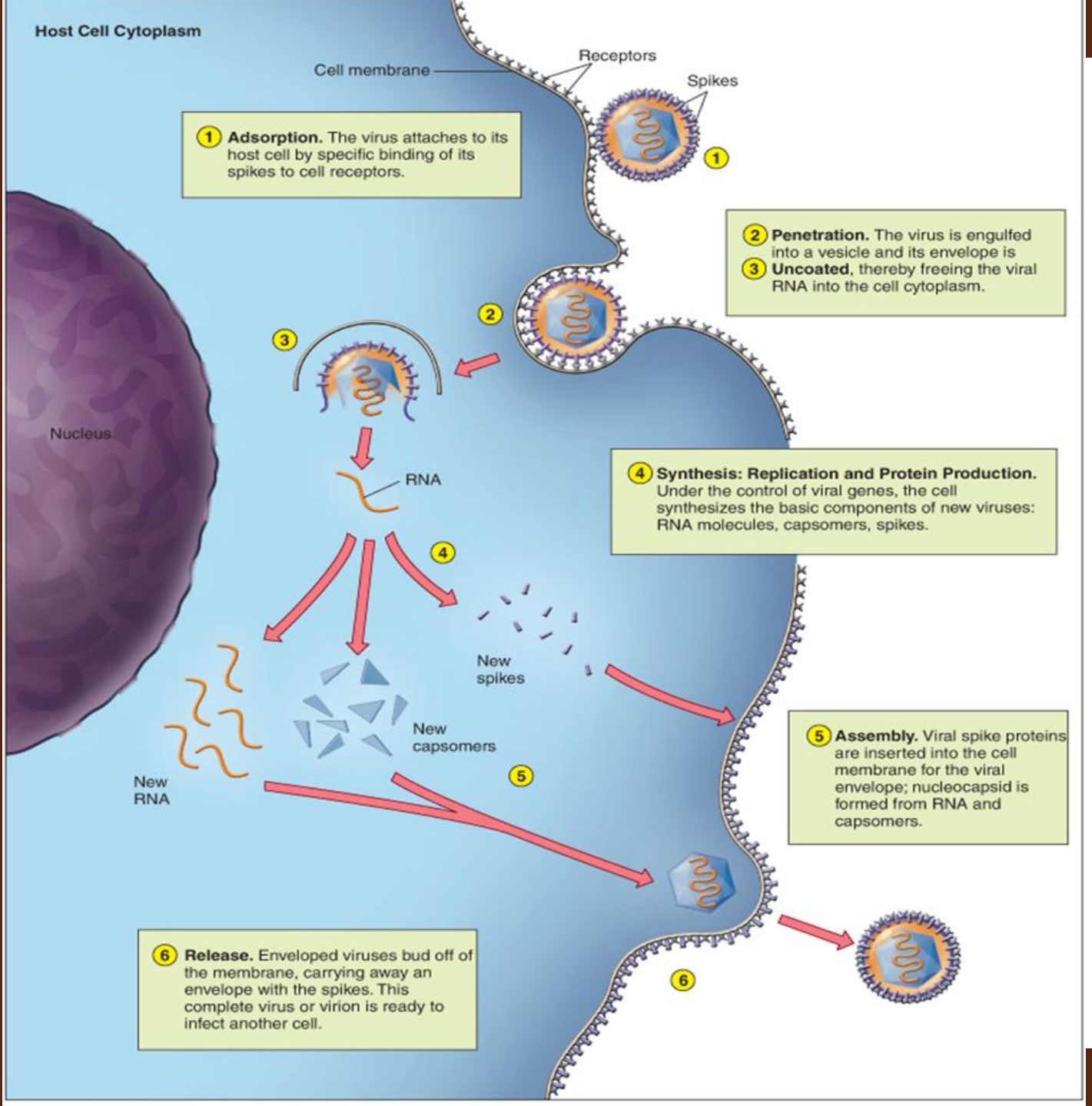

Take A Break!
pizza * pizza * pizza
* pizza
Donuts
VectorStock®
VectorStock.com/4488114

10% video assignment (20 July 2021)

In pair, prepare a **3-minute video** of any microbiology content of your choice.

In the video, **communicate clear, accurate and interesting information in an engaging manner** for an audience.

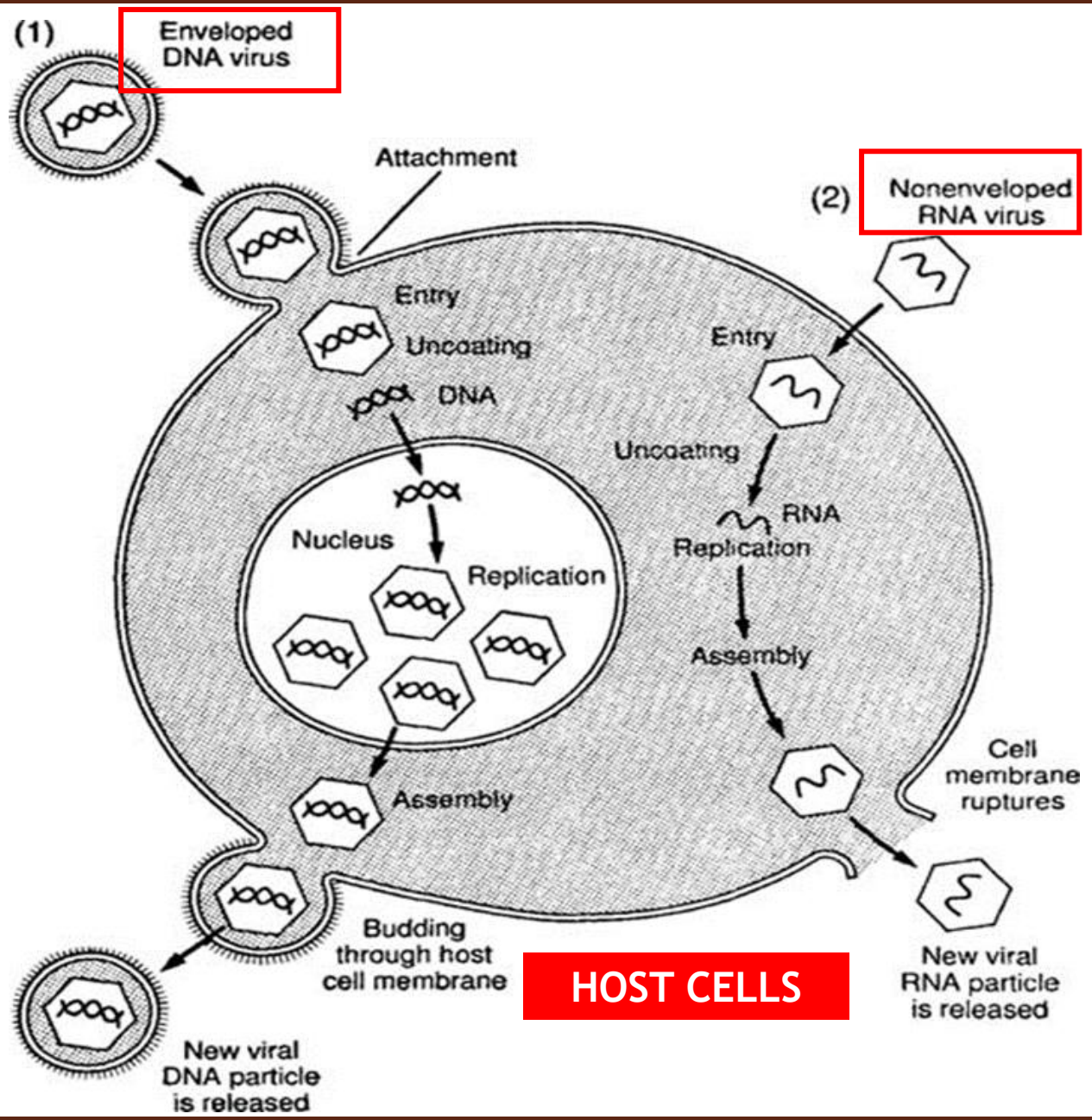
Your video should begin with descriptive **title,** your **name(s)** and the name of your **course**. We are going to set up the platform for you to submit this assignment (eg: Youtube).



Viral Multiplication

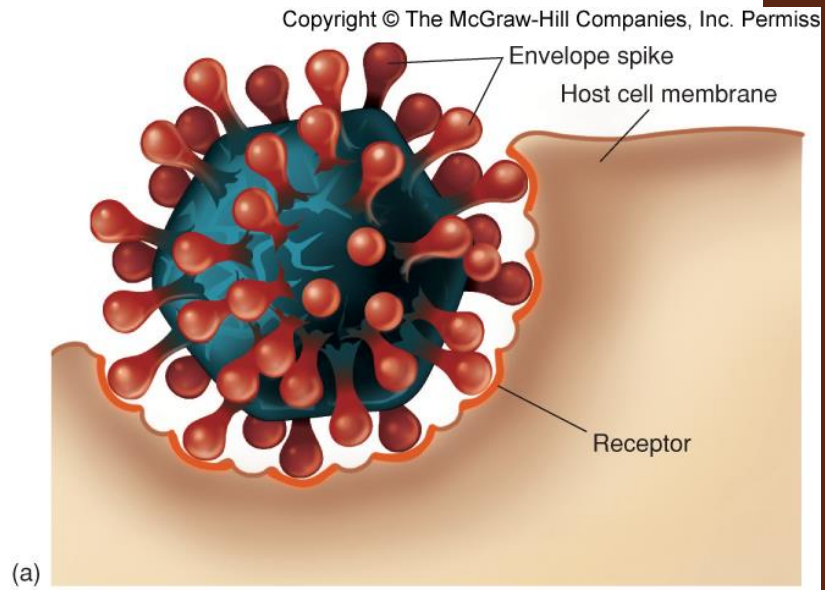
1. Adsorption
2. Penetration
3. Uncoating
4. Synthesis
5. Assembly
6. Release

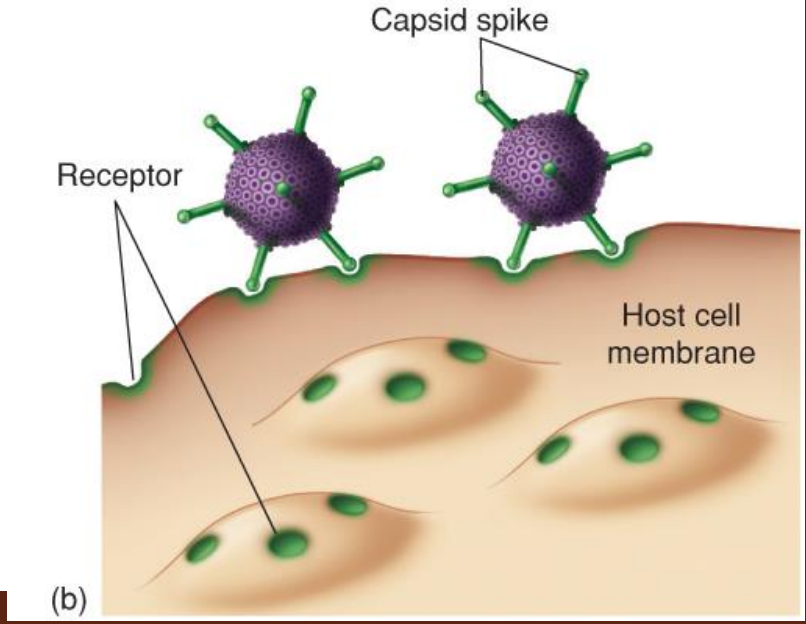
- The host cell is absolutely necessary for viral multiplication
- Minute parasites that seize control of the synthetic and genetic machinery of cells



1. Adsorption

- Virus encounters susceptible host cells
- Adsorbs specifically to receptor sites on the cell membrane (usually glycoprotein)
- Because of the exact fit required, viruses have a limited **host range** (Eg: Hepatitis B infects only liver cells)
- Mode of attachment varies between the two different virus:
  - In enveloped virus, glycoprotein spikes bind to the cell membrane receptors
  - Naked virus use molecules on their capsids that adhere to cell membrane receptors



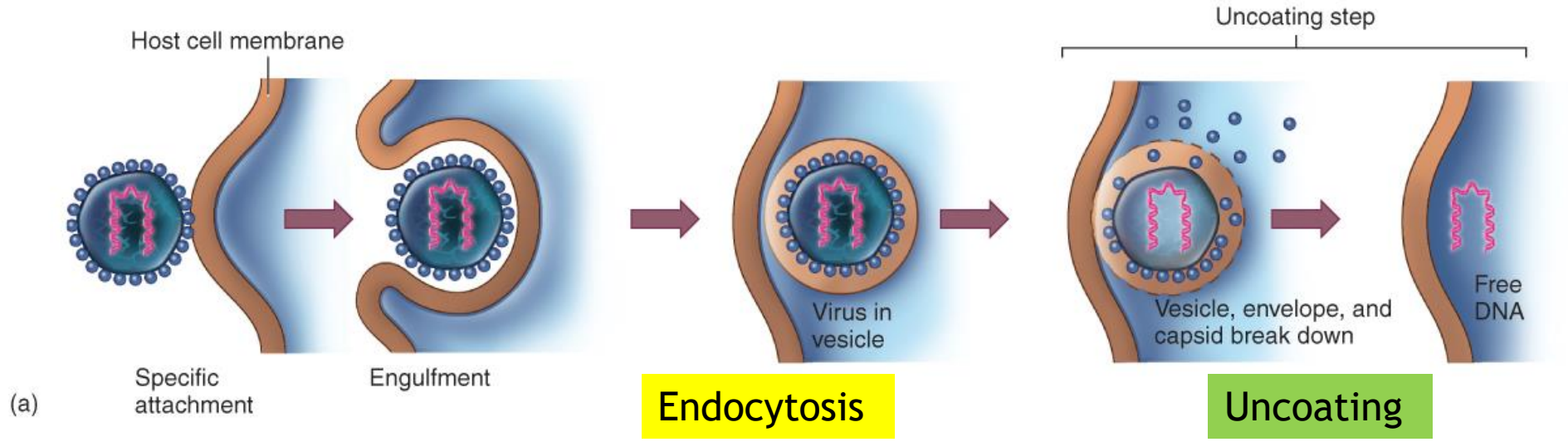


2. Penetration

- Flexible cell membrane of the host is penetrated by the whole virus or its nucleic acid

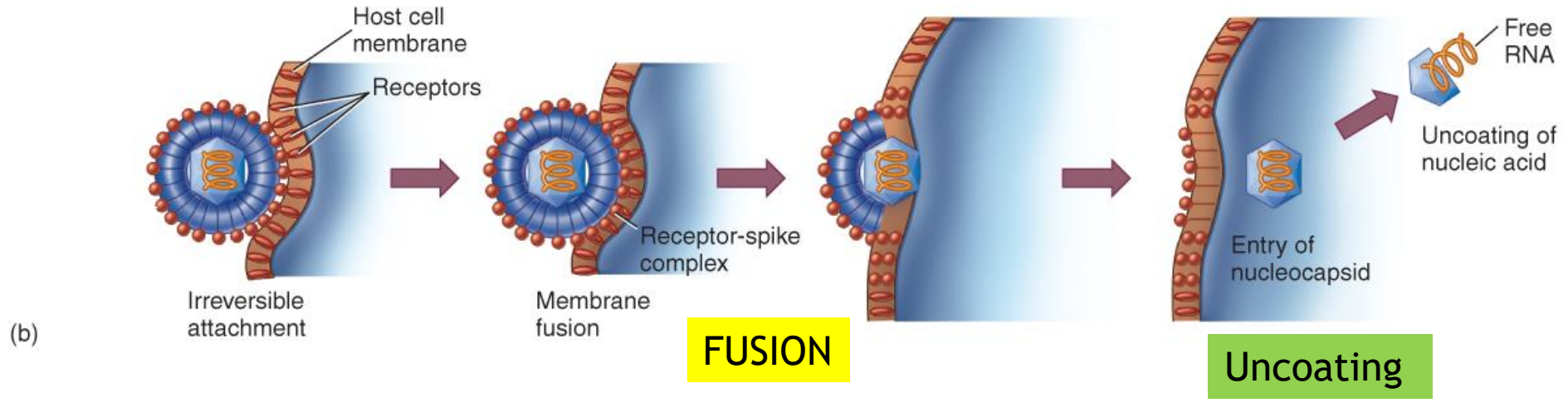
- Fusion or endocytosis
  - **Endocytosis** (enveloped or naked)
    - entire virus is engulfed by the cell and enclosed in a vacuole or vesicle
  - **Fusion** (enveloped virus only)
    - Virus is directly fuse with the host cell membrane
    - Lipids within the adjacent membranes become rearranged so that the nucleocapsid can be translocated into the cytoplasm

2. Penetration



Endocytosis

Uncoating

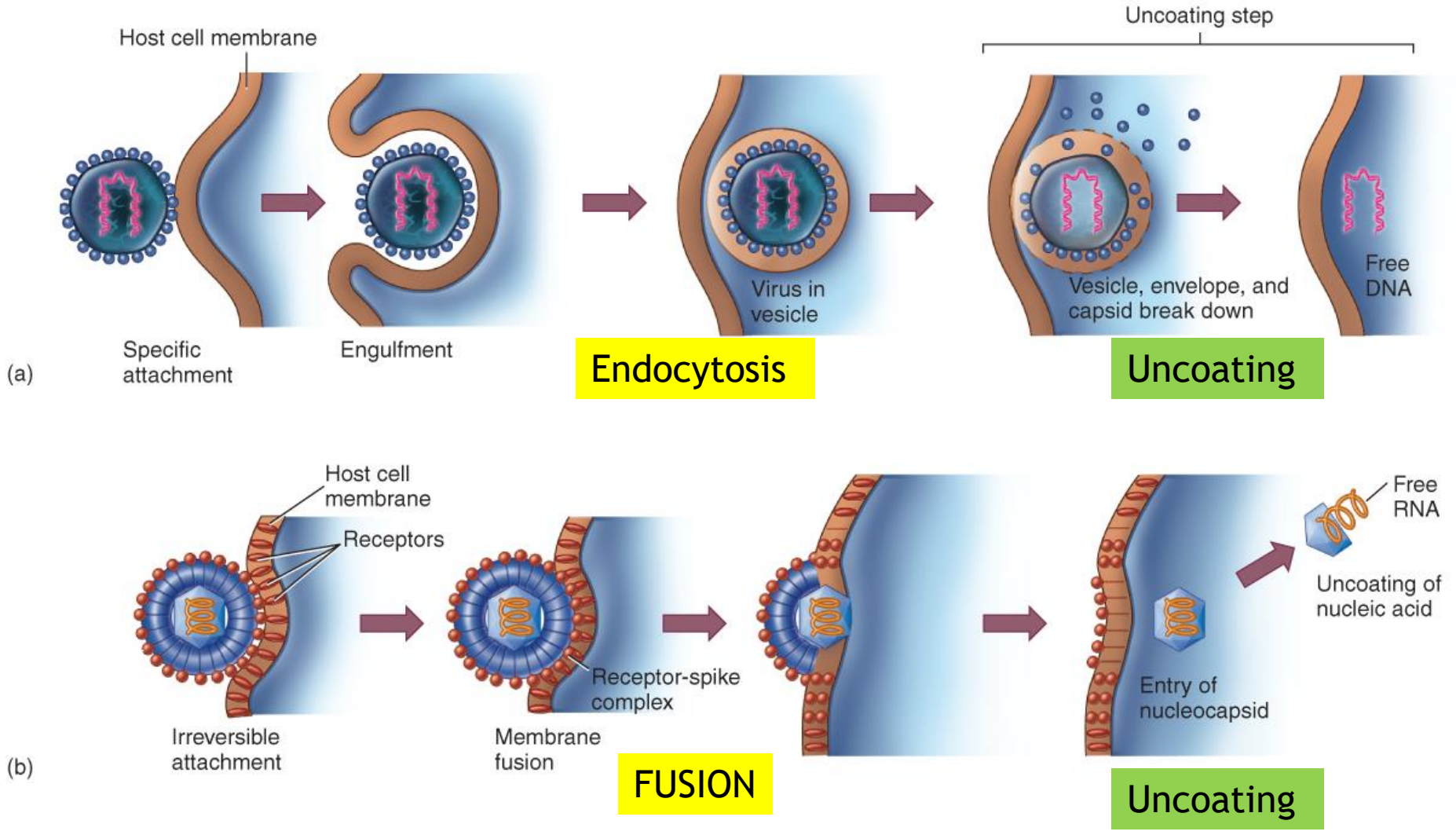


FUSION

Uncoating

3. Uncoating

- Enzymes in the vacuole dissolve the envelope and capsid
- The virus is now uncoated



4. Synthesis: Replication & Protein Production

- Free viral nucleic acid exerts control over the host's synthetic and metabolic machinery

- DNA viruses- enter host cell's **nucleus** where they are replicated and assembled
  - DNA enters the nucleus and is transcribed into RNA
  - The RNA becomes a message for synthesizing viral proteins (translation)
  - New DNA is synthesized using host nucleotides
- RNA viruses- replicated and assembled in the **cytoplasm**

5. Assembly

- Mature virus particles are constructed from the growing pool of parts
- The capsid is first laid down as an empty shell that will serve as a receptacle for the nucleic acid strand

6. Release

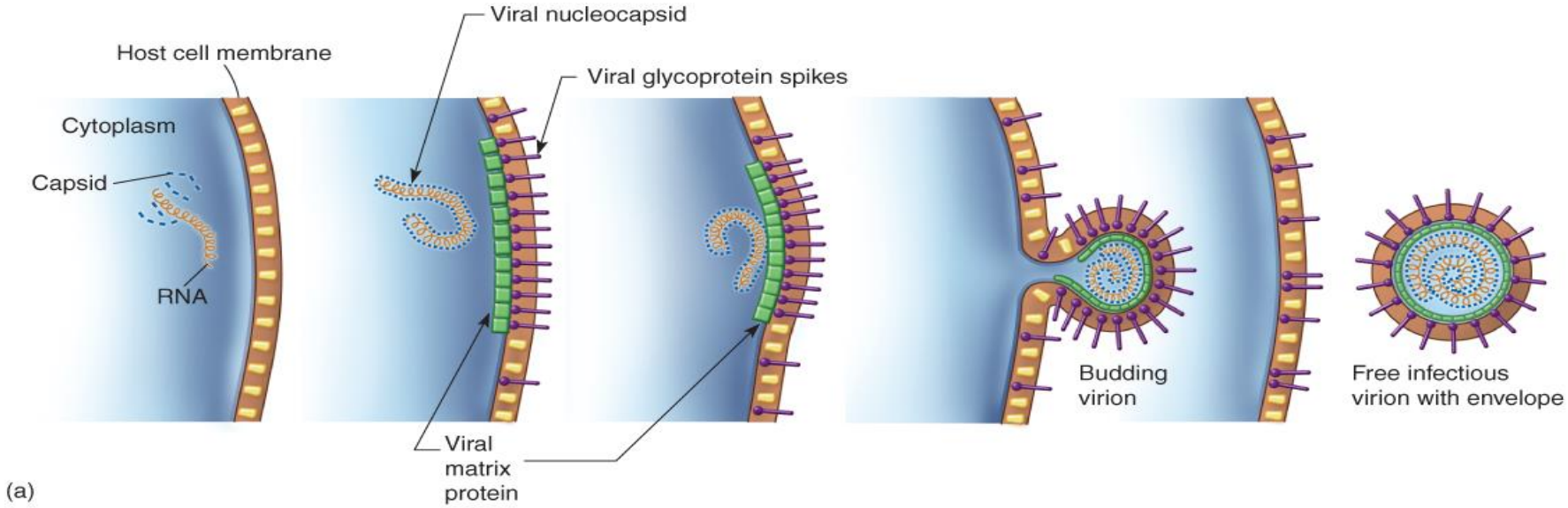
- **Nonenveloped** and complex viruses are released when the **cell lysis** or ruptures

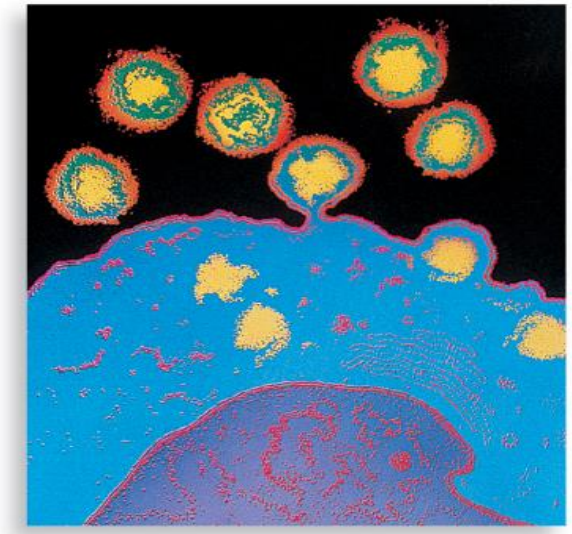
- **Enveloped** viruses are liberated by **budding** or **exocytosis**
  - Nucleocapsid binds to the membrane, which curves completely around it and forms a small pouch. Pinching off the pouch releases the virus with its envelope

- Anywhere from 3,000 to 100,000 virions may be released, depending on the virus
- Entire length of cycle- anywhere from 8 to 36 hours

6. Release

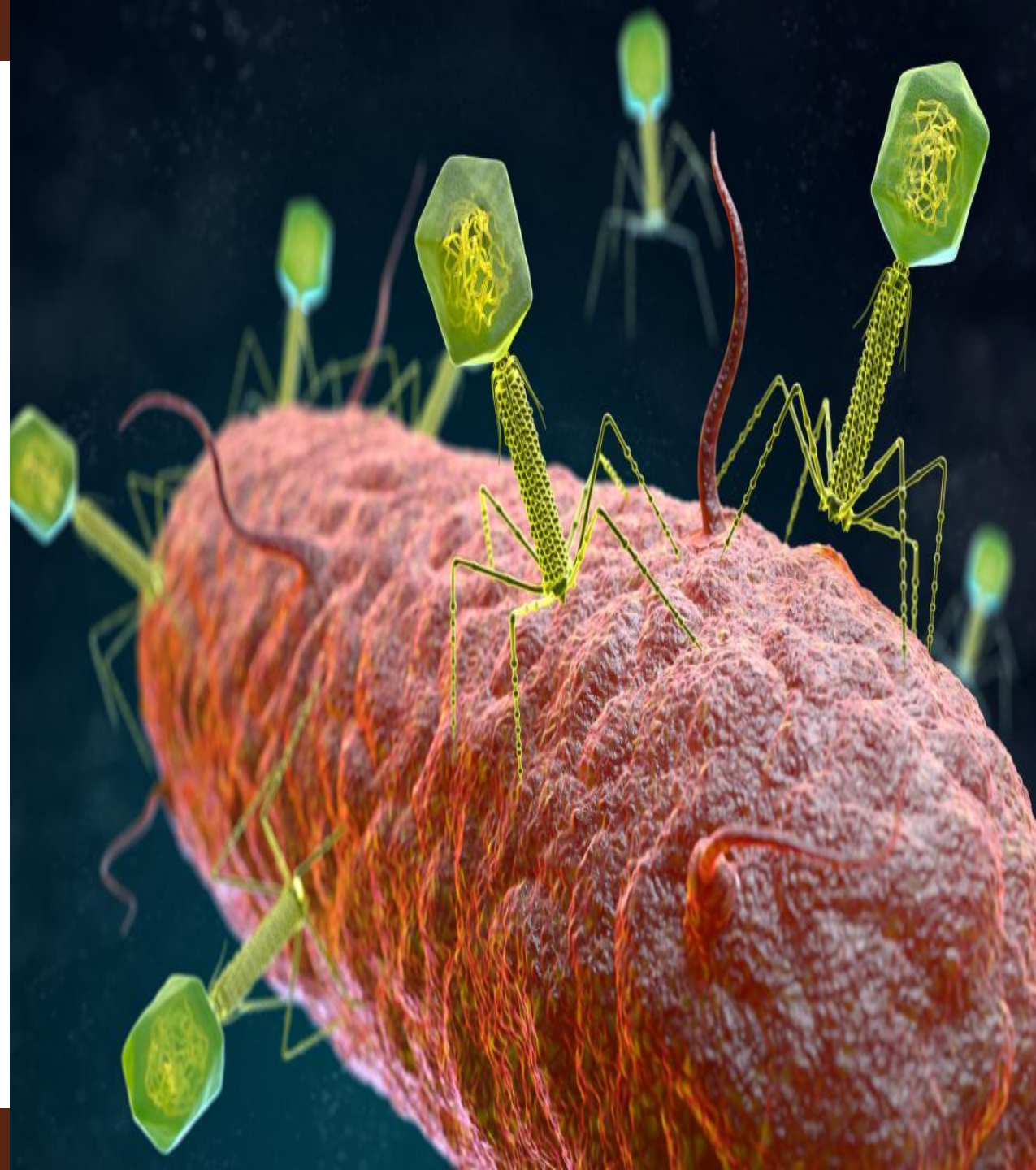
Exocytosis of enveloped virus





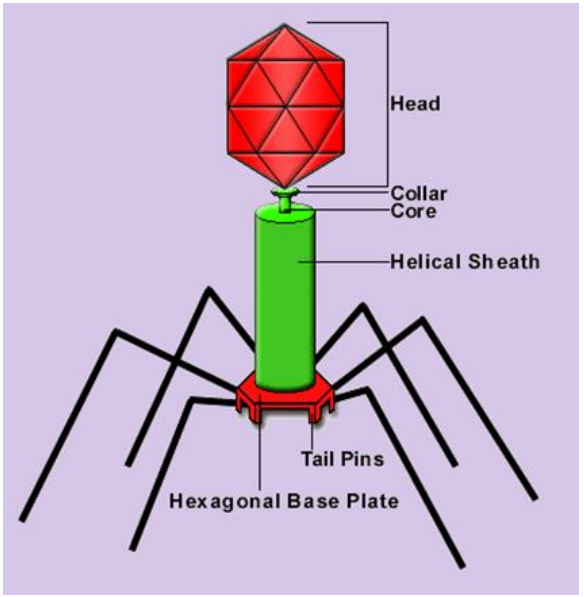
BACTERIOPHAGE:
Viruses that infect bacteria

- Bacteriophage T4 and Bacteriophage Lambda
- Most contain dsDNA
- Often make the bacteria they infect more pathogenic for humans



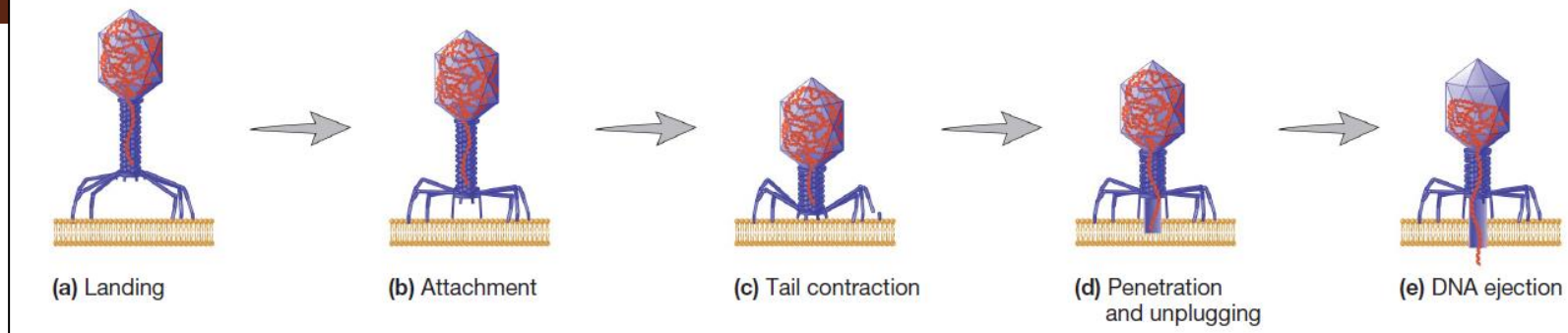
Bacteriophage T4

- Icosahedral capsid head containing DNA (mostly ds DNA)
- Similar stages as animal viruses
  - Adsorb to host bacteria
  - The nucleic acid penetrates the host after being injected through a rigid tube inserted through the bacterial membrane and wall
  - Entry of the nucleic acid
  - The host cell machinery is then used for viral replication and synthesis of viral proteins
  - As the host cell produces new parts, they spontaneously assemble



Bacteriophage T4

- Double stranded DNA genome
- Infect bacterial cells
- The host RNA polymerase synthesize the viral mRNA
- Virulent(lytic) bacteriophages
- Infections always ends with host cell lysis



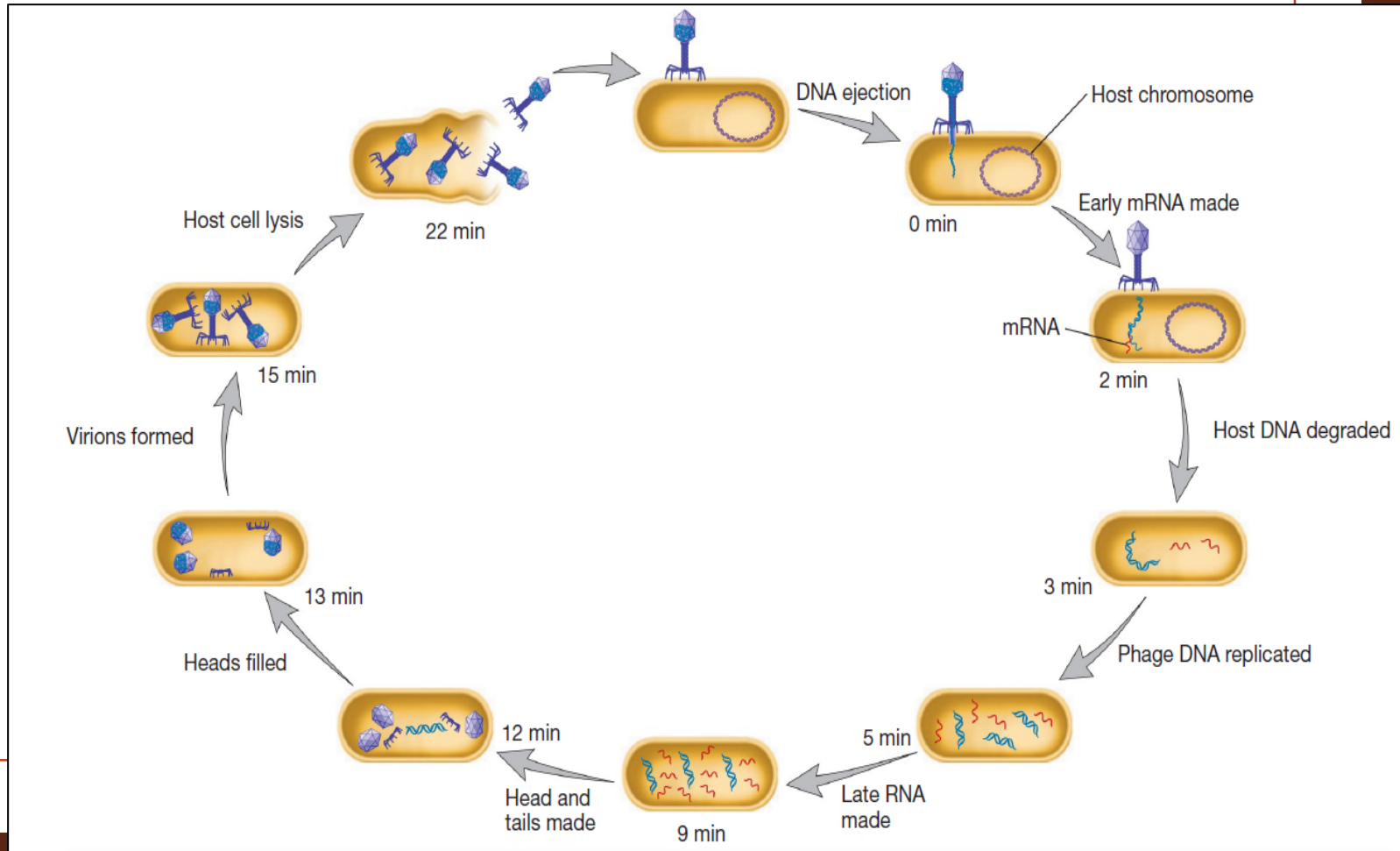


Figure 27.5 The Life Cycle of Bacteriophage T4. A diagram depicting the life cycle with the minutes after DNA ejection given for each stage.

Viral replication & protein synthesis

- The host cell is absolutely necessary for **viral replication** of DNA (copy their genetic material for new virion), and **transcription** of viral mRNA (to synthesis viral protein)

- Viral proteins can be made from the viral mRNA
  - Early proteins – synthesized soon after infection, enzymes
  - Late proteins – synthesized later, structural components of the virion

Viruses - Part 3: Viral Replication Process
https://youtu.be/-DGkZ2AM7RU

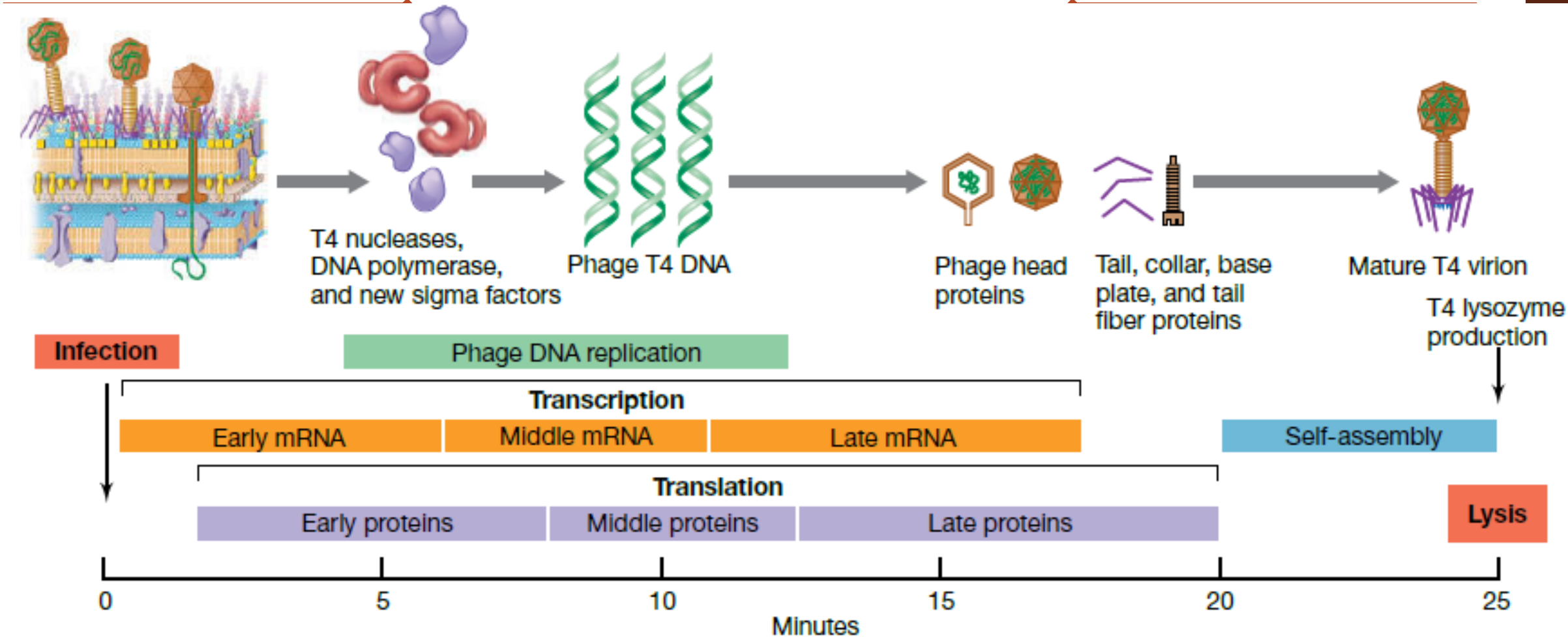
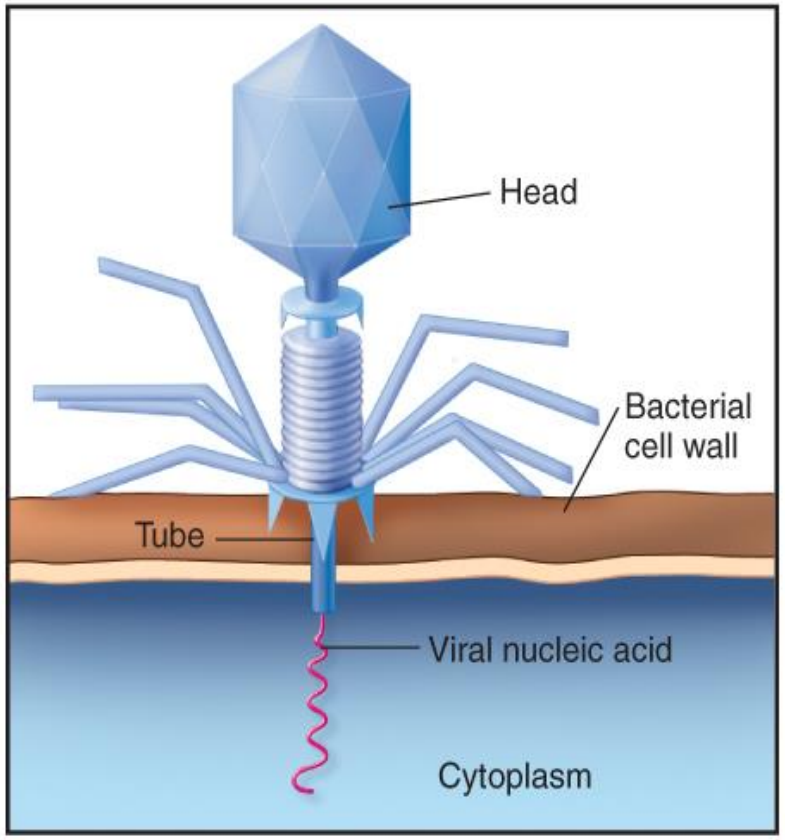
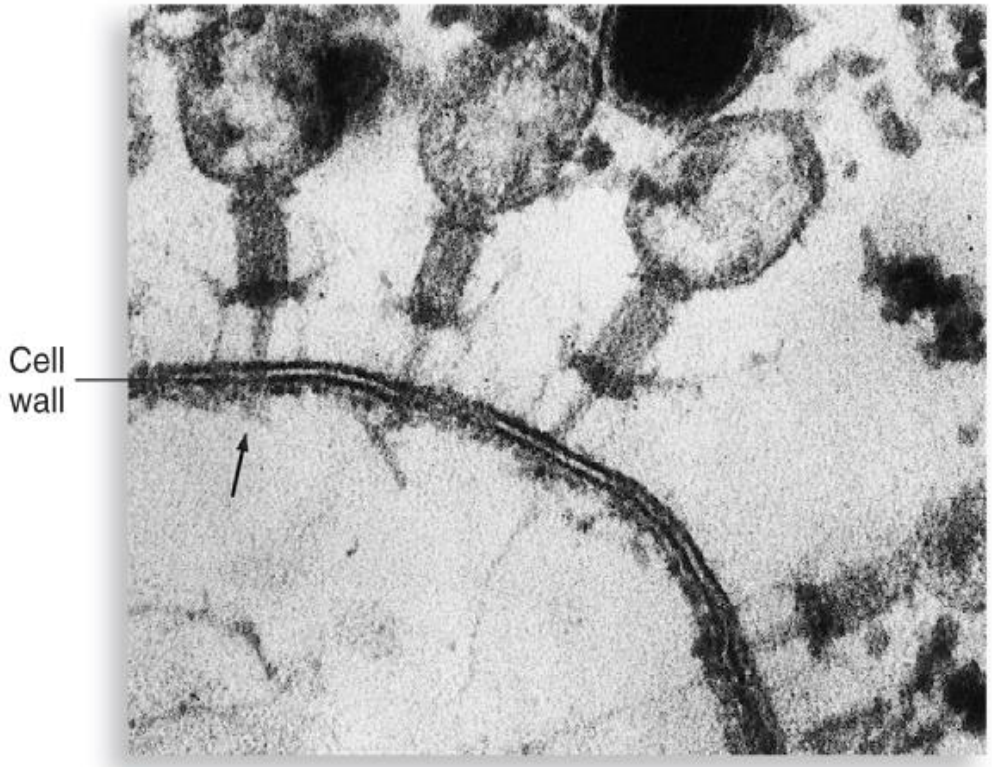


Figure 8.14 Time course of events in phage T4 infection. Following injection of DNA, early and middle mRNAs are produced that encode nucleases, T4 DNA polymerase, new phage-specific sigma factors, and other proteins needed for DNA replication. Late mRNAs encode virion structural proteins and T4 lysozyme, which are needed to lyse the cell and release new virions.

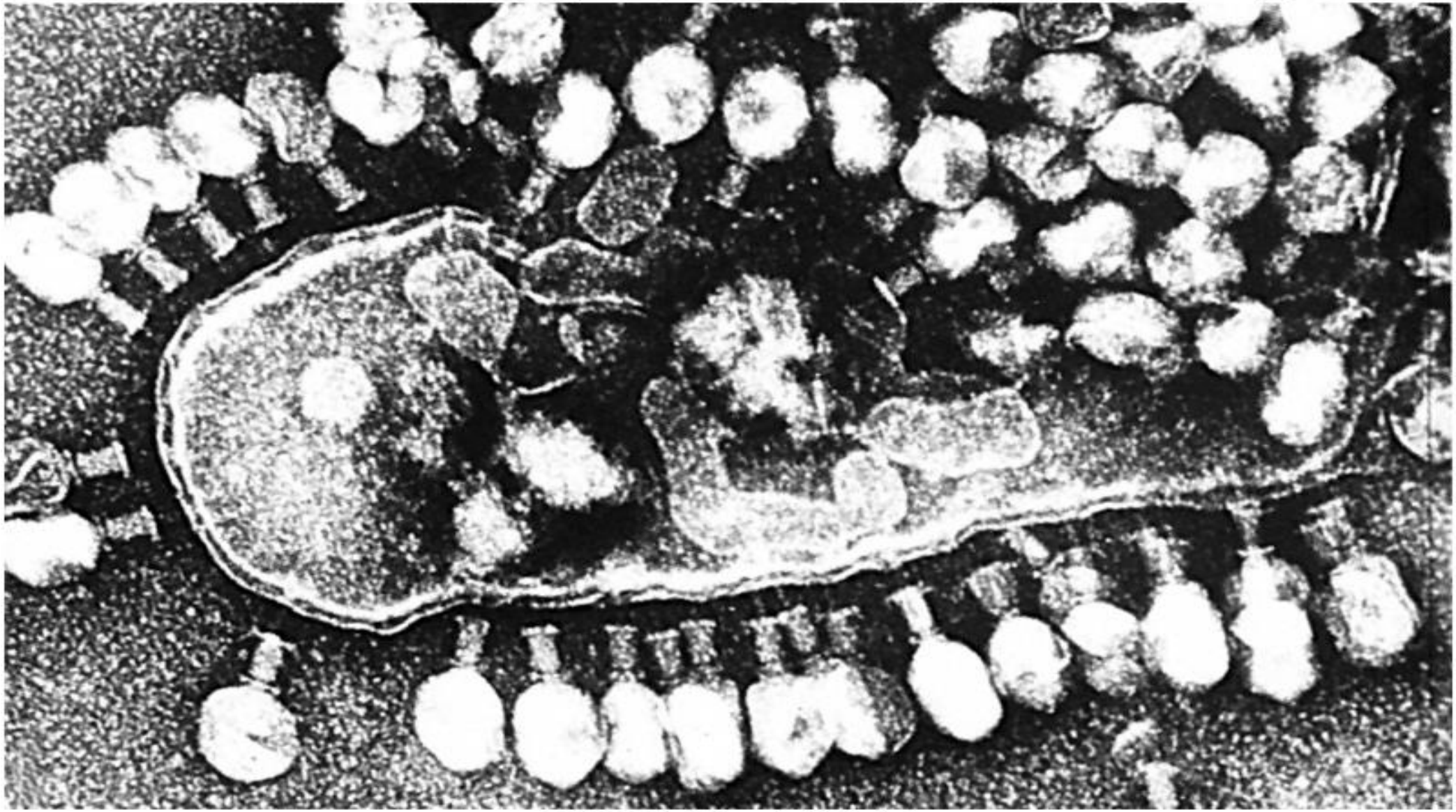
Multiplication of bacteriophage



(a)



(b)



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Bacteriophage Lambda : A temperate bacteriophage

- **Temperate phages-** special DNA phages that undergo adsorption and penetration but are not replicated or released immediately
- Instead the viral DNA enters an inactive **prophage stage** – inserted into the bacterial chromosome
- **Lysogeny:** Host chromosome carried bacteriophage DNA (no viral particle produced, no lysis)
- **Induction**: The prophage in the lysogenic cell will be activated and progress directly into viral replication and the lytic cycle
- **Lysogenic conversion**: when a bacterium acquires a new trait from its temperate phage
  - As the host cell produces new parts, they spontaneously assemble

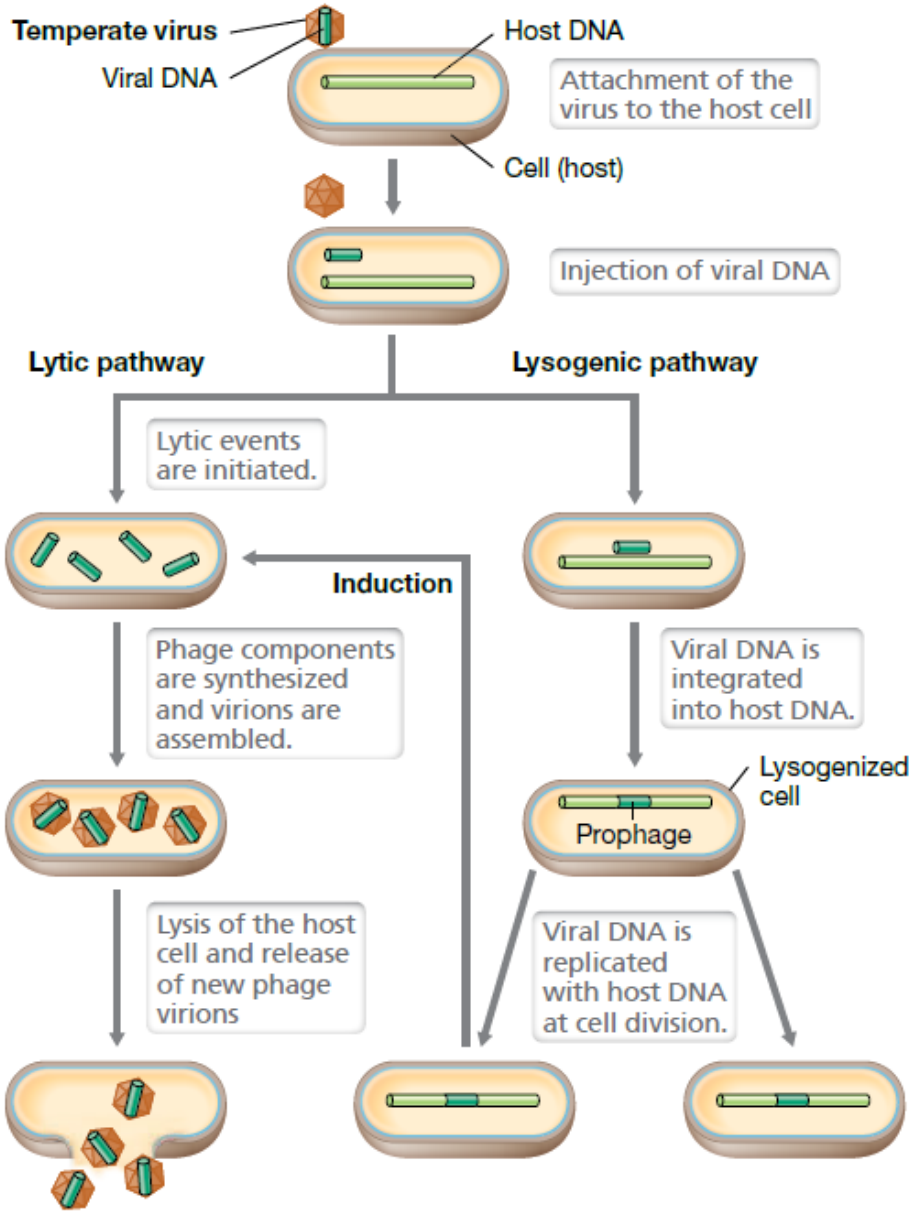


Figure 8.16 Consequences of infection by a temperate bacteriophage.
The alternatives upon infection are replication and release of mature virions (lysis) or lysogeny, often by integration of the virus DNA into the host DNA, as shown here. The lysogen can be induced to produce mature virions and lyse.

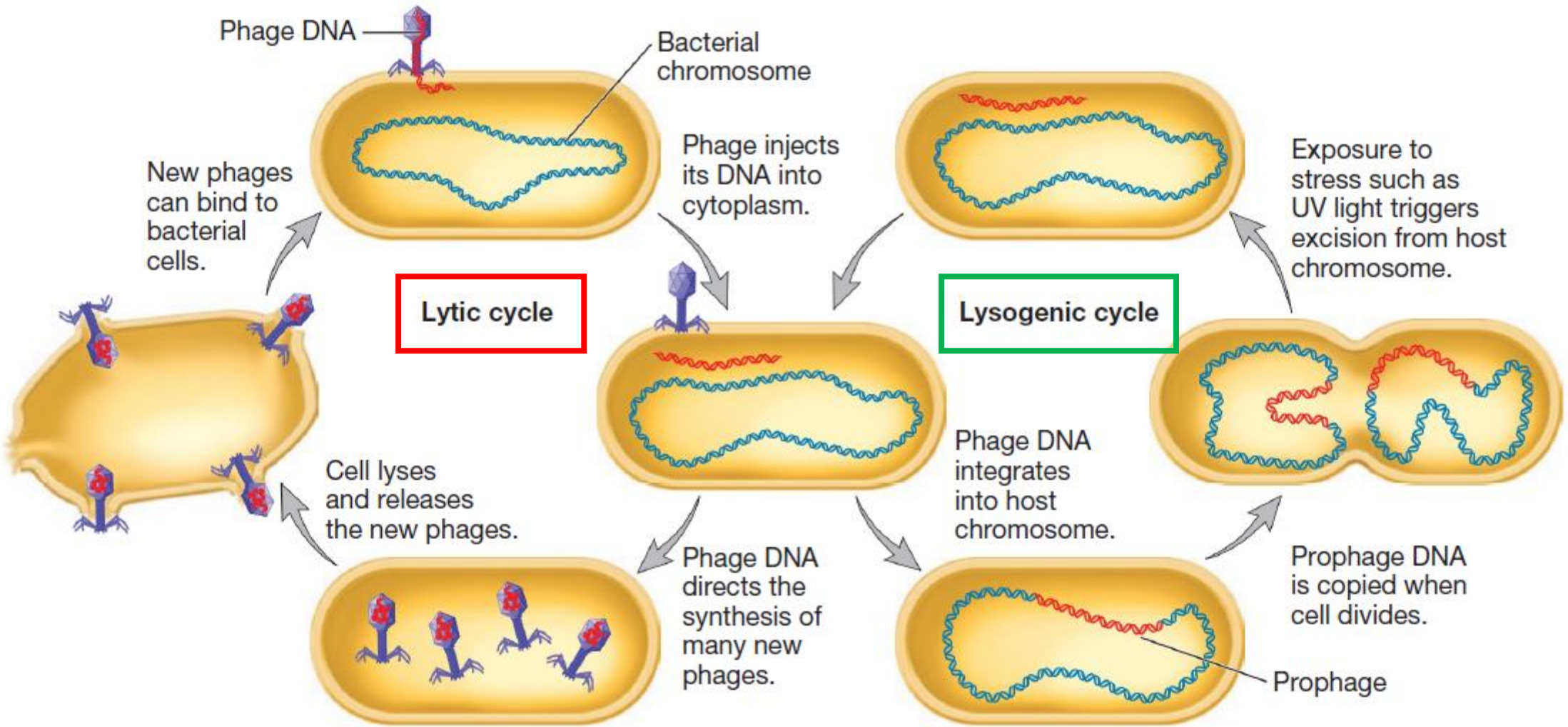
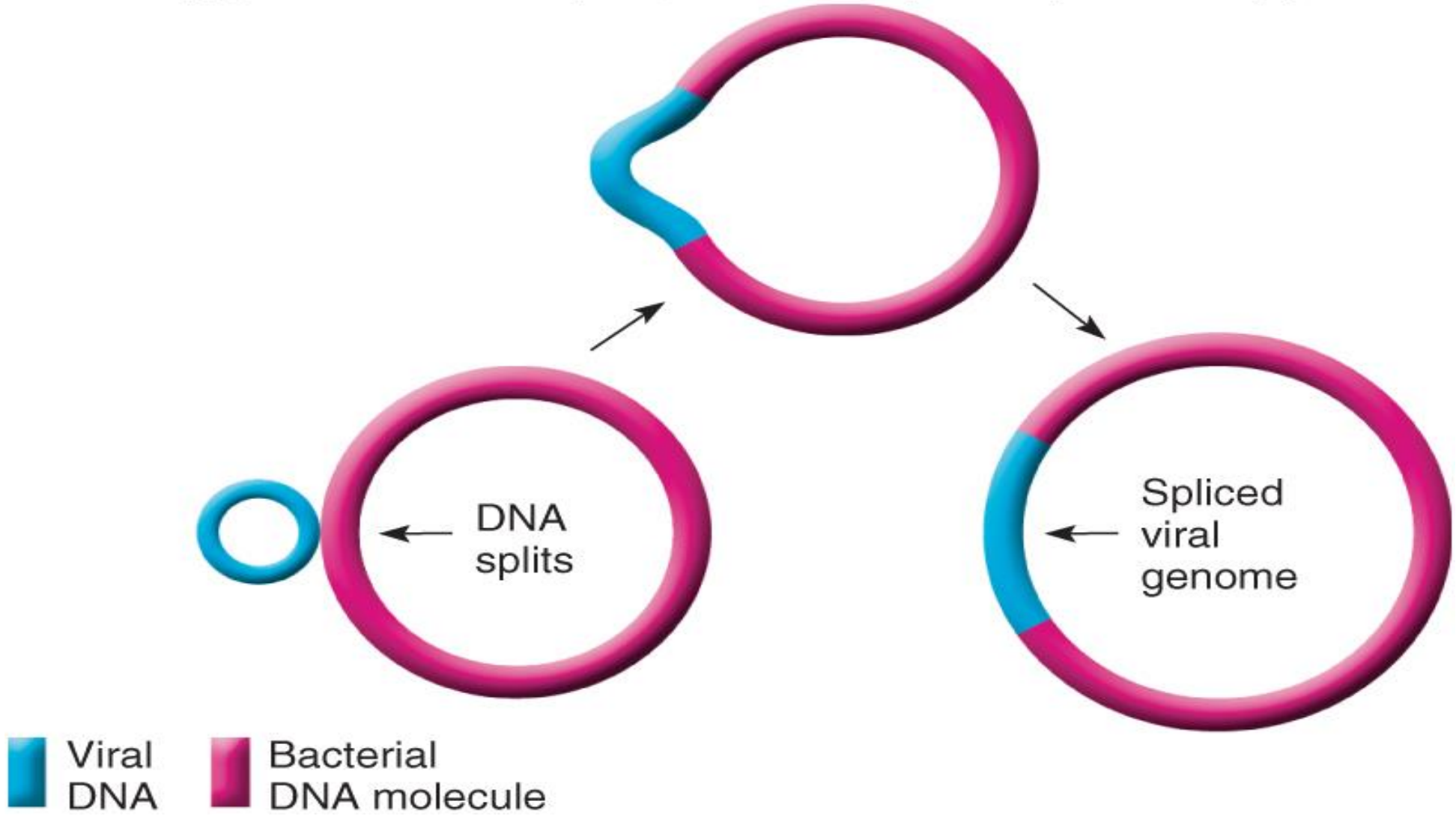


Figure 6.16 **Lytic and Lysogenic Cycles of Temperate Phages.** Temperate phages have two phases to their life cycles. The lysogenic cycle allows the genome of the virus to be replicated passively as the host cell's genome is replicated. Certain environmental factors such as UV light can cause a switch from the lysogenic cycle to the lytic cycle. In the lytic cycle, new virus particles are made and released when the host cell lyses. Virulent phages are limited to just the lytic cycle.

Lysogeny: The Silent Virus Infection



Transmission of viruses

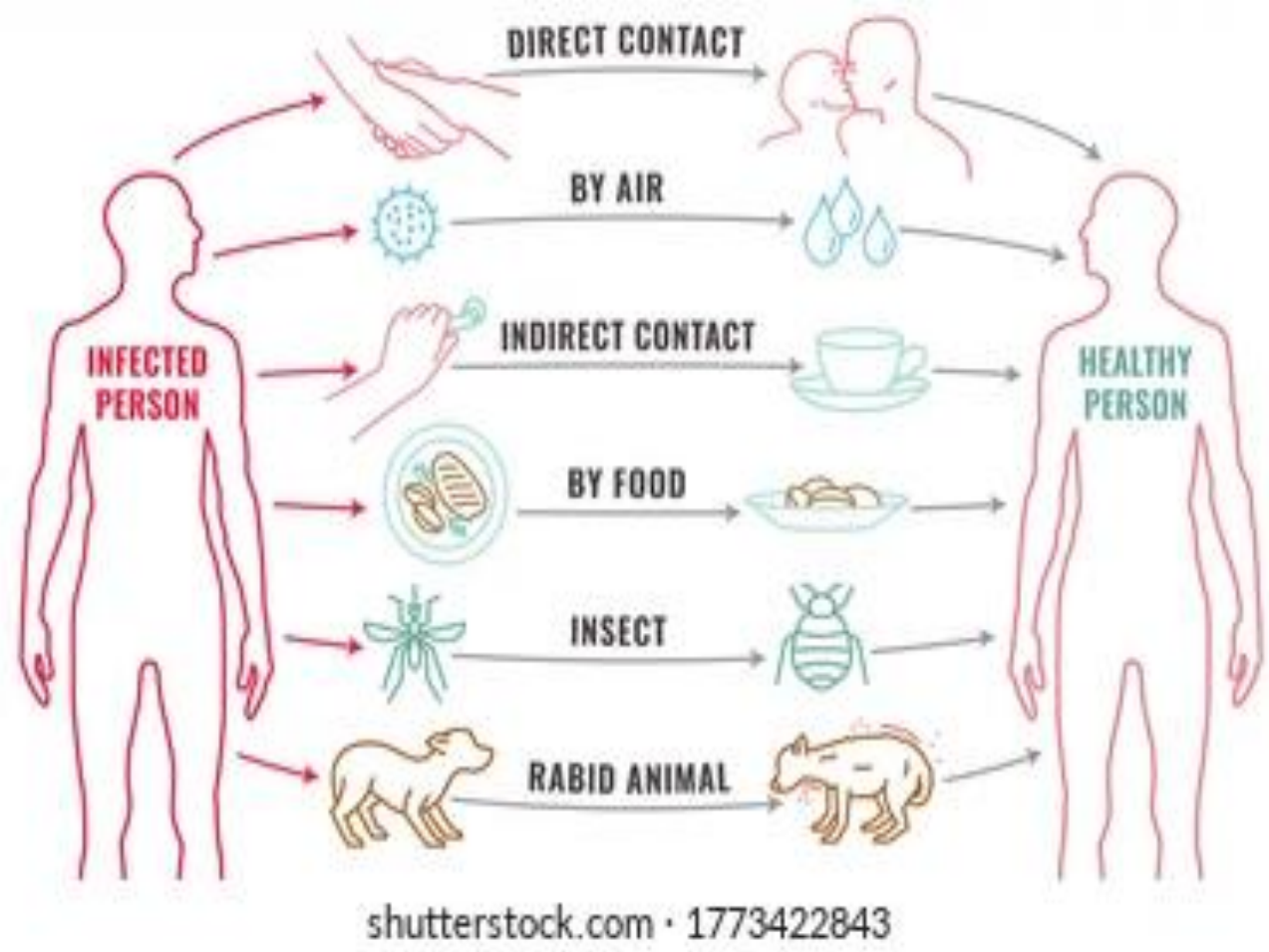
Respiratory transmission
- Influenza A virus, Coronavirus

Faecal-oral transmission
- Norovirus, Rotavirus, Hepatitis A virus

Blood-borne transmission
- Hepatitis B and C virus

Sexual Transmission
- HIV, Hepatitis B virus, Herpes simplex virus,

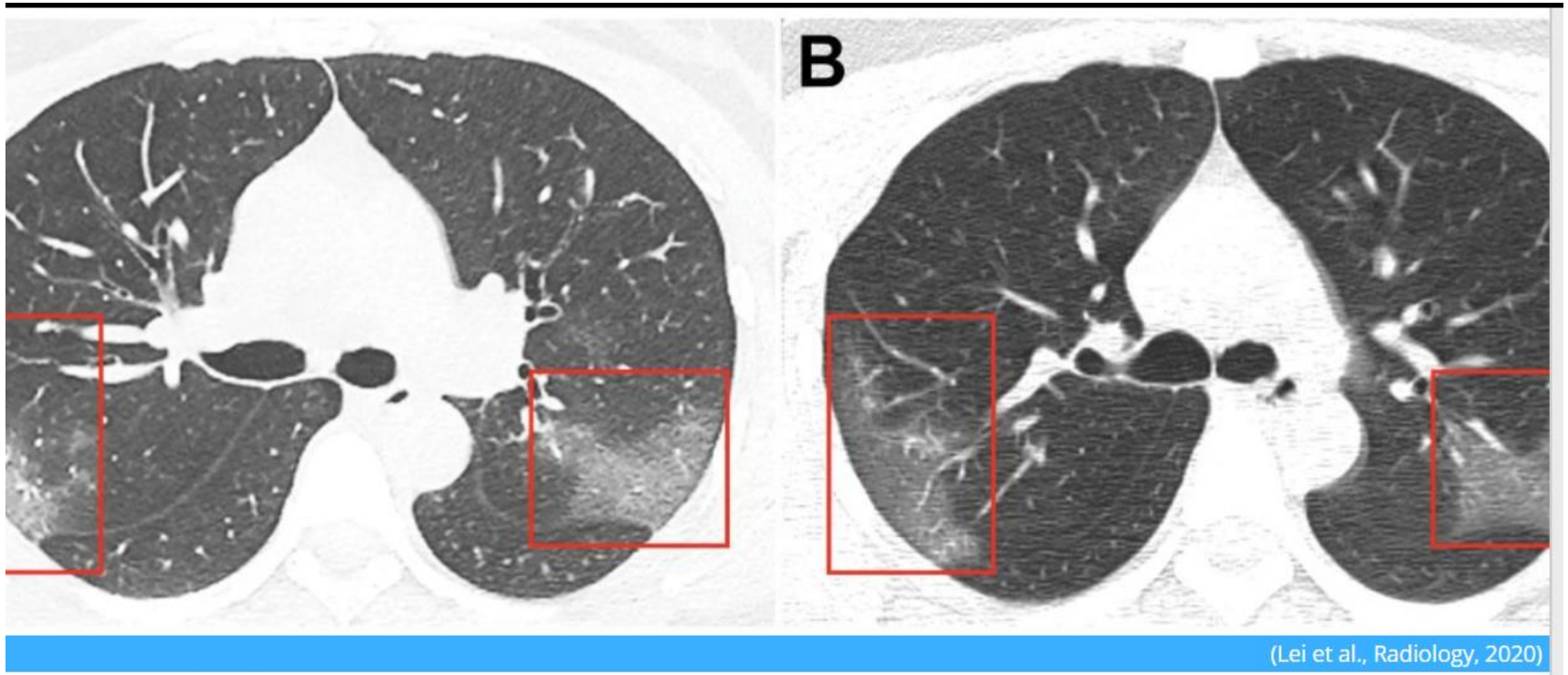
Animal or insect vectors
- Rabies virus, dengue virus, zika virus



Damage to the host cell and persistent infections

- **Cytopathic effects**- virus-induced damage to the cell that alters its microscopic appearance

- **Inclusion bodies-** compacted masses of viruses or damaged cell organelles

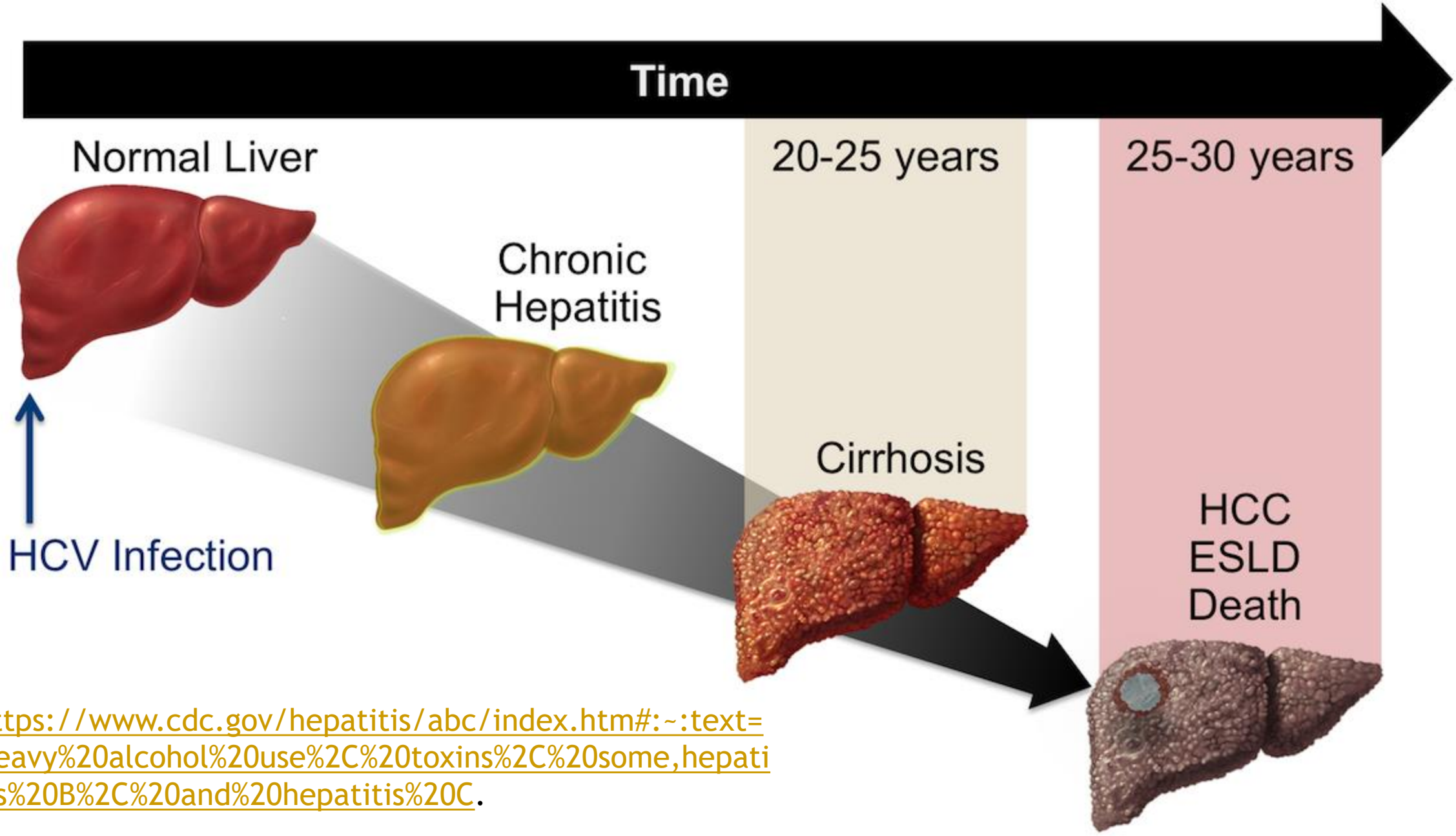


(Lei et al., Radiology, 2020)

HEALTH

Those Who Recover From Coronavirus Can Be Left With Reduced Lung Function, Say Doctors

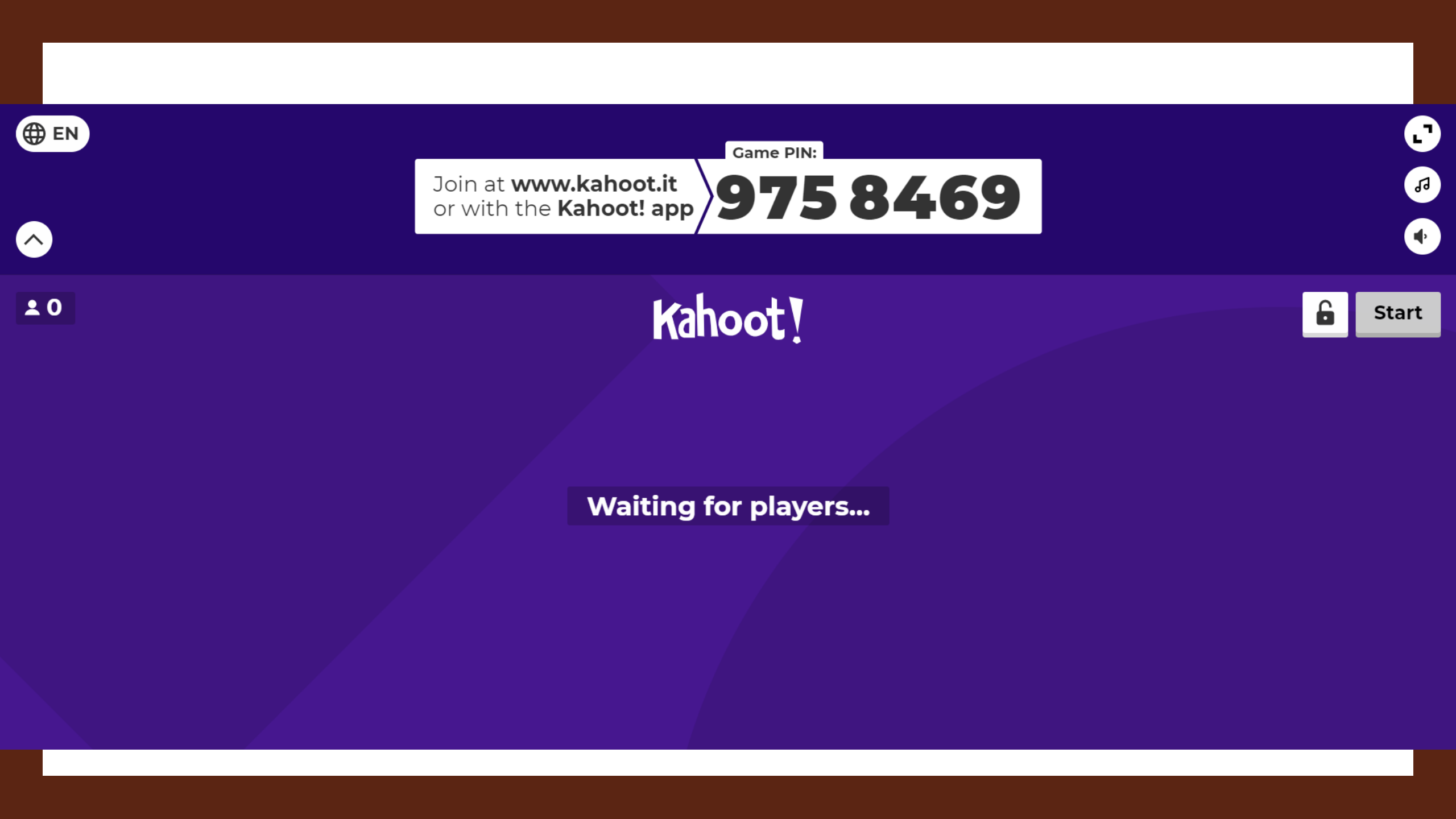
BI BILL BOSTOCK, BUSINESS INSIDER
14 MARCH 2020



https://www.cdc.gov/hepatitis/abc/index.htm#:~:text=Heavy%20alcohol%20use%2C%20toxins%2C%20some,hepatitis%20B%2C%20and%20hepatitis%20C.

Summary

- Definition of virus
- Structure of virus
- Taxonomy and classification
- DNA and RNA viruses
- Viral multiplication
- Bacteriophage T4 and Bacteriophage lambda
- Transmission of virus


EN
Game PIN:
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Start
Waiting for players...

THANK YOU