Virus

MIC 1001: General Microbiology

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Microbiology Course

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History

- The discovery of a filterable component smaller than a bacterium that causes tobacco mosaic disease (TMD) dates back to 1892.
- At that time, Dmitri Ivanovski, a Russian botanist, discovered the source of TMD by using a porcelain filtering device first invented by Charles Chamberland and Louis Pasteur in Paris in 1884.
- Porcelain Chamberland filters have a pore size of 0.1 µm, which is small enough to remove all bacteria ≥0.2 µm from any liquids passed through the device.

History

- An extract obtained from TMD-infected tobacco plants was made to determine the cause of the disease. Initially, the source of the disease was thought to be bacterial. It was surprising to everyone when Ivanovski, using a Chamberland filter, found that the cause of TMD was not removed after passing the extract through the porcelain filter. So if a bacterium was not the cause of TMD, what could be causing the disease? Ivanovski concluded the cause of TMD must be an extremely small bacterium or bacterial spore.

History

- Other scientists, including Martinus Beijerinck, continued investigating the cause of TMD. It was Beijerinck, in 1899, who eventually concluded the causative agent was not a bacterium but, instead, possibly a chemical, like a biological poison we would describe today as a toxin. As a result, the word virus, Latin for poison, was used to describe the cause of TMD a few years after Ivanovski's initial discovery. Even though he was not able to see the virus that caused TMD, and did not realize the cause was not a bacterium, Ivanovski is credited as the original discoverer of viruses and a founder of the field of virology.
- In 1935, after the development of the electron microscope, Wendell Stanley was the first scientist to crystallize the structure of the tobacco mosaic virus and discovered that it is composed of RNA and protein. In 1943, he isolated *Influenza B virus*, which contributed to the development of an influenza (flu) vaccine. Stanley's discoveries unlocked the mystery of the nature of viruses that had been puzzling scientists for over 40 years and his contributions to the field of virology led to him being awarded the Nobel Prize in 1946.

Characteristics of Viruses

- Infectious, acellular pathogens
- Obligate intracellular parasites with host and cell-type specificity
- DNA or RNA genome (never both)
- Genome is surrounded by a protein capsid and, in some cases, a phospholipid membrane studded with viral glycoproteins
- Lack genes for many products needed for successful reproduction, requiring exploitation of host-cell genomes to reproduce

Virus size

- In general, virions (viral particles) are small and cannot be observed using a regular light microscope. They are much smaller than prokaryotic and eukaryotic cells; this is an adaptation allowing viruses to infect these larger cells.
- The size of a virion can range from 20 nm for small viruses up to 900 nm for typical, large viruses. Recent discoveries, however, have identified new giant viral species, such as Pandoravirus salinus and Pithovirus sibericum, with sizes approaching that of a bacterial cell.

Naked and Enveloped Viruses

- Viruses formed from only a nucleic acid and capsid are called naked viruses or nonenveloped viruses. Capsids are made of repeat protein subunits known as capsomeres.
- Viruses formed with a nucleic-acid packed capsid surrounded by a lipid layer are called enveloped viruses. The viral envelope is a small portion of phospholipid membrane obtained as the virion buds from a host cell. The viral envelope may either be intracellular or cytoplasmic in origin.

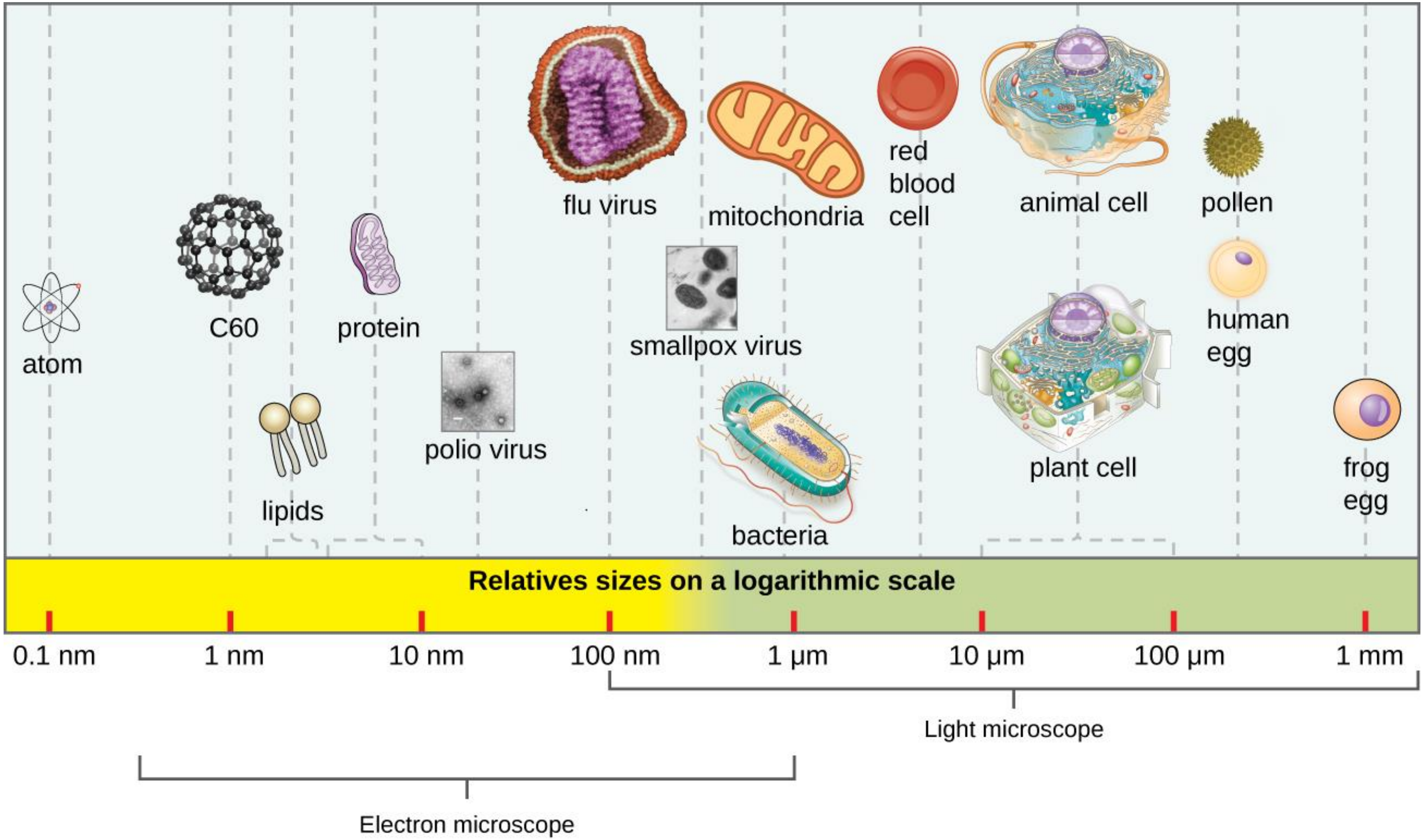

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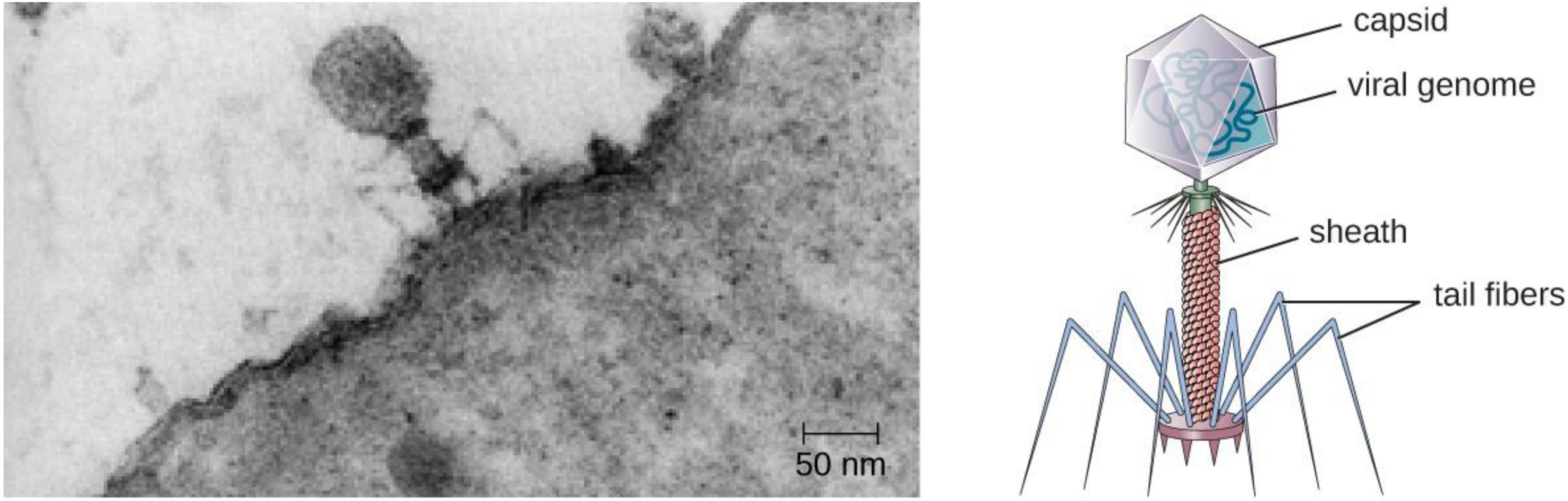
Figure 6.2 (a) Tobacco mosaic virus (TMV) viewed with transmission electron microscope. (b) Plants infected with tobacco mosaic disease (TMD), caused by TMV. (credit a: modification of work by USDA Agricultural Research Service—scale-bar data from Matt Russell; credit b: modification of work by USDA Forest Service, Department of Plant Pathology Archive North Carolina State University)

Hosts and Viral Transmission

- Viruses can infect every type of host cell, including those of plants, animals, fungi, protists, bacteria, and archaea. Most viruses will only be able to infect the cells of one or a few species of organism. This is called the host range.
- However, having a wide host range is not common and viruses will typically only infect specific hosts and only specific cell types within those hosts.
- The viruses that infect bacteria are called bacteriophages, or simply phages. The word phage comes from the Greek word for devour.
- Other viruses are just identified by their host group, such as animal or plant viruses. Once a cell is infected, the effects of the virus can vary depending on the type of virus. Viruses may cause abnormal growth of the cell or cell death, alter the cell's genome, or cause little noticeable effect in the cell.



(a) (b)

Figure 6.3 (a) In this transmission electron micrograph, a bacteriophage (a virus that infects bacteria) is dwarfed by the bacterial cell it infects. (b) An illustration of the bacteriophage in the micrograph. (credit a: modification of work by U.S. Department of Energy, Office of Science, LBL, PBD)

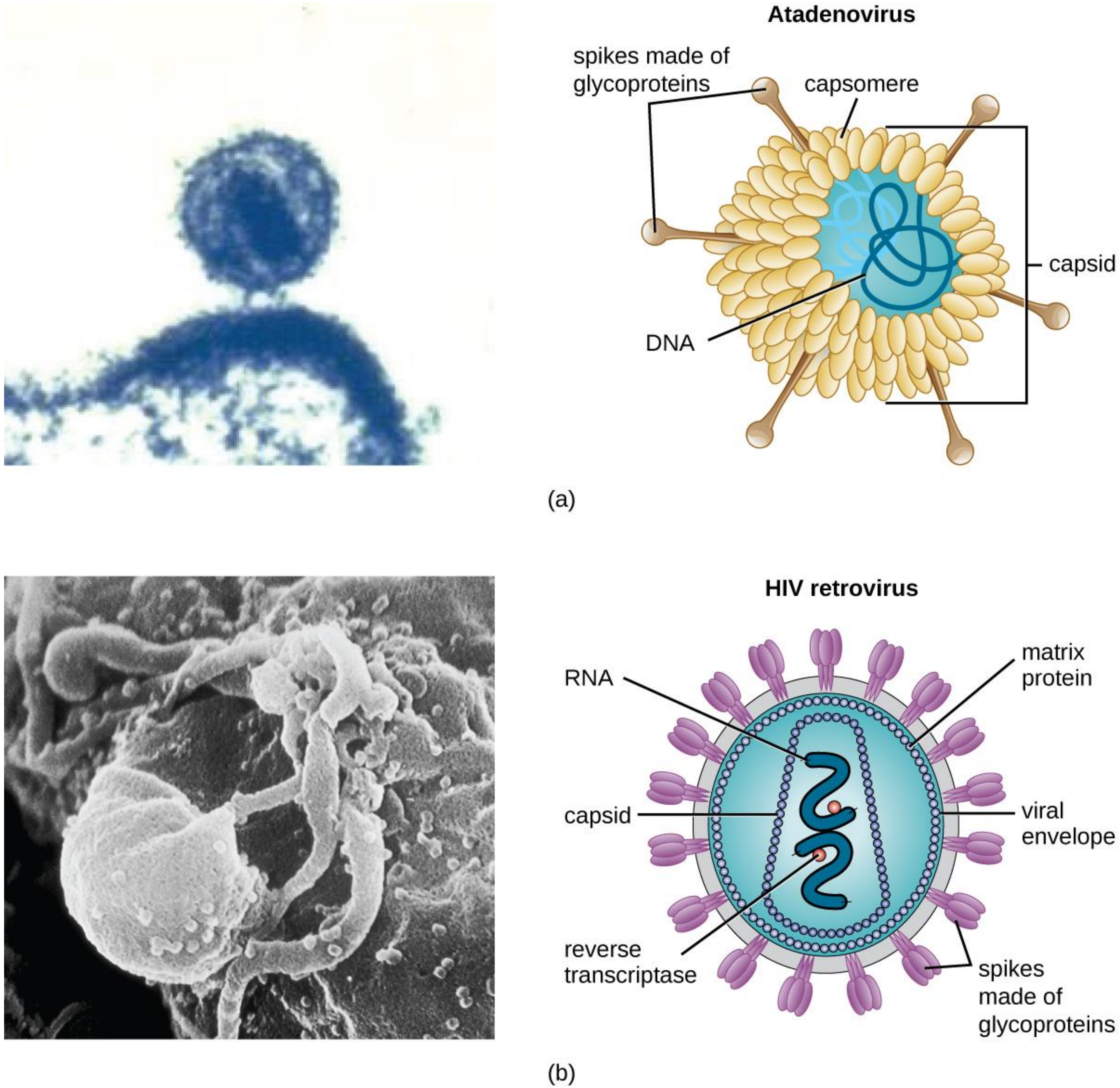


Figure 6.5 (a) The naked atadenovirus uses spikes made of glycoproteins from its capsid to bind to host cells. (b) The enveloped human immunodeficiency virus uses spikes made of glycoproteins embedded in its envelope to bind to host cells (credit a “micrograph”: modification of work by NIAID; credit b “micrograph”: modification of work by Centers for Disease Control and Prevention)

Capsid shape

- Viruses vary in the shape of their capsids, which can be either helical, polyhedral, or complex.
- A helical capsid forms the shape of tobacco mosaic virus (TMV), a naked helical virus, and Ebola virus, an enveloped helical virus. The capsid is cylindrical or rod shaped, with the genome fitting just inside the length of the capsid.
- Polyhedral capsids form the shapes of poliovirus and rhinovirus, and consist of a nucleic acid surrounded by a polyhedral (many-sided) capsid in the form of an icosahedron. An icosahedral capsid is a three-dimensional, 20-sided structure with 12 vertices. These capsids somewhat resemble a soccer ball.
- Both helical and polyhedral viruses can have envelopes. Viral shapes seen in certain types of bacteriophages, such as T4 phage, and poxviruses, like vaccinia virus, may have features of both polyhedral and helical viruses so they are described as a complex viral shape (see Figure 6.6).
- In the bacteriophage complex form, the genome is located within the polyhedral head and the sheath connects the head to the tail fibers and tail pins that help the virus attach to receptors on the host cell's surface. Poxviruses that have complex shapes are often brick shaped, with intricate surface characteristics not seen in the other categories of capsid.

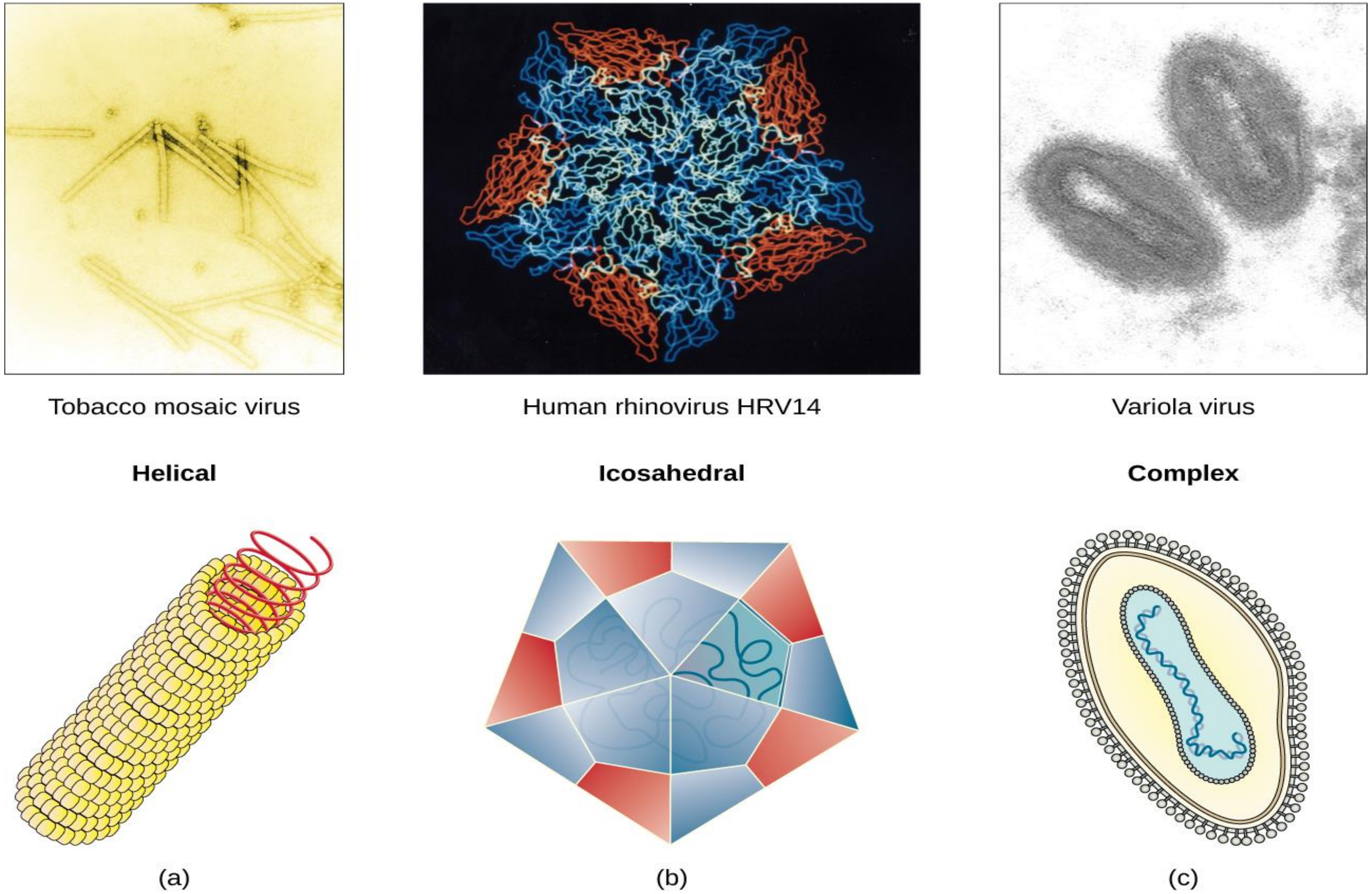


Figure 6.6 Viral capsids can be (a) helical, (b) polyhedral, or (c) have a complex shape. (credit a “micrograph”: modification of work by USDA ARS; credit b “micrograph”: modification of work by U.S. Department of Energy)

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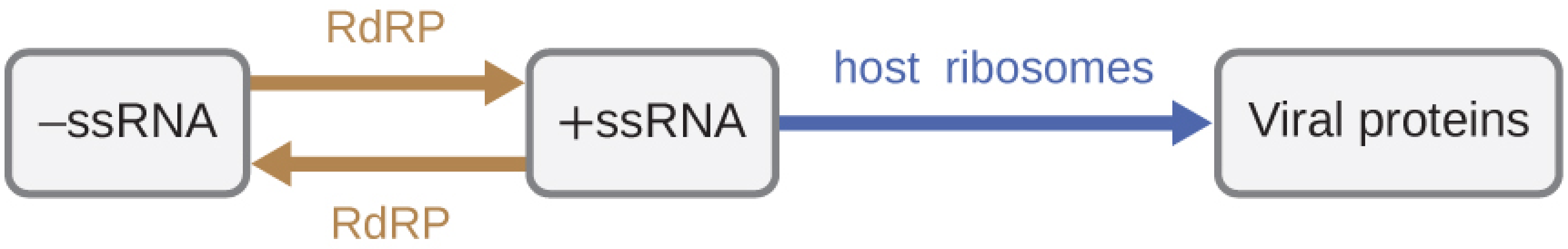
Viral Genome- RNA or DNA genome

DNA genome: ds DNA or ss DNA
RNA genome: ds RNA or +ssRNA or –ssRNA viruses



RdRP = viral RNA-dependent RNA polymerase
+ssRNA = positive (+) single strand
–ssRNA = negative (–) single-strand RNA

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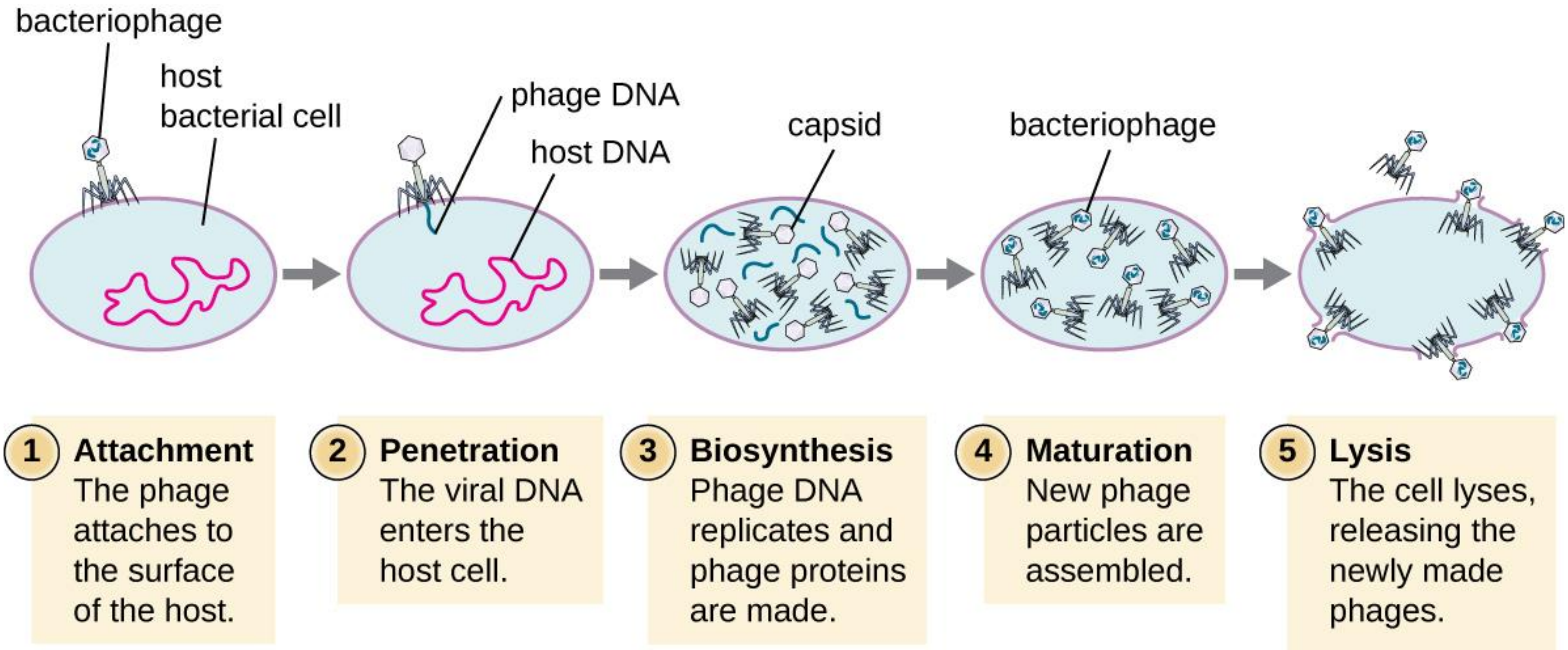
Classification and Taxonomy of Viruses

- Although viruses are not classified in the three domains of life, their numbers are great enough to require classification. Since 1971, the International Union of Microbiological Societies Virology Division has given the task of developing, refining, and maintaining a universal virus taxonomy to the International Committee on Taxonomy of Viruses (ICTV). Since viruses can mutate so quickly, it can be difficult to classify them into a genus and a species epithet using the binomial nomenclature system. Thus, the ICTV's viral nomenclature system classifies viruses into families and genera based on viral genetics, chemistry, morphology, and mechanism of multiplication. To date, the ICTV has classified known viruses in seven orders, 96 families, and 350 genera. Viral family names end in -viridae (e.g, Parvoviridae) and genus names end in −virus (e.g., Parvovirus). The names of viral orders, families, and genera are all italicized. When referring to a viral species, we often use a genus and species epithet such as Pandoravirus dulcis or Pandoravirus salinus.

- The Baltimore classification system is an alternative to ICTV nomenclature. The Baltimore system classifies viruses according to their genomes (DNA or RNA, single versus double stranded, and mode of replication). This system thus creates seven groups of viruses that have common genetics and biology.
- Categories may include naked or enveloped structure, single-stranded (ss) or double-stranded (ds) DNA or ss or ds RNA genomes, segmented or nonsegmented genomes, and positive-strand (+) or negative-strand (−) RNA. For example, herpes viruses can be classified as a dsDNA enveloped virus; human immunodeficiency virus (HIV) is a +ssRNA enveloped virus, and tobacco mosaic virus is a +ssRNA virus.

Life Cycle



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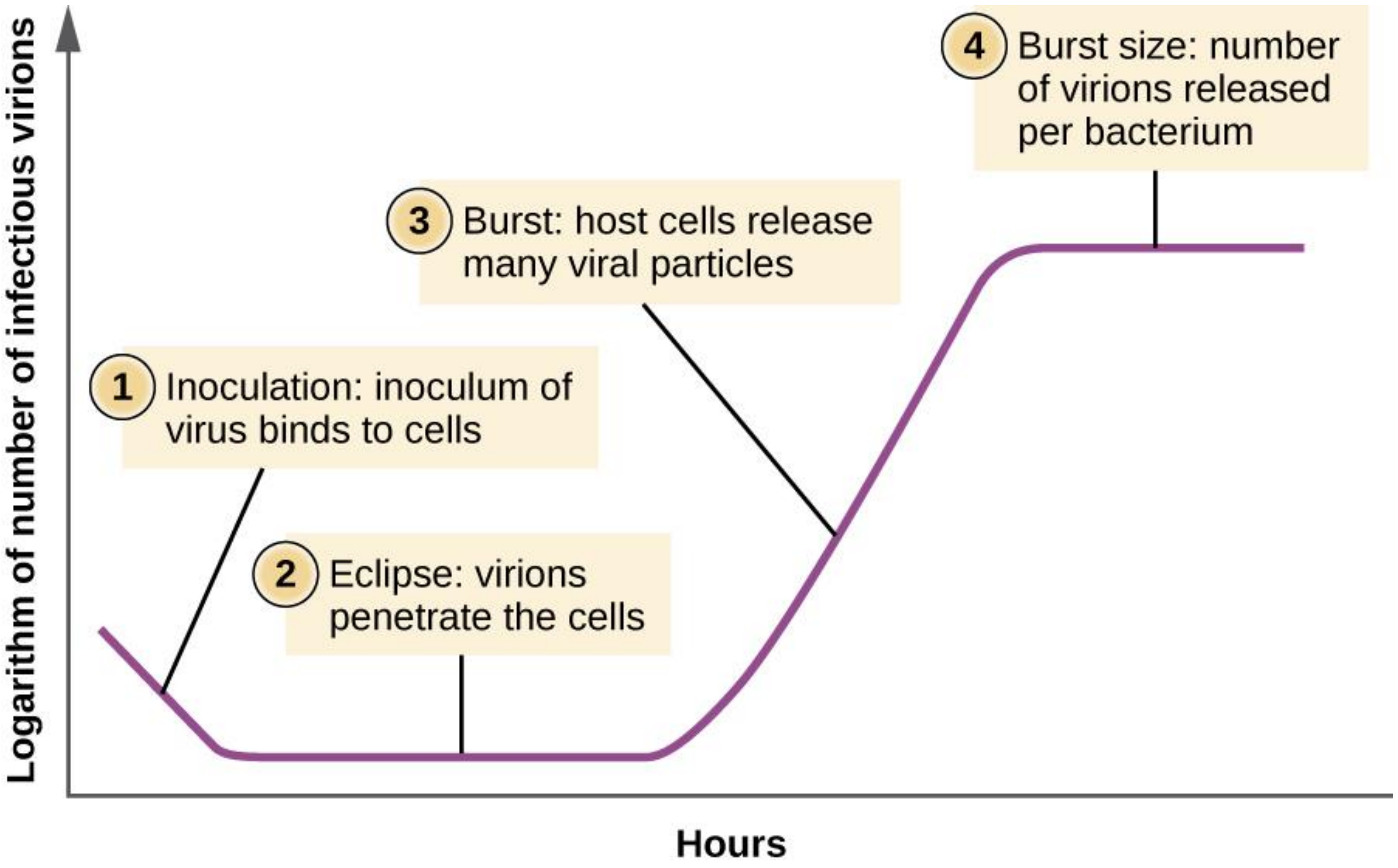
One Step Growth Curve



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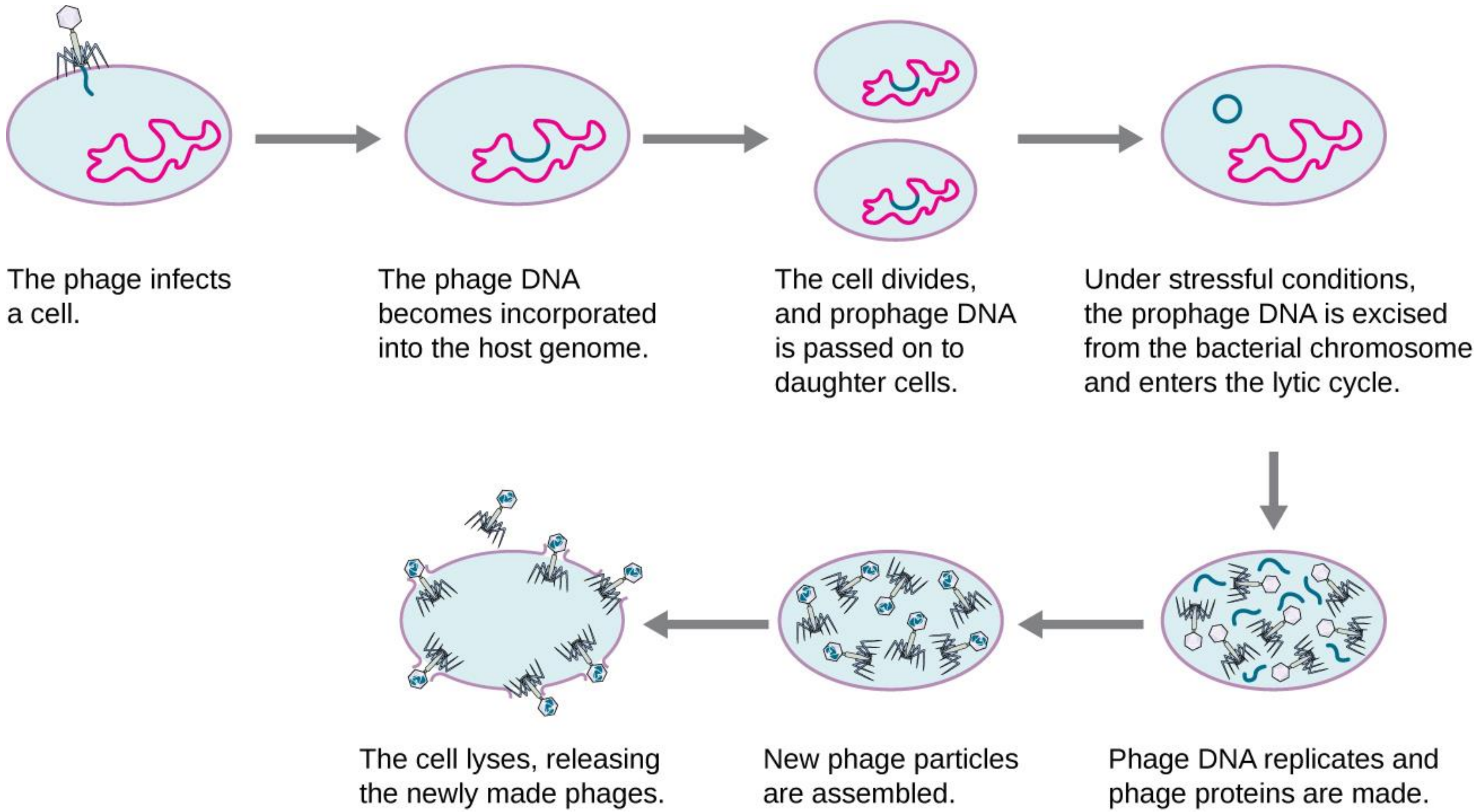
Lysogeny



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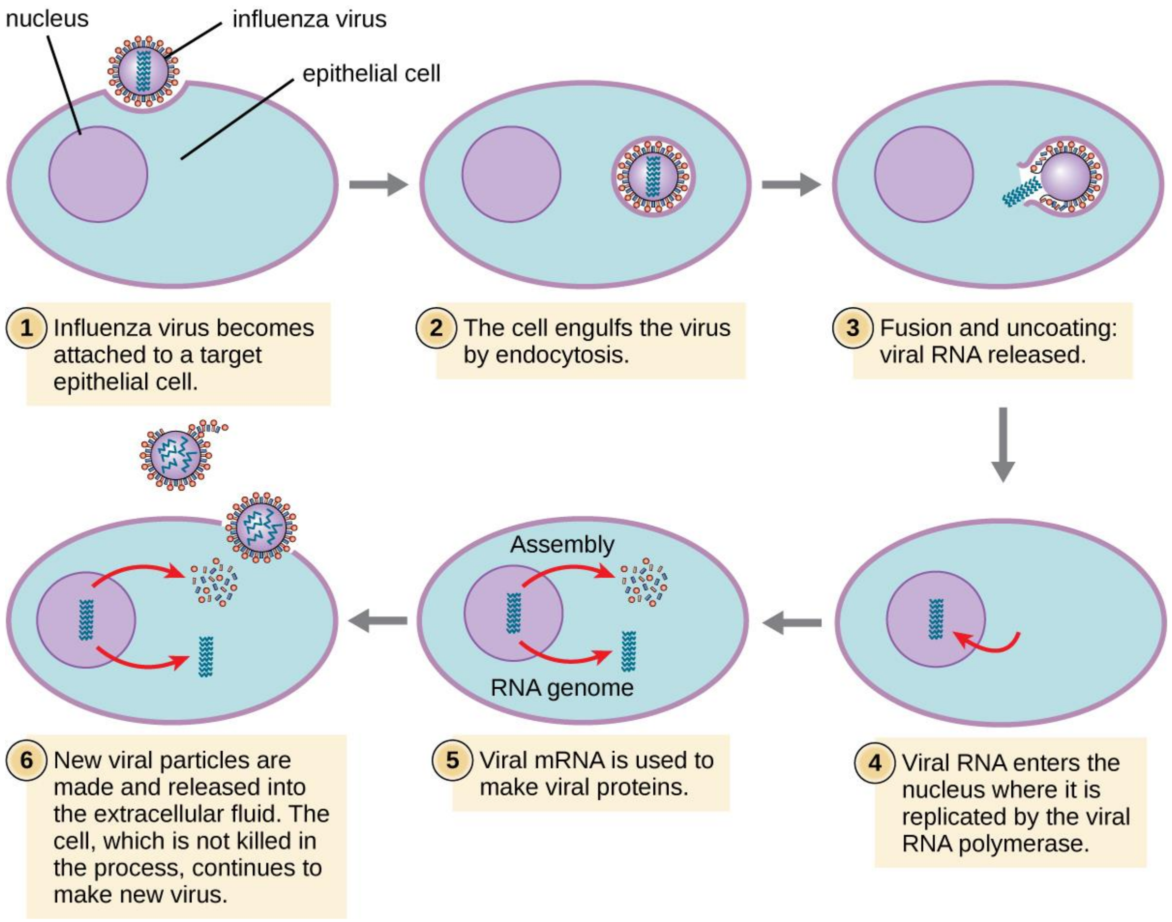
Animal Virus Life Cycle



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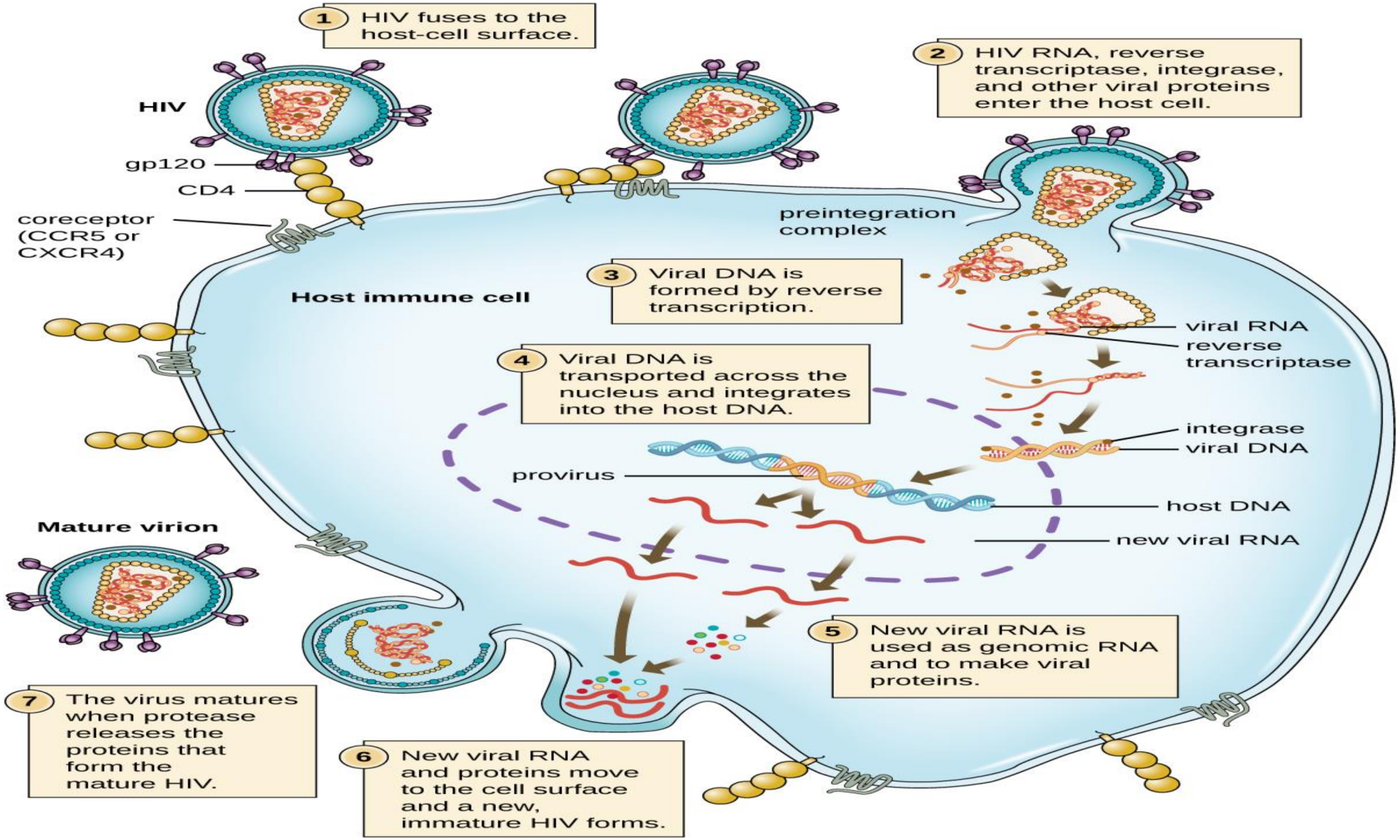
Virus Infections

- Persistent Infections
- Persistent infection occurs when a virus is not completely cleared from the system of the host but stays in certain tissues or organs of the infected person. The virus may remain silent or undergo productive infection without seriously harming or killing the host. Mechanisms of persistent infection may involve the regulation of the viral or host gene expressions or the alteration of the host immune response. The two primary categories of persistent infections are latent infection and chronic infection. Examples of viruses that cause latent infections include herpes simplex virus (oral and genital herpes), varicella-zoster virus (chickenpox and shingles), and Epstein-Barr virus (mononucleosis). Hepatitis C virus and HIV are two examples of viruses that cause long-term chronic infections.

- Latent Infection
- Not all animal viruses undergo replication by the lytic cycle. There are viruses that are capable of remaining hidden or dormant inside the cell in a process called latency. These types of viruses are known as latent viruses and may cause latent infections. Viruses capable of latency may initially cause an acute infection before becoming dormant.

Virus Infections



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Common Pathogenic Viruses

Genome	Family	Example Virus	Clinical Features
dsDNA, enveloped	*Poxviridae*	*Orthopoxvirus*	Skin papules, pustules, lesions
	Poxviridae	*Parapoxvirus*	Skin lesions
	Herpesviridae	*Simplexvirus*	Cold sores, genital herpes, sexually transmitted disease
dsDNA, naked	*Adenoviridae*	*Atadenovirus*	Respiratory infection (common cold)
	Papillomaviridae	*Papillomavirus*	Genital warts, cervical, vulvar, or vaginal cancer
	Reoviridae	*Reovirus*	Gastroenteritis severe diarrhea (stomach flu)
ssDNA, naked	*Parvoviridae*	*Adeno-associated dependoparvovirus A*	Respiratory tract infection
	Parvoviridae	*Adeno-associated dependoparvovirus B*	Respiratory tract infection
dsRNA, naked	*Reoviridae*	*Rotavirus*	Gastroenteritis
+ssRNA, naked	*Picornaviridae*	*Enterovirus C*	Poliomyelitis
	Picornaviridae	*Rhinovirus*	Upper respiratory tract infection (common cold)
	Picornaviridae	*Hepatovirus*	Hepatitis
+ssRNA, enveloped	*Togaviridae*	*Alphavirus*	Encephalitis, hemorrhagic fever
	Togaviridae	*Rubivirus*	Rubella
	Retroviridae	*Lentivirus*	Acquired immune deficiency syndrome (AIDS)
−ssRNA, enveloped	*Filoviridae*	*Zaire Ebolavirus*	Hemorrhagic fever
	Orthomyxoviridae	*Influenzavirus A, B, C*	Flu
	Rhabdoviridae	*Lyssavirus*	Rabies

Reference

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