Medical Virology for 2nd Year M.D. Students

General Properties of Viruses

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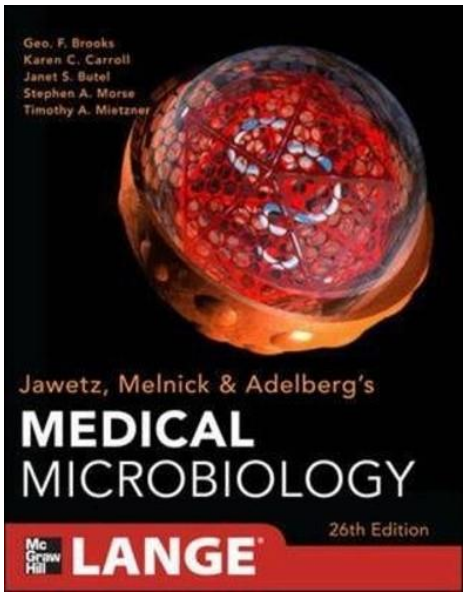
Introduction

References

- Jawetz, Melnick & Adelberg's Medical Microbiology. 26th edition. New York : London: McGraw-Hill Medical ; McGraw-Hill, 2013.
- Recent original and review articles in high impact and well renowned scientific journals



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General properties of viruses

- The smallest infectious agents.
- They contain only one kind of nucleic acid.
- The entire infectious unit is termed a virion.
- The universe of viruses is rich in diversity.

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Terms and definitions in Virology

- **Virion:** The complete virus particle.
- **Envelope:** A lipid-containing membrane that surrounds some viruses.
- **Capsid:** The protein coat that encloses the viral genome.
- **Capsomeres:** Morphologic units seen in the electron microscope on the surface of icosahedral viruses.
- **Defective virus:** A virus particle that is functionally deficient in some aspect of replication.

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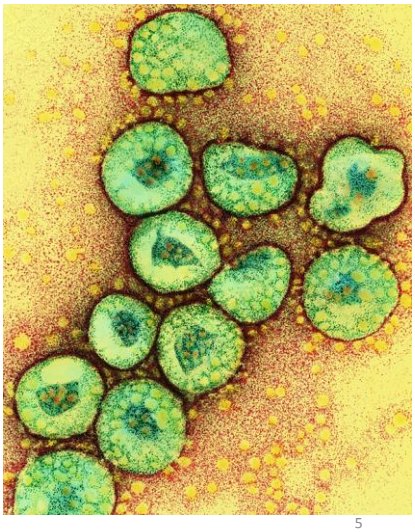
Terms and definitions in Virology

- **Peplomers:** Virus-encoded glycoproteins that are projected from the envelope.
- **Nucleocapsid:** The protein–nucleic acid complex.
- **Subunit:** A single folded viral polypeptide chain.
- **Structural units:** The basic protein building blocks of the coat. They are usually a collection of more than one non-identical protein subunit. The structural unit is often referred to as a protomer.



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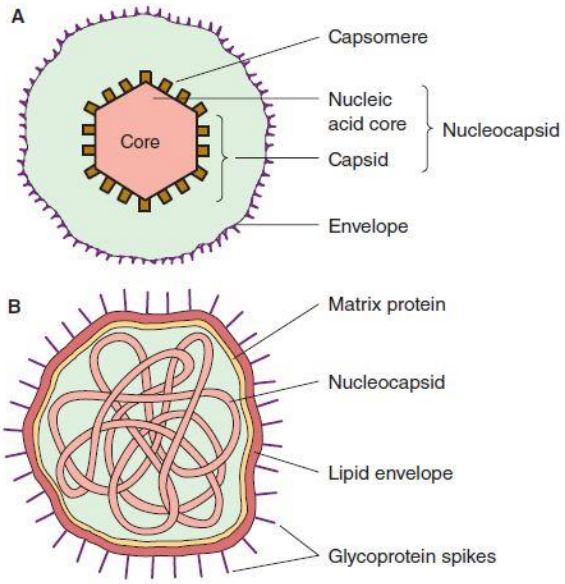
Terms and definitions in Virology



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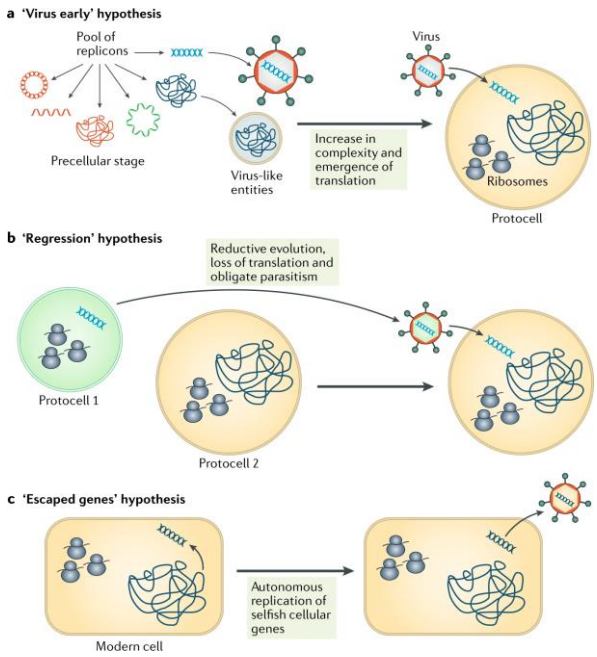
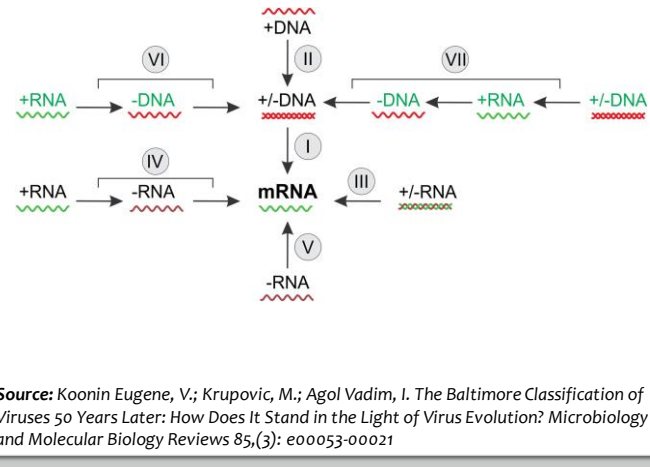
Evolutionary origin of viruses



Source: *Krupovic M, Dolja VV, Koonin EV. Origin of viruses: primordial replicators recruiting capsids from hosts. Nat Rev Microbiol. 2019 Jul;17(7):449-458*

Virus Classification

- Virion morphology (size, shape, symmetry, etc.)
- Virus genome properties
- Genome organization and replication
- Virus protein properties
- Antigenic properties
- Physicochemical properties of the virion (T, pH, ether, etc.)
- Biologic properties



Source: *Koonin Eugene, V.; Krupovic, M.; Agol Vadim, I. The Baltimore Classification of Viruses 50 Years Later: How Does It Stand in the Light of Virus Evolution? Microbiology and Molecular Biology Reviews 85,(3): e00053-00021*

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Universal System of Virus Taxonomy

TABLE 29-1 Families of Animal Viruses that Contain Members Able to Infect Humans

Nucleic Acid Core	Capsid Symmetry	Virion: Enveloped or Naked	Ether Sensitivity	Number of Capsomeres	Virus Particle Size (nm)[a]	Size of Nucleic Acid in Virion (kb/kbp)	Physical Type of Nucleic Acid[b]	Virus Family
DNA	Icosahedral	Naked	Resistant	32	18–26	5.6	ss	Parvoviridae
					30	2.0–3.9	ss circular	Anelloviridae
				72	45	5	ds circular	Polyomaviridae
				72	55	8	ds circular	Papillomaviridae
				252	70–90	26–45	ds	Adenoviridae
		Enveloped	Sensitive	180	40–48	3.2	ds circular[c]	Hepadnaviridae
				162	150–200	125–240	ds	Herpesviridae
	Complex	Complex coats	Resistant[d]		230 × 400	130–375	ds	Poxviridae
RNA	Icosahedral	Naked	Resistant	32	28–30	7.2–8.4	ss	Picornaviridae
					28–30	6.4–7.4	ss	Astroviridae
				32	27–40	7.4–8.3	ss	Caliciviridae
					27–34	7.2	ss	Hepeviridae
					35–40	4	ds segmented	Picobirnaviridae
					60–80	16–27	ds segmented	Reoviridae
		Enveloped	Sensitive	42	50–70	9.7–11.8	ss	Togaviridae
	Unknown or complex	Enveloped	Sensitive		40–60	9.5–12.5	ss	Flaviviridae
					50–300	10–14	ss segmented	Arenaviridae
					120–160	27–32	ss	Coronaviridae
					80–110	7–11[e]	ss diploid	Retroviridae
	Helical	Enveloped	Sensitive		80–120	10–13.6	ss segmented	Orthomyxoviridae
					80–120	11–21	ss segmented	Bunyaviridae
					80–125	8.5–10.5	ss	Bornaviridae
					75 × 180	13–16	ss	Rhabdoviridae
					150–300	16–20	ss	Paramyxoviridae
					80 × 1000[f]	19.1	ss	Filoviridae

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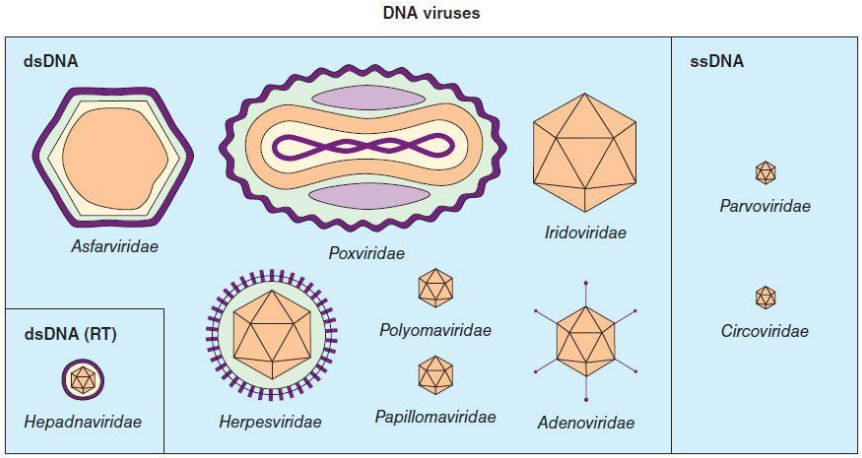
Shapes and relative sizes of animal DNA viruses of families that infect vertebrates



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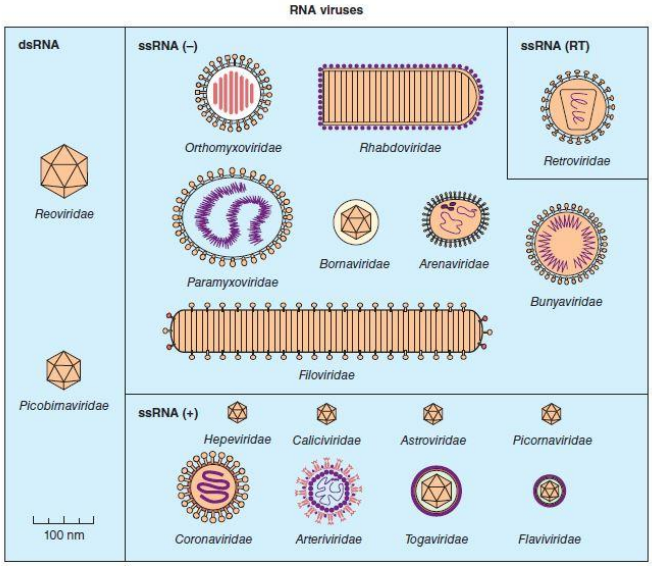
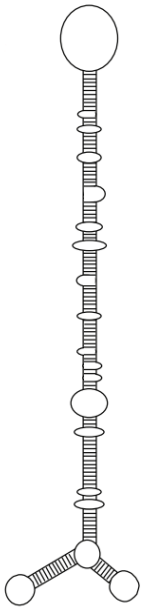
Shapes and relative sizes of animal RNA viruses of families that infect vertebrates



Other infectious agents

- **Viroids:** Small infectious agents that cause diseases of plants. They are composed of ss, ccc-RNA consisting of about 360 nucleotides and with a highly base-paired rod-like structure. Viroids replicate by an entirely novel mechanism.
- Viroid RNA does not encode any protein products and the devastating plant diseases induced by viroids occur by an unknown mechanism.
- To date, viroids have been detected only in plants; none have been demonstrated to exist in animals or humans.



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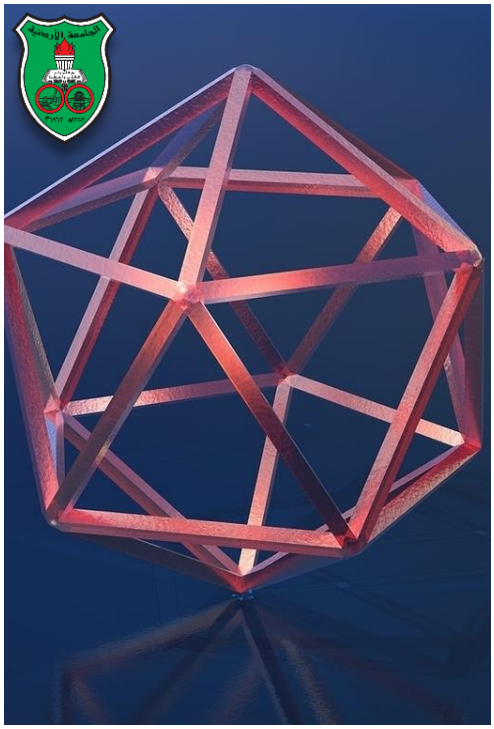
Other infectious agents

- **Prions:** infectious particles composed of protein with no detectable nucleic acid.
- They are highly resistant to inactivation by heat, formaldehyde, and ultraviolet light that inactivate viruses.
- The prion protein is encoded by a single cellular gene.
- Prion diseases, called "transmissible spongiform encephalopathies," include scrapie in sheep, mad cow disease in cattle, and kuru and Creutzfeldt-Jakob disease in humans.



Types of Symmetry of Virus Particles

- Methods used for fine resolution of the basic virus morphology include: EM, cryo-EM, and x-ray diffraction techniques.
- All cubic symmetry observed with animal viruses is of the icosahedral pattern, the most efficient arrangement for subunits in a closed shell.
- The **icosahedron** has 20 faces (each an equilateral triangle), 12 vertices, and fivefold, threefold, and twofold axes of rotational symmetry. The vertex units have five neighbors (pentavalent), and all others have six (hexavalent).

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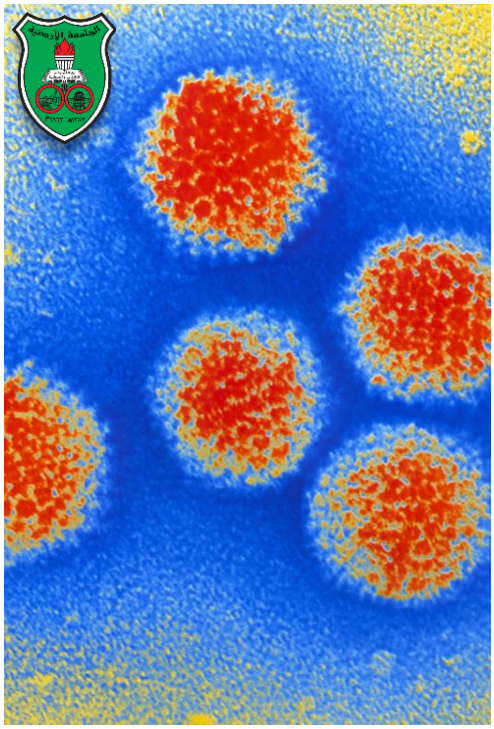

Icosahedral Symmetry

- There are exactly 60 identical subunits on the surface of an icosahedron.
- To build a particle size adequate to encapsidate viral genomes, viral shells are composed of multiples of 60 structural units.
- The use of larger numbers of chemically identical protein subunits, while maintaining the rules of icosahedral symmetry, is accomplished by sub-triangulation of each face of an icosahedron.
- Most viruses that have icosahedral symmetry show the physical appearance of a sphere rather than an icosahedron.

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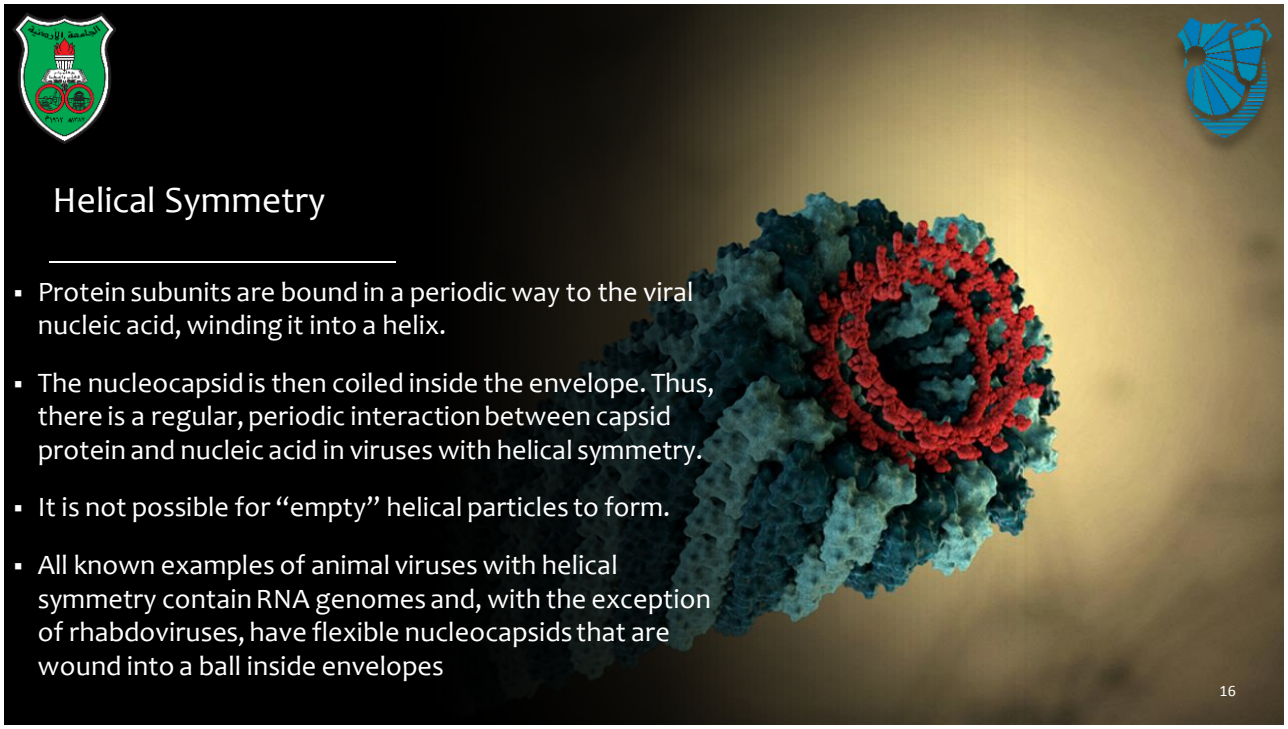
Helical Symmetry
Protein subunits are bound in a periodic way to the viral nucleic acid, winding it into a helix.
The nucleocapsid is then coiled inside the envelope. Thus, there is a regular, periodic interaction between capsid protein and nucleic acid in viruses with helical symmetry.
It is not possible for "empty" helical particles to form.
All known examples of animal viruses with helical symmetry contain RNA genomes and, with the exception of rhabdoviruses, have flexible nucleocapsids that are wound into a ball inside envelopes
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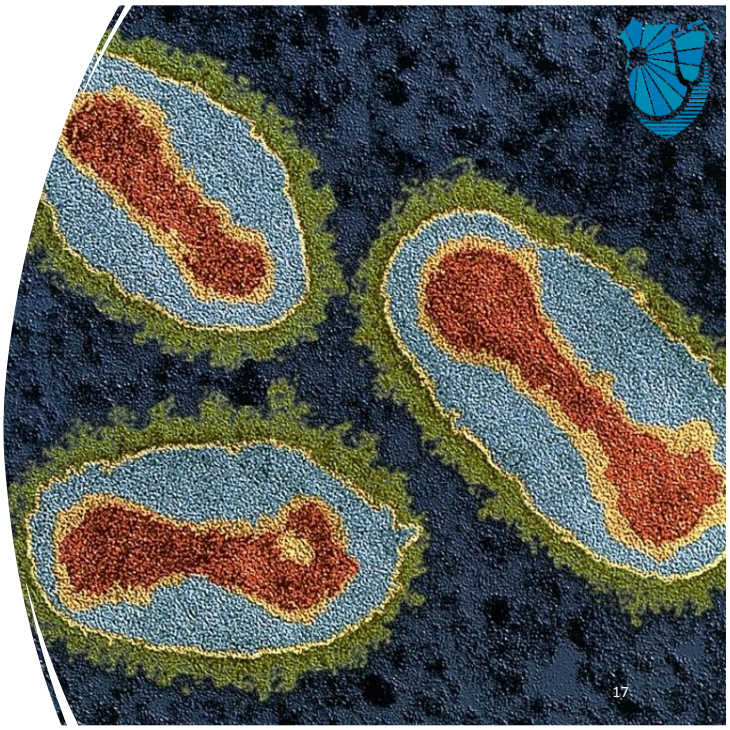
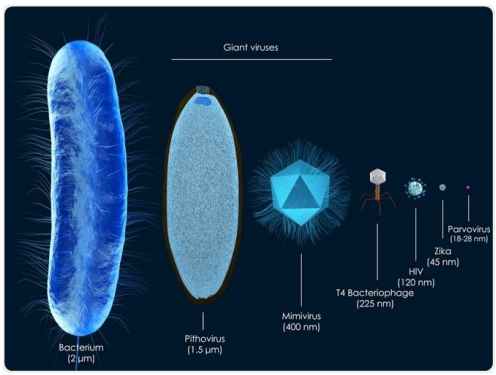
Complex Symmetry

- Some virus particles do not exhibit simple cubic or helical symmetry but are more complicated in structure.
- For example, poxviruses are brick shaped, with ridges on the external surface and a core and lateral bodies inside.



Measuring the Sizes of Viruses

- Direct observation in the electron microscope is the most widely used method for estimating particle size.
- For comparisons, *Staphylococcus* species have a diameter of about 1000 nm (1 µm). (2) Bacterial viruses (bacteriophages) vary in size (10–100 nm). Some are spherical or hexagonal and have short or long tails. (3) Representative protein molecules range in diameter from serum albumin (5 nm) and globulin (7 nm) to certain hemocyanins (23 nm). (4) Eukaryotic ribosomes are about 25–30 nm in size, with mitochondria being much larger (1–10 µm). (5) Red blood cells are about 6–8 µm in diameter. (6) The width of a human hair is about 100 µm.



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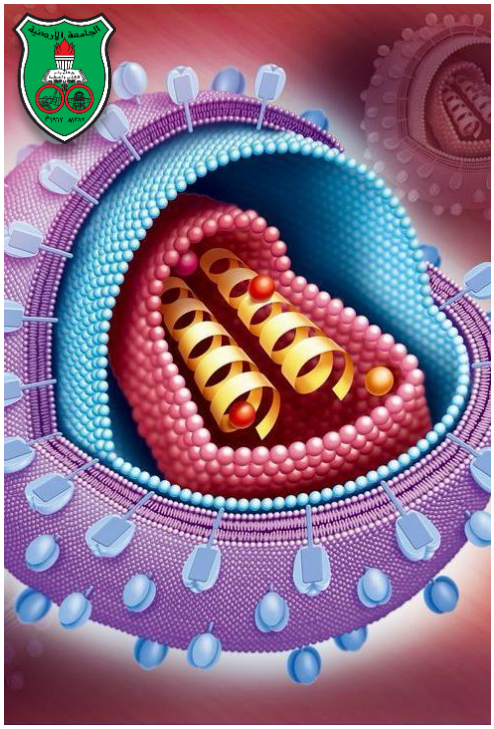

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Chemical composition of viruses

- The structural proteins of viruses facilitate transfer of the viral nucleic acid from one host cell to another, protect viral genome against inactivation by nucleases, and participate in the attachment of the virus particle to a susceptible cell.
- The proteins determine the antigenic characteristics of the virus.
- Some viruses carry enzymes (which are proteins) inside the virions. The enzymes are present in very small amounts and are essential for the initiation of the viral replicative cycle when the virion enters a host cell. Examples include an RNA polymerase carried by viruses with negative-sense RNA genomes

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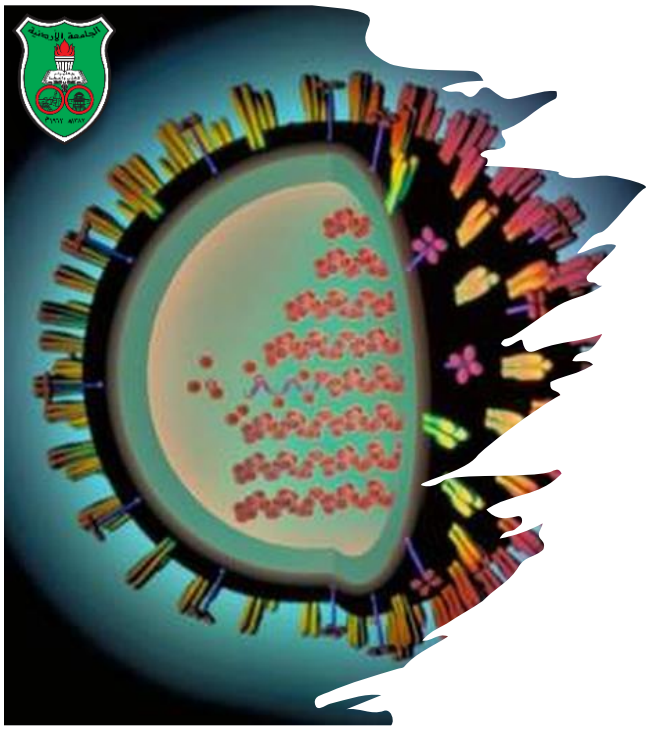

Chemical composition of viruses

- Viral genome may be ss or ds, circular or linear, and segmented or non-segmented.
- For DNA viruses, genome size ranges from 3.2 kb (hepadnaviruses) to 375 kb (poxviruses). The size of the viral RNA genome ranges from 4 kb (picobirnaviruses) to 32 kb (coronaviruses).
- The RNA may be a single linear molecule (e.g., picornaviruses). For other viruses (e.g., orthomyxoviruses), the genome consists of several segments of RNA. The isolated RNA of viruses with +sense genomes (i.e., picornaviruses, togaviruses) is infectious, and the molecule functions as an mRNA within the infected cell. The isolated RNA of the -s RNA viruses, such as rhabdoviruses and orthomyxoviruses, is not infectious.

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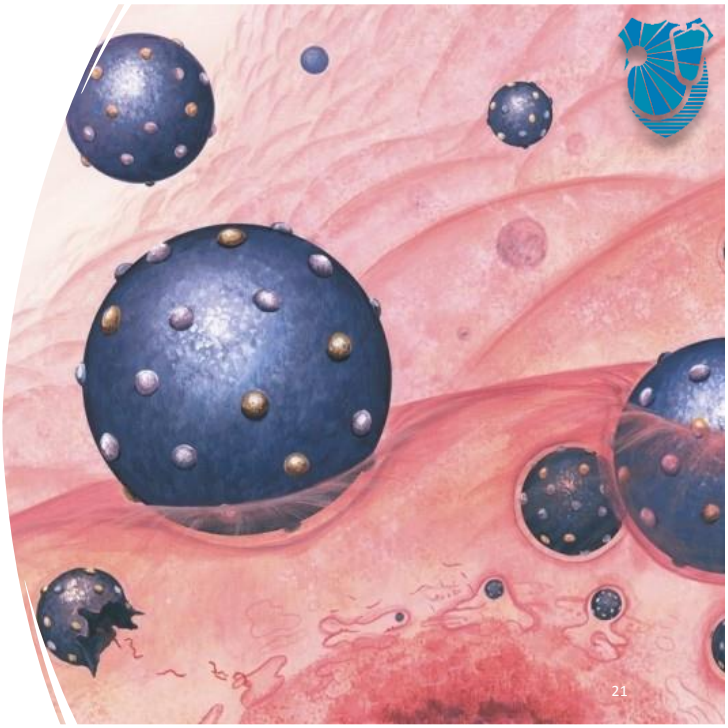
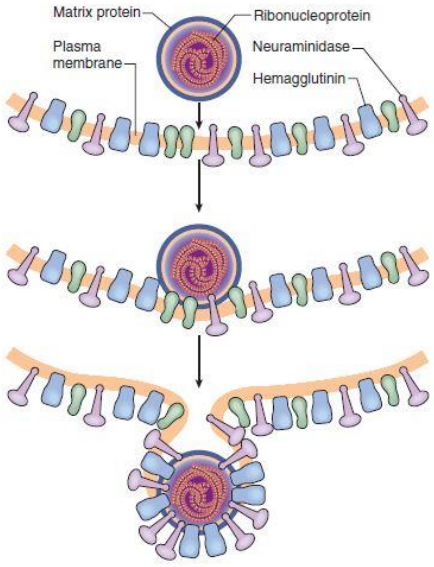
Chemical composition of viruses

- A number of different viruses contain lipid envelopes as part of their structure.
- There are always viral glycosylated proteins protruding from the envelope and exposed on the external surface of the virus particle.
- Lipid-containing viruses are sensitive to treatment with ether and other organic solvents, indicating that disruption or loss of lipid results in loss of infectivity.
- Non-lipid-containing viruses are generally resistant to ether.



Chemical composition of viruses

- In contrast to the lipids in viral membranes, which are derived from the host cell, the envelope glycoproteins are virus encoded.
- However, the sugars added to viral glycoproteins often reflect the host cell in which the virus is grown.



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Cultivation and assay of viruses

- Cells grown in vitro are central to the cultivation and characterization of viruses.
- Primary cultures are made by dispersing cells (usually with trypsin) from freshly removed host tissues, and they are unable to grow for more than a few passages.
- Diploid cell lines are secondary cultures that have undergone a change that allows their limited culture (up to 50 passages) but that retain their normal chromosome pattern.
- Continuous cell lines are cultures capable of more prolonged—perhaps indefinite—growth that have been derived from diploid cell lines or from malignant tissues. They invariably have altered and irregular numbers of chromosomes. The type of cell culture used for viral cultivation depends on the sensitivity of the cells to a particular virus.

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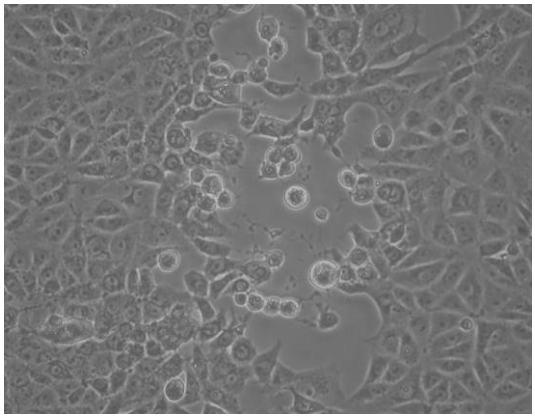
Cultivation and assay of viruses

Multiplication of a virus can be monitored in a variety of ways:

1. Development of cytopathic effects (i.e., morphologic changes in the cells). Types of virus-induced cytopathic effects include cell lysis or necrosis, inclusion formation, giant cell formation, and cytoplasmic vacuolization. Most viruses produce some obvious cytopathic effect in infected cells.

2. Appearance of a virus-encoded protein, such as the hemagglutinin of influenza virus. Specific antisera can be used to detect the synthesis of viral proteins in infected cells.



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Cultivation and assay of viruses

3. Detection of virus-specific nucleic acid. Molecular-based assays such as polymerase chain reaction provide rapid, sensitive, and specific methods of detection.

4. Adsorption of erythrocytes to infected cells, called hemadsorption, caused by the presence of virus-encoded hemagglutinin (parainfluenza, influenza) in cellular membranes.

5. Viral growth in an embryonated chick egg may result in death of the embryo (e.g., encephalitis viruses), production of pocks or plaques on the chorioallantoic membrane (e.g., herpes, smallpox, vaccinia), or development of hemagglutinins in the embryonic fluids or tissues (e.g., influenza).

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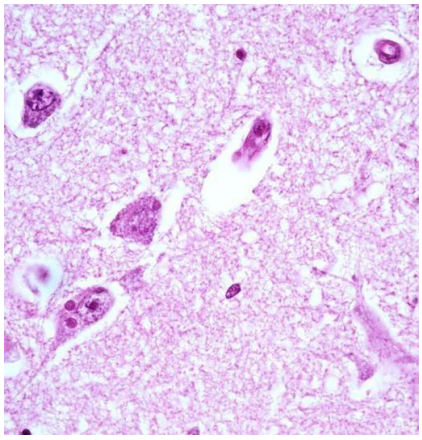
Cultivation and assay of viruses

In the course of viral multiplication within cells, virus-specific structures called inclusion bodies may be produced. They become far larger than the individual virus particle and often have an affinity for acid dyes (e.g., eosin). They may be situated in the nucleus (herpesvirus), in the cytoplasm (poxvirus), or in both (measles virus). In many viral infections, the inclusion bodies are the site of development of the virions (the viral factories).

Variations in the appearance of inclusion material depend largely on the tissue fixative used. The presence of inclusion bodies may be of considerable diagnostic aid. The intracytoplasmic inclusion in nerve cells—the Negri body—is pathognomonic for rabies.



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Quantitation of Viruses

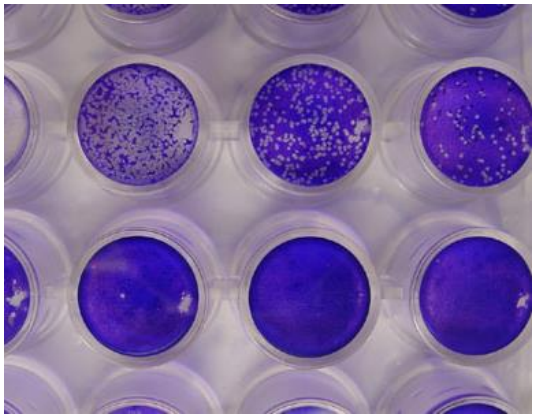
A. Physical Methods:

PCR, RIA, EIA, Agglutination/hemagglutination

B. Biologic methods:

End-point biologic assays depend on the measurement of animal death, animal infection, or cytopathic effects in tissue culture at a series of dilutions of the virus being tested.

The titer is expressed as the 50% infectious dose (ID50), which is the reciprocal of the dilution of virus that produces the effect in 50% of the cells or animals inoculated (Plaque assay, IFA).



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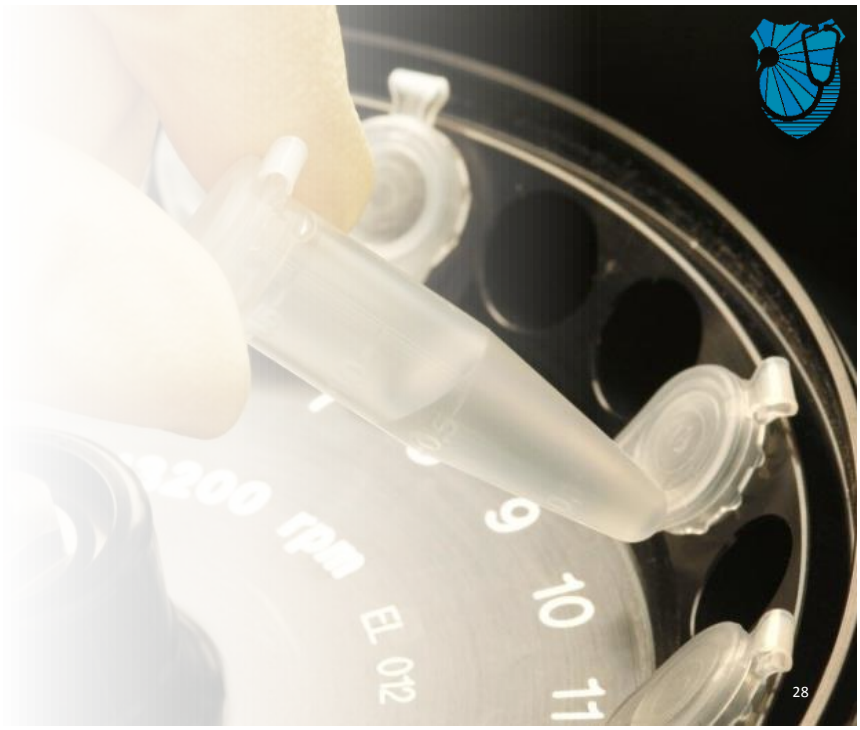
Purification of Virus Particles

- Concentration by precipitation with ammonium sulfate, ethanol, or polyethylene glycol or by ultrafiltration.
- After concentration, virus can be separated from host materials by differential centrifugation, density gradient centrifugation, column chromatography, and electrophoresis.



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- Heat and Cold: There is great variability in the heat stability of different viruses.
- Icosahedral viruses tend to be stable, losing little infectivity after several hours at 37°C. Enveloped viruses are much more heat labile, rapidly dropping in titer at 37°C. Viral infectivity is generally destroyed by heating at 50–60°C for 30 minutes, although there are some notable exceptions (e.g., hepatitis B virus, polyomaviruses).
- Viruses can be preserved by storage at subfreezing temperatures, and some may withstand lyophilization and can thus be preserved in the dry state at 4°C or even at room temperature. Viruses are sensitive to repeated freezing and thawing.

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Virus reaction to physical and chemical agents

- Many viruses can be stabilized by salts in concentrations of 1 mol/L (i.e., the viruses are not inactivated even by heating at 50°C for 1 hour) and the mechanism by which the salts stabilize viral preparations is not known.
- Viruses are preferentially stabilized by certain salts. $MgCl_2$, 1 mol/L, stabilizes picornaviruses and reoviruses; $MgSO_4$, 1 mol/L, stabilizes orthomyxoviruses and paramyxoviruses; and Na2SO4, 1 mol/L, stabilizes herpesviruses.
- **The stability of viruses is important in the preparation of vaccines.** The ordinary non-stabilized oral polio vaccine must be stored at freezing temperatures to preserve its potency. However, with the addition of salts for stabilization of the virus, potency can be maintained for weeks at ambient temperatures even in the high temperatures of the tropics.

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Virus reaction to physical and chemical agents

- Viruses are usually stable between pH values of 5.0 and 9.0. Some viruses (e.g., enteroviruses) are resistant to acidic conditions. All viruses are destroyed by alkaline conditions. In hemagglutination reactions, variations of less than 1 pH unit may influence the result.
- Ultraviolet, x-ray, and high-energy particles inactivate viruses. The dose varies for different viruses. Infectivity is the most radiosensitive property because replication requires expression of the entire genetic contents. Irradiated particles that are unable to replicate may still be able to express some specific functions in host cells.

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Virus reaction to physical and chemical agents

Ether susceptibility can be used to distinguish viruses that possess an envelope from those that do not.

Non-ionic detergents (e.g., Triton X-100) solubilize lipid constituents of viral membranes. The viral proteins in the envelope are released (undenatured).

Anionic detergents (e.g., sodium dodecyl sulfate) also solubilize viral envelopes; in addition, they disrupt capsids into separated polypeptides.

Viruses are penetrable to a varying degree by vital dyes such as toluidine blue, neutral red, and proflavine. These dyes bind to the viral nucleic acid, and the virus then becomes susceptible to inactivation by visible light.

Neutral red is commonly used to stain plaque assays so that plaques are more readily seen. The assay plates must be protected from bright light after the neutral red has been added; otherwise, there is the risk that progeny virus will be inactivated and plaque development will cease.

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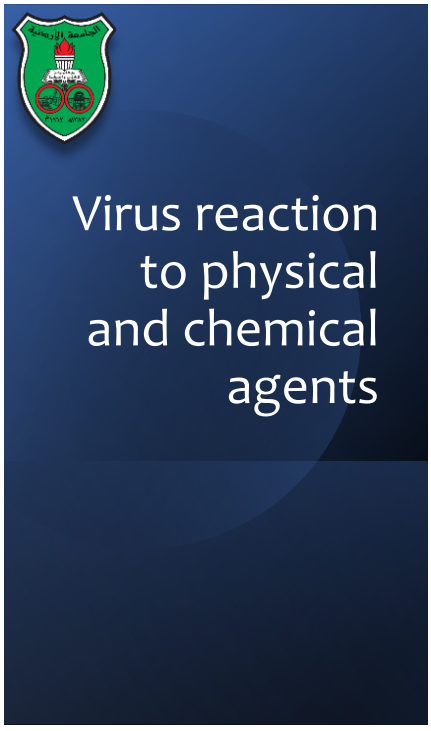

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- Antibacterial antibiotics have no effect on viruses.
- Some antiviral drugs are available.
- Quaternary ammonium compounds are not effective against viruses.
- Organic iodine compounds are also ineffective.
- Larger concentrations of chlorine are required to destroy viruses than to kill bacteria, especially in the presence of extraneous proteins.
- For example, the chlorine treatment of stools adequate to inactivate typhoid bacilli is inadequate to destroy poliomyelitis virus present in feces.
- Alcohols, such as isopropanol and ethanol, are relatively ineffective against certain viruses, especially picornaviruses.

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Common Methods of Inactivating Viruses for Various Purposes

- Viruses may be inactivated for various reasons, such as to sterilize laboratory supplies and equipment, disinfect surfaces or skin, make drinking water safe, and produce inactivated virus vaccines.
- Sterilization may be accomplished by steam under pressure, dry heat, ethylene oxide, and γ-irradiation.
- Surface disinfectants include sodium hypochlorite, glutaraldehyde, formaldehyde, and peracetic acid.
- Skin disinfectants include chlorhexidine, 70% ethanol, and iodophores.
- Vaccine production may involve the use of formaldehyde, β-propiolactone, psoralen + ultraviolet irradiation, or detergents (subunit vaccines) to inactivate the vaccine virus.

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Replication of viruses

- The unique feature of viral multiplication is that soon after interaction with a host cell the infecting virion is disrupted and its measurable infectivity is lost.
- This phase of the growth cycle is called **the eclipse period**; its duration varies depending on both the particular virus and the host cell, and it is followed by an interval of rapid accumulation of infectious progeny virus particles.
- The eclipse period is actually one of intense synthetic activity as the cell is redirected toward fulfilling the needs of the viral "pirate."

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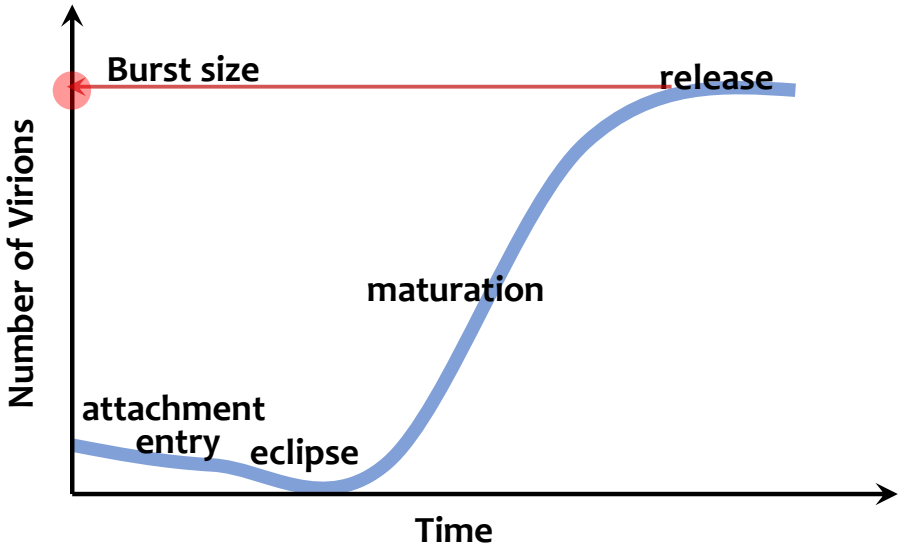
Virus Replication



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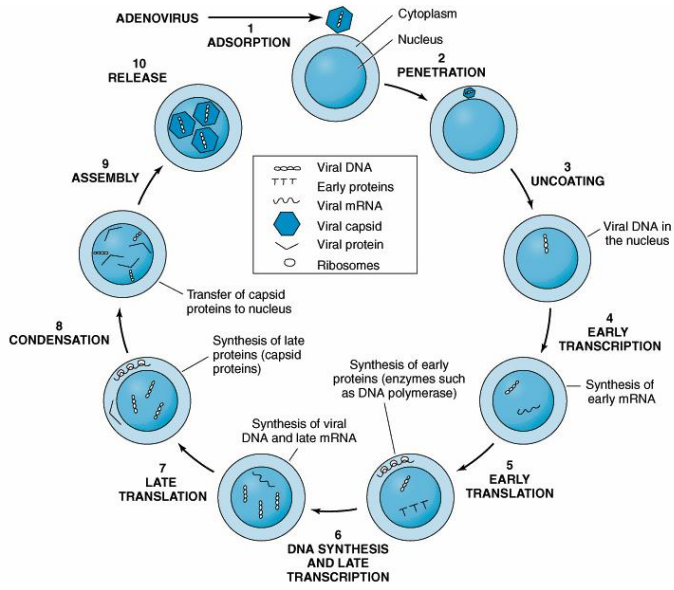
Virus Replication



Virus Replication

- Productive infections occur in permissive cells and result in the production of infectious virus.
- Abortive infections fail to produce infectious progeny, either because the cell may be non-permissive and unable to support the expression of all viral genes or because the infecting virus may be defective, lacking some functional viral gene.
- A latent infection may ensue, with the persistence of viral genomes, the expression of no or a few viral genes, and the survival of the infected cell. The pattern of replication may vary for a given virus, depending on the type of host cell infected.
- The yield of infectious virus per cell ranges widely, from modest numbers to more than 100,000 particles. The duration of the virus replication cycle also varies widely, from 6 to 8 hours (picornaviruses) to more than 40 hours (some herpesviruses).

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TABLE 29-2 Pathways of Nucleic Acid Transcription for Various Virus Classes

Type of Viral Nucleic Acid	Intermediates	Type of mRNA	Example	Comments
± ds DNA	None	+ mRNA	Most DNA viruses (eg, herpesvirus, adenovirus)	
+ ss DNA	± ds DNA	+ mRNA	Parvoviruses	
± ds RNA	None	+ mRNA	Reoviruses	Virion contains RNA polymerase that transcribes each segment to mRNA
+ ss RNA	± ds RNA	+ mRNA	Picornaviruses, togaviruses, flaviviruses	Viral nucleic acid is infectious and serves as mRNA. For togaviruses, smaller + mRNA is also formed for certain proteins
− ss RNA	None	+ mRNA	Rhabdoviruses, paramyxoviruses, orthomyxoviruses	Viral nucleic acid is not infectious; virion contains RNA polymerase, which forms + mRNAs smaller than the genome. For orthomyxoviruses, + mRNAs are transcribed from each segment
+ ss RNA	− DNA, ± DNA	+ mRNA	Retroviruses	Virion contains reverse transcriptase; viral RNA is not infectious, but complementary DNA from transformed cell is

−, negative strand; +, positive strand; ±, a helix containing a positive and a negative strand; ds, double stranded; ss, single stranded.

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TABLE 29-3 Comparison of Replication Strategies of Several Important RNA Virus Families

	Grouping Based on Genomic RNA[a]					
	Positive-Strand Viruses			Negative-Strand Viruses		Double-Stranded Viruses
Characteristic	Picornaviridae	Togaviridae	Retroviridae	Orthomyxoviridae	Paramyxoviridae and Rhabdoviridae	Reoviridae
Structure of genomic RNA	ss	ss	ss	ss	ss	ds
Sense of genomic RNA	Positive	Positive	Positive	Negative	Negative	
Segmented genome	0	0	0[b]	+	0	+
Genomic RNA infectious	+	+	0	0	0	0
Genomic RNA acts as messenger	+	+	+	0	0	0
Virion-associated polymerase	0	0	+[c]	+	+	+
Subgenomic messages	0	+	+	+	+	+
Polyprotein precursors	+	+	+	0	0	0

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TABLE 29-4 Summary of Replication Cycles of Major Virus Families

Virus Family	Presence of Virion Envelope	Intracellular Location			Multiplication Cycle (Hours)[b]
		Replication of Genome	Formation of Nucleocapsid[a]	Virion Maturation	
DNA viruses					
Parvoviridae	0	N	N	N	
Polyomaviridae	0	N	N	N	48
Adenoviridae	0	N	N	N	25
Hepadnaviridae	+	N	C	M–E	
Herpesviridae	+	N	N	M	15–72
Poxviridae	0	C	C	C	20
RNA viruses					
Picornaviridae	0	C	C	C	6–8
Reoviridae	0	C	C	C	15
Togaviridae	+	C	C	M–P	10–24
Flaviviridae	+	C	C	M–E	
Retroviridae	+	N	C	M–P	
Bunyaviridae	+	C	C	M–G	24
Orthomyxoviridae	+	N	N	M–P	15–30
Paramyxoviridae	+	C	C	M–P	10–48
Rhabdoviridae	+	C	C	M–P	6–10

[a]The synthesis of viral proteins always occurs in the cytoplasm.

[b]The values shown for duration of the multiplication cycle are approximate; ranges indicate that various members within a given family replicate with different kinetics. Different host cell types also influence the kinetics of viral replication.

C, cytoplasm; M, membranes; M–E, endoplasmic reticulum membranes; M–G, Golgi membranes; M–P, plasma membranes; N, nucleus.

Genetics of animal viruses

- Genetic analysis is a powerful approach toward understanding the structure and function of the viral genome, its gene products, and their roles in infection and disease.
- Viruses that have stable antigens on their surfaces (poliovirus, measles virus) can be controlled by vaccination. Other viruses that exist as many antigenic types (rhinoviruses) or change frequently (influenza virus A) are difficult to control by vaccination.
- Genetic analysis will help identify virus-specific processes that may be appropriate targets for the development of antiviral therapy.

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Genetics of animal viruses

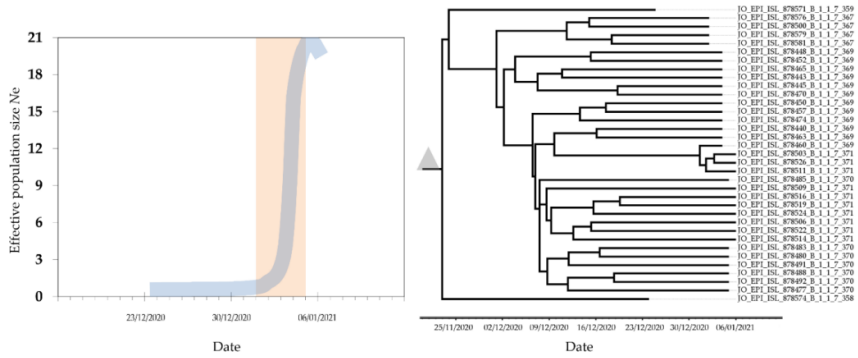

Figure 3. Maximum clade credibility (MCC) tree of the lineage B.1.1.7 (UK variant of concern) in Jordan, with the mean estimate for the tMRCA shown as the grey triangle (**right**). The median effective population size (*Ne*) shown in blue displayed a lag phase in December 2020 followed by an exponential increase in infections starting on 1 January 2021 highlighted in orange rectangle (**left**).

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Genetics of animal viruses

- Genotype: the genetic constitution of an organism.
- Phenotype: the observable properties of an organism, which are produced by the genotype in cooperation with the environment.
- A mutation is a heritable change in the genotype.
- The genome is the sum of the genes of an organism.
- Wildtype virus denotes the original virus from which mutants are derived and with which the mutants are compared; the term may not accurately characterize the virus as it is isolated in nature. Fresh virus isolates from the natural host are referred to as field isolates or primary isolates.

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Mapping of Viral Genomes

Biochemical and physical mapping can be done much more rapidly than genetic mapping using classic genetic techniques.

For isolates that can be cloned, sequence analysis and comparison with known viruses is often used.

Restriction endonucleases can be used for identification of specific strains of DNA viruses.

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Types of Virus Mutants

- Classic genetic studies with animal viruses require a sensitive and accurate quantitative assay method, such as a plaque assay for viral infectivity, and good mutants (resulting from single mutations) that are easily scored and reasonably stable.
- Some markers commonly used include plaque morphology, antibody escape or resistance to neutralizing antisera, loss of a virus protein, drug resistance, host range, and inability to grow at low or high temperatures.
- Conditional-lethal mutants are mutants that are lethal (in that no infectious virus is produced) under one set of conditions—termed nonpermissive conditions—but that yield normal infectious progeny under other conditions— termed permissive conditions.

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Defective Viruses

- A defective virus is one that lacks one or more functional genes required for viral replication. Defective viruses require helper activity from another virus for some step in replication or maturation.
- One type of defective virus lacks a portion of its genome (i.e., deletion mutant).
- Spontaneous deletion mutants may interfere with the replication of homologous virus and are called defective interfering virus particles.
- DIPs have lost essential segments of genome but contain normal capsid proteins; they require infectious homologous virus as helper for replication, and they interfere with the multiplication of that homologous virus

Defective Viruses

- Another category of defective virus requires an unrelated replication-competent virus as helper.
- Examples include the adeno-associated satellite viruses and hepatitis D virus (delta agent), which replicate only in the presence of coinfecting human adenovirus or hepatitis B virus, respectively.
- The essential helper function supplied by the helper virus varies, depending on the system.

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Defective Viruses

Pseudovirions, a different type of defective particle, contain host cell DNA rather than the viral genome.

During viral replication, the capsid sometimes encloses random pieces of host nucleic acid rather than viral nucleic acid.

Such particles look like ordinary virus particles when observed by electron microscopy, but they are not able to replicate.

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Interactions Among Viruses

- Recombination results in the production of progeny virus (recombinant) that carries traits not found together in either parent. The classic mechanism is that the nucleic acid strands break, and part of the genome of one parent is joined to part of the genome of the second parent.
- Complementation is the interaction of viral gene products in cells infected with two viruses, one or both of which may be defective. It results in the replication of one or both under conditions in which replication would not ordinarily occur. The basis for complementation is that one virus provides a gene product in which the second is defective, allowing the second virus to grow.
- Infection of either cell cultures or whole animals with two viruses often leads to an inhibition of multiplication of one of the viruses, an effect called interference.

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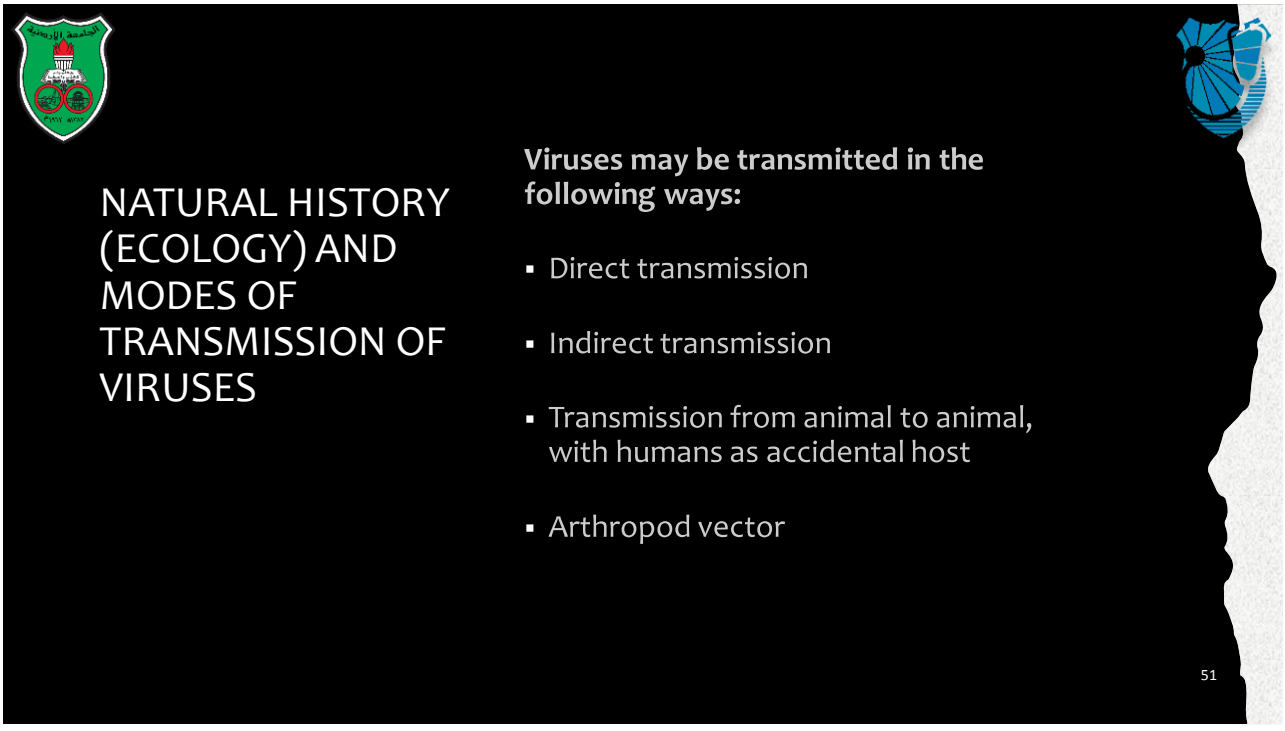
NATURAL HISTORY (ECOLOGY) AND MODES OF TRANSMISSION OF VIRUSES
Viruses may be transmitted in the following ways:
Direct transmission
Indirect transmission
Transmission from animal to animal, with humans as accidental host
Arthropod vector
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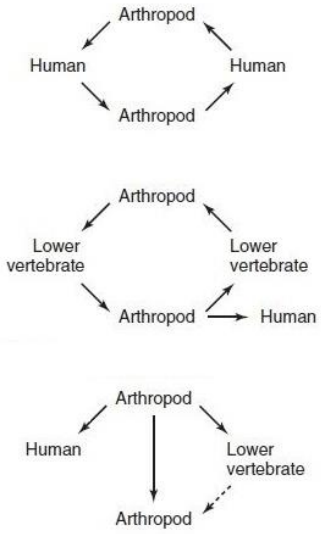
Transmission patterns among arboviruses



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Emerging Viral Diseases

Contributing factors

- Environmental changes
- Human behavior
- Socioeconomic and demographic phenomena
- Travel and commerce
- Food production
- Health care
- Microbial adaptation
- Public health measures

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Examples of emerging viral infections

Ebola virus

Nipah virus

Hantavirus pulmonary disease

Human immunodeficiency virus

West Nile virus

Rift Valley fever

Emerging Coronaviruses

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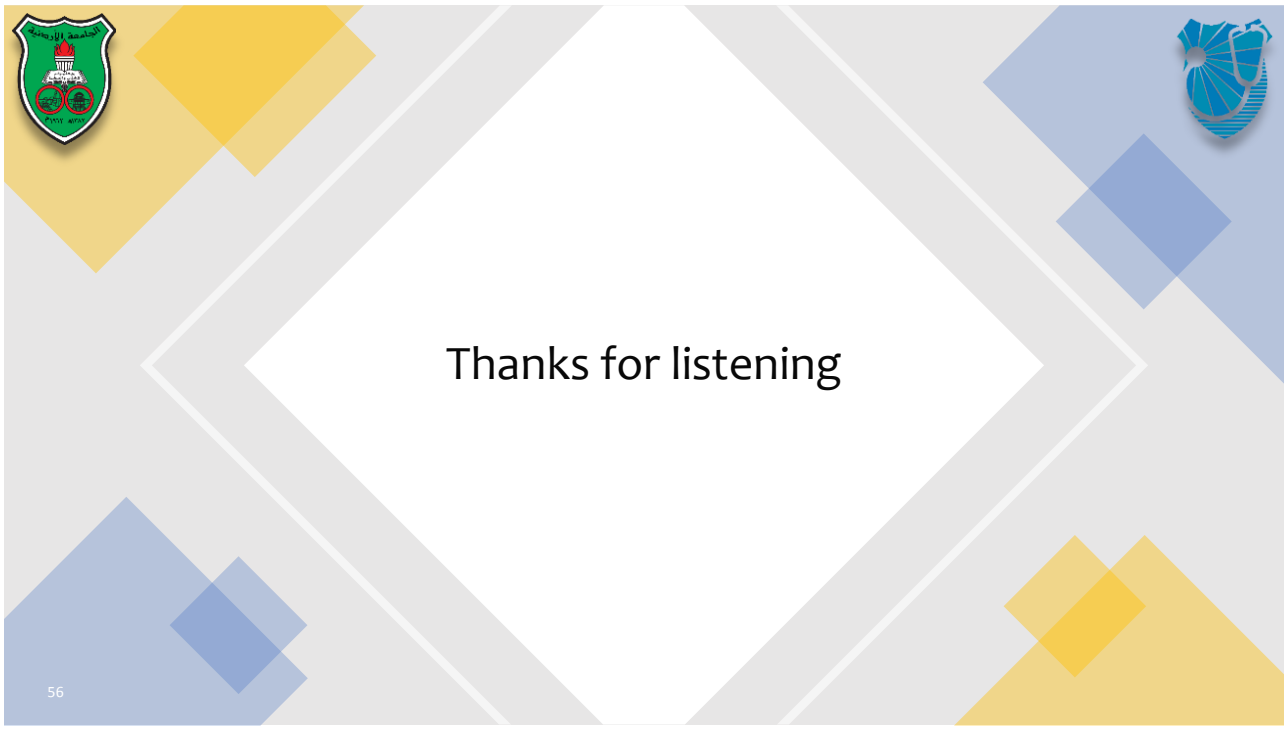
Bioterrorism Agents

- Microorganisms (or toxins) that could be used to produce death and disease in humans, animals, or plants for terrorist purposes.
- Potential bioterrorism agents are classified into risk categories based on the ease of dissemination or transmission from person to person, mortality rates, ability to cause public panic, and requirement for public health preparedness.
- Viral agents in the highest risk category are smallpox and the viral hemorrhagic fever.


Thanks for listening
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