Viruses, Viroids, and Prions
Are Viruses Living or Non-living?

Viruses are both and neither. They have some properties of life but not others. For example, viruses can be killed, even crystallized like table salt. However, they can't maintain a constant internal state (homeostasis).
What are Viruses?

A virus is a non-cellular particle made up of genetic material and protein that can invade living cells.
Discovery of Viruses

Beijerinck (1897) coined the Latin name “virus” meaning poison.

He studied filtered plant juices & found they caused healthy plants to become sick.
Tobacco Mosaic Virus

Wendell Stanley (1935) crystallized sap from sick tobacco plants. He discovered viruses were made of nucleic acid and protein.
Edward Jenner (1796) developed a smallpox vaccine using milder cowpox viruses. Deadly viruses are said to be virulent. Smallpox has been eradicated in the world today.
Viruses are smaller than the smallest cell. Measured in nanometers, viruses couldn’t be seen until the electron microscope was invented in the 20th century.
Size of Viruses

- Bacteriophage T4: 225 nm
- Rabies virus: 170 × 70 nm
- Chlamydia elementary body: 300 nm
- Ebola virus: 970 nm
- Human red blood cell in diameter: 10,000 nm
- Plasma membrane of red blood cell: 10 nm thick

Viruses:
- Adenovirus: 90 nm
- Rhinovirus: 30 nm
- Bacteriophages f2, MS2: 24 nm
- Tobacco mosaic virus: 250 × 18 nm
- Prion: 200 × 20 nm
- Vaccinia virus: 300 × 200 × 100 nm
- Poliovirus: 30 nm

E. coli (a bacterium): 3000 × 1000 nm
Viral Structure
Characteristics

Non living structures

Noncellular

Contain a protein coat called the capsid

Have a nucleic acid core containing DNA or RNA

Capable of reproducing only when inside a HOST cell
Characteristics

Some viruses are enclosed in an protective envelope

Some viruses may have spikes to help attach to the host cell

Most viruses infect only SPECIFIC host cells
Viral capsids (coats) are made of individual protein subunits. Individual subunits are called capsomeres.
Characteristics

Outside of host cells, viruses are inactive.

Lack ribosomes and enzymes needed for metabolism.

Use the raw materials and enzymes of the host cell to be able to reproduce.
Characteristics

Some viruses cause disease
Smallpox, measles, mononucleosis, influenza, colds, warts, AIDS, Ebola
Some viruses may cause some cancers like leukemia
Virus-free cells are rare

MEASLES
Viral Shapes

Viruses come in a variety of shapes.

Some may be helical shape like the Ebola virus.

Some may be polyhedral shapes like the influenza virus.

Others have more complex shapes like bacteriophages.
Helical Viruses

(a) A helical virus

(b) Ebola virus
Polyhedral Viruses

(a) A polyhedral virus

(b) A Mastadenovirus
Complex Viruses

(a) A T-even bacteriophage
Taxonomy of Viruses
Viral Taxonomy

Family names end in -viridae
Genus names end in -virus
Viral species: A group of viruses sharing the same genetic information and ecological niche (host).
Common names are used for species
Subspecies are designated by a number
Viral Taxonomy

Examples

Herpesviridae
Herpesvirus
Human herpes virus 1, HHV 2, HHV 3

Retroviridae
Lentivirus
Human Immunodeficiency Virus 1, HIV 2

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Herpes Virus

SIMPLEX I and II
Adenovirus

COMMON COLD
Influenza Virus
Chickenpox Virus
Papillomavirus – Warts!
Used for Virus Identification

RNA or DNA Virus
Do or do NOT have an envelope
Capsid shape
HOST they infect
Bacteriophages
Viruses that attack bacteria are called \textit{bacteriophage} or just \textit{phage}.

\textbf{T-phages} are a specific class of \textit{bacteriophages} with icosahedral heads, double-stranded DNA, and tails.
T-phages

The most commonly studied T-phages are T4 and T7.

They infect *E. coli*, an intestinal bacteria.

Six small spikes at the base of a contractile tail are used to attach to the host cell.

Inject viral DNA into cell.
Escherichia Coli Bacterium

T - EVEN PHAGES ATTACK THIS BACTERIUM
T-Even Bacteriophages
Diagram of T-4 Bacteriophage

Head with 20 triangular surfaces
Capsid contains DNA
Head & tail fibers made of protein

Schematic of T4 Bacteriophage

- Icosahedral Head
- Tail
- Long Tail Fibers
- Short Tail Fibers (located beneath the baseplate)
- Baseplate
Retroviruses
Characteristics of Retroviruses

- Contain RNA, not DNA
- Family Retroviridae
- Contain enzyme called Reverse Transcriptase
- When a retrovirus infects a cell, it injects its RNA and reverse transcriptase enzyme into the cytoplasm of that cell
Diagram of a Retrovirus
Retroviruses

The enzyme reverse transcriptase (or RTase), which causes synthesis of a complementary DNA molecule (cDNA) using virus RNA as a template.
Retroviruses

HIV, the AIDS virus, is a retrovirus.

Feline Leukemia Virus is also a retrovirus.
Viroids & Prions
Viroids

Small, circular RNA molecules without a protein coat

Infect plants

Potato famine in Ireland

Resemble introns cut out of eukaryotic
Prions are “infectious proteins”

They are normal body proteins that get converted into an alternate configuration by contact with other prion proteins.

They have no DNA or RNA.

The main protein involved in human and mammalian prion diseases is called “PrP”.
Prion Diseases

Prions form insoluble deposits in the brain. Causes neurons to rapidly degenerate.

Mad cow disease (bovine spongiform encephalitis: BSE) is an example.

People in New Guinea used to suffer from kuru, which they got from eating the brains of their enemies.
Viral Replication
Viral Attack

Viruses are very specific as to which species they attack

HOST specific

Humans rarely share viral diseases with other animals

Eukaryotic viruses usually have protective envelopes made from the host cell membrane
5 Steps of Lytic Cycle

1. **Attachment** to the cell
2. **Penetration** (injection) of viral DNA or RNA
3. **Replication (Biosynthesis)** of new viral proteins and nucleic acids
4. **Assembly (Maturation)** of the new viruses
5. **Release** of the new viruses into the environment (cell lyses)
Bacteriophage Replication

Bacteriophage inject their nucleic acid. They lyse (break open) the bacterial cell when replication is finished.
<table>
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<td><strong>Attachment</strong></td>
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Attachment: Phage attaches to host cell.

Penetration: Phage penetrates host cell and injects its DNA.

Merozoites released into bloodstream from liver may infect new red blood cells.
Maturation: Viral components are assembled into virions.

Release: Host cell lyses and new virions are released.
One-step Growth Curve

- **Burst size**
- **Penetration**
- **Biosynthesis and maturation**
- **Phage particles released by lysis**

**Number of infective phage particles (log scale)**

**Time (minutes)**

**Attachment**

**Burst time**
Viral Latency

Some viruses have the ability to become dormant inside the cell. Called latent viruses, they may remain inactive for long periods of time (years). Later, they activate to produce new viruses in response to some external signal. HIV and Herpes viruses are examples.
Lysogenic Cycle

Phage DNA injected into host cell
Viral DNA joins host DNA forming a prophage
When an activation signal occurs, the phage DNA starts replicating
Lysogenic Cycle

Viral DNA (part of prophage) may stay inactive in host cell for long periods of time.

Replicated during each binary fission.

Over time, many cells form containing the prophages.
Viral Latency

Once a prophage cell is activated, host cell enters the lytic cell.

New viruses form and the cell lyses (bursts).

Virus is said to be virulent (deadly).

**ACTIVE STAGE**

**INACTIVE STAGE**
Virulent Viruses

(a) HOST CELL
(b) LYSSES & DIES

(f) Lytic
(e) Cro

(d) cl
(c) Lysogenic

HOST CELL LYSSES & DIES
The Lysogenic Cycle

1. Phage attaches to host cell and injects DNA
2. Phage DNA circularizes and enters lytic cycle or lysogenic cycle
3A. New phage DNA and proteins are synthesized and assembled into virions
3B. Phage DNA integrates within the bacterial chromosome by recombination, becoming a prophage
4A. Cell lyses, releasing phage virions
4B. Lysogenic bacterium reproduces normally
5. Occasionally, the prophage may excise from the bacterial chromosome by another recombination event, initiating a lytic cycle

Bacterial chromosome

Many cell divisions

Prophage

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Latency in Eukaryotes

Some eukaryotic viruses remain dormant for many years in the nervous system tissues.

Chickenpox (caused by the virus *Varicella zoster*) is a childhood infection. It can reappear later in life as shingles, a painful itching rash limited to small areas of the body.
Latency in Eukaryotes

Herpes viruses also become latent in the nervous system.

A herpes infection lasts for a person’s lifetime.

Genital herpes (Herpes Simplex 2)

Cold sores or fever blisters (Herpes Simplex 1)

SKIN TO SKIN CONTACT

PASSED AT BIRTH TO BABY

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Virulence

VIRUS DESTROYING HOST CELL
Lytic and Lysogenic Cycles

**Lytic Cycle:**
- Phage attaches to host cell and injects DNA.
- Phage DNA circularizes.
- New phage DNA and proteins are synthesized and assembled into phages.
- Cell lyses, releasing phages.
- Many cell divisions produce a colony of bacteria infected with prophage.

**Lysogenic Cycle:**
- Phage DNA integrates into the bacterial chromosome, becoming a prophage.
- Bacterium reproduces normally, copying the prophage and transmitting it to daughter cells.
- Occasionally, a prophage exits the bacterial chromosome, initiating a lytic cycle.
Treatment for Viral Disease
Vaccines

An **attenuated virus** is a weakened, less vigorous virus.

"Attenuate" refers to procedures that weaken an agent of disease (heating).

A **vaccine** against a viral disease can be made from an attenuated, less virulent strain of the virus.

Attenuated virus is capable of stimulating an immune response and creating immunity, but not causing illness.
Other Viral Treatments

- Interferon are naturally occurring proteins made by cells to fight viruses.
- Genetic altering of viruses (attenuated viruses)
- Antiviral drugs (AZT)
- Protease inhibitors - prevent capsid formation