VIRUSES

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VIRUSES

Viruses are non-cellular infectious agents that are capable of disturbing the equilibrium of a host organism and causing disease. They are obligate intracellular parasites that hijack the molecular machinery of a cell. They use the host cell's resources to assemble new infectious particles (**virions**) that can infect other cells. Viruses are non-living as they cannot autonomously perform all the functions of life – they lack metabolism and they cannot replicate independently. Additionally, they cannot grow and do not maintain homeostasis.

VIRAL STRUCTURE

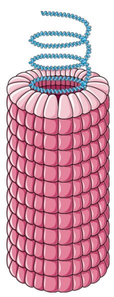
Viruses are very diverse in terms of their structure however all viruses share some basic common features:

- **Protein coat** – Every virus consists of an encapsulating protective shell made of protein (called a **capsid**)
- **Internal components** – Viruses do not contain any cytoplasm and will have few enzymes (or none at all)
- **Genetic material** – Viruses contain a nucleic acid core within a capsid (consisting of either DNA or RNA)
- **Size** – Viruses contain few molecules and have a very small, fixed size (they are not capable of growth)

Because viruses are **non-cellular**, they lack characteristic features that are used to classify living organisms. However, viruses are highly diverse and can be differentiated according to a number of distinct properties:

- **Capsid** – The protein shell can vary in terms of its structure (helical, polyhedral, spherical or complex)
- **Attachment proteins** – Viruses have distinct proteins to enable binding to specific host cell receptors
- **Genetic material** – May be either RNA or DNA (single-stranded or double-stranded, linear or circular)
- **Envelope** – Some viruses are enclosed within an external lipid membrane (while other viruses are not)
- **Size** – Viruses can exist in a range of different sizes (but all are extremely small – usually 20 to 300 nm)

Examples of viruses with distinguishing characteristics include bacteriophage lambda, coronavirus and HIV.



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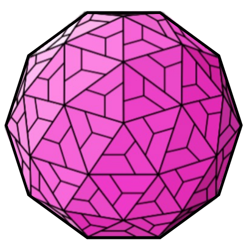

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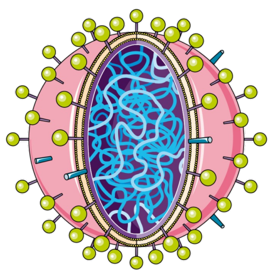
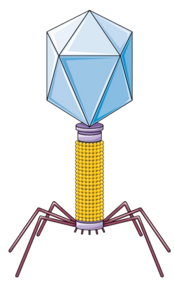


SPHERICAL



COMPLEX

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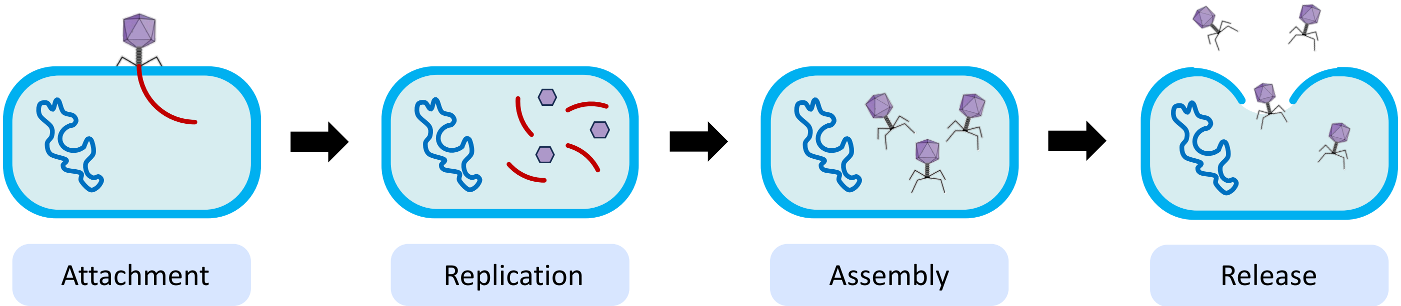
VIRAL REPLICATION

The basic steps of viral replication are common to all viruses – they attach to specific receptor proteins on host cells, insert their genetic material into the cell and then commandeer the cell machinery (ribosomes) to synthesise viral proteins and assemble new viral particles (virions). Virions are then released by rupturing the infected cell via a process called the **lytic cycle**. Enzymes (such as lysozymes) are synthesised from viral genetic material and degrade the plasma membrane or cell wall. The cell lyses and the virions are released.

Certain viruses can assimilate their genetic material into the host cell's genome via the **lysogenic cycle**. This results in the continuous production of infected cells containing viral genetic material. The lysogenic cycle involves a viral enzyme (called *integrase*) that catalyses the insertion of viral sequences into the genome of the host cell. A viral repressor protein prevents the integrated viral sequences from being expressed while the cell remains in a state of latency and reproduces. The viral sequences remain dormant until activated by environmental stressors. At this point, the lytic cycle is triggered and destroys the entire infected cell line.

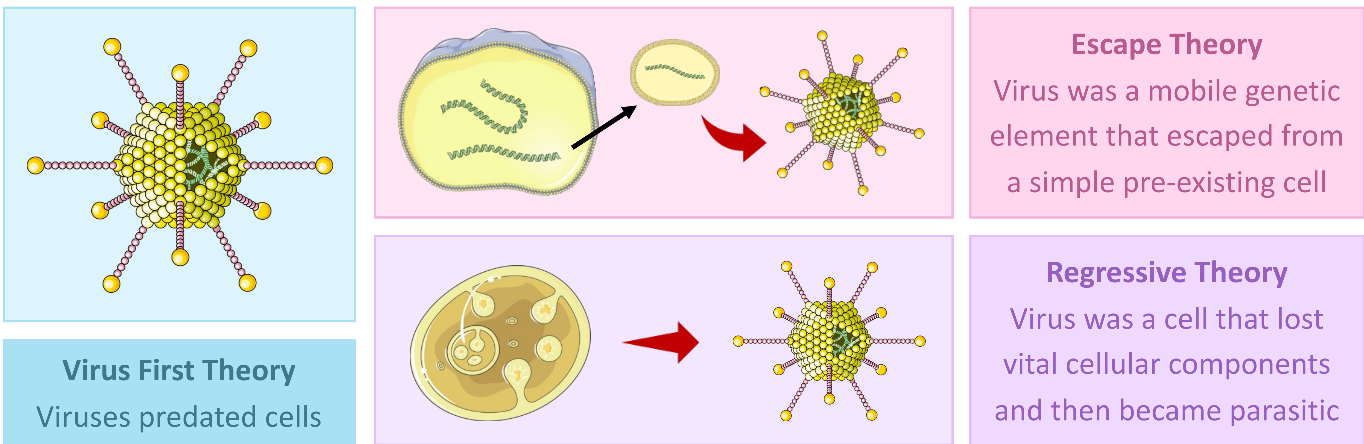


VIRAL ORIGINS

The origin of viruses is under debate within the scientific community and multiple different theories exist:

- The **virus-first theory** states that a simplistic virus may have predated cells as the first replicating unit
- The **escape theory** suggests that viruses originated as genetic elements in cells that were able to spread
- The **regressive theory** claims that viruses are remnants of a primordial cell that lost vital components

The virus-first theory is considered unlikely as viruses are obligate parasites and so are not expected to exist before living cells. Universality of the genetic code suggests that viruses must have evolved from a common ancestor shared by cells (i.e. LUCA). The presence of viral enzymes that are capable of synthesising nucleic acids within host cells (e.g. reverse transcriptase) supports the theory that viral genetic material originated within cells. The presence of an encapsulating membrane in some viruses and the existence of large viruses (750 nm) support the theory that viruses evolved from a parasitic prokaryote that lost cellular components. As viruses share an extreme form of obligate parasitism as a mode of existence, it is possible that the many structural features viruses have in common could arise from the **convergent evolution** of distinct ancestors.



VIRAL EVOLUTION

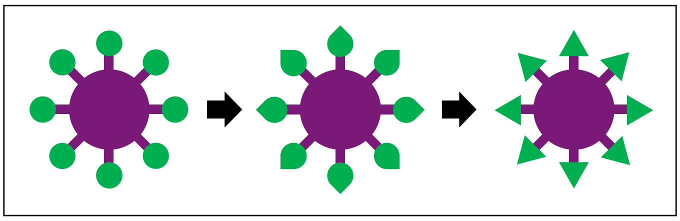
Viral genomes are able to undergo evolution very rapidly – this is due to a number of different reasons:

- **High mutation rates** – RNA and ss-DNA are both less stable and viruses lack any proofreading enzymes
- **Short generation times** – Evolution occurs across generations and viruses have a short infectious cycle
- **Large population sizes** – Each infectious cycle can produce large quantities of virions for rapid growth

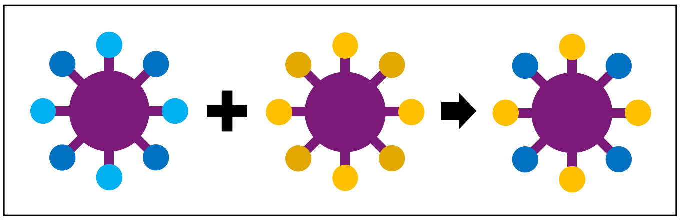
One example of a virus that can evolve very rapidly is the **influenza virus**, which has an infectious cycle of only 6 – 12 hours and may produce populations of up to 10,000 virions per infected cell. Another example is **HIV**, which has one of the highest mutation rates of any virus (0.34 mutations per each replication cycle).

DISEASE CONSEQUENCES

Rapidly evolving viruses are able to evade detection by an organism's immune system in order to cause a disease. There are two different mechanisms by which viruses evolve to avoid immunological destruction. **Antigenic drift** occurs when an accumulation of point mutations results in gradual changes to viral proteins. The immune system can no longer recognise the viral antigens as an entirely new viral strain has developed. **Antigenic shift** occurs when cells get infected with multiple viral strains and the genomes of the two strains become reassorted. This causes a dramatic change in antigenicity as a new viral sub-type has been created. Antigenic shift can result in the emergence of zoonotic diseases and lead to massive outbreaks (pandemic).



Antigenic Drift (*progressive* changes)



Antigenic Shift (*spontaneous* changes)

VIRUS EXAMPLES

	Bacteriophage λ	Coronavirus	HIV
Host Cell	*Escherichia coli*	Epithelial cells (airway)	Helper T cells
Genetic Material	ds-DNA (linear)	RNA	RNA
Capsid	Complex	Helical	Icosahedral
Envelope	No envelope	Enveloped	Enveloped
Replication	Lytic and lysogenic	Lytic only	Lytic and lysogenic
Human Disease	None	COVID-19	AIDS
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