

Viruses

Revision notes • Features shared by all viruses, their diversity, the lytic and lysogenic cycles of lambda phage, viral origins and rapid evolution of influenza and HIV.

For IB Diploma Biology, Standard Level and Higher Level (first assessment 2025). **HL only** is additional higher level content, for HL students only.

Viruses Spec A2.3 HL only

Structure and diversity of viruses Spec A2.3.1, A2.3.2

Viruses are not cells. **Relatively few features are shared by all viruses:**

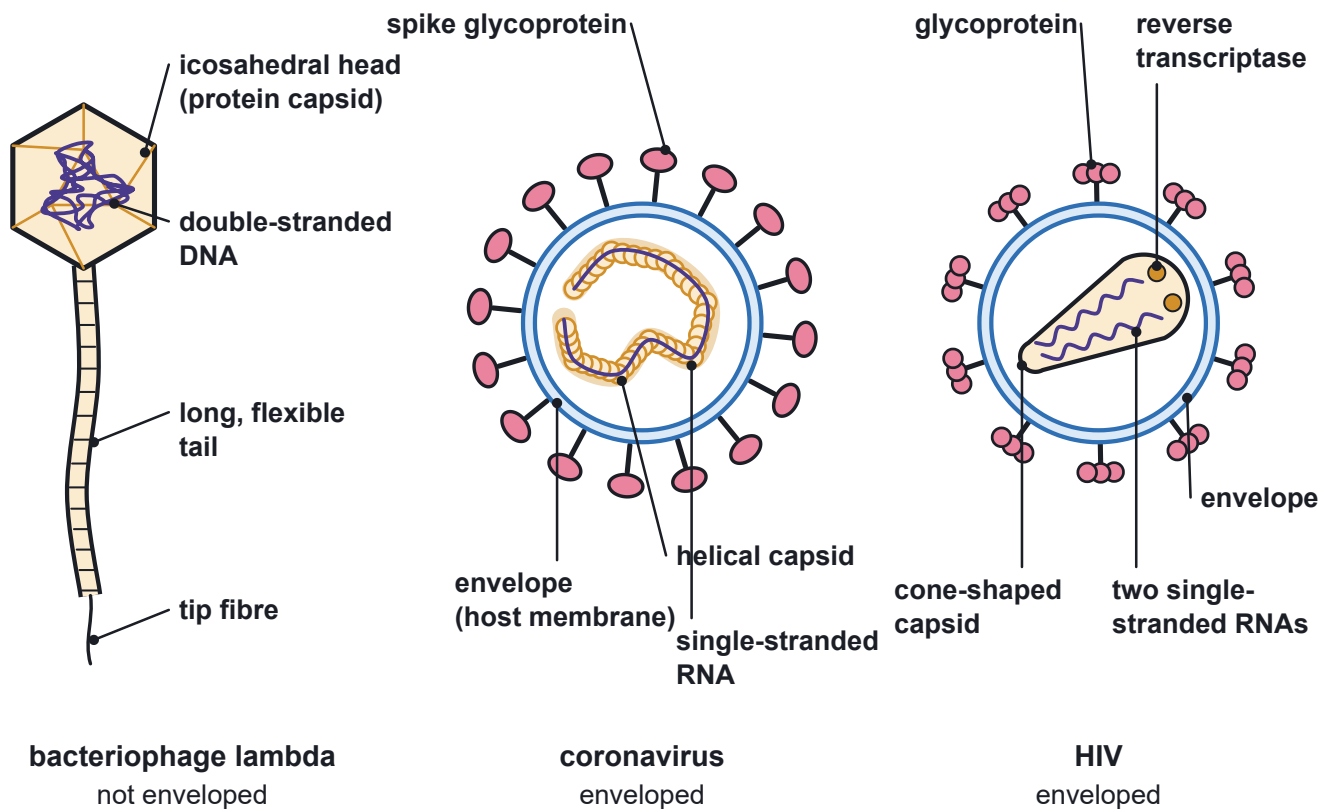
- A small, fixed size: most are about 20–300 nm across, far smaller than bacteria, and they do not grow.
- Nucleic acid as genetic material: either DNA or RNA.
- A **capsid** made of protein subunits, which protects the nucleic acid.
- No cytoplasm.
- Few or no enzymes, so they depend on a host cell for metabolism.

Diversity of structure

Viruses are **highly diverse** in shape and structure. Their genetic material may be RNA or DNA, and either can be single- or double-stranded. Some viruses are **enveloped** in membrane taken from the host cell; others are not enveloped.

Three example viruses			
Feature	Bacteriophage lambda	Coronaviruses (e.g. SARS-CoV-2)	HIV
Host	The bacterium <i>Escherichia coli</i>	Mammals and birds; SARS-CoV-2 infects cells lining the human airways	Humans, mainly helper T cells
Genetic material	Double-stranded DNA	Single-stranded RNA	Single-stranded RNA (two copies)
Capsid	Icosahedral head on a long, flexible tail; the tail tip binds the host	Helical capsid wrapped around the RNA	Cone-shaped capsid
Envelope	Not enveloped	Enveloped, with spike glycoproteins that bind host cell receptors	Enveloped, with glycoproteins that bind receptors on helper T cells
Enzymes carried	None	None	Reverse transcriptase, integrase and protease

An envelope is a piece of host plasma membrane picked up as the virus buds out of the host cell, with viral glycoproteins inserted into it.



not drawn to scale

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Viruses are diverse: **DNA or RNA**, and **enveloped or not**

Exam tip: Guiding question: how can viruses exist with so few genes? They need no genes for ribosomes, ATP production or most metabolism, because the host cell supplies all of these.

Lytic and lysogenic cycles Spec A2.3.3, A2.3.4

Viruses **rely on a host cell** for energy supply, nutrition, protein synthesis and other life functions. Bacteriophage lambda infects *E. coli* and can follow either of two cycles.

Lytic cycle

1. **Attachment:** the tip of the phage tail binds to a specific receptor protein on the outer surface of *E. coli*.
2. **Injection:** the phage injects its DNA into the cell; the empty capsid stays outside.
3. **Replication and synthesis:** the linear viral DNA forms a circle. Viral genes are transcribed by the host's RNA polymerase and translated by host ribosomes, using the host's ATP, nucleotides and amino acids. The viral DNA is replicated many times.
4. **Assembly:** capsid proteins assemble into heads and tails, and copies of the viral DNA are packed into the heads.
5. **Lysis and release:** viral proteins make holes in the plasma membrane and a viral enzyme (endolysin) breaks down the cell wall, so the cell bursts, and around 100 new phages are released to infect other cells.

Lysogenic cycle

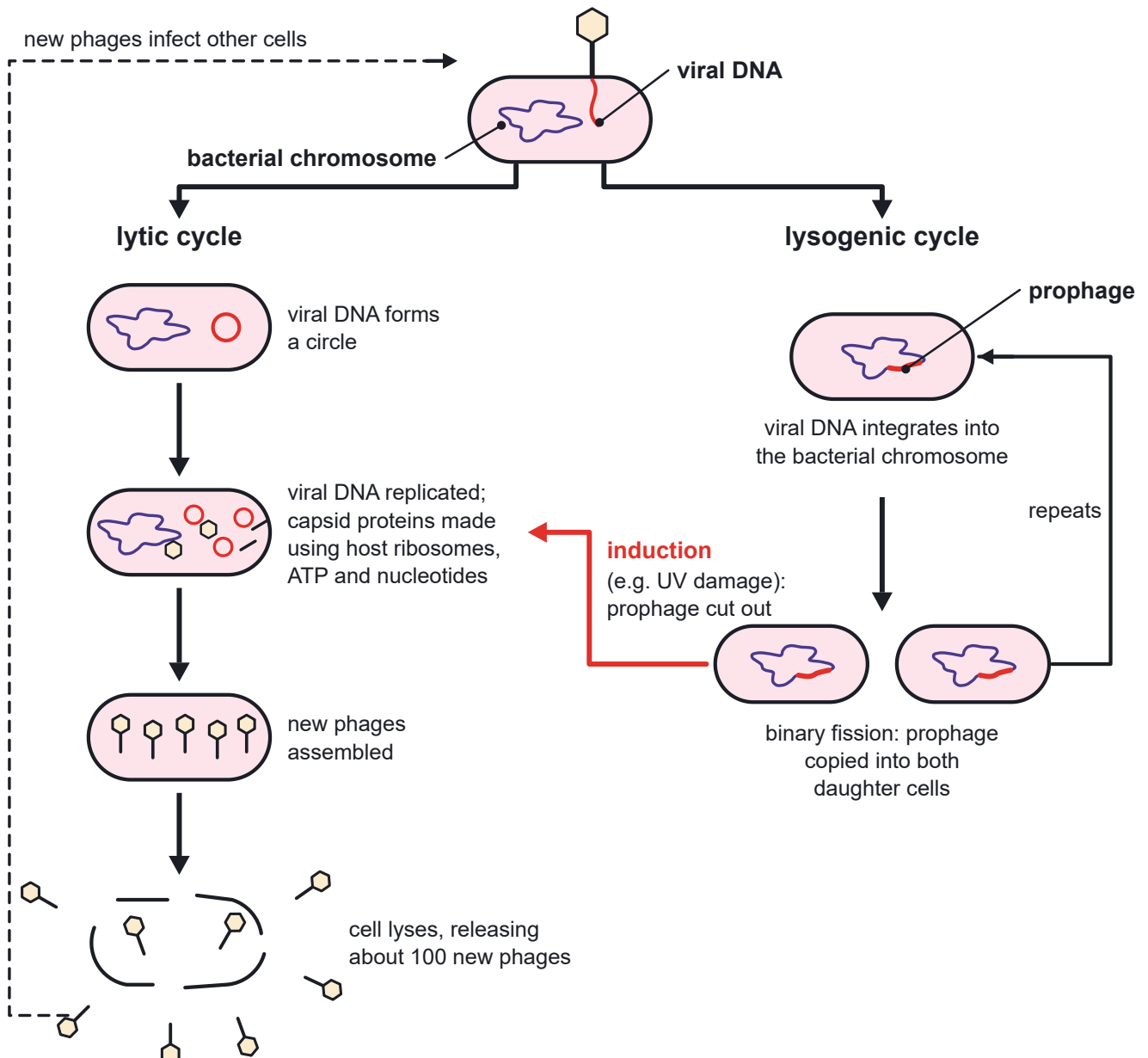
1. Attachment and injection happen as in the lytic cycle.

2. The lambda DNA integrates into the host chromosome at a specific site, catalysed by a viral enzyme, integrase. The integrated viral DNA is called a prophage.
3. A viral repressor protein switches off the genes needed for the lytic cycle, so no new viruses are made and the host survives.
4. Each time the bacterium divides by binary fission, the prophage is replicated with the host chromosome and passed to both daughter cells.
5. If the host is stressed, for example when its DNA is damaged by ultraviolet light, the prophage is cut out of the chromosome and the lytic cycle begins. This is called induction.

Lytic and lysogenic cycles compared

Feature	Lytic cycle	Lysogenic cycle
Viral DNA	Stays separate from the host chromosome	Integrated into the host chromosome as a prophage
New virus particles	Made quickly	Not made while the prophage is dormant
Effect on the host	Killed by lysis	Survives and divides normally
How the virus spreads	Released phages infect new cells	Copied to daughter cells when the host divides

phage attaches to *E. coli* and injects its DNA



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Lambda phage can kill its host at once (**lytic**) or lie dormant as a **prophage** (lysogenic) until induction.

Exam tip: In a lytic cycle answer, name the host resources used: **ATP, nucleotides, amino acids, ribosomes and enzymes**. These earn the marks for 'viruses rely on a host cell'.

Origins and rapid evolution of viruses Spec A2.3.5, A2.3.6

Evidence for several origins

The great **diversity of viruses** suggests several possible origins from other organisms, rather than one common ancestor of all viruses.

- Viruses share an **extreme form of obligate parasitism**: none can reproduce outside a host cell. The features they have in common, such as a small size and a protein capsid, could be **convergent evolution**: similar features evolving separately in different lineages because of the same way of life.
- The **genetic code is shared** between viruses and living organisms, which suggests that viruses arose from cellular life rather than independently of it.

Possible ways viruses arose from other organisms

Hypothesis	Idea
Escape	Pieces of genetic material, such as plasmids, escaped from cells and gained a protein coat
Reduction	Parasitic cells lost genes until little more than those for replication and capsids remained; very large viruses with many genes fit this idea

Different groups of viruses may have arisen in different ways, which would fit their diversity.

Exam tip: Linking question: what mechanisms contribute to convergent evolution? The same selection pressures, here entering host cells and protecting a genome between hosts, can produce similar features in unrelated lineages.

Rapid evolution in viruses

- **High mutation rate:** RNA viruses copy their genome with RNA polymerases, and HIV uses reverse transcriptase. These enzymes do not proofread, so copying errors are frequent.
- Short generation time: a new generation of virus particles can be produced within hours.
- Huge numbers: each infected cell releases many virus particles, so there is a lot of variation for natural selection to act on.
- Mixing of genes: when two strains infect the same cell, their genetic material can combine.

Influenza

Influenza A viruses have an RNA genome in eight segments and two surface glycoproteins, haemagglutinin (H) and neuraminidase (N), which antibodies recognise. Frequent mutations gradually change these antigens (**antigenic drift**), so antibodies from earlier infections or vaccines bind less well. If two strains infect the same host, for example a pig, their segments can mix (antigenic shift), producing a new subtype to which few people are immune. The vaccine is therefore reformulated every year to match the strains expected to circulate.

HIV

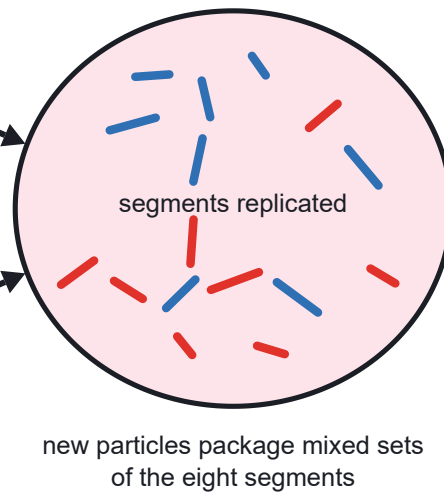
HIV's reverse transcriptase makes many errors and huge numbers of new virus particles are produced every day, so many variants exist within each infected person. When one antiviral drug is used, variants carrying resistance mutations are selected and multiply. Patients therefore take **combination antiretroviral therapy**: several drugs acting on different targets, so a variant would need several resistance mutations at once. The variability of HIV's surface glycoproteins has also made a vaccine very difficult to develop.

Exam tip: Consequences for treatment: vaccines need regular updating, antiviral drugs lose effectiveness as resistance evolves, and immunity from earlier infections gives less protection.

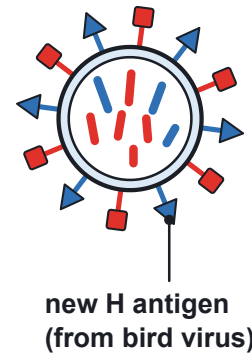
bird influenza virus



pig cell infected by both viruses



new subtype



little existing immunity

human influenza virus



▷ H (haemagglutinin) ◻ N (neuraminidase) — blue — bird — red — human

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Antigenic shift: mixing of RNA segments in one host produces a **new subtype**

Quick check

1. What is the protein coat of a virus called?
2. What is a prophage?
3. Which host does bacteriophage lambda infect?
4. Give two reasons why HIV evolves rapidly.

Quick check answers

Viruses

1. The capsid.
2. Viral DNA integrated into the host bacterium's chromosome.
3. The bacterium E. coli.
4. Reverse transcriptase does not proofread, so the mutation rate is high; and huge numbers of virus particles are produced with a short generation time.