HL IB Biology

Your notes

Viruses

Contents

Virus Structure (HL)

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Structural Features of Viruses

Virus structure

- **Viruses** are **non-cellular infectious particles**; they are not organisms as they are **not considered to be alive**
- Viruses possess none of the characteristic features used for classifying organisms so they sit **outside** of the three-domain classification system
- They are relatively simple in structure and much smaller than prokaryotic cells, with diameters between 20 and 300 nm
  - They can only be seen with an electron microscope
- They have **no cellular structures** and so **no metabolism** so they are considered to be **acellular**
- Structural features common to all viruses include
  - A **small size**
    - Viruses contain few molecules, so do not form large structures
  - A **fixed size**
    - Viruses do not grow
  - A **nucleic acid core**
    - Their genomes are made up of either **DNA or RNA**
    - Nucleic acids in viruses can be **single or double-stranded**
    - Nucleic acids can have a **linear or circular** structure
  - A **protein coat** called a **'capsid'**
    - **Attachment proteins** are present on the outer surface of a capsid that allow viruses to **bind to and enter host cells**
  - **No** cytoplasm
  - Very **few**, or no, **enzymes**
- **Some** viruses have an additional outer layer called a **lipid envelope**, formed usually from the **membrane-phospholipids** of a cell they were made in
  - Lipid envelope structures can be involved with cell recognition
- All viruses are **parasitic** in that they **can only reproduce by infecting living cells** and using their protein-building machinery (ribosomes) to produce new viral particles
  - The energy that viruses need for replication is released by the host cell; viruses do not respire

General virus structure diagram

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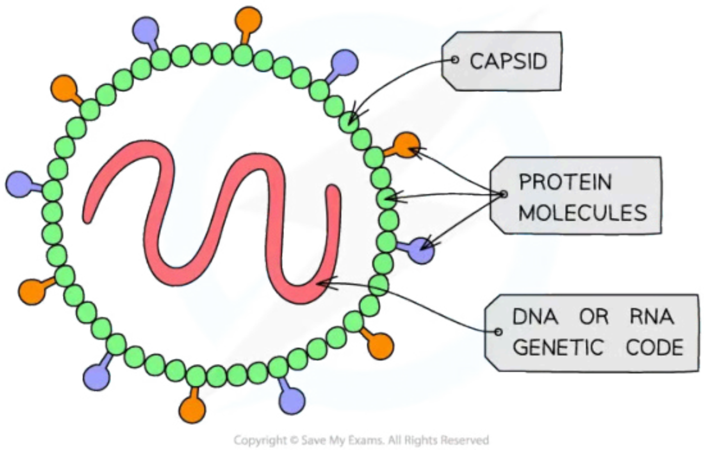

Virus structure can vary, but all viruses have genetic material and a protein capsid with attachment proteins

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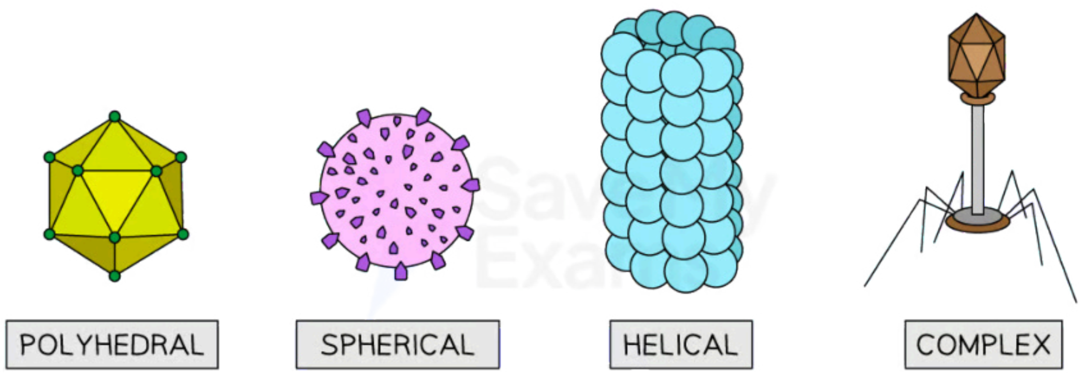
Structural Diversity

Diversity of structure in viruses

- Although simple, there is huge **variety and diversity** of virus structure and shape:
  - **Genetic material** can be either RNA or DNA which can either be double or single stranded
  - Some viruses are **enveloped**, others are not
  - Viral shapes can be threadlike, polyhedral and spherical
- Each type of virus is able to attach to and infect a **specific type of host cell**; the host cell to which it can attach is determined by the **attachment proteins**, e.g.
  - HIV infects white blood cells
  - Hepatitis infects liver cells

Virus structure variety diagram



Virus structure varies widely

- Examples of viruses that have different structures are:
  - **Bacteriophage lambda**
  - **Coronaviruses**
  - **HIV**

Bacteriophage lambda

- This is a bacterial virus and it **infects the bacterial species *Escherichia coli*** *(E.coli)*
- It has a **double stranded DNA** genome contained within its **capsid** head
- The **tail and fibrils** enable it to attach itself to its host and insert its DNA into the cell
  - The tail consists of proteins that contract, allowing the virus to move the tail through the bacterial cell wall
  - **DNA** from the virus is **injected into the host cell** through the tail

Bacteriophage lambda structure diagram

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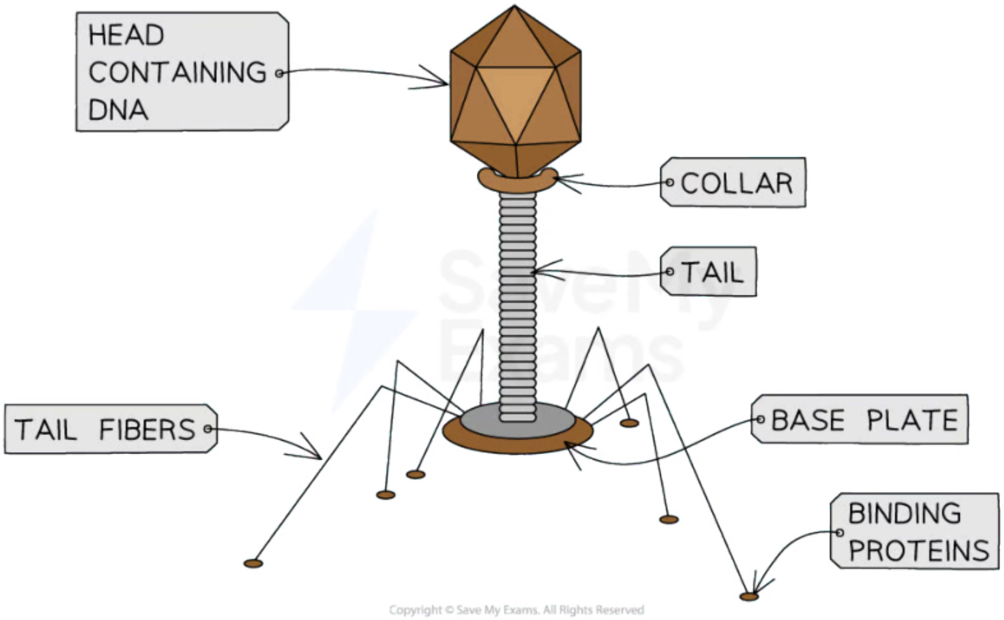
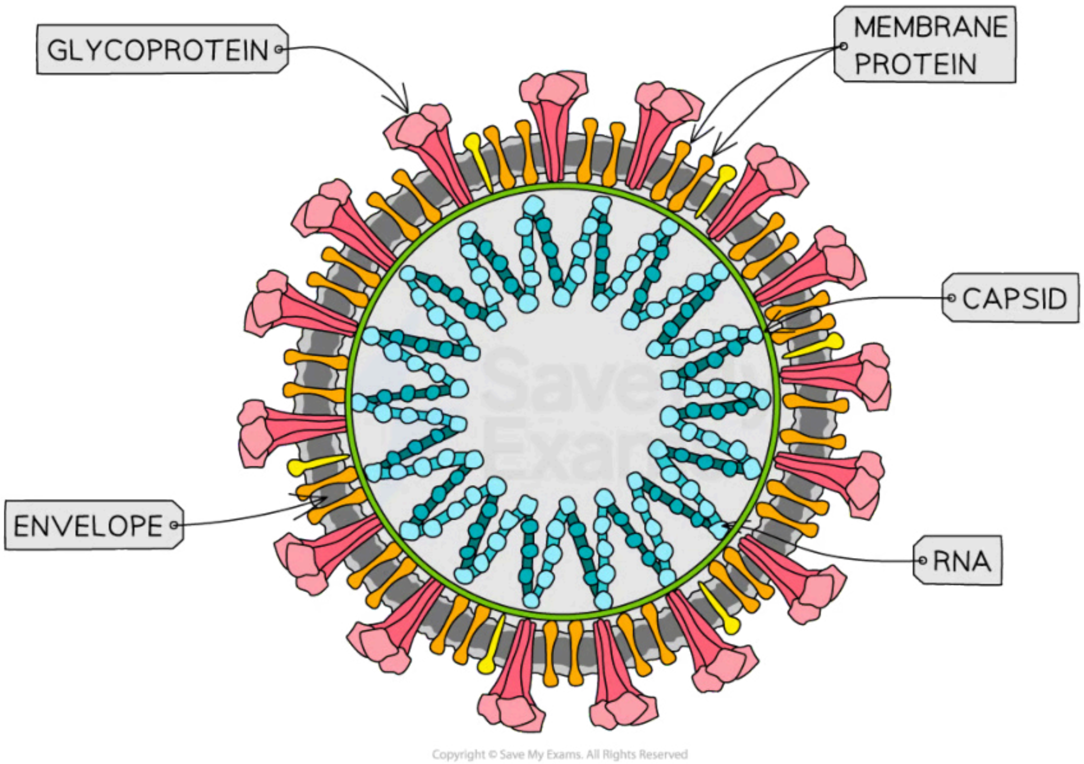


A bacteriophage virus

Coronaviruses

- Coronaviruses are a group of viruses that cause **respiratory diseases in mammals and birds**
  - They can be transmitted via respiratory fluids
- Their structure includes:
  - Single stranded **RNA**
  - A **spherical** shape
  - An **envelope** outside their **capsid**
  - Many **glycoproteins** that project from their surface, producing a "corona"
- Examples include SARS-Cov-2 (COVID-19), Middle East Respiratory Syndrome (MERS), and Severe Acute Respiratory Syndrome (SARS)

Coronavirus structure diagram

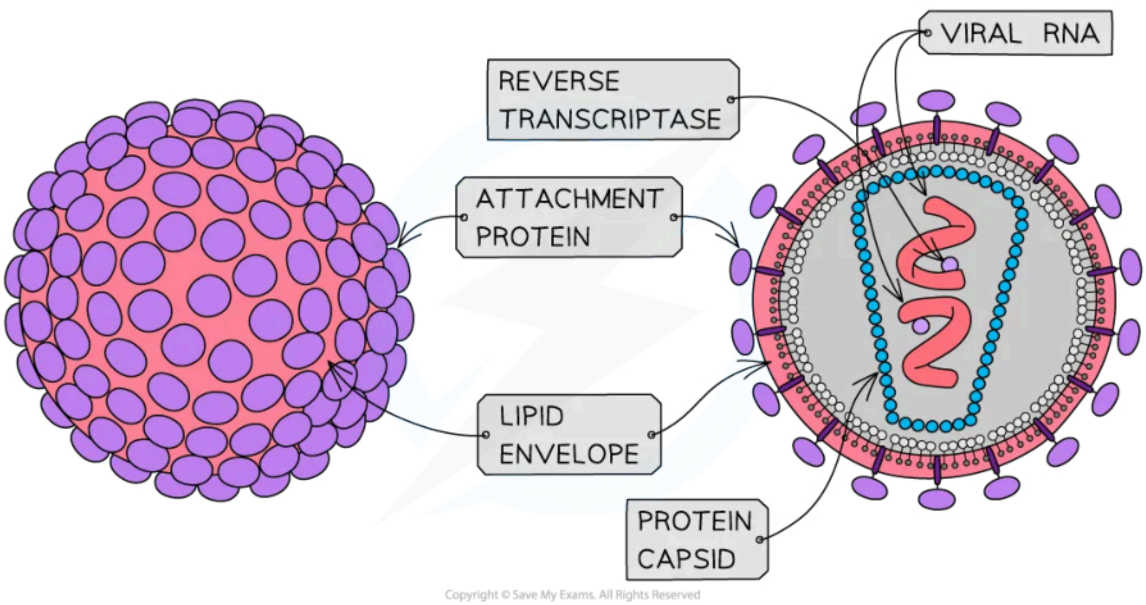


A coronavirus

HIV

- The Human Immunodeficiency Virus is spread by intimate human contact and can only be **transmitted by direct exchange of body fluids**
- This means HIV can be transmitted in the following ways:
  - Sexual intercourse
  - Blood donation
  - Sharing of needles used by intravenous drug users
  - From mother to child across the placenta
  - Mixing of blood between mother and child during birth
  - From mother to child through breast milk
- HIV contains:
  - Two **RNA** strands
  - Proteins (including the **enzyme** reverse transcriptase)
    - Reverse transcriptase allows the **production of DNA from the viral RNA**; for this reason HIV is known as a **retrovirus**
  - A protein **capsid**
  - A viral **envelope** consisting of a **lipid bilayer** and **glycoproteins** that act as **attachment proteins**
    - The lipid bilayer is derived from the cell membrane of the host helper T cell that the particle escaped from

HIV structure diagram



A HIV particle

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Replication in Viruses (HL)

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The Lytic Cycle

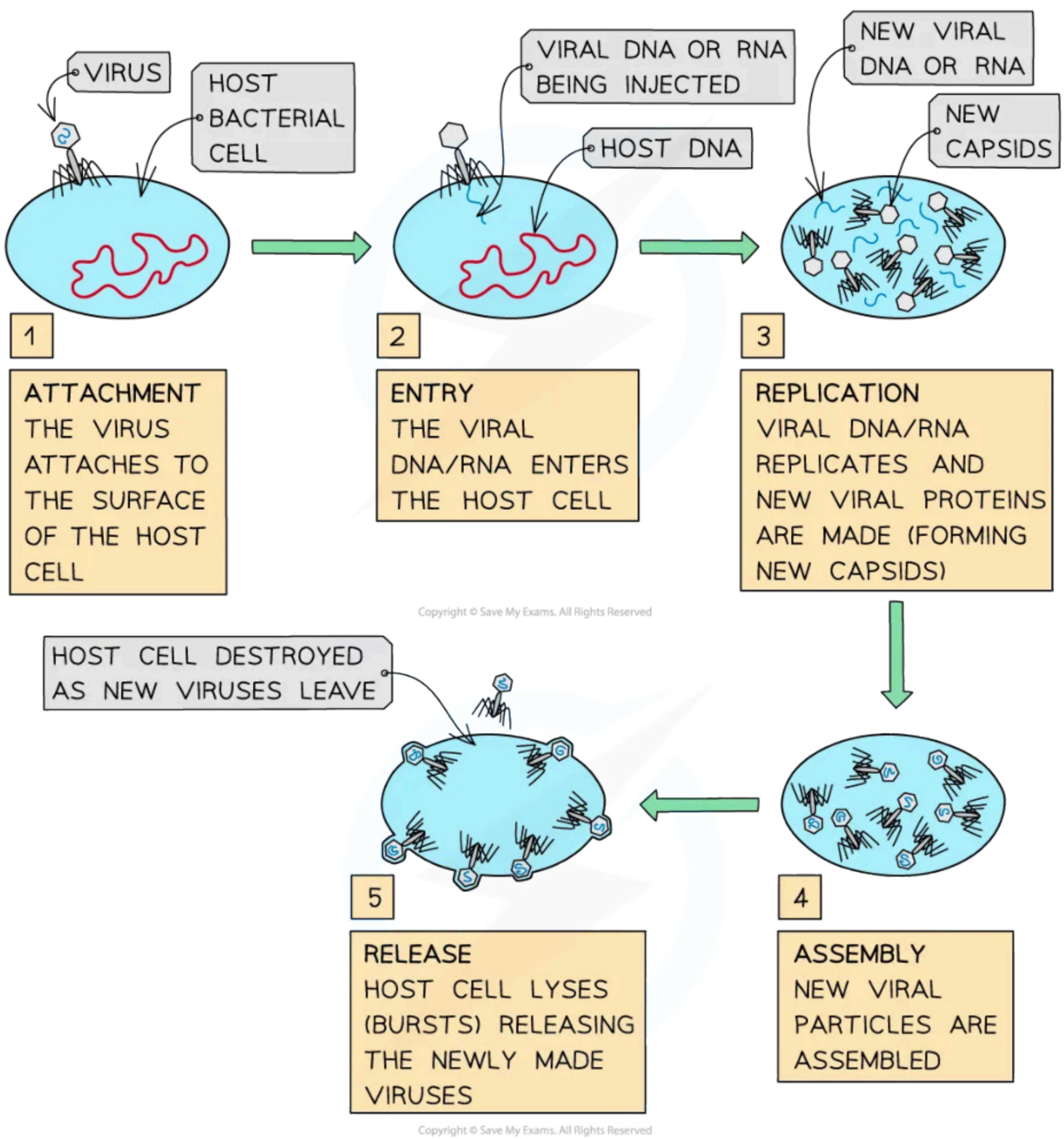
Viral replication

- Being non-living, viruses **do not undergo cell division**
- All viruses are **parasitic**, meaning they can **only reproduce** by infecting living cells, referred to as **host cells**
- To replicate all viruses must:
  - Attach to a specific attachment site on the host cell
  - Inject their nucleic acid into the cytoplasm of the host cell
  - Use the protein synthesis machinery of their host cell to produce viral proteins
  - Assemble new viral particles
  - Release the new viral particles from the host cell
- Viral replication occurs via a **lytic pathway**, but some viruses undergo a series of events known as the **lysogenic pathway** in between reproductive cycles

The lytic pathway

- This is named as such because the new virus particles are released during **lysis (bursting) of the host cell**
  - This is caused by an enzyme called **lysozyme** which is coded for by the virus genetic material
- Lysis occurs after the production of fully functional virus particles called **virions**
- The steps of the lytic pathway are as follows:
  1. The virus **attaches** to the cell membrane of the host cell using **attachment proteins**
  2. The virus infects the host cell by **injecting its DNA** into the cytoplasm
  3. Next, the virus uses proteins and enzymes within the host cell to produce new virus particles in a process called **biosynthesis**
  4. Virus particles are assembled and matured into **virions**
  5. Finally, the **host cell undergoes lysis**, releasing the virions into the host organism to infect more cells

Lytic cycle diagram



Viruses use the protein synthesis machinery of host cells to replicate themselves in the lytic pathway

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The Lysogenic Cycle

The lysogenic pathway

- A key difference between the lytic pathway and the lysogenic pathway is that here **new virus particles are not immediately released** and will **not immediately** cause disease once they infect a host cell
- During the lysogenic pathway **viral nucleic acid combines with the host DNA**
- A viral gene coding for a **repressor protein** prevents the viral nucleic acid from being transcribed and translated
  - This is called **latency** and the time during which it occurs is known as a **period of lysogeny**
- The host cell will continue to function as normal, including reproduction and cell division which means that subsequent cells will contain the **virus nucleic acid within the host's genome**
  - This can result in continuous production of host cells containing the virus nucleic acid within its genome
  - This stage of the lysogenic pathway can continue until a lytic event is triggered
- The **viral DNA is inactive**, or dormant, until a change in the cell's environment **triggers the virus DNA to enter the lytic pathway**
  - Changes include exposure to UV rays and certain chemicals

Lysogenic cycle diagram

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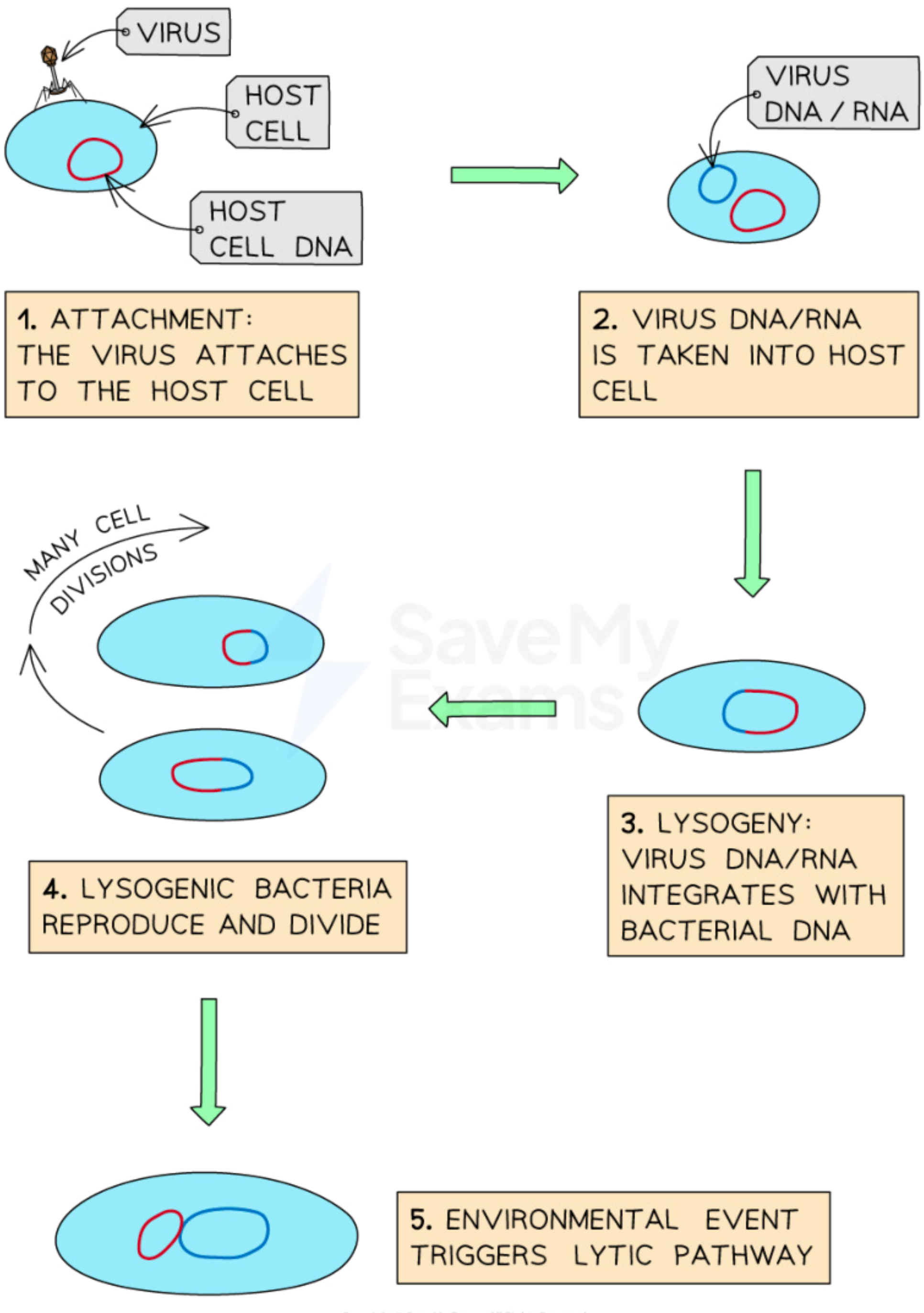

Viruses lay dormant in the lysogenic pathway until the lytic pathway is triggered

Origin & Evolution of Viruses (HL)

Origin of Viruses

- Viruses can infect nearly all living species and are estimated to have **been on Earth 3.5 billion years before humans evolved**
- There is evidence that viruses evolved alongside other species, a process known as **coevolution**
  - Around 8 % of the human genome contains small segments of viral DNA thought to be left over from ancient infections
  - These DNA fragments are called endogenous retroviruses (ERVs) and have been passed along and modified over millions of years of evolution
- The **origin of viruses** is still under debate in the scientific community and among virologists
  - One issue is that viruses are not found in fossils so there is limited evidence for their evolution

There are **three key theories** as to the origin of viruses:

Escape theory

- Viruses **arose from genetic elements**, such as DNA and RNA, that gained the ability to move between cells
- These genetic elements became surrounded by an outer boundary forming a virus particle

Regressive/reduction theory

- Viruses are **remnants of cellular organisms** or were once small cells that became parasites of larger cells
- Over time the cellular structures that were no longer needed were shed , leaving behind just viral structures

Virus-first theory

- Viruses **predate their current cellular hosts**
- During evolution we expect simpler organisms to give rise to more complex organisms, so the simple nature of virus particles could indicate that viruses evolved first

Theories of virus origin diagram

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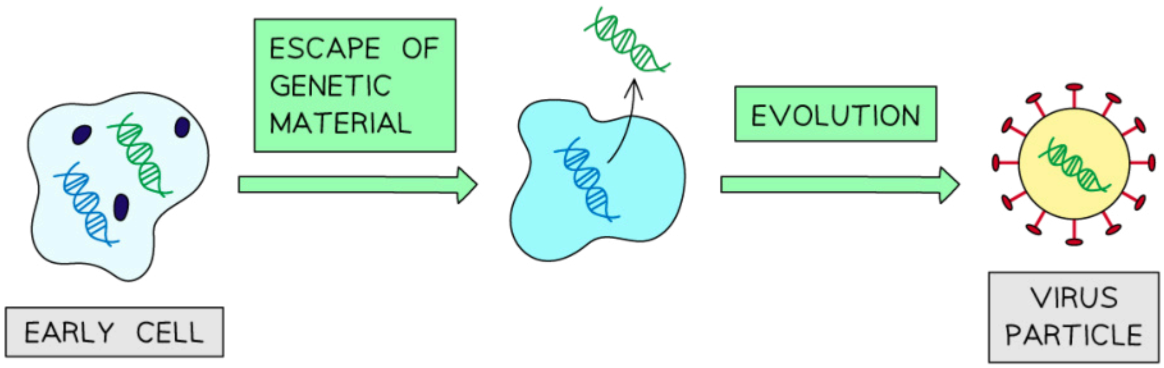
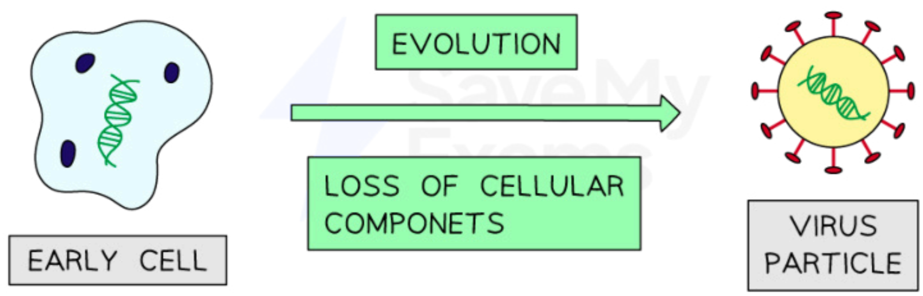
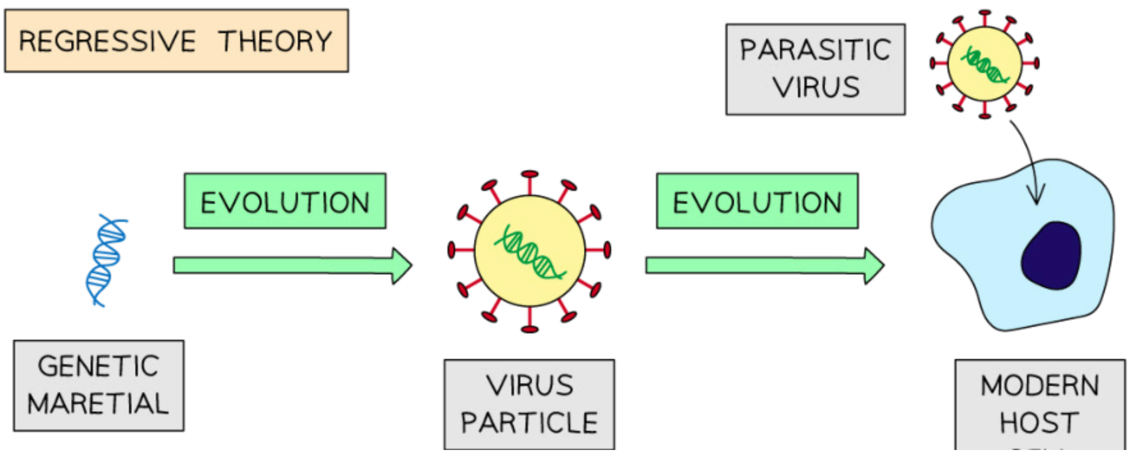
ESCAPE THEORY



REGRESSIVE THEORY



REGRESSIVE THEORY



There are multiple theories for the origin of viruses

- Viruses are diverse and this diversity suggests that there may have been **different origins for different viruses**
  - It is possible that all of the above theories or correct, or indeed that none of them are correct and that a different process occurred
- There are some features that are common among many viruses which indicates that convergent evolution may have occurred
  - All viruses have a **capsid** protein outer boundary and no cytoplasm contained within this boundary
  - All viruses have **genetic material**, either DNA or RNA
    - The genetic code is the same as that used by other organisms
  - All viruses are **parasitic** in nature and cannot replicate or or carry out their functions without a host cell

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Evolution in Viruses

Viral evolution

- Viruses can undergo very **evolution extremely rapidly**
- Two examples that demonstrate this are:
  - The evolution of **influenza viruses**
  - The evolution of **HIV**
- Both of these viruses:
  - Have **high mutation rates**
    - This is largely due to the fact that these viruses have **RNA** as their genetic material; mutations can occur during the process of converting viral RNA into DNA during viral replication
  - Have **large population sizes**
  - Have **short generation times**
- These features mean that both of these viruses can quickly evolve to **evade the immune systems** of their hosts

Antigenic drift and antigenic shift

Viruses can undergo genetic change either by **antigenic drift** or **antigenic shift**

Antigenic drift

- The accumulation of **small changes** to viral genetic material over time
- **Variation** in the **surface proteins** of the virus appear slowly
- Eventually the host's **immune system cannot recognise the virus**
- **HIV** undergoes antigenic drift

Antigenic shift

- A **major change** occurs in the viral genetic material in a short time period
  - **Two or more** virus types **infect the same cell** within the host
  - They **combine their genetic material**
- **Rapid variation** is produced in the **surface proteins** of the virus
- A new virus is created which is not recognised by the host's immune system
- The **influenza virus** undergoes antigenic shift

Treating disease caused by rapidly evolving viruses

- **Vaccines**
  - For rapidly evolving viruses, **vaccines need to be changed and updated** yearly so that they remain effective
  - This is a **successful** approach for viruses that undergo **antigenic drift** because the changes are small and not hugely rapid

        - Although HIV undergoes genetic drift, it does so at an unusually rapid rate so a vaccine has not yet been successful
    - For viruses undergoing **antigenic shift** vaccines are **not so successful** because the changes are rapid and not predictable
- Fast-evolving viruses may need to be dealt with by the **isolation of infected individuals** to stop the spread of infection

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