

Bacteria, viruses and infection

Revision notes · Comparing bacteria and viruses, the lytic and latent cycles, how TB bacteria and HIV infect cells, and the routes and barriers that decide infection.

For Pearson Edexcel International AS Biology XBI11 and International A Level Biology YBI11. **A Level only** is IA2 content (Units 4 to 6), not needed for the International AS.

Bacteria, viruses and infection Spec 6.5–6.7 A Level only

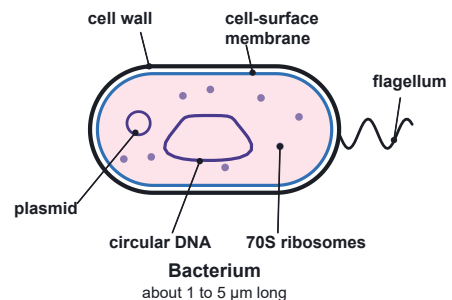
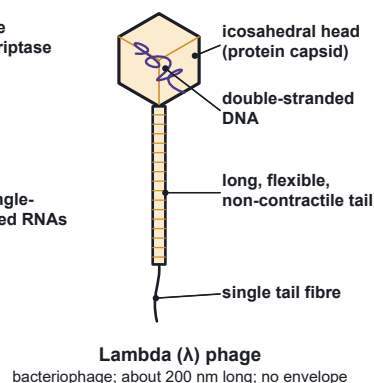
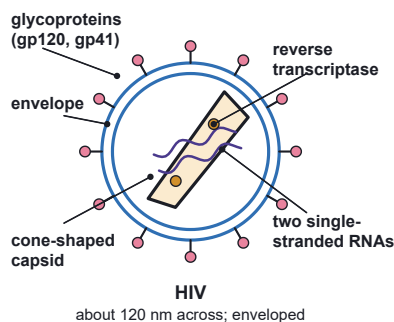
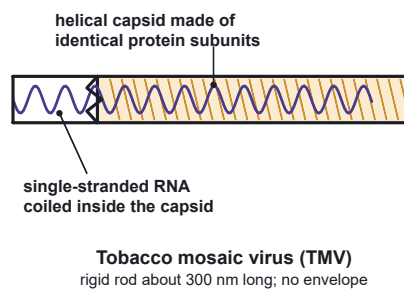
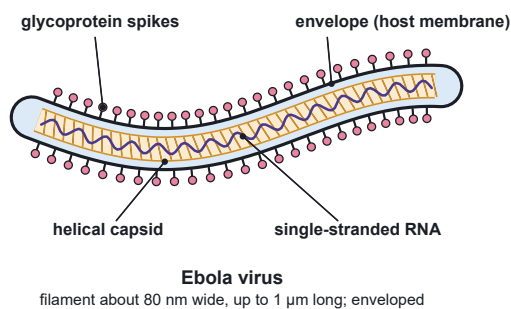
Structure of bacteria and viruses Spec 6.5(i)

Bacteria are living prokaryotic cells, about 0.5 to 5 μm long. **Viruses** are far smaller (most are about 20 to 300 nm across; Ebola filaments are about 80 nm wide but often over 1 μm long) and are not cells: they have no cytoplasm, no ribosomes and no metabolism of their own, and they can reproduce only inside a host cell.

Bacteria compared with viruses		
Feature	Bacterium	Virus
Cell structure	Prokaryotic cell: cell-surface membrane, cell wall of peptidoglycan, cytoplasm	Acellular: no membrane or cytoplasm of its own
Genetic material	Circular DNA (nucleoid), often plasmids too	DNA or RNA (single or double stranded), never both, in small amounts
Protein coat	None (cell wall is a different structure)	Capsid made of protein subunits (capsomeres) around the nucleic acid
Envelope	None	Present in some viruses: lipid bilayer from the host membrane with viral glycoproteins
Ribosomes	70S ribosomes	None; uses host ribosomes
Reproduction	Binary fission; can reproduce outside a host	Only inside a host cell, using its enzymes, ribosomes and ATP
Susceptible to antibiotics	Yes	No

Four named viruses

Structure of the viruses named in the specification				
Virus	Nucleic acid	Capsid	Envelope	Notes
Ebola virus	Single-stranded RNA	Helical capsid forming a long filament	Yes, with glycoproteins	Infects human cells; filamentous particle
Tobacco mosaic virus (TMV)	Single-stranded RNA	Helical (rod-shaped) capsid of identical protein subunits	No	Infects plant cells, causing mosaic discolouration of leaves
HIV	Two copies of single-stranded RNA, plus reverse transcriptase	Cone-shaped capsid	Yes, with glycoproteins (gp120, gp41) that bind to host cells	Infects helper T cells
Lambda phage (λ phage)	Double-stranded DNA	Icosahedral head with a tail and tail fibres	No	A bacteriophage: infects bacteria (<i>Escherichia coli</i>)



Not drawn to scale: sizes are approximate.

The viruses named in the specification compared with a bacterium (not drawn to scale).

Common mistake: Viruses are not cells and are not made of 'a nucleus and cytoplasm'. Say 'nucleic acid in a capsid, with or without an envelope'. Never say viruses are killed by antibiotics.

The terms lytic and latency Spec 6.5(ii)

Lytic cycle	A viral life cycle in which the virus uses the host cell to make many copies of itself at once; the host cell bursts (lyses) and releases the new particles.
Latency	A state in which viral nucleic acid persists in the host cell without producing new virus particles, and no symptoms need occur; the virus can later become active.

The lytic cycle (for example lambda phage)

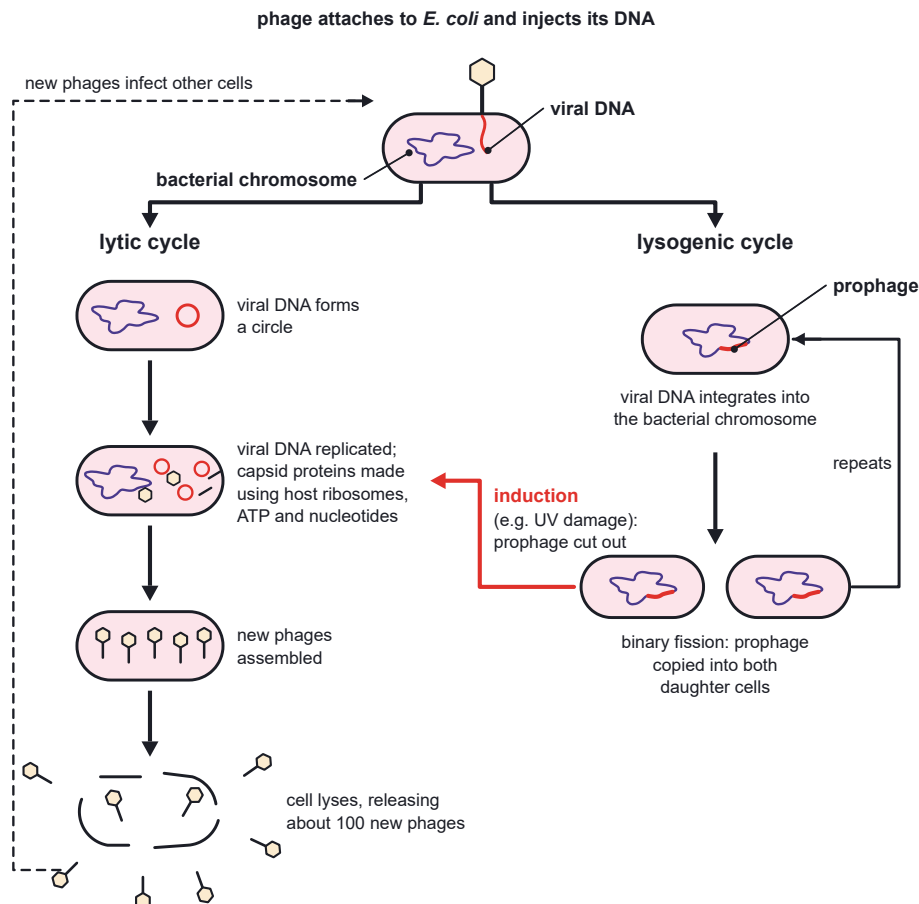
1. Attachment: tail fibres bind to specific receptors on the bacterial surface.
2. Injection: the phage DNA enters the bacterium; the empty capsid stays outside.
3. Replication and synthesis: the host's enzymes and ribosomes copy the viral DNA and make viral capsid proteins.
4. Assembly: new capsids form and are filled with DNA.
5. Lysis: viral lysozyme breaks down the cell wall; the host bursts and releases hundreds of phage particles.

Latency (the lysogenic state of lambda phage; HIV)

In latency the viral DNA is inserted into the host chromosome. In a bacterium it is called a **prophage** and in a human cell infected by HIV, a **provirus** (made by reverse transcriptase from the RNA genome). It is copied each time the host DNA replicates and passed to daughter cells, and the host cell is not destroyed. A trigger such as stress, ultraviolet light or activation of the infected cell switches the virus into the lytic cycle.

Lytic cycle compared with latency		
Feature	Lytic cycle	Latency
Viral nucleic acid	Replicated separately from the host DNA; many copies made	Integrated into host DNA (or held silent)
New virus particles	Made at once in large numbers	None made
Host cell	Destroyed (lysed)	Survives and divides
Symptoms	Usually during the lytic phase	Often none; the host can be a hidden carrier

Exam tip: Latent HIV in a provirus is protected from the immune system and antiviral drugs because no viral proteins are being made. That is why people with HIV need life-long treatment.



The lytic cycle and latency of **lambda phage**: in latency the viral DNA is a **prophage** inside the host chromosome.

How *Mycobacterium tuberculosis* and HIV cause disease Spec 6.6

Tuberculosis (TB)

TB is caused by the bacterium *Mycobacterium tuberculosis*. It is spread in droplets coughed out by an infected person and breathed in. The bacteria reach the alveoli and are engulfed by **macrophages**. The bacterium has a thick, waxy cell wall and prevents the lysosomes fusing with the phagosome, so it is not digested and multiplies slowly inside the macrophage.

1. Bacteria in droplets are inhaled and reach the alveoli of the lung.
2. Macrophages engulf them but cannot destroy them; the bacteria multiply inside the macrophages.
3. The immune system responds: macrophages and T cells gather round the infected cells and form a ball of cells and dead tissue called a **tubercle**, which walls off the bacteria. Most people have no symptoms at this stage (latent TB).
4. If the immune system is weakened (for example by HIV, malnutrition or age), the bacteria multiply, the tubercle breaks down and spreads to other parts of the lung. Lung tissue is destroyed, leaving cavities.
5. Symptoms include a persistent cough with blood-stained sputum, weight loss, fever and night sweats. Without treatment, lung function fails and the infection can spread through the blood, causing death.

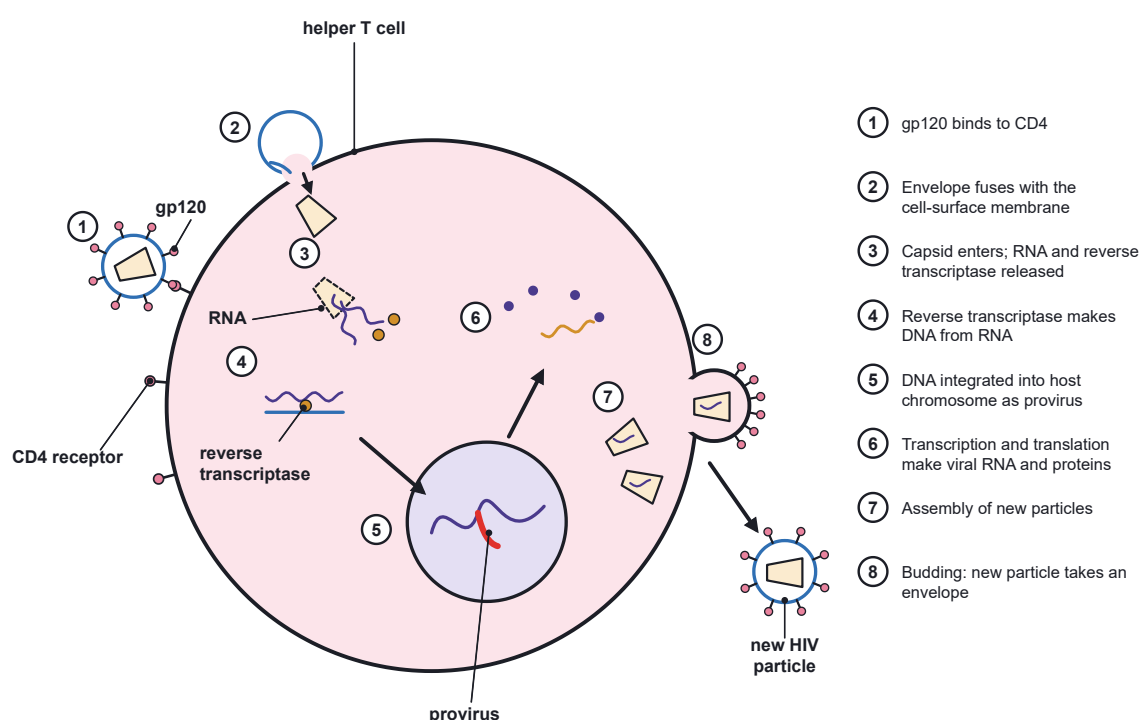
HIV and AIDS

The human immunodeficiency virus (HIV) is spread by exchange of body fluids (sexual contact, blood, mother to child). It infects **helper T cells** (and some macrophages), which carry the CD4 receptor.

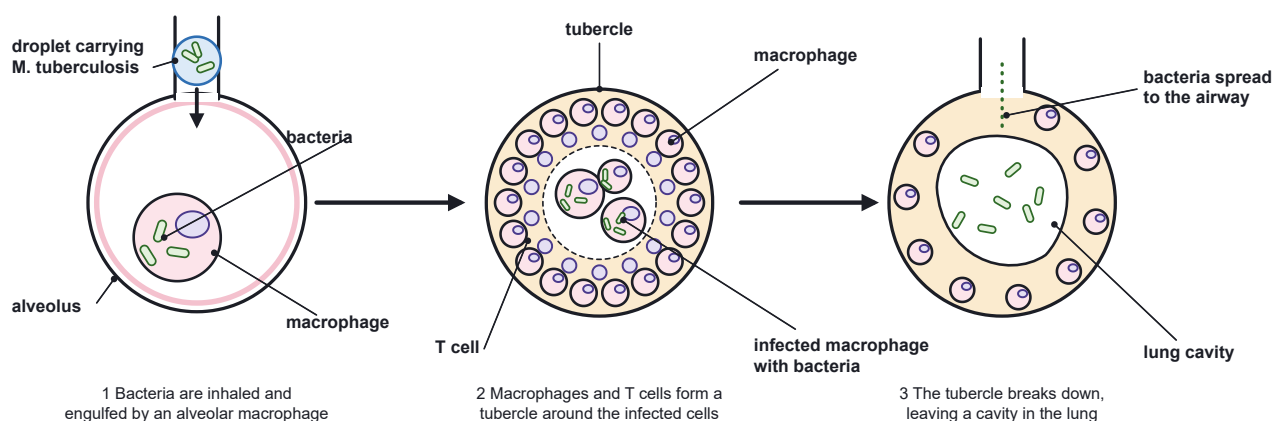
1. A glycoprotein on the HIV envelope (gp120) binds to the CD4 receptor on the helper T cell.
2. The viral envelope fuses with the cell-surface membrane and the capsid enters the cytoplasm.

3. The capsid breaks down, releasing RNA and the enzyme reverse transcriptase. This makes a DNA copy of the RNA, and the DNA is inserted into the host chromosome by the enzyme integrase as a provirus (latency).
4. When the cell is activated, the host's enzymes transcribe the proviral DNA to make viral RNA and proteins, which are assembled into new virus particles.
5. New particles bud off from the cell-surface membrane, taking a piece as their envelope. Large numbers of virus particles are released and the T cell dies.

Helper T cells are essential for activating B cells and killer T cells. As HIV destroys them, the number of helper T cells falls and the person develops **AIDS** (acquired immune deficiency syndrome): they lose the ability to fight infections and some cancers. Death usually results from opportunistic infections such as TB, pneumonia or a cancer, rather than from HIV directly. HIV makes people far more likely to develop active TB, and TB is a leading cause of death in people with HIV.



HIV life cycle in a helper T cell, from binding to CD4 to budding of new particles.



TB in the lung: bacteria in macrophages are walled off in a **tubercle**, which can break down to leave a cavity.

Exam tip: A 'describe how HIV causes death' answer needs the chain: infects helper T cells, destroys them, fewer B and killer T cells activated, immune system fails, death from opportunistic infection.

Routes of entry and protective barriers Spec 6.7

Major routes of entry

Routes pathogens take into the body		
Route	How	Examples
Gas exchange system	Breathing in droplets or spores	TB, influenza, measles
Digestive system	Eating or drinking contaminated food or water	Cholera, <i>Salmonella</i> food poisoning
Breaks in the skin	Cuts, wounds, bites from vectors, injections, needles	Tetanus, malaria (mosquito bite), HIV and hepatitis B (needles)
Mucous membranes of the genital tract and eye	Direct contact with infected fluids or surfaces	HIV, gonorrhoea, chlamydia, conjunctivitis
Across the placenta or in breast milk	Mother to fetus or baby	HIV, rubella

Barriers to infection

Non-specific barriers	
Barrier	How it protects
Skin	A tough layer of keratinised dead cells forms a physical barrier. Sebum from sebaceous glands contains fatty acids, making the surface acidic and hostile to many microorganisms. Cuts are sealed quickly by blood clotting.
Stomach acid	Hydrochloric acid keeps the stomach at about pH 1 to 2, killing most microorganisms taken in with food and drink. Pepsin works at this pH.
Gut flora	Harmless bacteria in the gut compete with pathogens for nutrients and space, and produce substances (such as lactic acid) that inhibit pathogens. Antibiotics can reduce gut flora and allow pathogens to grow.
Skin flora	Resident bacteria on the skin compete with pathogens for nutrients and space and produce acids and antimicrobial substances. Normal flora can themselves cause infection if they enter the body through broken skin.

Other barriers are mucus, which traps microorganisms, and cilia on the lining of the airways, which sweep mucus up and out of the gas exchange system. Tears and saliva contain lysozyme (see the next subtopic).

*Common mistake: 'Gut flora fight pathogens' is too vague. Say they **compete** for nutrients and space and produce inhibitory substances, so pathogens cannot establish themselves.*

Quick check

- 1 . What is the difference between a capsid and an envelope?
- 2 . Why do viruses only reproduce inside host cells?
- 3 . What is a provirus?
- 4 . Where does *Mycobacterium tuberculosis* survive in the body?
- 5 . Name two ways that gut flora protect against infection.

Quick check answers

Bacteria, viruses and infection

1. The capsid is the protein coat around the viral nucleic acid. The envelope is an outer lipid layer, taken from the host cell membrane, present in some viruses.
2. They have no ribosomes or metabolism, so they use the host's enzymes, ribosomes and ATP.
3. A DNA copy of the HIV genome made by reverse transcriptase and integrated into the host cell's chromosome.
4. Inside macrophages in the lungs, which cannot digest it.
5. They compete with pathogens for nutrients and space, and they produce substances that inhibit pathogens.