St. Ambrose College

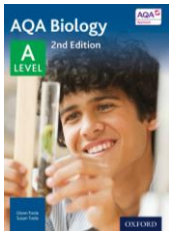
A Level Biology (Year 12)

Knowledge Organiser: Unit 2 Cells (2.4)

2.4 Cell recognition and the immune system

For every 1 hour A Level Biology lesson you are expected to spend at least 1 hour independently reviewing the subject content. The following resources should be referred to regularly to support your independent work.

You have been provided with a printed copy of the full subject specification (also available on the AQA website https://www.aqa.org.uk/subjects/science/as-and-a-level/biology-7401-7402/specification-at-a-glance). Use this to follow the learning in lessons…track your progress and be aware of what is still to come.



Use the textbook on www.kerboodle.com after every lesson to develop your understanding. Read the relevant pages, add detail to your class notes and complete the summary tasks. Create your own summary notes/flashcards for future use in the run up to exams.

Unit 2 Cells on pages 56-127 Cell recognition and the immune system **(pg102-127)**

Use regularly between lessons to review basic content and to become more familiar with key terminology. https://senecalearning.com/en-GB/

Access detailed revision notes, key definitions, flash cards, past paper questions and mark schemes.
https://www.physicsandmathstutor.com/biology-revision/a-level-aqa/

As an A Level student you are expected to take a proactive approach to your studies; arrive to lessons fully equipped and prepared for what you will be learning about (read ahead in the specification/textbook), focus and participate in lessons, ask for help/clarification when you are unsure and spend time after the lesson consolidating/embedding new learning.

2.4 Cell recognition and the immune system

Antigen definition

- Molecules which, when recognised as non-self/foreign by the immune system, can stimulate an immune response and lead to the production of antibodies
- Often proteins/glycoproteins on the surface of cells

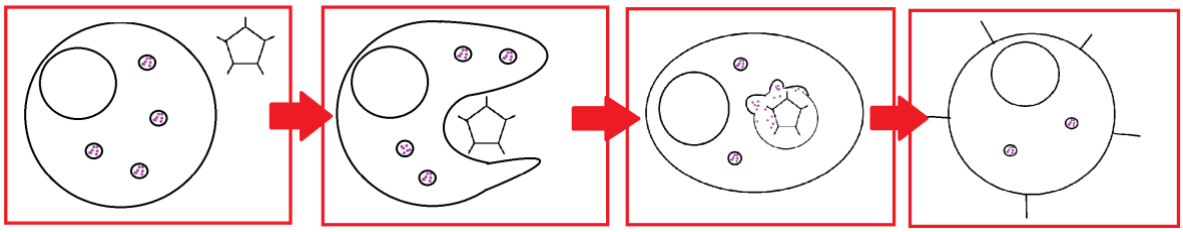
Remember: proteins have a specific tertiary structure / shape allowing different proteins to act as specific antigens

Antigens are specific so allow the immune system to identify…

- Pathogens (disease causing organisms) e.g. viruses, fungi, bacteria
- Cells from other organisms of the same species e.g. organ transplant, blood transfusion
- Abnormal body cells e.g. cancerous cells / tumours
- Toxins released from bacteria

Phagocytosis of pathogens – non-specific immune response

1. Phagocyte **e.g. macrophage** recognises foreign antigens on the pathogen and binds to the antigen
2. Phagocyte **engulfs** pathogen by surrounding it with its cell surface membrane / cytoplasm
3. Pathogen contained in vacuole/vesicle called a **phagosome** in cytoplasm of phagocyte
4. Lysosome fuses with phagosome (phagolysosome) and releases **lysozymes** (hydrolytic enzymes) into the phagosome
5. These hydrolyse / digest the pathogen
6. Phagocyte becomes **antigen presenting (APC)** and stimulates specific immune response



The cellular response (the response of T lymphocytes to a foreign antigen e.g. infected cells, cells of the same species)

1. T lymphocytes recognises antigen presenting cells after phagocytosis (foreign antigen)
2. Specific T helper cell with receptor complementary to specific antigen binds to it, becoming activated and dividing rapidly by mitosis to form clones which:
   a) Stimulate B cells for the humoral response
   b) Stimulate cytotoxic T cells to kill infected cells by producing perforin
   c) Stimulate phagocytes to engulf pathogens by phagocytosis

The humoral response (the response of B lymphocytes to a foreign antigen e.g. in blood/tissues)

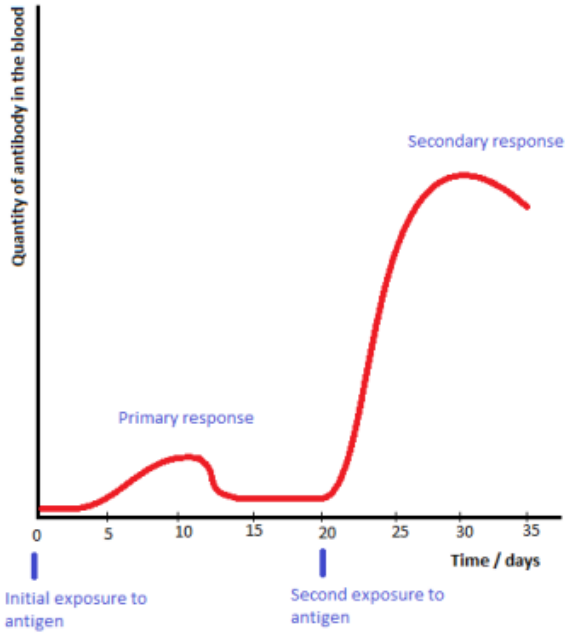
1. Clonal selection:
   a) Specific B cell binds to antigen presenting cell and is stimulated by helper T cells which releases cytokines
   b) Divides rapidly by mitosis to form clones (clonal expansion)
2. Some become B plasma cells for the primary immune response – secrete large amounts of monoclonal antibody into blood
3. Some become B memory cells for the secondary immune response

Primary response – antigen enters body for the first time (role of plasma cells)

- Produces antibodies slower and at a lower concentration because
  - Not many B cells available that can make the required antibody
  - T helpers need to activate B plasma cells to make the antibodies (takes time)
- So infected individual will express symptoms

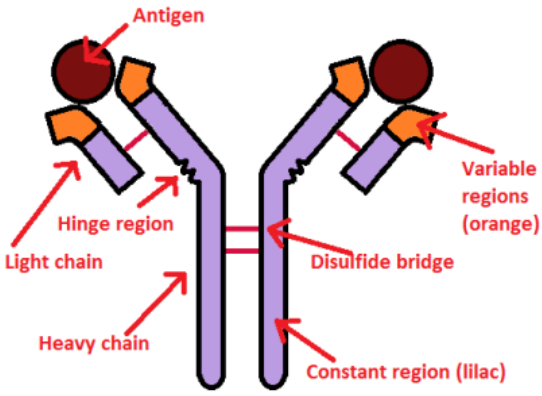
Secondary response – same antigen enters body again (role of memory cells)

- Produces antibodies faster and at a higher concentration because
- B and T memory cells present
- B memory cells undergo mitosis quicker / quicker clonal selection



Antibodies

- Quaternary structured protein (immunoglobin)
- Secreted by B lymphocytes e.g. plasma cells and produced in response to a specific antigen
- Binds specifically to antigens (monoclonal) forming an antigen-antibody complex
- two binding sites so one antibody can bind to two pathogens at a time (at variable region/binding site) forming two separate antigen-antibody complex
- Enables antibodies to clump the pathogens together – agglutination = easier for engulfing
  **the hinge regions aid binding to antigens*



What is a vaccination?

- Injection of antigens
- From attenuated (dead or weakened) pathogens
- Stimulates the formation of memory cells
- A vaccine can lead to symptoms because some of the pathogens might be alive / active /viable; therefore, the pathogen could reproduce and release toxins, which can kill cells

Vaccines to provide protection for individuals against disease

- Normal immune response but the important part is that memory cells are produced
- On reinfection / secondary exposure to the same antigen, the secondary response therefore produces antibodies faster and at a higher concentration
- Leading to the destruction of a pathogen/antigen (e.g. agglutination and phagocytosis) before it can cause harm / symptoms = immunity

Vaccines to provide protection for populations against disease (herd immunity)

- Large proportion but not 100% of population vaccinated against a disease – herd immunity
- Makes it more difficult for the pathogen to spread through the population because…
  - More people are immune so fewer people in the population carry the pathogen / are infected
  - Fewer susceptible so less likely that a susceptible / non-vaccinated individual will come into contact with an infected person and pass on the disease

Ethical issues associated with the use of vaccines

- Tested on animals before use on humans → animals have a central nervous system so feel pain (some animal based substances are also used to produce vaccines)
- Tested on humans → volunteers may put themselves at unnecessary risk of contracting the disease because they think they're fully protected e.g. HIV vaccine so have unprotected sex → vaccine might not work
- Can have side effects
- Expensive – less money spent on research and treatments of other diseases

Antigen variability is often an explanation for why…

- New vaccines against a disease need to be developed more frequently e.g. influenza
- Vaccines against a disease may be hard to develop or can't be developed in the first place eg. HIV
- May experience a disease more than once e.g. common cold

Explain the effect of antigen variability on disease

- Change in antigen shape (due to a genetic mutation)
- Not recognised by B memory cell → no plasma cells / antibodies
- Not immune
- Must re-undergo primary immune response → slower / releases lower concentration of antibodies
- Disease symptoms felt

Explain the effect of antigen variability on disease prevention (vaccines)

- Change in antigen shape (due to a genetic mutation)
- Existing antibodies with a specific shape unable to bind to changed antigens / form antigen-antibody complex
- Immune system i.e. memory cells won't recognise different antigens (strain)

Evaluate methodology, evidence and data relating to the use of vaccinations

- A successful vaccination programme:
    - Produce suitable vaccine
        - Effective – make memory cells
        - No major side effects → side effects discourage individuals from being vaccinated
        - Low cost / economically viable
        - Easily produced / transported / stored / administered
    - Provides herd immunity
- Evaluating a conclusion that's been made from a set of data / study
    - If there is a scatter graph, the relationship between two variables may be a positive /negative correlation, or no correlation
        - But correlation between two variables doesn't always mean there's a causal relationship – correlation could be due to change or another variable / factor
    - Repeatability (when an experiment is repeated using the same method and equipment and obtains the same results)
        - Have there been other experiments / studies showing the same?
    - Validity (suitability of the investigative procedure to answer the question being asked)
        - Does the data answer the question set out to investigate?
        - Example: research project on potential vaccines to protect people against HIV used monkeys and a virus called SIV (which only infects monkeys and causes a condition similar to AIDS in them) . Scientists have questioned the value of the research because there may be differences between human and money responses / immune systems, and a vaccine developed against SIV may not work against HIV / may be (significant) differences between SIV and HIV
    - Potential bias?

The use of monoclonal antibodies

- Monoclonal antibody = antibody produced from a single group of genetically identical (clones) B cells / plasma cells
    - Identical structure
- Bind to specific complimentary antigen
    - Have a binding site / variable region with a specific tertiary structure / shape
    - Only one complementary antigen will fit

Why are monoclonal antibodies useful in medicine?

- Only bind to specific target molecules / antigens because…
- Antibodies have a specific tertiary structure (binding site / variable region) that's complementary to a specific antigen which can bind/fit to the antibody

Monoclonal antibodies: targeting medication to specific cell types by attaching a therapeutic drug to an antibody

Example: cancer cell

1. Monoclonal antibodies made to be complementary to antigens specific to cancer cells → cancer cells are abnormal body cells with different antigens (tumour markers)
2. Anti-cancer drug attached to antibody
3. Antibody binds / attaches to cancer cells (forming antigen-antibody complex)
4. Delivers attached anti-cancer drug directly to specific cancer cells so drug accumulates → fewer side effects e.g. fewer normal body cells killed

Exam question example: *some cancer cells have a receptor protein in their cell-surface membrane that binds to a hormone called growth factor. This stimulates the cancer cells to divide. Scientists have produced a monoclonal antibody that stops this stimulation.* ***Use your knowledge of monoclonal antibodies to suggest how this antibody stops the growth of a tumour (3 marks)***

- ✓ Antibody has specific tertiary structure / binding site / variable region
- ✓ Complementary (shape / fit) to receptor protein / GF / binds to receptor protein
- ✓ Prevents GF binding (to receptor)

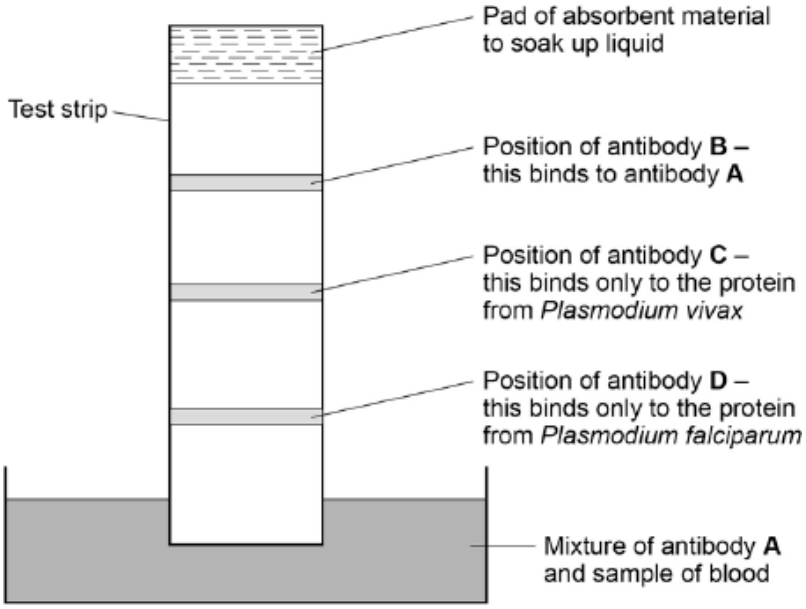
Monoclonal antibodies: medical diagnosis

Example: pregnancy test

- Pregnant women have the hormone hCG in their urine
- Urine test strip has 3 parts with 3 different antibodies
    - Application area, position 1: antibodies complementary to hCG (bound to a blue coloured bead)
    - Middle, position 2: antibodies complementary to hCG-antibody complex
    - End, position 3: antibodies complementary to antibody without hCG attached
- If pregnant
    - hCG binds to antibodies in application area = hCG-antibody complex
    - Travels up test strip, binds to antibodies at position 2 = blue line
- If not pregnant
    - No hCG in urine so hCG doesn't bind to antibodies in application area so doesn't bind to antibodies at position 2 = no blue line
    - Bind to antibodies at position 3 → blue line = control

Exam question example: *Malaria is a disease caused by parasites belonging to the genus Plasmodium. Two species that cause malaria are Plasmodium falciparum and Plasmodium vivax. A test strip that uses monoclonal antibodies can be used to determine whether a person is infected by Plasmodium. It can also be used to find which species of Plasmodium they are infected by.*

- *A sample of a person's blood is mixed with a solution containing n antibody, A, that binds to a protein found in both species of Plasmodium. This antibody has a coloured dye attached.*
- *A test strip is then put into the mixture. The mixture moves up the test strip by capillary action to an absorbent pad.*
- *Three other antibodies, B, C and D are attached to the test strip. The position of these antibodies and what they bind to is shown in* ***figure 1.***

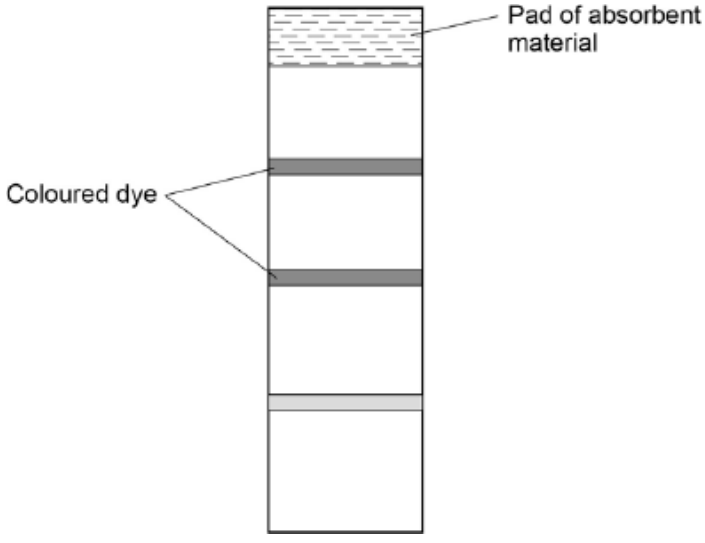


(a) ***Explain why antibody A attaches only to the protein found in species of Plasmodium.*** ***(2 marks)***

- ✓ Antibody has tertiary structure
- ✓ Complementary to binding site on protein

(b) ***Antibody B is important is this test shows a person is not infected with Plasmodium. Explain why antibody B is important.*** ***(2 marks)***

- ✓ Prevents false negative results
- ✓ (Since) shows antibody A has moved up strip / has not bound to any Plasmodium protein

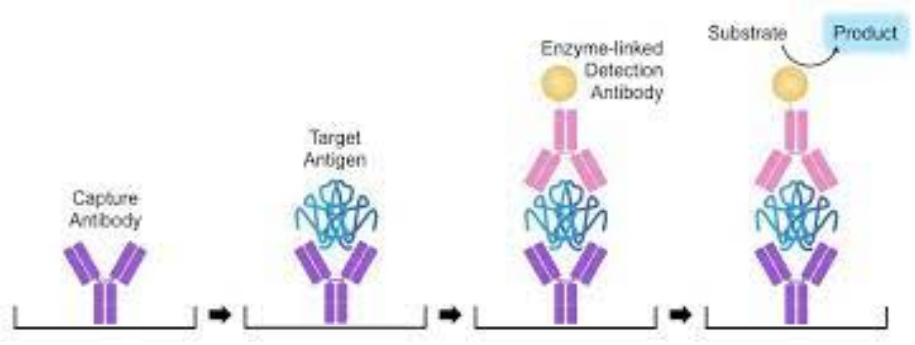


(c) *One of these test strips was used to test a sample from a person thought to be infected with Plasmodium. Figure 2 shows the result.*
What can you conclude from this result? Explain how you reached your conclusion. ***(4 marks)***

- ✓ Person is infected with Plasmodium / has malaria
- ✓ Infected with (plasmodium) vivax
- ✓ Coloured dye where antibody C present
- ✓ That only binds to protein from vivax / no reaction with antibody for falciparum

The use of antibodies in the ELISA (enzyme linked immunosorbent assay) test

An ELISA test can be used to determine if a patient has
a) Antibodies to a certain antigen
b) Antigen to a certain antibody
for example used to diagnose diseases or allergies (e.g. HIV / Lactose intolerance)



For the ELISA test an enzyme is attached to the antibody. The enzyme catalyses a reaction with a substrate that results in turning the solution a different colour; which indicates a positive.

The secondary and detection antibody must be washed away during an ELISA test.
If not washed out → enzymes will react with the substrate
Therefore give a positive result even if no antigen present (false positive)

Controls must- be used when performing the ELISA test to enable a comparison and to
- Only the enzyme and nothing else causes colour change
- Washing is effective and all unbound antibody is washed away

Exam question example: *A test has been developed to find out whether a person is infected with G. lambia. The test is shown in the flow chart.*

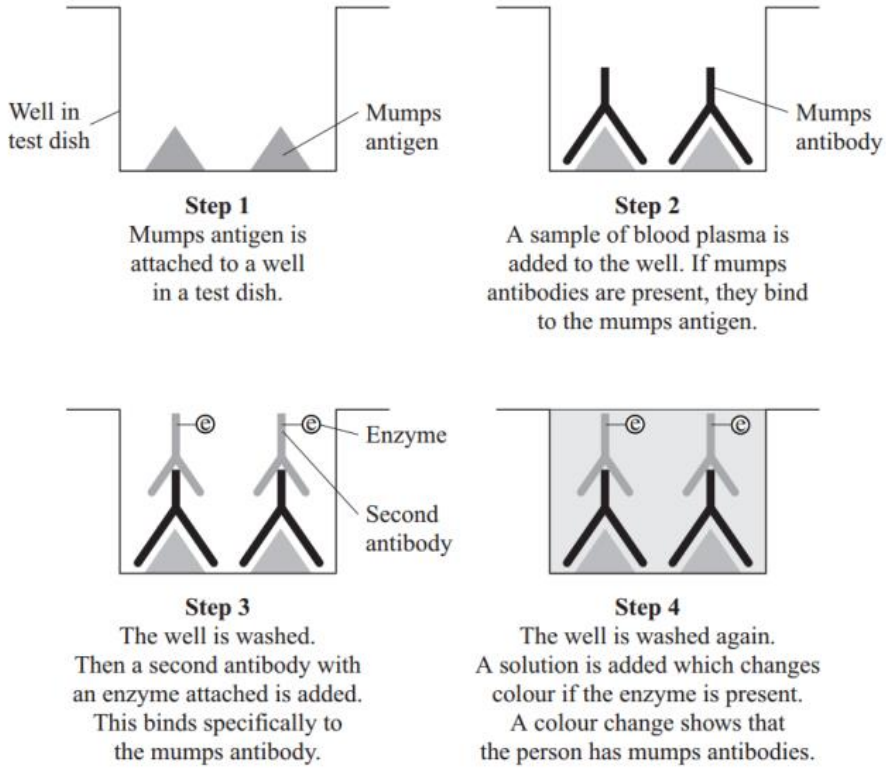
1. Monoclonal antibodies against *G. lamblia* are attached to a test plate.
2. Sample from a person added to the plate. If *G. lamblia* is present the antibody will bind to the *Giardia* antigen.
3. The plate is washed. A second antibody is added. This antibody has an enzyme attached to it. The second antibody binds to the *Giardia* antigen.
4. The plate is washed again. A colourless substrate is added which is converted to a yellow product by the enzyme. This shows that the person is infected with *G. lamblia*.

(i) *Explain why the antibodies used in this test must be monoclonal antibodies.* ***(1 mark)***
- ✓ All have same shape / only binds to Giardia / one type of / specific antigen

(ii) *Explain why the Giardia antigen binds to the antibody in step 2. (****1 mark)***
- ✓ Has complementary 9shape) / due to (specific) tertiary structure / variable region (of antibody)

(iii) *The plate must be washed at the start of step 4, otherwise a positive result could be obtained when the Giardia antigen is not present. Explain why a positive result could be obtained if the plate is not washed at the start of step 4.* ***(2 marks)***
- ✓ Enzyme / second antibody would remain / is removed by washing
- ✓ Enzyme can react with substrate (when no antigen is present)

Exam question example: *A test has been developed to find out whether a person has antibodies against the mumps virus. The test is shown in the diagram.*



(a) ***Explain why this test will detect mumps antibodies, but not other antibodies in the blood.***
(1 mark)
- ✓ Antibodies are specific to mumps antigen
- ✓ 2nd antibodies specific to mumps antibody

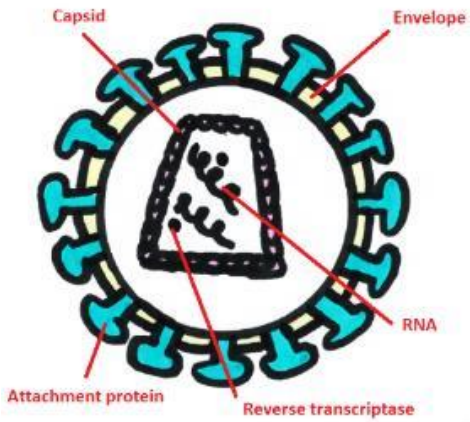
(b) ***Explain why it is important to wash the well at the start of step 4.***
(2 marks)
- ✓ Removes unbound 2nd antibodies
- ✓ Otherwise enzyme may be present / get a colour change anyway / false positive

(c) ***Explain why there be no colour change if mumps antibodies are not present in the blood.***
(2 marks)
- ✓ No antibodies to bind (to antigen)
- ✓ Therefore 2nd antibody (with the enzyme) won't bind
- ✓ No enzyme/enzyme-carrying antibody present (after washing in step 4)

Ethical issues associated with the use of monoclonal antibody

- Animals are involved in the production of monoclonal antibodies i.e. by producing cancer in mice who have a CNS so feel pain, and it is unfair to give them a disease
- Although effective treatment for cancer and diabetes has caused deaths when used in treatment of Multiple Sclerosis
    - Patients need to be informed of risk and benefits before treatment so they can make informed decisions

HIV – human immunodeficiency virus



1. HIV infects **T helper cells** (host cell)
    - HIV **attachment protein** (GP120) attaches to a **receptor on the helper T-cell** membrane
2. Virus lipid envelope fuses with cell surface membrane and capsid released into cell which uncoats, releasing **RNA** and **reverse transcriptase** into cytoplasm
3. Viral DNA is made from viral RNA
    - Reverse transcriptase produces a complementary viral DNA strand from viral RNA template
    - Double stranded DNA is made from this (**DNA polymerase**)
4. Viral DNA integrated into host cell's DNA (by **enzyme integrase**)
5. This remains **latent** for a long time in host cell until activated
6. Host cell enzymes used to make viral proteins from viral DNA (within human DNA) → viral proteins assembled with viral RNA to make a new virus
7. New virus bud from cell (taking some of cell surface membrane as envelope)
8. Eventually kills helper T cells
9. Most host cells are infected and process repeat

HIV causes the symptoms of AIDS – acquired immune deficiency syndrome

- Infects and kills helper T cells (host cell) as it multiplies rapidly
    - T helper cells then can't stimulate cytotoxic T cells, B cells and phagocytes → impaired immune response
        - E.g. B plasma cells can't secrete antibodies for agglutination and destruction of pathogens by phagocytosis
- Immune system deteriorates
    - More susceptible to infections
    - Diseases that wouldn't cause serious problems in healthy immune system are deadly (opportunistic infections) e.g. pneumonia

Antibiotics are ineffective against viruses

- Antibiotics can't enter human calls – but viruses exists in its host cell (they are acellular)
- Viruses don't have own metabolic reactions e.g. ribosomes (use of the host cell's) which antibiotics target
- If we did use them… act as a selection pressure + gene mutation = resistant strain of bacteria via natural selection → reducing effectiveness of antibiotics and waste money