

The immune response

Revision notes · Non-specific defences, antigens and antibodies, B and T cells, natural and artificial immunity, and the evolutionary race between pathogens and hosts.

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.

The immune response **Spec 6.8–6.12** **A Level only**

Non-specific responses to infection **Spec 6.8**

Inflammation

When tissue is damaged or infected, mast cells and damaged cells release **histamine** and other signalling molecules (cytokines).

1. Histamine causes vasodilation of arterioles, increasing blood flow to the area, so the tissue becomes red and warm.
2. Capillary walls become more permeable, so more fluid leaves the blood as tissue fluid, causing swelling, which may press on nerve endings and cause pain.
3. Chemical signals attract phagocytes (neutrophils and monocytes that become macrophages), which leave the capillaries and engulf pathogens.

Lysozyme

Lysozyme is an enzyme found in tears, saliva, mucus and in phagocytes. It hydrolyses the peptidoglycan in the cell walls of bacteria. The weakened wall can no longer resist osmotic pressure, so water enters by osmosis and the bacterium bursts (lysis). Lysozyme does not act on viruses.

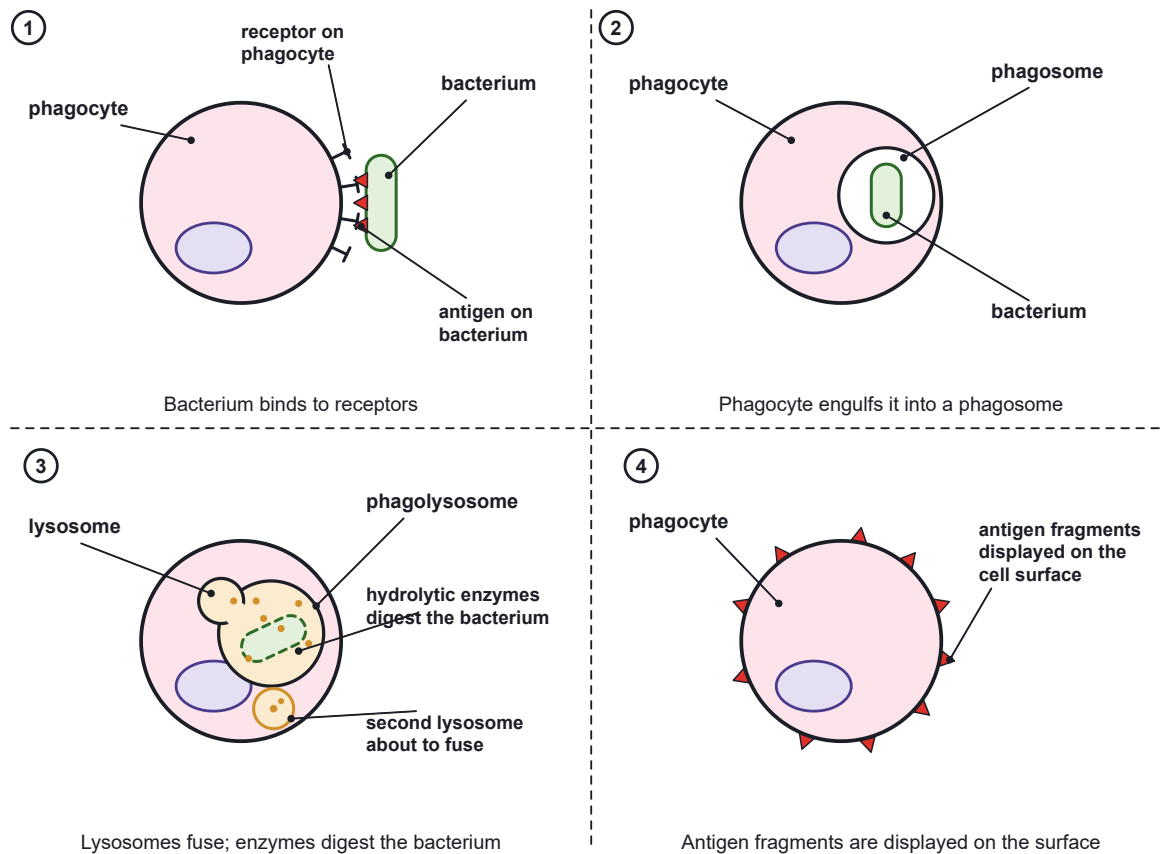
Interferon

Interferons are cytokines (signalling proteins) released by cells infected with a virus. They diffuse to neighbouring uninfected cells and bind to receptors on the cell-surface membrane. This switches on genes that make enzymes that break down viral mRNA and inhibit protein synthesis. Viral proteins cannot be made, so the virus cannot replicate in these cells and its spread is slowed.

Phagocytosis

1. A phagocyte (neutrophil or macrophage) recognises a pathogen, often because it is coated with antibodies or has foreign surface molecules, and the pathogen binds to receptors on the phagocyte.
2. The phagocyte engulfs the pathogen by endocytosis, enclosing it in a vesicle called a phagosome.
3. Lysosomes fuse with the phagosome and release lysozyme and other hydrolytic enzymes, which digest the pathogen.
4. Soluble products are absorbed into the cytoplasm. A macrophage then displays pieces of the pathogen's antigens on its surface (antigen presentation) to start the specific response.

Exam tip: 'Non-specific' means the response is the same whatever the pathogen. Do not say it is 'not immune': it is the first part of the innate immune response.



Phagocytosis and antigen presentation by a phagocyte.

Antigens, antibodies and antigen-presenting cells Spec 6.9

Antigen	A molecule (usually a protein or glycoprotein) on the surface of a pathogen, a foreign cell or a toxin, that is recognised as foreign by the immune system and stimulates an immune response.
Antibody	A protein (immunoglobulin) made by a plasma cell that binds specifically to one antigen.

Antibody structure

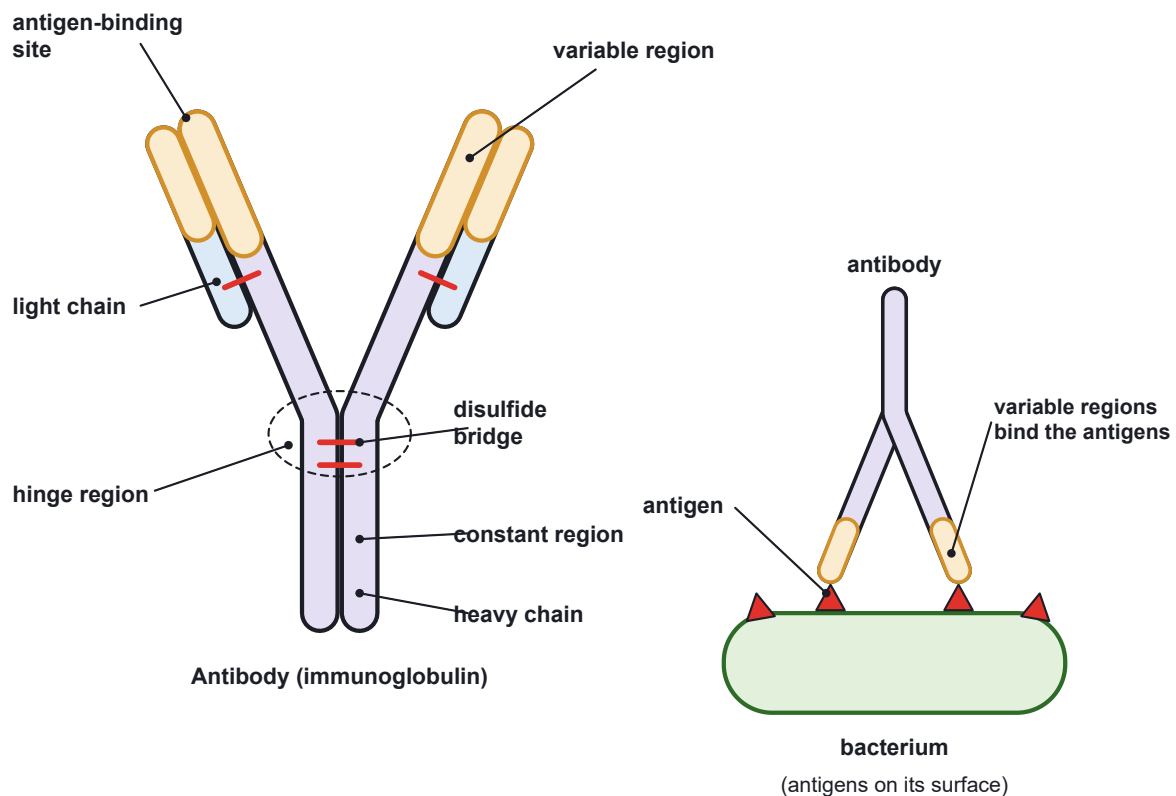
An **antibody** is a Y-shaped protein with four polypeptide chains: two identical heavy chains and two identical light chains, held together by disulfide bridges. Each arm has a **variable region** whose shape is complementary to one antigen and forms the antigen-binding site. The rest is the constant region, which is the same for all antibodies of one class, and a flexible hinge region lets the arms move. The tertiary structure of the variable region is different for each antibody, which is why each antibody binds only one antigen.

How antibodies help to destroy pathogens

- **Agglutination:** each antibody has two binding sites, so antibodies link pathogens together into clumps, which are easier for phagocytes to engulf.
- **Opsonisation (marking):** antibodies bound to the surface of a pathogen make phagocytosis easier, because phagocytes have receptors for the constant region.
- **Neutralising toxins and blocking attachment:** antibodies bind to toxins or to the proteins pathogens use to attach to or enter host cells.

The cells involved

Cells in the specific response	
Cell	Role
Macrophage	Engulfs pathogen, digests it, and displays pieces of its antigens on its surface so that T cells can recognise them; also a phagocyte in the non-specific response
Antigen-presenting cell (APC)	Any cell that displays foreign antigen on its surface to T cells (macrophages, dendritic cells, and body cells infected by a virus). Presents the antigen to T cells with a complementary receptor
Plasma cell	A differentiated B cell (B effector cell) packed with rough endoplasmic reticulum, which secretes large numbers of one type of antibody



An **antibody**: the **variable regions** at the tips bind a specific antigen.

Common mistake: Antibodies are made by plasma cells, not by 'B memory cells' or by macrophages, and they are proteins, not cells.

B cells and T cells in the immune response Spec 6.10

The specific immune response depends on lymphocytes, white blood cells made in the bone marrow. Each lymphocyte has receptors for one antigen. **B cells** mature in the bone marrow and **T cells** mature in the thymus.

Sequence of the response to a new pathogen

1. A macrophage or other antigen-presenting cell engulfs the pathogen and displays its antigens on its surface.
2. A T helper cell with a receptor complementary to this antigen binds to the antigen-presenting cell and is activated. It divides by mitosis (clonal expansion) to make a clone of T helper cells.

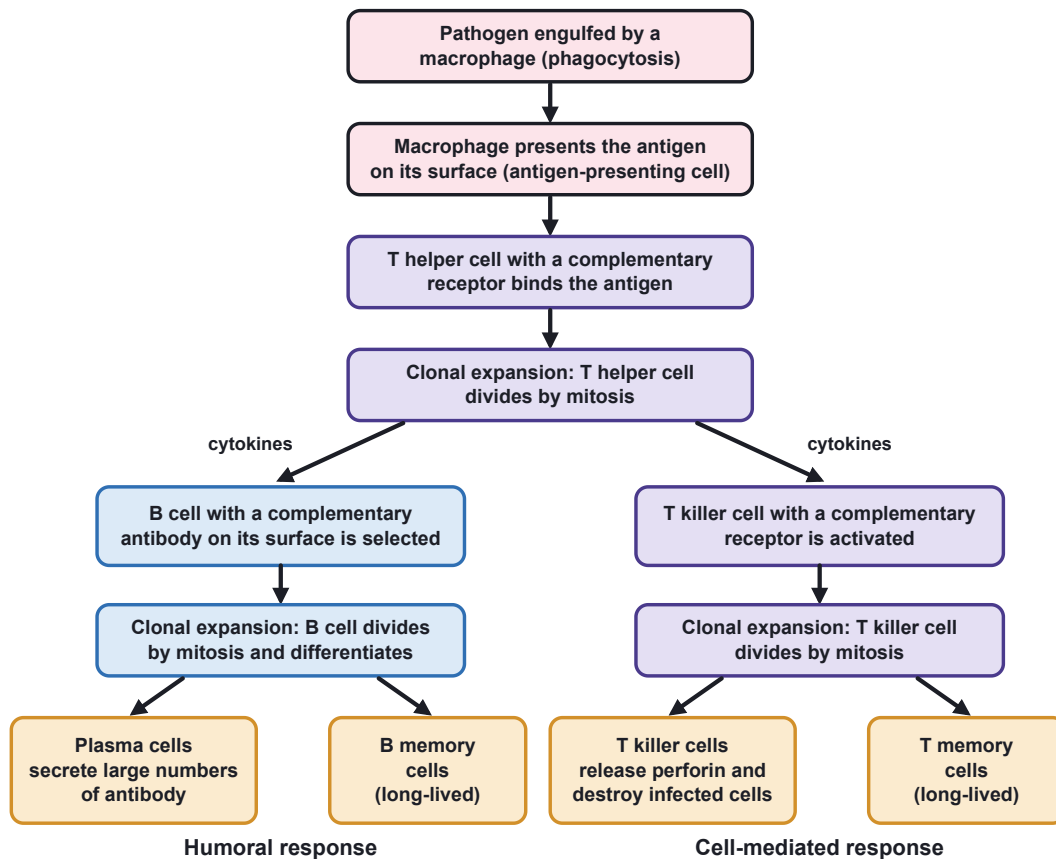
3. T helper cells release cytokines. These stimulate B cells whose antibodies on the surface are complementary to the antigen (clonal selection) to divide by mitosis, and they also activate T killer cells.
4. The B cells differentiate into plasma cells (B effector cells), which secrete large quantities of antibody into the blood, and into B memory cells.
5. Activated T killer cells find body cells displaying the antigen (for example virus-infected cells) and kill them.
6. T and B memory cells remain in the blood after the infection has been cleared.

Roles of B cells and T cells		
Cell	Type	Role
B cell	B effector (plasma cell)	Makes and secretes antibodies for the humoral response; short-lived
B cell	B memory cell	Long-lived; remains in the blood and, on re-exposure to the same antigen, divides rapidly to form plasma cells and more memory cells
T cell	T helper cell	Binds antigen presented by APCs and releases cytokines that activate B cells, T killer cells and macrophages
T cell	T killer (cytotoxic) cell	Kills infected body cells and cancer cells. Releases perforin to make pores in the target cell membrane and enzymes that cause apoptosis (cell-mediated response)
T cell	T memory cell	Long-lived; gives a faster response of killer and helper T cells when the antigen is met again

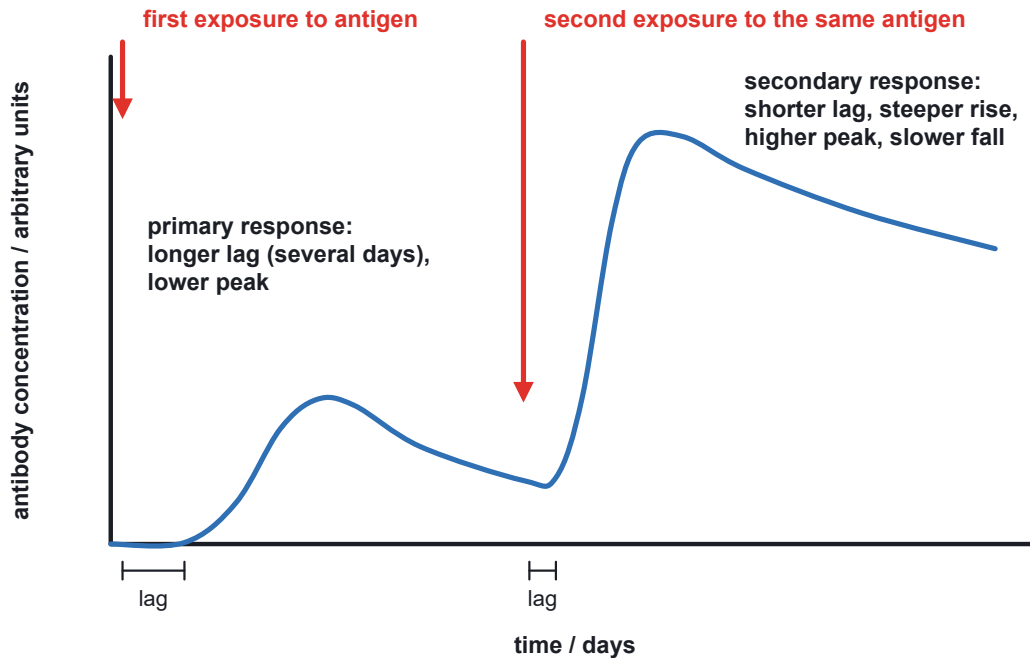
The antibody response by B cells is called the **humoral response** (antibodies are in the body fluids). The response by T cells, which directly kill infected cells, is the **cell-mediated response**.

Primary and secondary responses

The first time a pathogen is met (the **primary response**), only a few B and T cells have receptors for its antigens, so it takes several days for enough plasma cells to make antibody, and the person may become ill. On a second exposure (the **secondary response**), B and T memory cells are activated immediately and divide to produce a large number of plasma cells much faster. Antibody concentration rises faster, reaches a higher level and lasts longer, so the pathogen is destroyed before symptoms appear.



Clonal selection and the humoral and cell-mediated responses.



Primary and **secondary** immune responses: memory cells give a faster, larger response.

Exam tip: Quote the cells in order: antigen-presenting cell, T helper, then B cell and T killer. Questions often lose marks by missing the T helper step.

Natural, artificial, active and passive immunity Spec 6.11

Types of immunity		
Type	How it develops	Example
Natural active	Infection by a pathogen: the body makes antibodies and memory cells	Recovering from chickenpox
Natural passive	Antibodies pass from mother to baby: IgG across the placenta, and IgA in colostrum and breast milk	Newborn protected by mother's antibodies
Artificial active	Vaccination: weakened or inactivated pathogen, or its antigens, are given and the body makes antibodies and memory cells	MMR vaccine, tetanus vaccine
Artificial passive	Injection of ready-made antibodies from another person or animal	Antivenom after a snake bite; tetanus immunoglobulin after a deep wound

Active compared with passive immunity		
Feature	Active	Passive
Antibodies made by	The person's own plasma cells	Another person or animal
Memory cells formed	Yes	No
Time to protection	Days to weeks (primary response)	Immediate
Length of protection	Long-lasting (years or life)	Short (weeks to months) as antibodies are broken down

Vaccines contain antigens but do not cause the disease. They stimulate the primary response, so memory cells are in place. If the real pathogen is met later, the secondary response is fast enough to prevent symptoms. Vaccination of a high proportion of the population also protects those who are not vaccinated, because the pathogen has fewer people to spread between (herd immunity).

Common mistake: 'Natural' and 'artificial' describe how the antibodies or antigens get in (infection or mother, versus medicine). 'Active' and 'passive' describe whether the person makes their own antibodies. Do not mix these up.

The evolutionary race between pathogens and hosts Spec 6.12

Pathogens have short generation times and high mutation rates, so they evolve quickly. A pathogen that survives host defences reproduces and passes on the allele. Hosts with a more effective immune response also survive and reproduce, so their offspring are better defended. The pressure from each side selects for change in the other: an **evolutionary race**. Evidence is shown by the many ways pathogens evade the immune system.

Evasion mechanisms shown by pathogens

Mechanism	Example	Why it works
Antigenic variation: changing surface antigens	Influenza virus (mutations and reassortment give new surface proteins); HIV (reverse transcriptase makes many errors); <i>Trypanosoma</i> (switches its surface protein)	Memory cells and antibodies for the old antigen no longer recognise the new type, so there is no secondary response and a new vaccine may be needed
Hiding inside host cells	HIV (inside helper T cells, as a latent provirus); <i>Mycobacterium tuberculosis</i> (inside macrophages); malaria parasite (liver and red blood cells)	Antibodies cannot reach the pathogen inside the cell, and few or none of its antigens are displayed on the host cell surface
Killing or disabling immune cells	HIV destroys helper T cells	Fewer B cells and killer T cells are activated, so the immune response collapses
Preventing digestion by phagocytes	<i>M. tuberculosis</i> stops lysosome fusion; some bacteria have a capsule	Pathogen survives phagocytosis, or is not engulfed at all

These mechanisms are examples of adaptations produced by natural selection. Because the pathogen population keeps producing new variants, the host immune system, vaccines and drugs always have to respond to a moving target.

Exam tip: To support the theory, name the mechanism, give the organism, and link it to the host: 'HIV mutates rapidly, so new antigen variants are not recognised by memory cells'.

Quick check

1. How does lysozyme kill bacteria?
2. How does interferon protect a neighbouring cell?
3. Which cell secretes antibodies?
4. What is the difference between natural passive and artificial passive immunity?
5. Why does antigenic variation help a pathogen survive?

Quick check answers

The immune response

1. It hydrolyses peptidoglycan in the cell wall, so the bacterium bursts by osmosis.
2. It switches on genes for enzymes that break down viral mRNA and block protein synthesis, so the virus cannot replicate.
3. The plasma cell (B effector cell).
4. Natural passive: antibodies pass from mother to baby. Artificial passive: ready-made antibodies are injected.
5. Memory cells and antibodies for the old antigen do not recognise the new antigen, so there is no fast secondary response.