Learning Intention:

- To understand how adaptive immune response is initiated.
- To learn about the components of adaptive immune response.
- To explain the role of B lymphocytes and T lymphocytes

Success Criteria:

- I can explain the process of antigen presentation.
- I can explain the role and characteristics of cells involved in third line of defence.

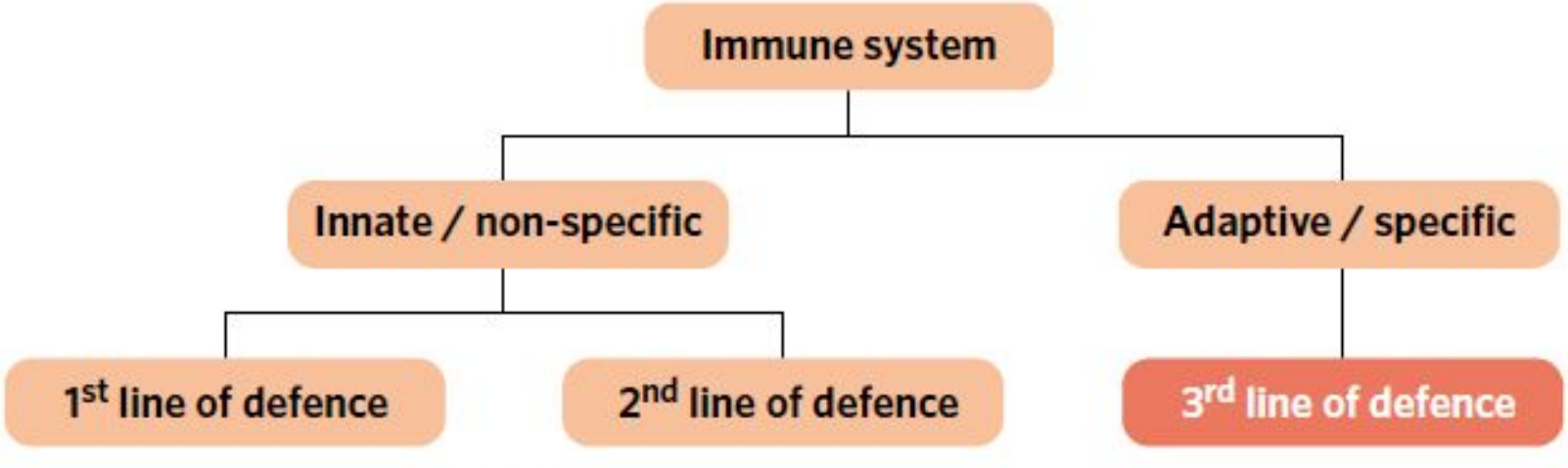
Study design dot point

- initiation of an immune response, including antigen presentation, ~~the distinction between self-antigens and non-self antigens, cellular and non-cellular pathogens, and allergens~~
- the characteristics and roles of the components of the adaptive immune response against both extracellular and intracellular threats, including the actions of B lymphocytes and their antibodies, helper T, and cytotoxic T cells.

The third line of defence is a key component of the immune system in humans. It is designed to combat and destroy pathogens that have breached the first line of defence. Two unique features of the adaptive immune system are:

• **Specificity** – the adaptive immune system responds to each distinct pathogen in a unique and tailored manner

• **Immunological memory** – the adaptive immune system results in the production of cells that allow the body to respond to future re-infections by a previously encountered pathogen quickly and effectively.



Extracellular and Intracellular Threats

Extracellular threats: Pathogens such as bacteria that are able to move about the host organisms and grow and reproduce within the host. They must first enter the organism and avoid the innate immune system and adaptive immune system to survive. These are easily detected by cells of immune system and host organism recovers after a short illness.

Intracellular threats: Include viruses and bacteria that are able to hide inside the host's cell. They can evade the innate and adaptive immune response. Example HIV (Human immunodeficiency virus) causing AIDS.

Lymphocytes- Cellular components of adaptive immune response:

The adaptive immune response is composed of specialised white blood cells which can be divided into two main groups: T- lymphocyte and B-lymphocyte.
T- lymphocyte and B-lymphocytes are generated from stem cells in the bone marrow.
These cells are able to store memory of antigens they have met before.
Difference between T- lymphocyte and B-lymphocyte:

- B-lymphocytes mature before they leave bone marrow
- T- lymphocyte must travel to and mature in the thymus before they are released into rest of the body.

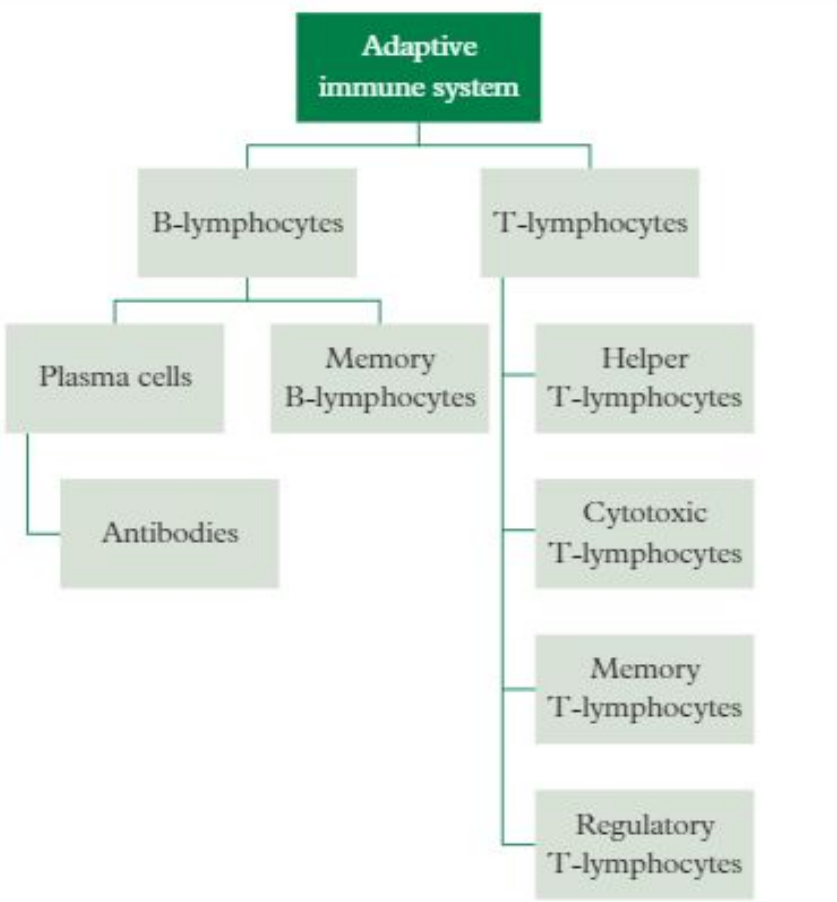


FIGURE 2 The structure of the adaptive immune response.

Antigen Presentation

A key process in the initiation of the adaptive immune response involves the selection of a type of T lymphocyte called a T helper cell via a process called **antigen presentation**.
Each T helper cell has a unique set of T cell receptors for a single antigen on its surface, facilitating the specificity of the adaptive immune response. When this interaction occurs, the T helper cell becomes activated and is said to be 'selected'. The activated T helper cell can then help initiate the adaptive immune response through either the humoral or cell-mediated immune responses.

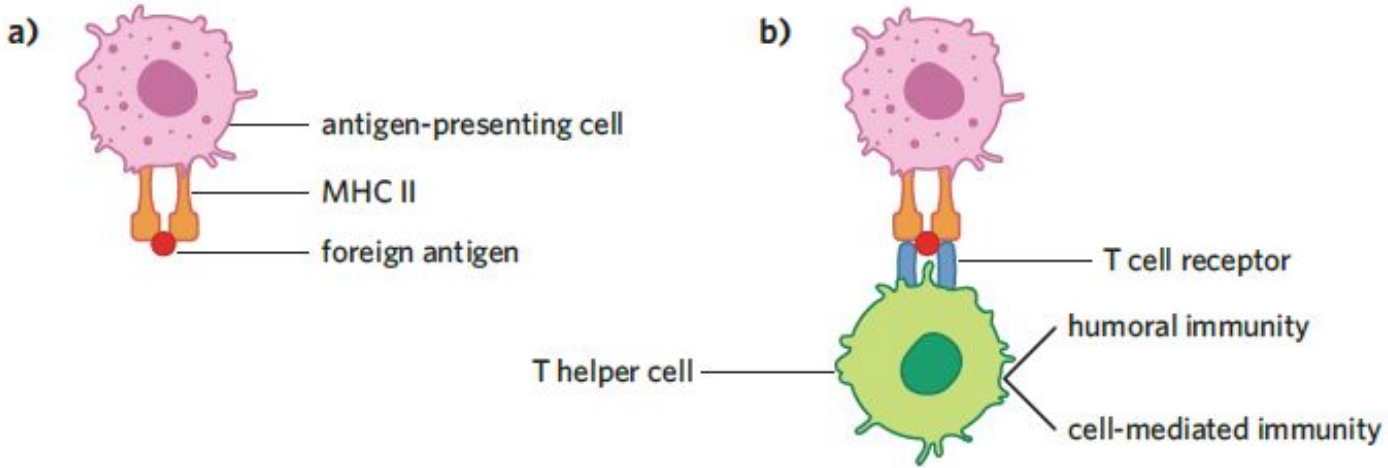


Figure 3 **(a)** An antigen-presenting cell displaying a foreign antigen via MHC II. **(b)** An antigen-presenting cell presenting an antigen to a complementary T cell receptor on a T helper cell, consequently activating it.

Humoral Immunity

Humoral immunity involves the neutralisation and destruction of extracellular pathogens via the **production and secretion of antibodies**. It involves B lymphocytes, which produce specific antibodies against non-self antigens and release them into the blood and lymph.

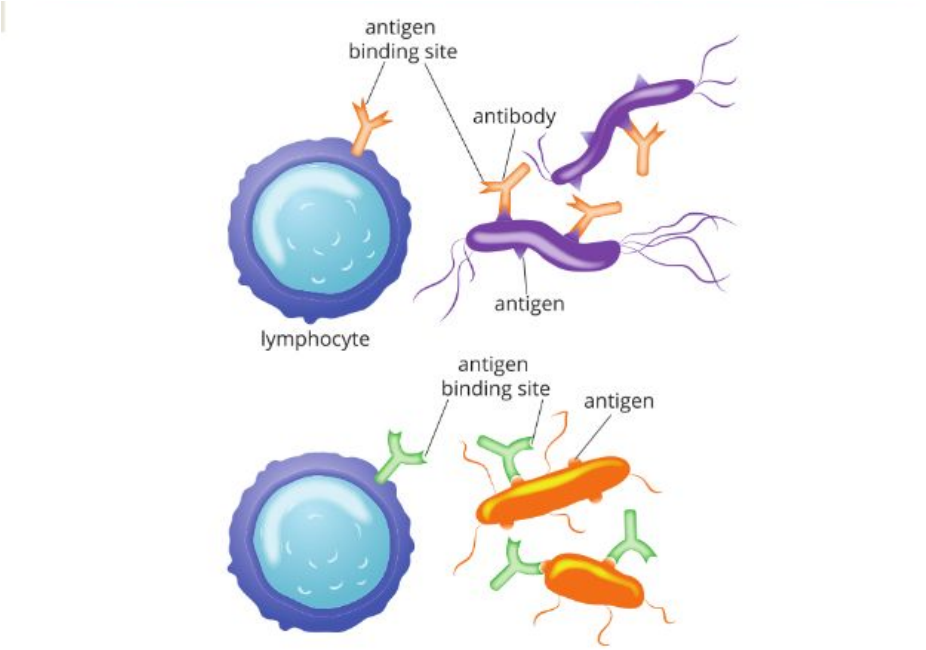


FIGURE 9.2.3 Antibodies specific to a foreign antigen will bind to it, helping to eliminate the invading pathogen.

Stages of humoral Immune response

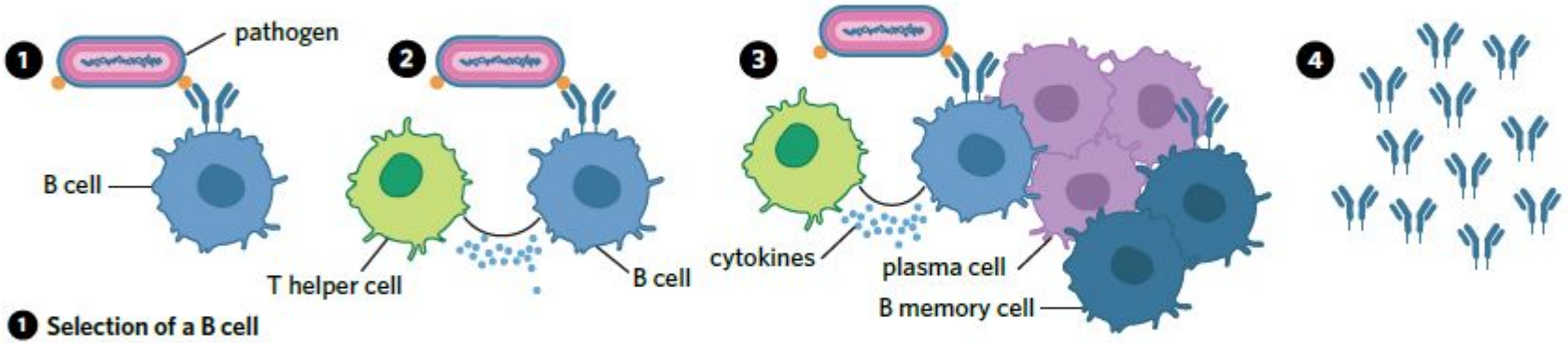
Stage 1 (Selection of a B cell)- A pathogen with an antigen that is complementary in shape to the antigen-binding site on the receptor of a B cell interacts with that B cell.

Stage 2 (Stimulation of the selected B cell through the production of cytokines by a selected T helper cell)- T helper cell selected through antigen presentation, which also has a complementary receptor to the antigen, will recognise the selected B cell and secrete a number of different cytokines. These cytokines cause the B cell to undergo clonal expansion, through which many copies of the selected B cell are produced. The process of selecting the specific T helper cell and B cell is termed **clonal selection.**

Stage 3 Differentiation of the selected B cell into plasma cells and B memory cells- the T helper cell stimulates the selected B cell via cytokines to undergo the process of differentiation, forming two different types of B cells – B memory cells and plasma cells.

Stage 4 (Production and release of antibodies to defend against a specific pathogen)- Plasma cells secrete antibodies into the blood in order to defend against the selected pathogen.

Stages of humoral Immune response



1. Selection of a B cell
2. Stimulation of the selected B cell through the production of cytokines by a selected T helper cell
3. Differentiation of the selected B cell into plasma cells and B memory cells
4. Production and release of antibodies to defend against a specific pathogen

Products of B-cell differentiation

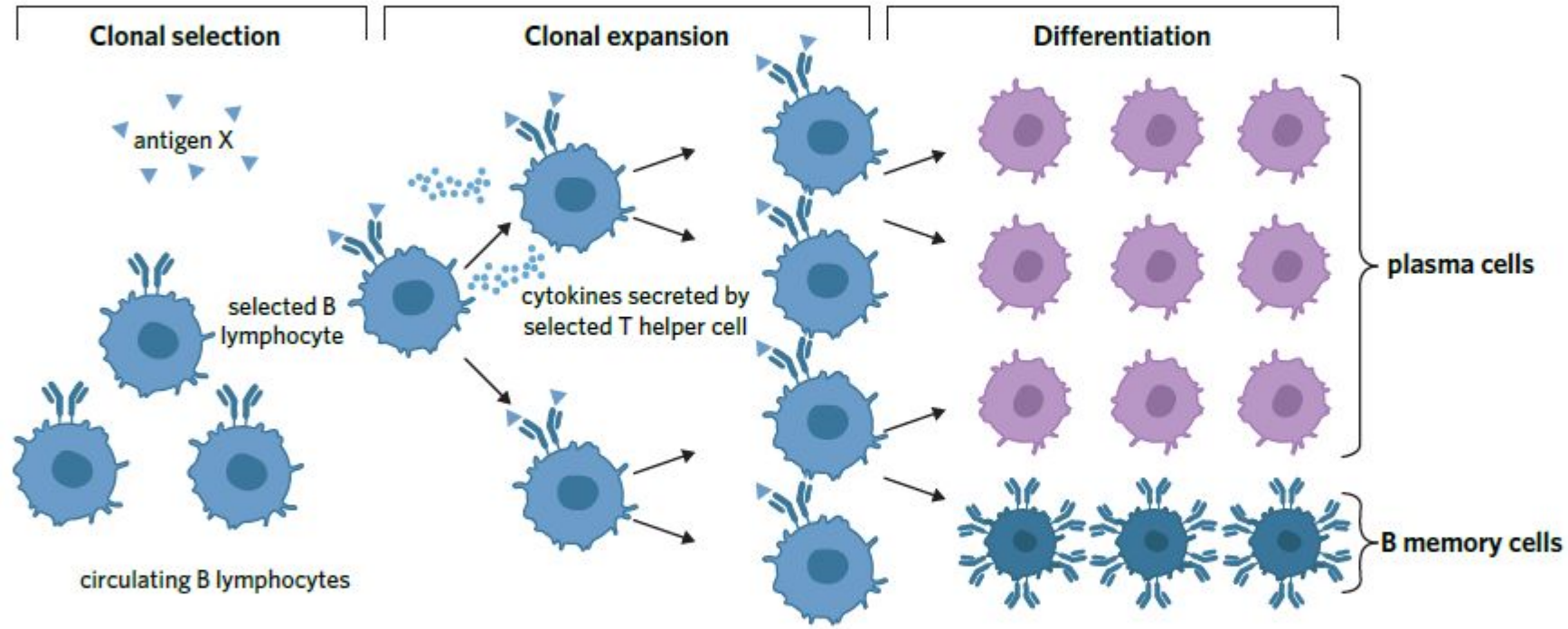


Figure 6 The processes of B cell clonal selection, expansion, and differentiation

Antibodies

- Antibodies released by plasma cells are proteins.
- They are composed of four polypeptide chains, including two heavy chains and two light chains.
- The two heavy chains are joined by a disulphide bond.
- Each antibody also has a constant region and a variable region. These regions come together to form two identical antigen-binding sites
- As there are two antigen-binding sites present, an antibody can bind with two pathogens at once.

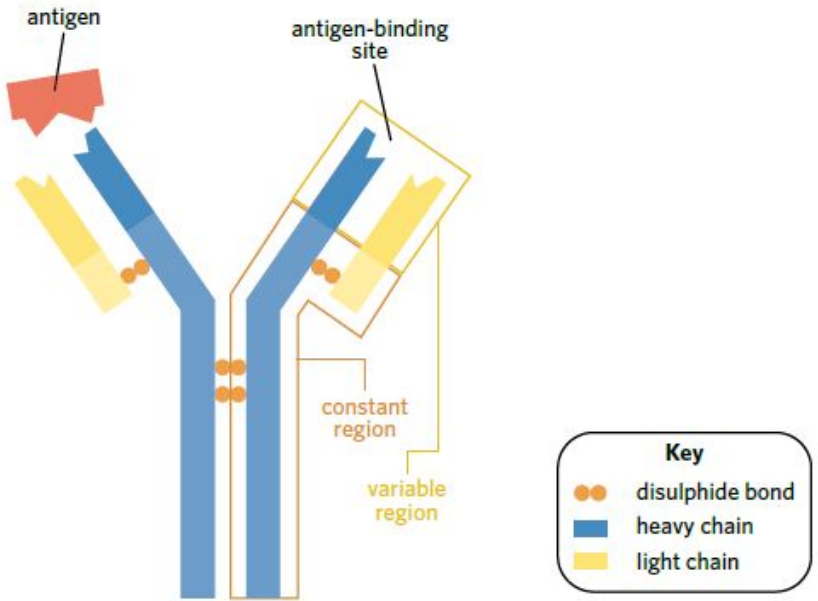


Figure 7 The structure of an antibody. Note the complementary structures of the antigen-binding site and the specific antigen.

Types of antibodies

TABLE 9.2.1 Structure and function of mammalian immunoglobulins

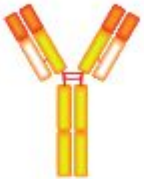
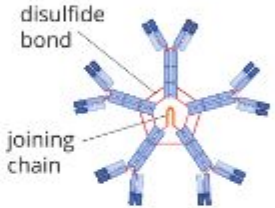
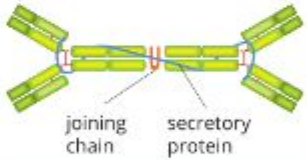
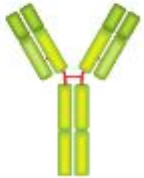
Class	Half-life in serum	Presence	Functions	Structure
IgG	21 days	blood, lymph and extracellular fluid; most circulating antibodies (>80%); crosses placenta	agglutination, complement activation	
IgM	10 days	blood and lymph; produced early in infection response	agglutination, complement activation	
IgA	6 days	found in secretions such as tears, saliva and milk	mucosal immunity	
IgD	3 days	blood and lymph; mostly present on B lymphocyte surfaces; small amount in circulation; binds to basophils and mast cells	functions not well understood; possible role in regulating innate immune responses	
IgE	2 days	blood and lymph; attaches to mast cells	involved in allergic reactions	

Table 1 Types of antibodies

Type	Characteristic
IgA	Found in mucus, breast milk, and saliva.
IgD	Important for the activation of other immune cells.
IgE	Protects against parasitic worms. Also responsible for allergic reactions.
IgG	Most common antibody found in the body. Able to cross the placenta and travel to the foetus.
IgM	The first type of antibody produced by plasma cells in response to an infection.

Table 2 The key functions of antibodies

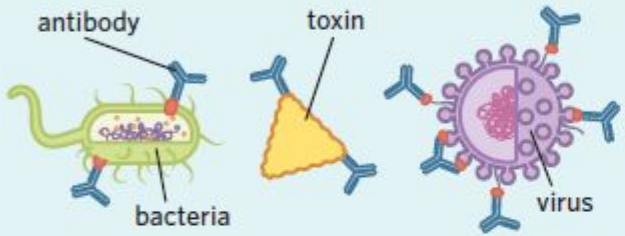
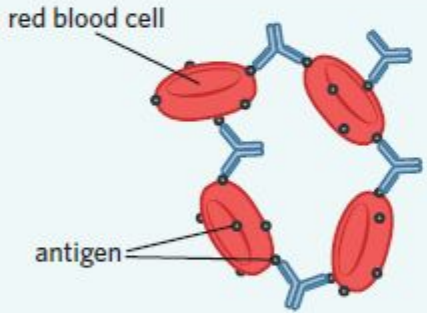
Function	Description	Diagram
Neutralisation	Antibodies can block the sites of pathogens that are used to attack host cells (e.g. the site used by a virus to enter a cell) and can block the active sites of toxins.	
Agglutination	Antibodies can bind together with antigens on two separate pathogens, forming large **antigen-antibody complexes**. This makes it easier for phagocytes to recognise the pathogens as foreign bodies and destroy them.	
Immobilisation	Antibodies can also restrict the movement of pathogens around the body through the formation of large antigen-antibody complexes.	

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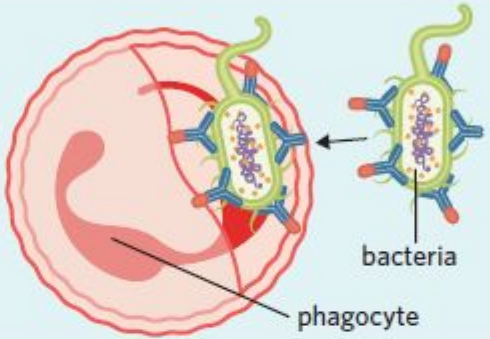
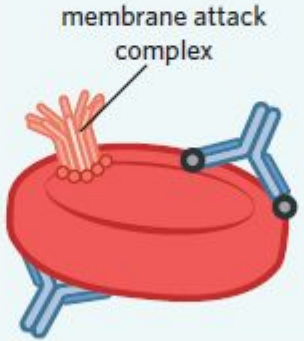
Table 2 Continued

Function	Description	Diagram
Opsonisation	Antibodies can bind directly to the surface of a pathogen to make it easier to phagocytose.	
Activation of complement proteins	Antibodies attached to the surface of pathogens can facilitate the actions of complement proteins, including the formation of **membrane attack complexes (MACs)**.	

Cell mediated immunity

Cell-mediated immunity involves the destruction of infected or abnormal cells via the clonal selection of a cytotoxic T cell.

Cytotoxic T cells are a type of T lymphocyte and are the key players of cell-mediated immunity. They primarily carry out their role by assessing the MHC I marker of infected cells. In addition to their role of self-recognition, MHC I can also display antigens that have been broken down in a cell on its surface.

Therefore, in a cell that has been infected with a virus, their MHC I may present foreign viral antigens on its surface, which can be detected by cytotoxic T cells.

Stages of Cell mediated Immune response

Stage 1 (clonal selection, clonal expansion and differentiation)

At the same time as the selection of T helper cells, antigen-presenting cells eventually come upon a naive T cell with a T cell receptor that matches the antigen being presented, initiating the process of clonal selection. When this occurs, the naive T cell becomes selected and is stimulated by cytokines released by the selected T helper cell to undergo the processes of clonal expansion and differentiation.

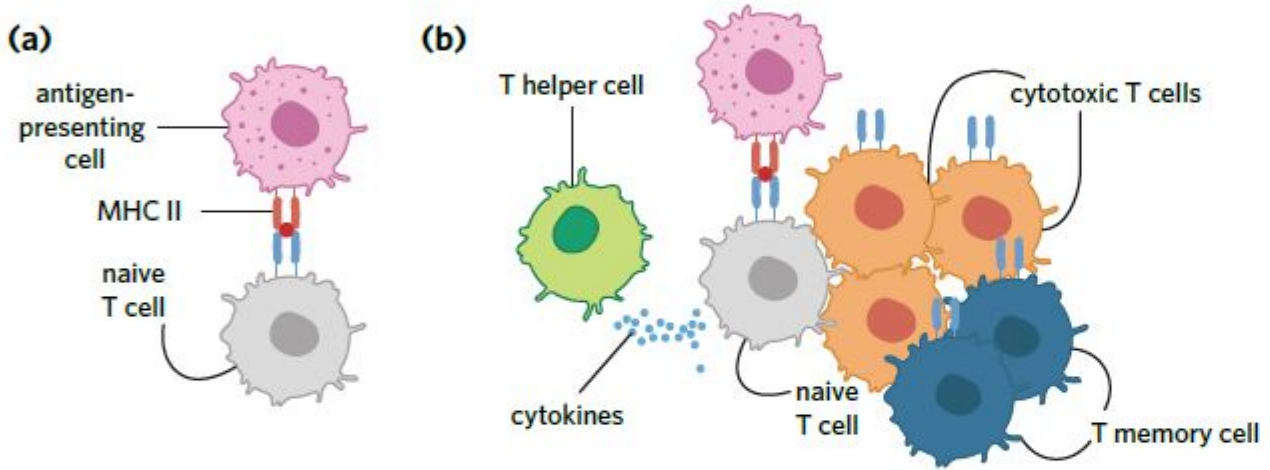


Figure 10 **(a)** Antigen-presenting cell presenting an antigen to a complementary T cell receptor on a naive T cell, consequently selecting it. **(b)** Cloning and differentiation of a selected T cell into cytotoxic T cells and T memory cells via the secretion of cytokines from a selected T helper cell.

Stage 2 (clonal expansion and differentiation)

The clones of the selected T cell differentiate into two types of T cells – cytotoxic T cells and T memory cells. T memory cells reside in the body for extended periods of time and help form immunological memory. The majority of selected T cells differentiate into cytotoxic T cells, which leave the lymph node and travel throughout the body, eventually reaching the site of infection.

Stage 3 (Apoptosis)

Due to the process of clonal selection, the cytotoxic T cells that arrive at the site of infection all have T cell receptors that are specific to the foreign antigen selected for. Once the cytotoxic T cell has found an abnormal cell it binds to it via interactions between its T cell receptor and the antigen-MHC I complex. Chemicals, such as perforin, are then secreted by the cytotoxic T cell to induce apoptosis in the cell

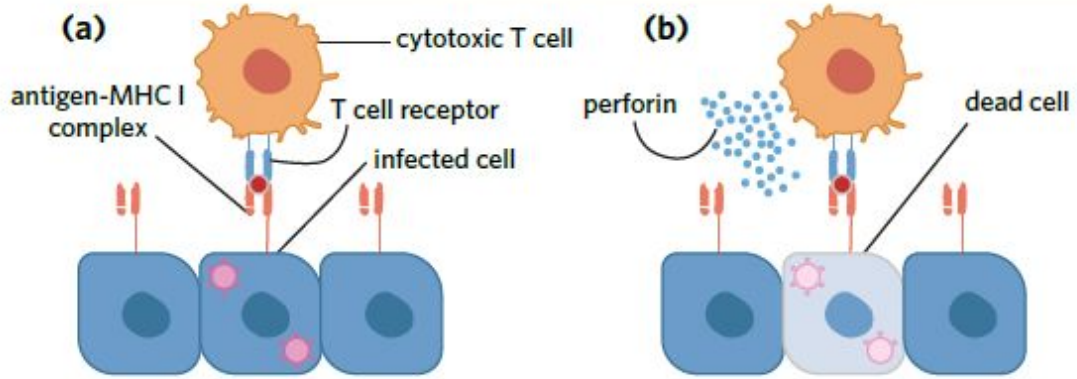


Figure 11 **(a)** A cytotoxic T cell recognising an infected cell via interaction with its MHC I receptor. **(b)** A cytotoxic T cell killing an infected cell by releasing chemicals that induce apoptosis.

Apoptosis is the controlled death of cells in the body. Also known as programmed cell death.

Immunological memory

- B memory cells contribute to immunological memory by rapidly dividing and forming new antibody-producing plasma cells when they encounter an antigen that matches their receptor.
- T memory cells proliferate rapidly into T helper cells and cytotoxic T cells upon stimulation by an antigen-presenting cell that is presenting a previously encountered antigen.

B memory cells also create immunological memory by constantly secreting low amounts of their antibody.

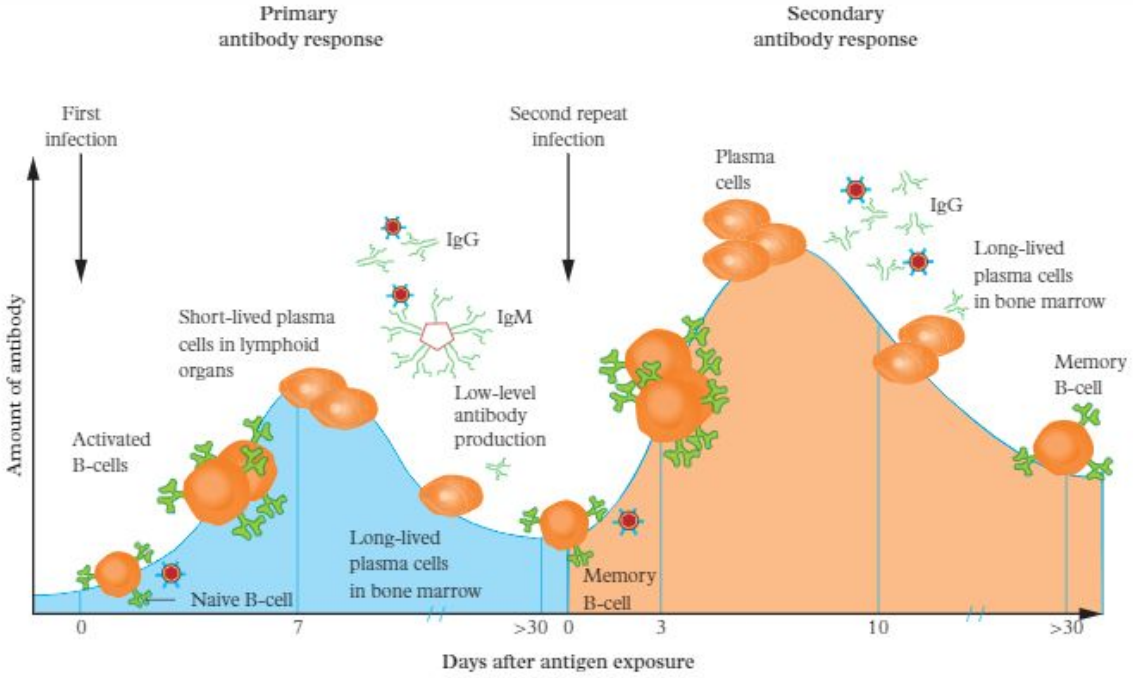


FIGURE 6 The second time the antigen is presented, the memory B-cells are able to produce a large number of antibodies in a short time period.

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Worked Example

Q. Contrast plasma cells and memory B-lymphocytes.

Plasma cells are mature B-lymphocytes that can produce large amounts of identical antibodies. Memory B-lymphocytes are also mature B-lymphocytes; however, they are stored in the lymph nodes to enable the immune system to respond quickly if it encounters the same antigen. Memory B-lymphocytes, once activated, undergo clonal proliferation to differentiate into many plasma cells

Summary

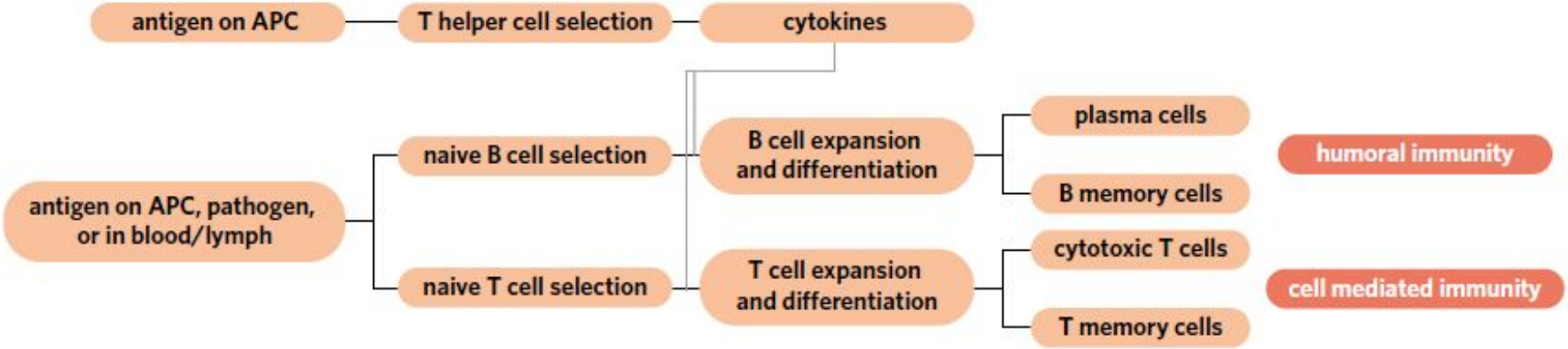

Figure 12 A flowchart depicting the third line of defence

Summary

- An adaptive immune response is one that is specific to a certain antigen.
- The adaptive immune response in vertebrates is classified as humoral or cell-mediated.
- Humoral immunity involves B lymphocytes
- Antibodies, also known as immunoglobulins, are proteins that bind to specific antigen molecules.
- Antibodies are Y-shaped proteins that have a constant ‘tail’ and variable ‘arm’ regions. The variable regions have antigen-binding sites and the constant region recruits components of the immune system.
- Cell-mediated immunity involves T lymphocytes:
  - Cytotoxic T cells recognise and kill foreign, infected or abnormal host cells by releasing toxic compounds. They kill infected cells, which are identi俸able by pathogen antigens on MHC-I.
  - Helper T cells secrete cytokines that activate leukocytes, including cytotoxic T cells and B cells
- Memory B and T cells persist after an infection to enable a larger and faster response upon reinfection with the same pathogen.
- The first infection with a pathogen produces a primary immune response, while reinfection with the same pathogen produces a secondary response due to the presence of memory cells from the primary response (this is known as immunological memory).

Reflection

Quizlet
https://quizlet.com/au/713069519/third-line-of-defence-flash-cards/?new

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