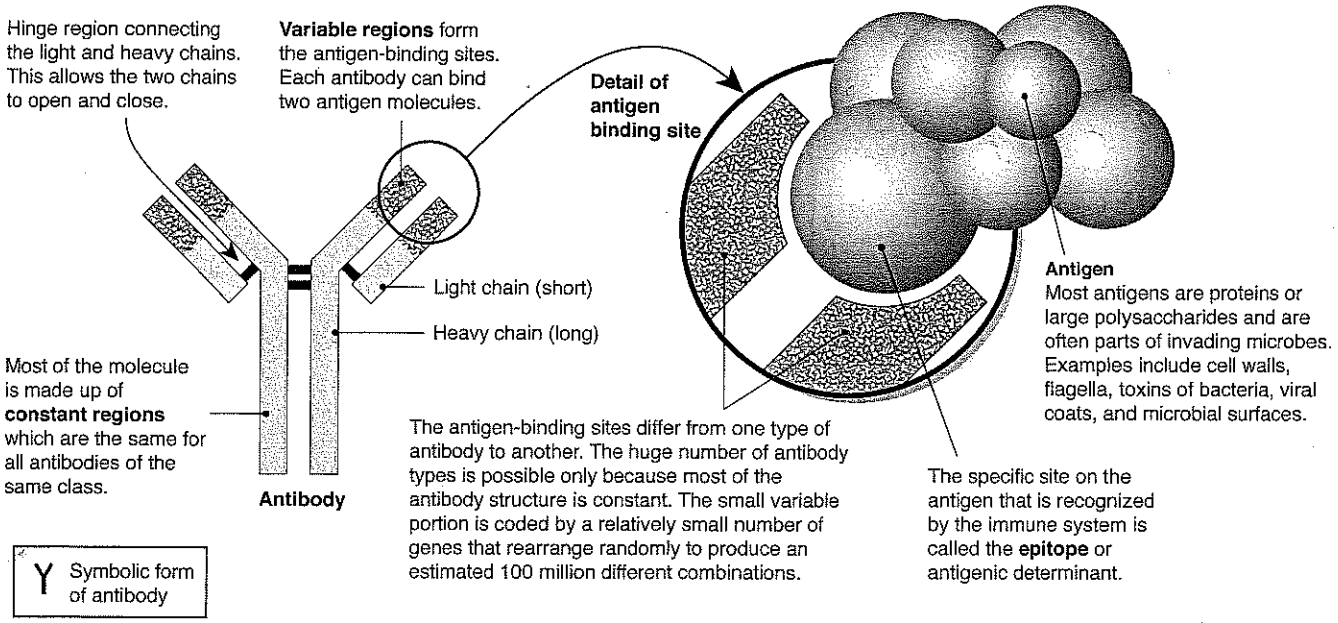
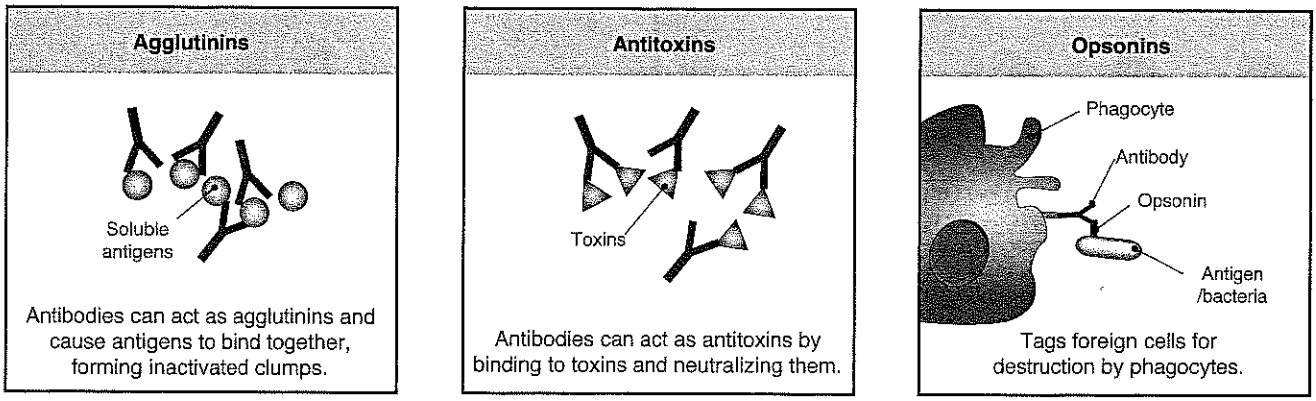
Key Idea: Antibodies are large, Y-shaped proteins made by plasma cells, which destroy specific antigens.

Antibodies and antigens play key roles in the response of the immune system. **Antigens** are foreign molecules which promote a specific immune response. Antigens include pathogenic microbes and their toxins, as well as substances such as pollen grains, blood cell surface molecules, and the surface proteins on transplanted tissues. **Antibodies** (or immunoglobulins) are proteins made in response to antigens. They are secreted from B-cells into the plasma where they can recognize, bind to, and help destroy antigens. There are five classes of antibodies, each plays a different role in the immune response. Each type of antibody is specific to only one particular antigen.



How antibodies inactivate antigens



1. Describe the structure of an antibody, identifying the specific features of its structure that contribute to its function:

_____

_____

_____

2. Explain how the following actions by antibodies enhance the immune systems ability to stop infections:

(a) Acting as agglutinins: _____

_____

(b) Acting as antitoxins: _____

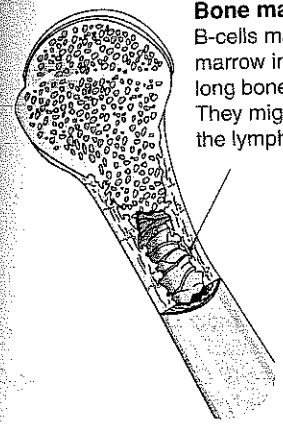
_____

(c) Working with opsonins: _____

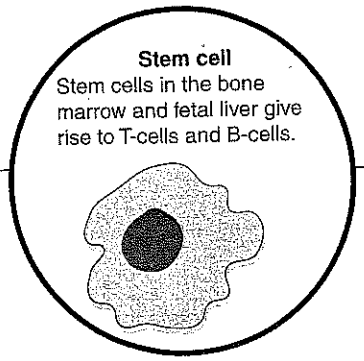
Key Idea: Antigens, such as the cell walls of microbial cells, when processed by antigen-presenting cells, activate the B and T cells of the immune system against specific pathogens. There are two main components of the adaptive immune system: the humoral and the cell-mediated responses. They work separately and together to protect against disease. The **humoral immune response** is associated with the serum (the non-cellular part of the blood) and involves the action of antibodies secreted by B-cells (B lymphocytes). Antibodies are found in extracellular fluids including lymph, plasma, and mucus secretions and protect against viruses, and bacteria and their toxins. The **cell-mediated immune response** is associated with the production of specialized lymphocytes called **T-cells**. Antigens are recognized by T-cells only after antigen processing. The antigen is first engulfed by a macrophage, which processes the antigen and presents it on its surface. T-helper cells can then recognize the antigen and activate other cells of the immune system.

Lymphocytes and their functions

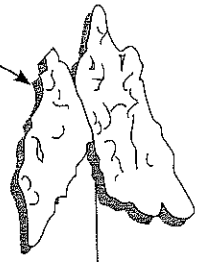
Bone marrow
B-cells mature in the bone marrow in the shaft of the long bones (e.g. the femur). They migrate from here to the lymphatic organs.



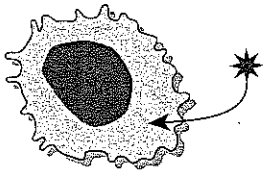
Stem cell
Stem cells in the bone marrow and fetal liver give rise to T-cells and B-cells.



Thymus gland
The thymus gland is located above the heart. It is large in infants but regresses with age. Immature T-cells move to the thymus to mature before migrating to other lymphatic organs.

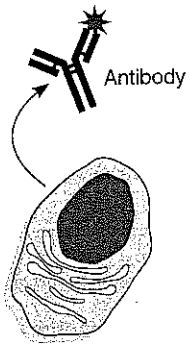


B cell



B-cells recognize and bind antigens. Each B cell recognizes one specific antigen. Helper T cells recognize specific antigens on B cell surfaces and induce their maturation and proliferation. A mature B-cell may carry as many as 100,000 antigenic receptors embedded in its surface membrane. B-cells defend against bacteria and viruses outside the cell and toxins produced by bacteria (free antigens).

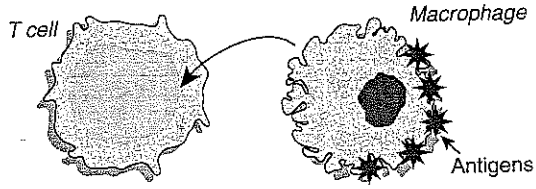
Differentiate into two kinds of cells



Memory cells
Some B-cells differentiate into long-lived memory cells (see Clonal Selection). When these cells encounter the same antigen again (even years or decades later), they rapidly differentiate into antibody-producing plasma cells.

Plasma cells
When stimulated by an antigen (see Clonal Selection), some B-cells differentiate into plasma cells, which secrete **antibodies** into the bloodstream. The antibodies then inactivate the circulating antigens.

T cell



T-cells respond only to antigen fragments that have been processed and presented by infected cells or macrophages (phagocytic cells) (see opposite). They defend against:

- Intracellular bacteria and viruses
- Protozoa, fungi, flatworms, and roundworms
- Cancerous cells and transplanted foreign tissue

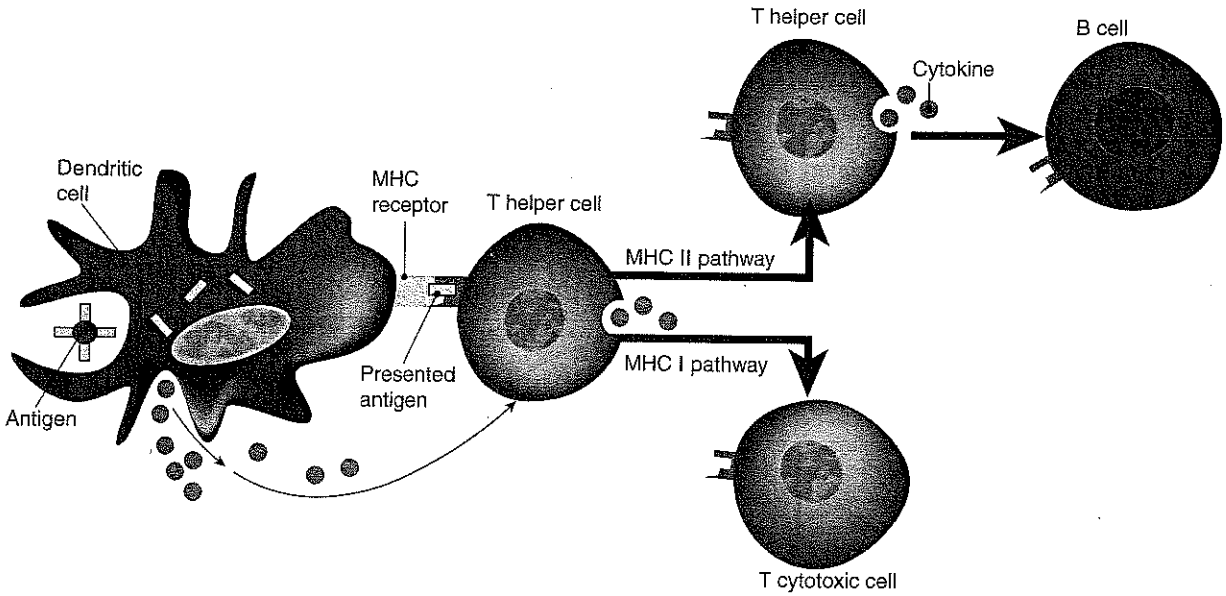
Differentiate into various kinds of cells:

T helper cell activates T cytotoxic cells and other helper T-cells. They are needed for B cell activation.

T cytotoxic cell destroys target cells on contact. Recognizes tumour or virus-infected cells by their surface markers. Also called T killer cells.

There are also other types of T-cells:
T memory cells have encountered specific antigens before and can respond quickly and strongly when the same antigen is encountered again.
T regulator cells control immune response by turning it off when no more antigen is present. They are important in the development of self tolerance.

Dendritic cells stimulate the activation and proliferation of lymphocytes



Immature dendritic cells (DCs) originate in the bone marrow and migrate throughout the body. Once they have processed an antigen they begin to mature. They migrate to lymph nodes and, through antigen presentation and secretion of cytokines, stimulate the activation and proliferation of T-cells. DCs exhibiting MHC I receptors stimulate the production of T cytotoxic cells. DCs exhibiting MHC II receptors stimulate the production of T helper cells. These in turn go on to stimulate the production of antibody-producing B-cells.

1. Where do B-cells and T-cells originate (before maturing)? _____

2. (a) Where do B-cells mature? _____

   (b) Where do T-cells mature? _____

3. Describe the nature and general action of the two major divisions in the immune system:

   (a) Humoral immune system: _____

   _____

   _____

   (b) Cell-mediated immune system: _____

   _____

   _____

4. Explain how an antigen causes the activation and proliferation of T-cells and B-cells, including the role of dendritic cells:

   _____

   _____

   _____

   _____

5. In what way do dendritic cells act as messengers between the innate and the adaptive immune systems?

   _____

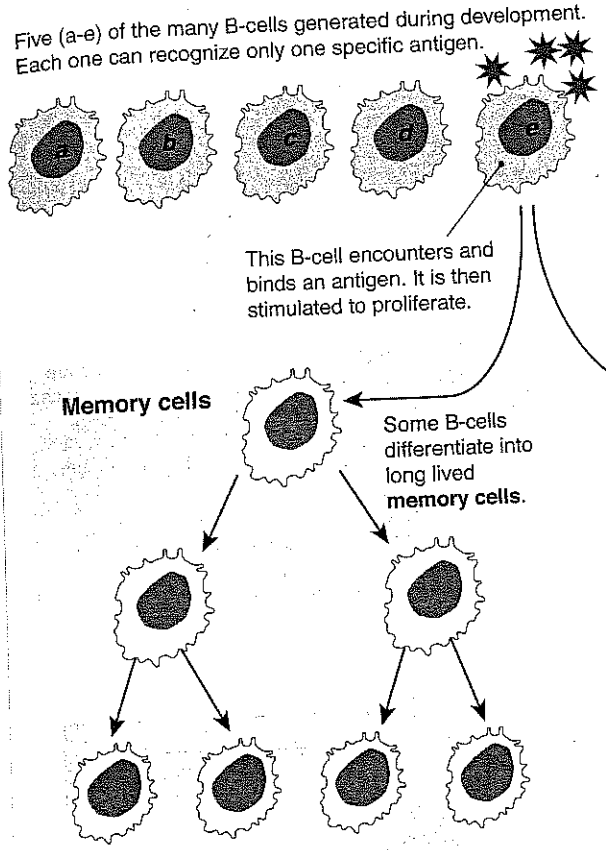
   _____

6. Describe the function of each of the following cells in the immune system response:

   (a) T helper cells: _____

   (b) T cytotoxic cells: _____

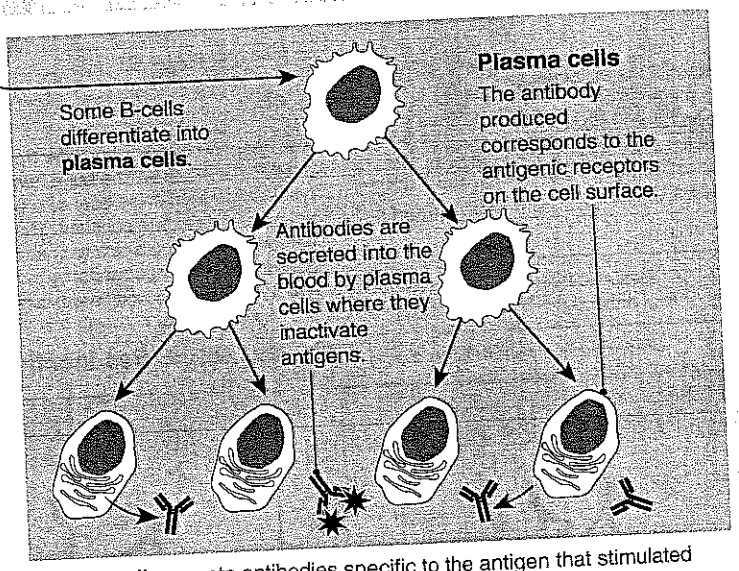
Key Idea: Clonal selection theory explains how lymphocytes can respond to a large and unpredictable range of antigens. The **clonal selection theory** explains how the immune system can respond to the large and unpredictable range of potential antigens in the environment. The diagram below describes clonal selection after antigen exposure for B-cells. In the same way, a T-cell stimulated by a specific antigen will multiply and develop into different types of T-cells. Clonal selection and differentiation of lymphocytes provide the basis for **immunological memory.**



Some B-cells differentiate into long lived **memory cells**. These are retained in the lymph nodes to provide future immunity (**immunological memory**). In the event of a second infection, memory B-cells react more quickly and vigorously than the initial B-cell reaction to the first infection.

Clonal selection theory

Millions of B-cells form during development. Antigen recognition is randomly generated, so collectively they can recognize many antigens, including those that have never been encountered. Each B-cell has receptors on its surface for specific antigens and produces antibodies that correspond to these receptors. When a B-cell encounters its antigen, it responds by proliferating and producing many clones that produce the same kind of antibody. This is called clonal selection because the antigen selects the B cells that will proliferate.



Plasma cells secrete antibodies specific to the antigen that stimulated their development. Each plasma cell lives for only a few days, but can produce about 2000 antibody molecules per second. Note that during development, any B-cells that react to the body's own antigens are selectively destroyed in a process that leads to **self tolerance** (acceptance of the body's own tissues).

1. Describe how clonal selection results in the proliferation of one particular B-cell clone: _____

2. (a) What is the function of the plasma cells in the immune system response? _____

   (b) What is the significance of B-cells producing antibodies that correspond to (match) their antigenic receptors?

3. (a) Explain the basis of immunological memory: _____

   (b) Why are B memory cells able to respond so rapidly to an encounter with an antigen long after an initial infection?