

Defences: the immune system

Components

White blood cells or leucocytes (leukocytes) are responsible for the different immune defence systems.

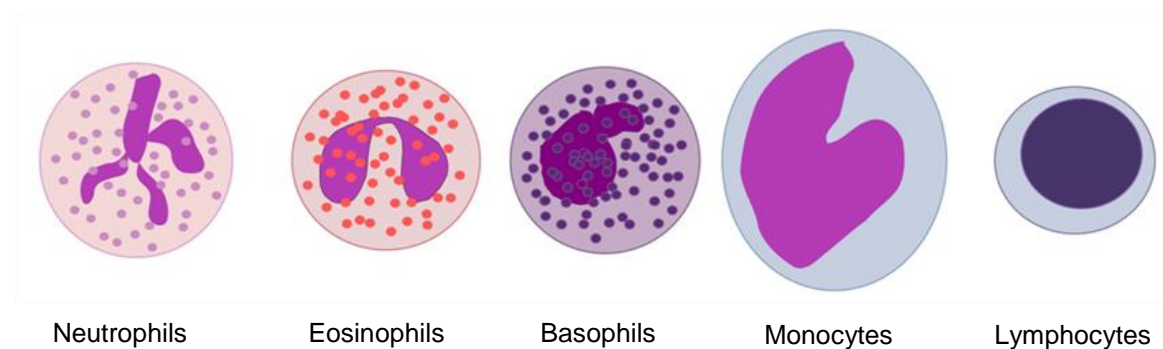


Figure 1 There are five types of white blood cells (also called leucocytes).

Most leucocytes develop from stem cells in bone marrow. Lymphoid tissues produce, store or process lymphocytes. These include bone marrow, lymph nodes, spleen, thymus, tonsils, adenoids, appendix, skin associated lymphoid tissue and gut associated lymphoid tissue (Peyer's patches). Tissues also contain mast cells (similar to basophils) and macrophages which develop from monocytes.

Functions

The defence of the body against invaders involves two systems, the integumentary system and the immune system. These systems interact to defend the body. The immune system defends against invaders which have entered the body and against cancer cells. It identifies and neutralises or destroys 'foreign' materials in the body that are potentially harmful. Functions include:

- identifying and eliminating foreign cells and material, including defence against invading pathogens (disease causing organisms like viruses and bacteria) and neutralisation of toxins;
- identifying and destroying abnormal or mutated cells (immune surveillance), including cancer cells;
- removing damaged or worn out cells such as old red blood cells and tissue debris from wounds or disease.

Key mechanisms

There are two fundamentally different responses carried out by the immune system:

- innate non-specific inflammatory response
- adaptive specific immune response

Inflammatory response

This is a non-specific response to injury or invasion that produces local inflammation and pathogens are destroyed by lymphocytes.

Basophils in blood and mast cells in tissues release histamine into an infected area or wound. Histamine relaxes smooth muscle in arterioles increasing blood flow and causing capillaries to leak

so that plasma escapes. The effects are enhanced by prostaglandins, which increase inflammation and cause pain, and bradykinins, which cause pain and increase the permeability of capillaries.

Other chemicals released by damaged cells attract phagocytes (chemotaxis) which are able to squeeze through the gaps in the leaky capillary walls (a process called diapedesis). Neutrophils arrive first but are replaced by macrophages in major infections.

Phagocytes identify, engulf and digest bacteria and cell debris (this is phagocytosis) – receptors in the surface membrane bind with pathogen markers, such as carbohydrates typical to bacterial cell walls, to trigger phagocytosis.

Phagocytes and the liver produce a variety of complement proteins which are activated when they come into contact with bacteria. Some bind to bacteria to promote phagocytosis.

Basophils release granules to stimulate immune reactions.

Eosinophils have surface receptors which allow them to bind to the surface of larger parasites while they release an enzyme which digests the parasite.

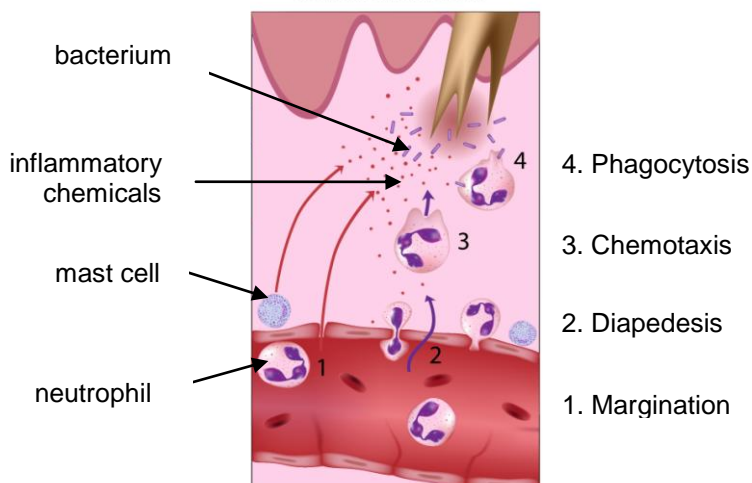


Figure 2 Stages in the inflammatory response.

Interferon and natural killer cells

In another non-specific innate response, cells infected with viruses release interferon. Interferon is a type of cytokine, a group of chemical messengers which stimulate lymphocytes to destroy cancer cells and cause fever, division of lymphocytes and release of prostaglandins.

Interferon temporarily interferes with virus replication in other potential host cells by stimulating them to produce virus-blocking enzymes, which break down viral messenger RNA and inhibit protein synthesis. It also enhances macrophage phagocytotic activity.

Interferon has anticancer effects. It slows cell division to suppress tumour growth and it enhances the activity of cell killing cells (lymphocyte-like cells that destroy virus infected cells and cancer cells).

Specific immune response

Inflammation can isolate and mop up local infections, but if the infection spreads the specific immune response takes over. It selectively attacks specific targets when exposed to them. This takes time to develop as large numbers of new cells need to be produced.

There are two types of lymphocyte, B cells and T cells, involved in specific immune responses:

- B cells in antibody-mediated (humoral) immunity, attacking bacteria and their toxins.
- T cells in cell-mediated immunity, attacking virus infected cells and cancer cells.

Antigens and antibodies

An antigen is a molecule foreign to the body and is usually a large, complex unique molecule, e.g. a protein or large polysaccharide. An antibody is a Y-shaped molecule comprised of four polypeptide chains. The ends of the arms of the 'Y' form variable regions which can bind to specific antigens leading to their neutralisation or destruction.

B cells and T cells have receptors on their surface membranes. These can combine with a specific antigen in a 'lock and key' manner to stimulate a response by the cell. During their development each cell is programmed to react to a specific antigen before it has been exposed to it.

In a B cell response, a few B cells in the body will carry cell surface receptors capable of binding to a specific antigen. This causes these cells to divide rapidly. Most become plasma cells which secrete antibodies specific to the antigen detected and neutralise or destroy bacteria and their toxins. Some of the cells become long-lived memory cells which remain in the blood ready to respond to any return of the antigen.

In a T cell response, a variety of cells are produced in response to the presence of an antigen. These include killer cells which destroy target cells (such as virus infected cells or cancer cells), helper cells which assist the production of plasma cells from B cells, and memory cells ready for a rapid future response.

Memory cells make a second immune response much more rapid and can prevent the onset of disease – the body has become 'immune' to that pathogen or toxin.

Role in homeostasis

Homeostasis can only be maintained if body cells are (a) not damaged or disrupted by pathogens, (b) dead and injured, (c) replaced by abnormal cells such as cancer cells.

The immune defence system therefore contributes indirectly to homeostasis by protecting other cells and keeping them healthy.

Examples of what can go wrong

Ageing

Both B and T cells originate in the bone marrow. B cells migrate from the **b**one marrow directly to lymphoid tissues, whereas some immature lymphocytes migrate to the **t**hymus gland to become T cells before moving to lymphoid tissues

After the T cells have formed and left the thymus it begins to atrophy. It continues to produce thymosin, which stimulates the production of new T cells in lymphoid tissues. Secretion of thymosin declines after age 30-40 and this may contribute to aging of body systems. Diminishing T cell capacity with aging may cause increased susceptibility to viral infections, like flu.

Vaccines

The production of plasma cells takes time, during which more virulent pathogens can multiply and cause damage to body systems. About a quarter of all deaths are caused by infectious killer diseases. They include tuberculosis, measles, tetanus, meningitis, polio and hepatitis B.

Vaccines are used to introduce the antigens of pathogens into the body in a harmless form. Once the immune system has been able to produce memory cells, it is able to respond rapidly to the return of an antigen. Large numbers of plasma cells which secrete the necessary specific antibody can be produced very rapidly. Any harmful invader can be knocked out before it can cause harm.

Other vaccines used weakened or dead pathogens to introduce antigens into the body. New genetic engineering techniques are allowing antigens to be targeted and artificially synthesised for vaccine production, making them more effective and cheaper.

Finding out

HIV, the human immunodeficiency virus, inactivates T helper cells (Th cells). Progressive depletion of these cells eventually debilitates the immune system, causing acquired immunodeficiency syndrome (AIDS). This leaves the body open to opportunistic infections and cancers. Since the virus attacks the immune system, a traditional vaccine is not effective.

Find out how HIV infection is treated and the development of AIDS suppressed.