

Immunity - Immune System, Meaning, Function, Types

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The ability of a person to defend itself from the harmful effects of microorganisms and their byproducts is known as "**immunity**." The human immune system is made up of lymphoid organs, cells like WBCs and antibodies made of protein. Also, the immune system is classified as an active immune system or a passive immune system, an acquired immune system and an immune system acquired by vaccination.

The immune system can identify foreign antigens, react to them, and retain information about them for the future. Furthermore, the immune system is crucial for organ transplantation, autoimmune illnesses, and allergic reactions.

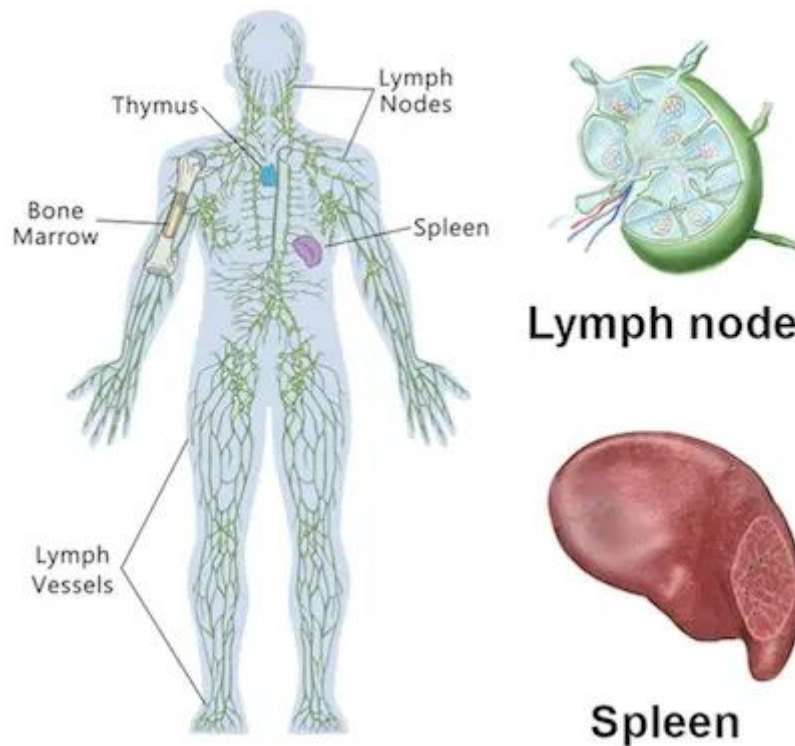
Immune System

The lymphoid organs, tissues, cells, and soluble molecules like antibodies and cytokines make up the human immune system.

Lymphoid Organs

These are the organs where lymphocytes originate, mature, and proliferate. The thymus and bone marrow are the primary lymphoid organs where immature lymphocytes differentiate into antigen-sensitive lymphocytes. Spleen, lymph nodes, tonsils, Peyer's patches, etc. are secondary lymphoid organs (or tissues that make these organs)

where lymphocytes interact with the antigens.

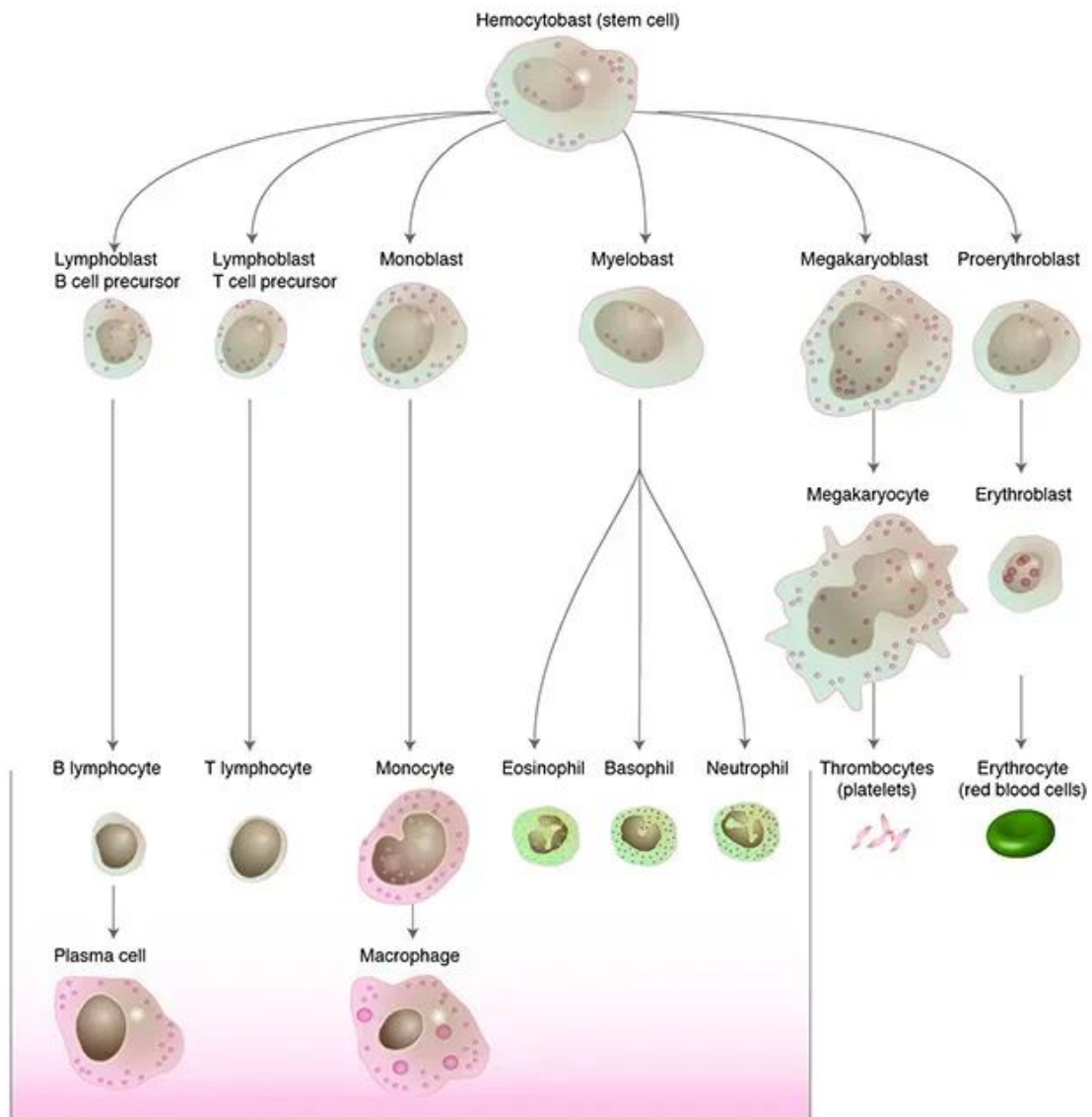


- **Bone marrow and thymus:**

- The bone marrow creates **all blood cells including lymphocytes**. B-lymphocytes mature in the bone marrow.
- In the thymus, **T-lymphocytes** (formed in bone marrow) mature.
- **Spleen:** This bean-shaped organ primarily consists of phagocytes and lymphocytes.
- As a secondary lymphoid organ, it interacts with antigens.
- It controls and filters the blood.
- **Lymph nodes:** Little, solid structures called lymph nodes are dispersed at various points alongside the lymphatic system.
- Antigens that manage to enter the tissue and lymph fluid are captured by lymph nodes and activate the lymphocytes.
- **MALT:** Mucosa-associated lymphoid tissue is found inside the lining of the major tracts of the digestive, urogenital, and respiratory systems.
 - Approximately 50% of the lymphoid tissue in the human body is composed of it.

Cells Involved in the Immune System

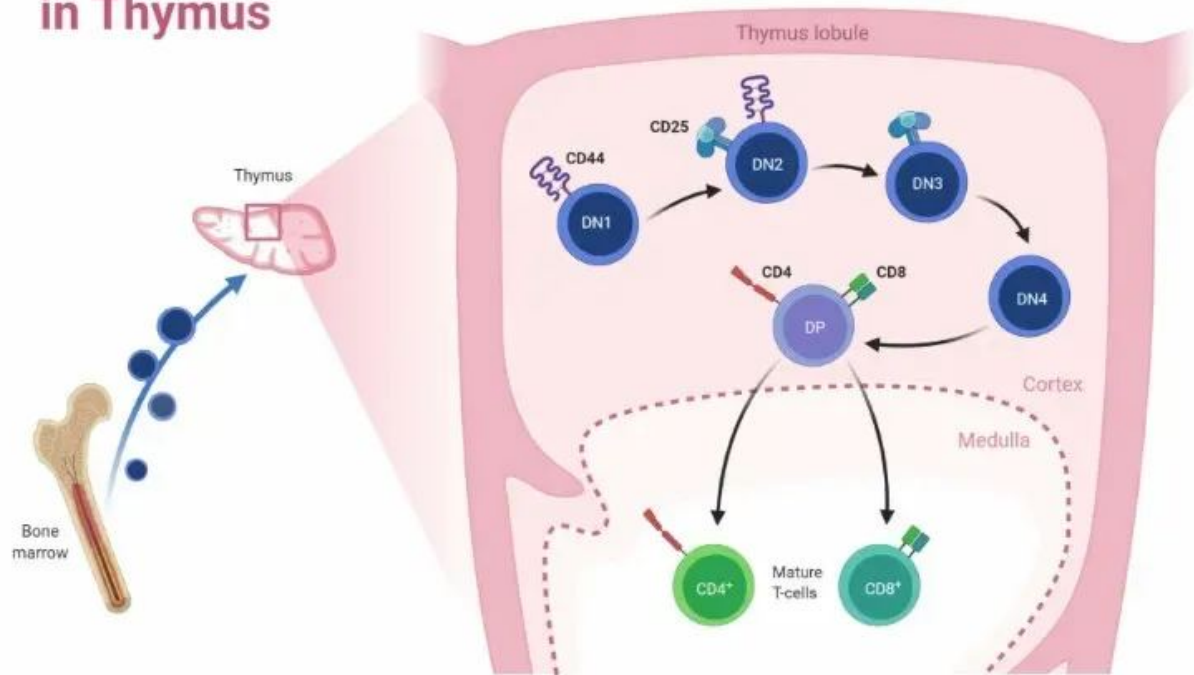
White blood cells (WBC) are immune response cells. These WBCs are lymphocytes and myeloid cells (granulocytes and monocytes), which are all generated in the bone marrow. Lymphocytes are the basic cells of the immune system, accounting for 20-40% of WBCs. Both granulocytes and monocytes have a role in innate and acquired immune responses.



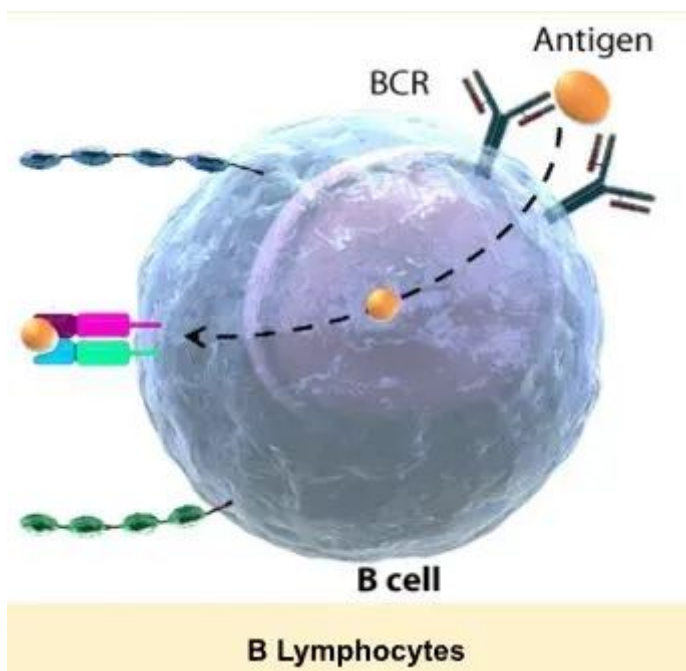
Lymphocytes - white blood cells

- **T lymphocytes:** Maturing in the thymus gland, they exhibit cell-mediated immunity in the secondary lymphoid organs. They contain T-cell receptors (TCR) on their surface.

T-Cell Development in Thymus

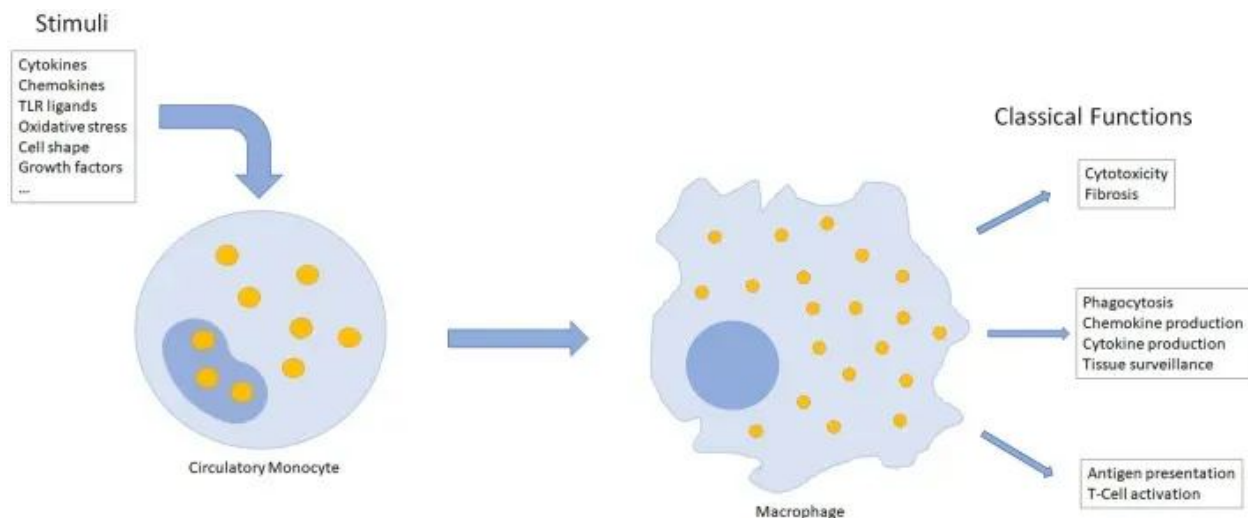


- **Helper T cells** (TH) express **CD4** molecules on their surface. They activate macrophages (for phagocytosis), cytotoxic T-cells (killing of pathogens) and B-cells (to secrete antibodies).
 - Thus, they are **central to the adaptive immune response**.
- **Cytotoxic T cells** (TC) express **CD8** molecules on their surface. They are directly involved in killing of intracellular pathogens as well as eliminating cancerous cells.
- **Suppressor T cells** (TS) are involved in suppressing humoral and cell-mediated immune responses.
- **B lymphocytes:** After maturation in bone marrow, they migrate to secondary immune organs.



- The two most important roles that B cells play in the body's defence are the production of **antigen-specific antibodies** and the **antigen-presenting cells** to T helper cells for the adaptive immune response.

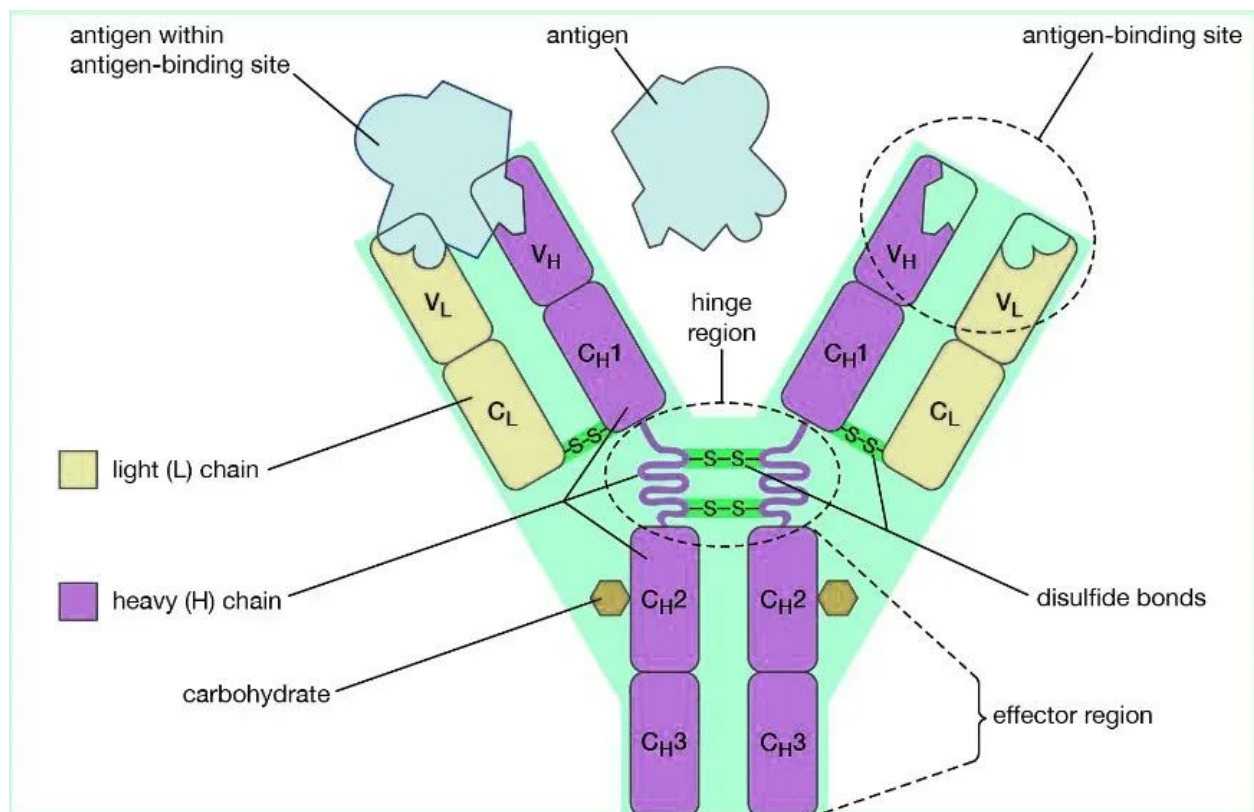
- T-helper cells activate B cells to produce plasma cells and memory cells.
- The **plasma cells produce antibodies** (immunoglobulins) specific to the antigen. Memory B cells acquire immunological memory for the same antigen, which is used in future.
 - Because memory B cells live for a long time, they offer lifetime immunity against various pathogens.
- The B cell immune response is also referred to as the **humoral immune response** (humor or body fluid) because it necessitates the synthesis of antibodies in the blood and lymph in order to kill the antigen.
- **Neutrophils:** They make up between 50-70 percent of circulating WBCs produced from myeloid progenitor cells.
 - The first cells to arrive at an infection site are neutrophils, as the innate immune response.
- **Macrophages: Developed from the myeloid progenitor cell, they are the cells of the innate immune system.**
- They release various cytotoxic proteins that help destroy a broad range of pathogens, such as tumour cells, intracellular bacteria, and virus-infected cells.
- They also function like antigen-presenting cells for T-helper cells; in turn, T-H cells activate them for phagocytosis.
- **Phagocytosis** involves engulfing and eliminating pathogens by using lysosomes.



Immunoglobulins (Antibodies)

Immunoglobulins (Ig) are glycoproteins produced by **plasma B cells** as a part of the Humoral immune response. They constitute around 20% of the total protein in the plasma of the blood.

- **Basic Structure:** All immunoglobulins consist of **four polypeptide chains** (two heavy and two light, joined by disulphide bonds) in a Y-shaped structure.
 - In all four chains, there are both constant domains (CH and CL) and variable domains (VH and VL). The variable domains are antigen-binding sites.
 - The simplest immunoglobulin has two identical antigen-binding sites (bivalent).
 - The human body consists of five classes of immunoglobulins, depending on the types of heavy chains.
- **First as receptors:** The first antibodies produced by the naive B cell are not secreted but inserted into its plasma membrane. It serves as part of the **BCRs**, receptors for antigens.
 - Each B cell makes a unique species of antibody, with a unique antigen-binding site.



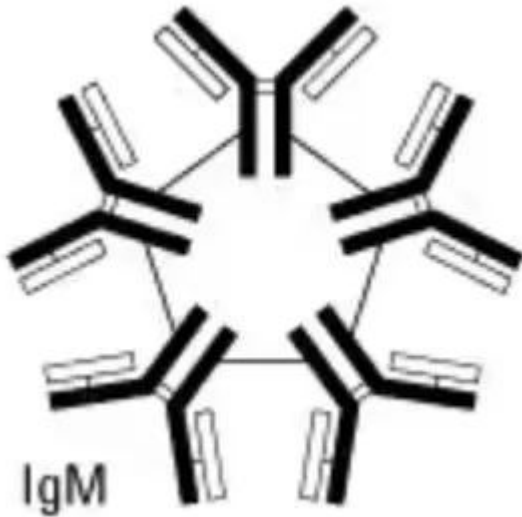
- **IgG:** It is the simplest, a monomer and bivalent. The majority of IgG synthesis occurs during the secondary immune response to infections.
 - It is the major type of immunoglobulins.
 - Other than activating complements (antigen-antibody complement), it binds to specific receptors of macrophages and neutrophils.
 - The complements neutralise the pathogen by preventing them entering into the cells; present B cells for the cell-mediated immunity (to T-H cells).
 - Binding with macrophages and neutrophils activates phagocytosis.
 - IgG is the **only type of Ig that can pass through the human placenta**, thereby protecting the newborn in its first few months of life.
 - It is also found in mothers' milk.



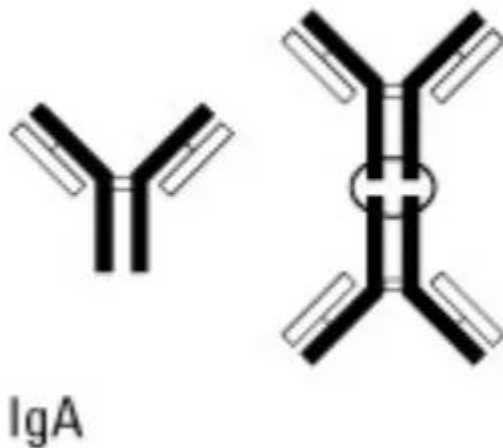
IgG

- **IgM:** It is a pentamer (that is, it attaches to five antigens at once).
 - It is the most effective complement-fixing immunoglobulin and dominates primary immune responses to most antigens.

- IgM is a potent agglutinin and a monomer of IgM is used as a B cell receptor (BCR) like IgG.



- **IgA:** IgA has both monomeric (in serum) and dimeric (secretory) structures.
 - Secretory IgA provides the primary defence mechanism against local infections because of its abundance in mucosal secretions (like saliva and tears).
 - The primary function of secretory IgA may not be to destroy antigens but to prevent the passage of foreign substances into the circulatory system.
 - It is the most abundant immunoglobulin found in mother's milk.



- **IgE:** It is a monomer.
 - It causes **allergic reactions** and provides protection against parasites.
- **IgD:** A monomer that is present in a meagre amount in the serum and has unknown function against pathogens.
 - Regarded as a part of BCR, IgD may play a critical role in antigen-triggered lymphocyte differentiation.



- **Monoclonal and polyclonal antibodies:**

Polyclonal	Monoclonal
- Refers to a mixture of immunoglobulin molecules (heterogeneous) that are secreted against a particular antigen.	- Refers to a homogeneous population of antibodies.
- Produced by different clones of plasma B cells.	- Produced by the same clone of plasma B cells.
- Production does not require hybridoma cell lines.	- Production requires hybridoma cell lines.
- Interact with different epitopes on the same antigen.	- Interact with a particular epitope on the antigen.

Types of Immunity

Immunity can be Innate, a non-specific form of defence that exists from birth, or Acquired, which is pathogen-specific and developed in the body.

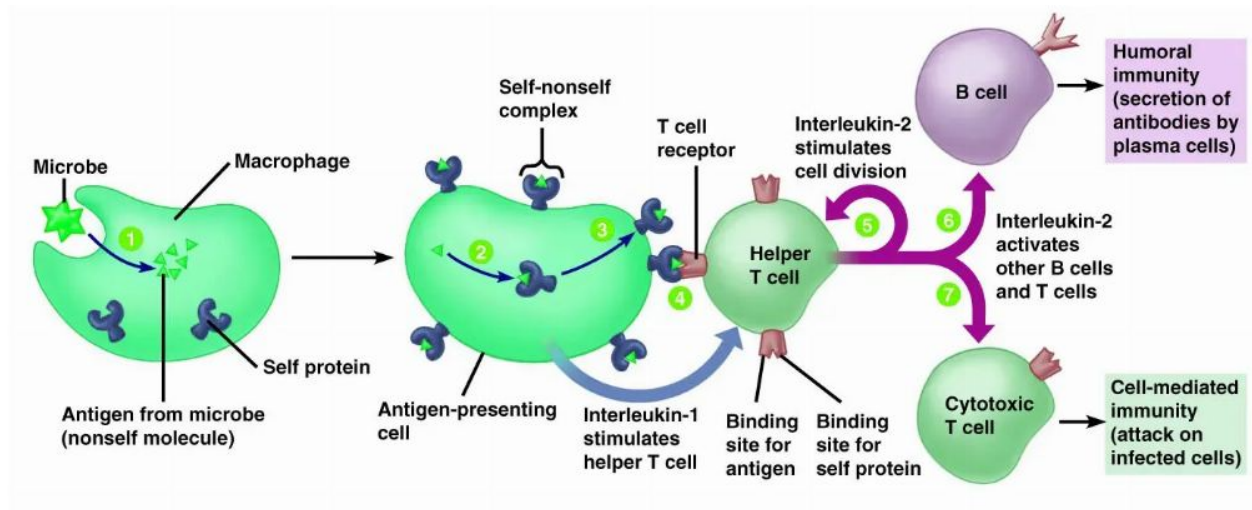
Innate Immunity

Innate Immunity is achieved by building barriers that prevent foreign agents from entering our bodies. There are four different kinds of barriers to innate immunity.

- **Physical barriers:** The primary barrier preventing microorganisms from entering our bodies is the skin. The mucus layer, that coats the epithelium lining of our gastrointestinal, respiratory, and urogenital tracts, aids in the capture of microbes.
- **Physiological barriers:** Saliva in the mouth, tears in the eyes, Human milk, and acid in the stomach all inhibit the growth of microorganisms.
- **Cellular barriers:** They comprise certain leukocytes (WBCs) in our bodies, such as monocytes, natural killers (type of lymphocytes), polymorphonuclear leukocytes (PMNL-neutrophils), and macrophages.
- **Cytokine barriers:** Interferons are proteins secreted by virus-infected cells that shield uninfected cells from contracting new viruses.

Acquired Immunity

Acquired immunity is **pathogen-specific** and is characterised by memory.



- **Primary response:** When the body encounters a pathogen, it produces a primary response of low intensity.
- **Secondary response:** Later encounters with the same pathogen induce a highly intensified secondary response.
 - This response is due to the memory plasma cells (B cells).
- **Types:**
 - **Humoral immune response:** The action of antibodies is called **humoral immune response**, as the antibodies are found in the blood.
 - **Cell-mediated immune response:** The T-lymphocytes mediate CMI.
 - In this, T-H cells encounter antigens due to the APCs (through the MHC complex).
 - This activates T-H cells, which in turn activate cytotoxic T cells and macrophages for the CMI response.
 - T-H cells also activate B-cells (for humoral response).

Active and Passive Immunity

- **Active immunity:** When antibodies are created in response to the exposure of antigens (proteins or microorganisms), it is known as active immunity.
 - It develops gradually and takes some time to fully show its effects.
 - It is induced by intentionally injecting microbes during **immunisation** or by infectious organisms entering the body naturally.
- **Passive immunity:** When artificially made antibodies are directly given to protect the host body against foreign agents, it is referred to as passive immunity. For example:
 - A mother's milk is considered essential for a newborn infant. The yellowish fluid **colostrum** secreted by the mother during the initial lactation days has abundant antibodies (IgA) to protect the infant.
 - The foetus also receives some antibodies through the placenta from their mother.

Vaccination and Immunisation

The immune system's "memory" is the foundation for the immunisation and vaccination theory.

- Preparation of the pathogen's antigenic proteins, or an inactivated or weakened pathogen is injected into the body during vaccination.

- During an actual infection, the pathogenic agents would be neutralised by the antibodies the body produced in response to these antigens.
- Additionally, the vaccines produce memory B and T cells, which upon re-exposure, promptly identify the pathogen and overwhelm the invaders with a massive production of antibodies.

Other Applications of Immunoglobulins

The **antigen-antibody binding** (complement) is so specific that immunoglobulins have wider applications across biomedical research.

- **Research:** They are used in the research of immunoassay, immunofluorescence microscopy, DNA and protein microarray analysis, immunohistochemistry, flow cytometry, immunoprecipitation, etc.
- **Clinical diagnostics:** They are used to identify disease-specific antibodies in a blood sample and are matched to a particular pathogen, which makes them useful for diagnosing certain diseases (**antibody testing**).
- Antibody testing identifies the antibodies produced in reaction to the infection, not the pathogens that actually cause the infection.
- A positive result indicates that the antigen or antibody has been found by the test. A negative outcome indicates "no," and a borderline result is deemed inconclusive.
- **For example: the recent COVID-19 testing**
 - **Treatment of diseases:** When an individual does not produce a sufficient amount of antibodies, passive immunisation using immunoglobulins is appropriate. It is immunoglobulin therapy, which is used in immunology, haematology, neurology, and other medical specialities all over the world. In this case, two types of antibody concentrates are possible.
 - **Standard human immune serum globulin:** Extracted from large pools of human plasma.
 - **Special human immune serum globulins:** Derived from plasma pools of a limited number of convalescent or actively immunised populations.

Immunity UPSC PYQs

Question 1: Which one of the following statements best describes the role of B cells and T cells in the human body? (**UPSC Prelims 2022**)

1. They protect the body from environmental allergens.
2. They alleviate the body's pain and inflammation.
3. They act as immunosuppressants in the body.
4. They protect the body from the diseases caused by pathogens.

Answer: (d)

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