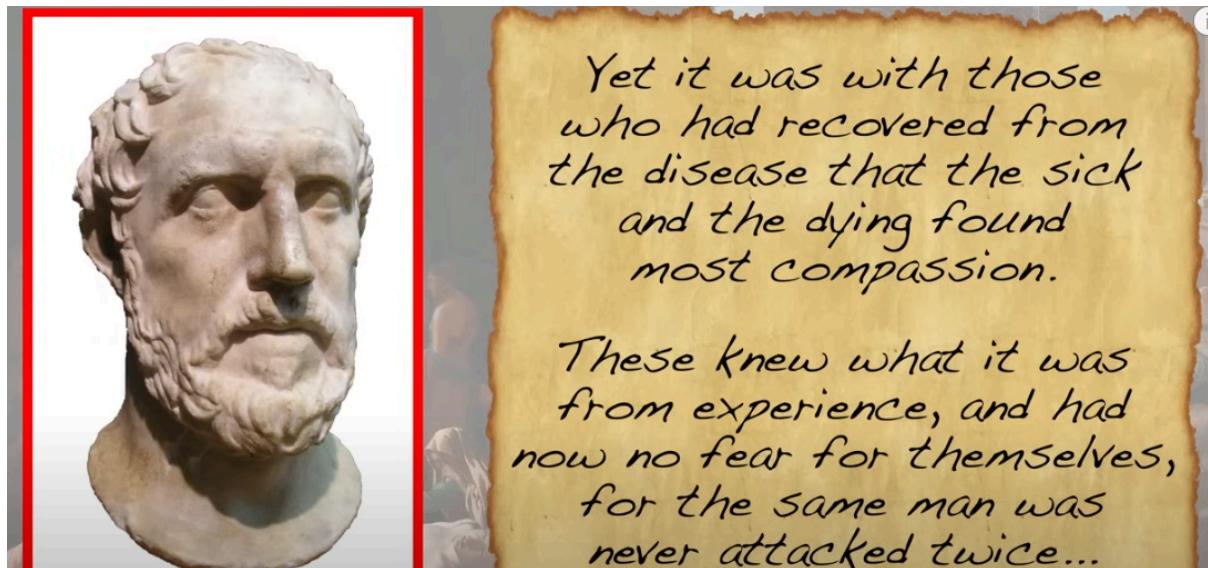


Understanding Our Body's Defense System (Immunology)

1. What is the Immune System?

The immune system is like the body's army. It protects us from harmful germs like **bacteria** and **viruses**. It can tell the difference between what belongs in the body and what doesn't.



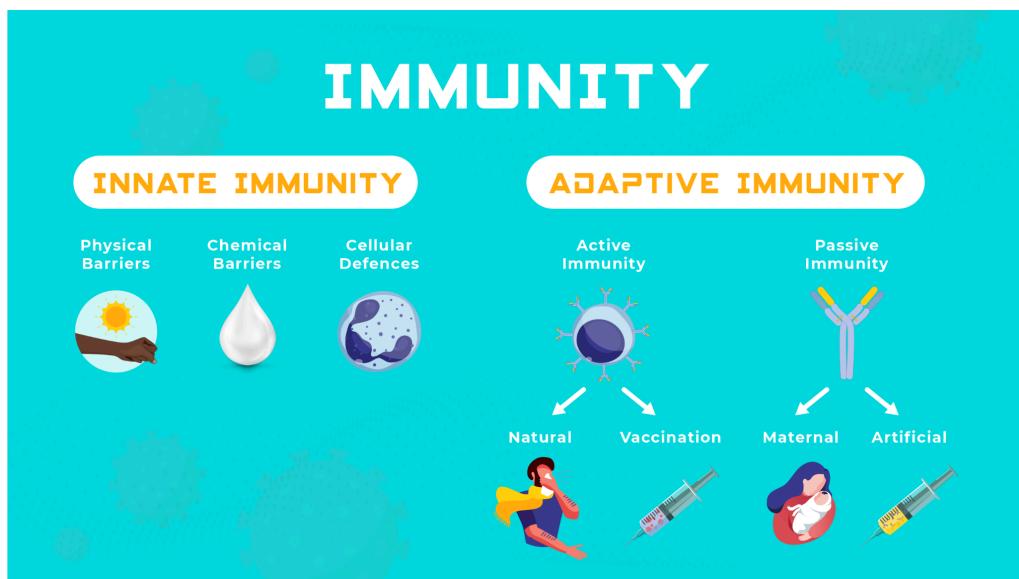
Thucydides

2. First Line of Defense: Barriers Against Infection

Our body has natural barriers to stop germs before they enter:

- **Skin:** Acts like a wall, blocking germs.
- **Saliva & Tears:** Contain special substances that kill bacteria.
- **Mucus in Lungs & Gut:** Traps germs before they can cause harm.
- **Tiny Hairs in Airways:** Sweep away dirt and germs from the lungs.

If these barriers fail, the immune system steps in to fight the infection.



The immune system has two main parts:

- Innate Immunity (Born-with Defense):
 - First line of defense (skin, mucus, stomach acid).
 - Acts fast but doesn't remember past infections.
 - Includes white blood cells like neutrophils and macrophages that eat germs.

The Innate Immune System (First Response Team)

- **Mast Cells & Basophils:** Release histamine to cause inflammation, helping fight infections.
- **Neutrophils & Macrophages:** Eat and destroy germs (a process called phagocytosis).
- **Natural Killer (NK) Cells:** Destroy infected and cancerous cells.
- **Eosinophils:** Special cells that fight larger parasites, like worms.
- **Complement System:** A group of proteins in the blood that helps destroy bacteria.

In 1796, Edward Jenner, a British physician, discovered that inoculation with cowpox could protect against smallpox, leading to the development of the first successful vaccine and the term "vaccination".



In 1796, **Dr. Edward Jenner**, an English physician, observed that **milkmaids who contracted cowpox (a mild disease in cows) did not get smallpox**. He hypothesized that exposure to cowpox provided immunity against smallpox.

Adaptive Immunity (Learned Defense):

Takes time to respond but remembers past infections.

Includes T cells (which attack infected cells) and B cells (which make antibodies).

Two Types of Adaptive Immune Responses

- **Cellular Immunity (T Cells at Work)**
 - T cells hunt down and kill infected cells.
- **Humoral Immunity (B Cells & Antibodies)**
 - B cells make antibodies that float in the blood and attack germs.

The Adaptive Immune System (Memory & Targeted Defense)

- **B Cells:** Make **antibodies** that stick to germs and mark them for destruction.
- **T Cells:**
 - **Helper T Cells (CD4+):** Tell other immune cells what to do.
 - **Cytotoxic T Cells (CD8+):** Kill infected or cancerous cells.

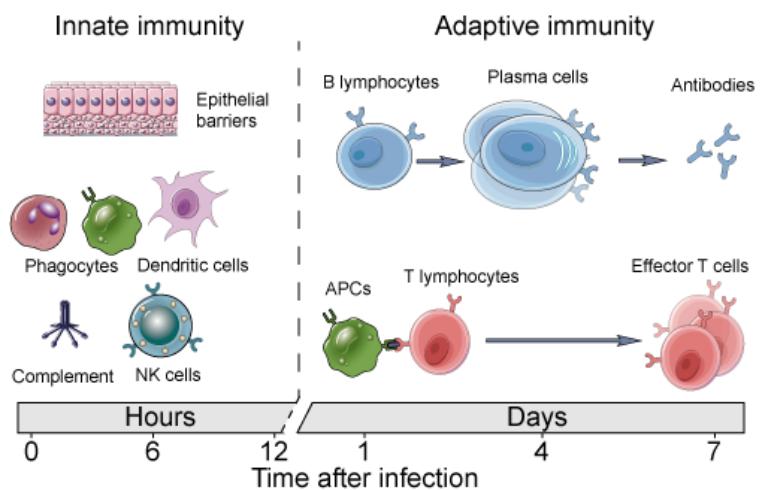
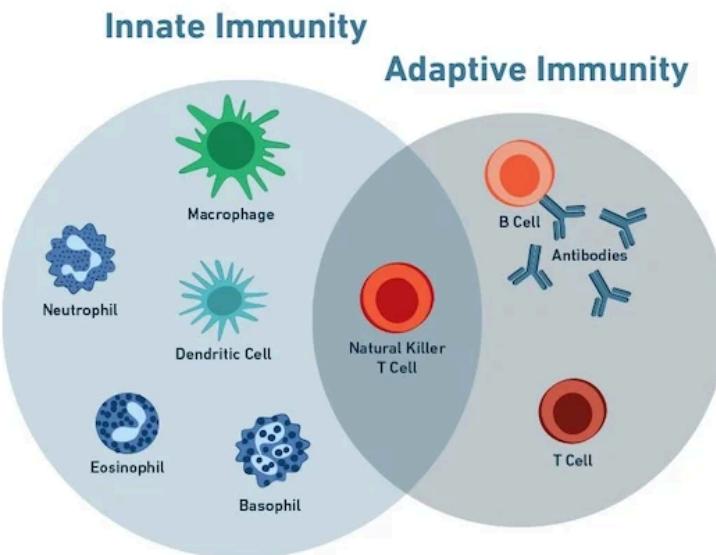
All immune cells are made in the **bone marrow**.

- **T cells** mature in the **thymus**.
- Immune cells are stored in places like the **lymph nodes, spleen, and mucosal tissues** (gut & lungs).

The **lymphatic system** helps move immune cells and fight infections.

- White Blood Cells (WBCs): The body's soldiers that fight germs.

- Neutrophils: The first to fight germs.
- Macrophages: Eat germs and show the pieces to T cells.
- T Cells:
 - **Helper T cells (CD4+): Tell other immune cells to act.**
 - **Cytotoxic T cells (CD8+): Kill infected cells.**
- B Cells: Make antibodies that stick to germs and help destroy them.
- Natural Killer (NK) Cells: Kill virus-infected and cancerous cells.



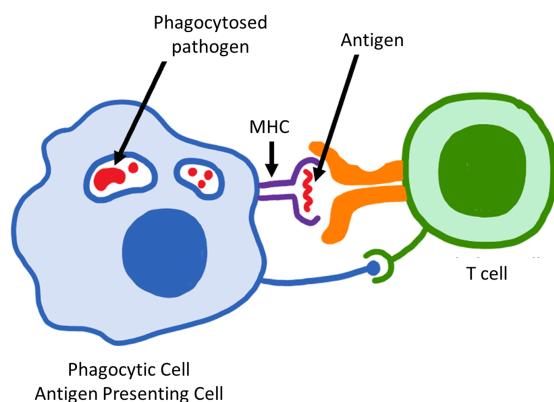
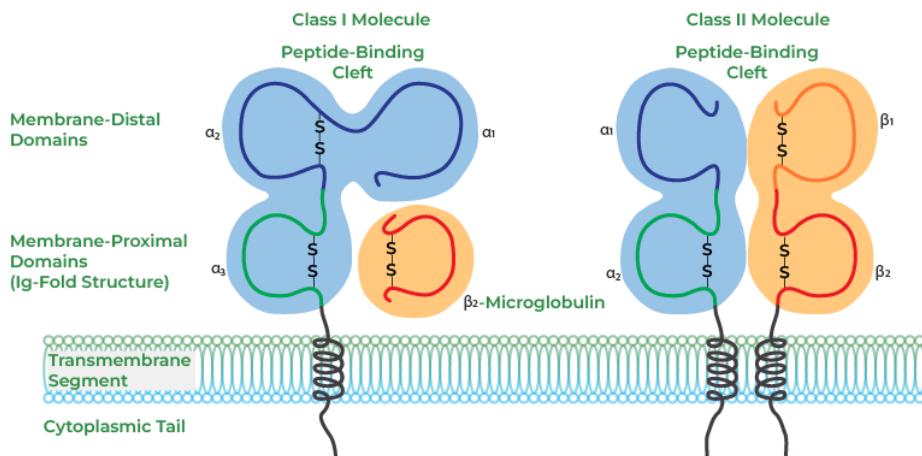
Cell	Image	% in adults	Nucleus	Functions	Lifetime	Main targets
Macrophage*		Varies	Varies	<ul style="list-style-type: none"> • Phagocytosis • Antigen presentation to T cells 	Months – years	<ul style="list-style-type: none"> • Various
Neutrophil		40-75%	Multi-lobed	<ul style="list-style-type: none"> • Phagocytosis • Degranulation (discharge of contents of a cell) 	6 hours – few days	<ul style="list-style-type: none"> • Bacteria • Fungi
Eosinophil		1-6%	Bi-lobed	<ul style="list-style-type: none"> • Degranulation • Release of enzymes, growth factors, cytokines 	8-12 days (circulate for 4-5 hours)	<ul style="list-style-type: none"> • Parasites • Various allergic tissues
Basophil		< 1%	Bi- or tri-lobed	<ul style="list-style-type: none"> • Degranulation • Release of histamine, enzymes, cytokines 	Lifetime uncertain; likely a few hours – few days	<ul style="list-style-type: none"> • Various allergic tissues
Mast cell		Common in tissues	Central, single-lobed	<ul style="list-style-type: none"> • Degranulation • Release of histamine, enzymes, cytokines 	Months to years	<ul style="list-style-type: none"> • Parasites • Various allergic tissues
Lymphocytes (T cells)		20-40%	Deeply staining, eccentric	<p>T helper (Th) cells (CD4+): immune response mediators</p> <p>Cytotoxic T cells (CD8+): cell destruction</p>	Weeks to years	<ul style="list-style-type: none"> • Th cells: intracellular bacteria • Cytotoxic T cells: virus infected and tumour cells • Natural killer cells: virus-infected and tumour cells
Monocyte		2-6%	Kidney shaped	Differentiate into macrophages and dendritic cells to elicit an immune response	Hours – days	<ul style="list-style-type: none"> • Various
Natural killer (NK) cell		15% (varies) of circulating lymphocytes and tissues	Single-lobed	<ul style="list-style-type: none"> • Tumour rejection • Destruction of infected cells • Release of perforin and granzymes which induce apoptosis 	7-10 days	<ul style="list-style-type: none"> • Viruses • Tumour cells

3. Important Soldiers of the Immune System

How Does the Body Start an Immune Response?

- **Antigen-Presenting Cells (APCs):** Special cells (like dendritic cells and macrophages) grab pieces of germs and show them to T cells, telling them to fight.
- **MHC (Major Histocompatibility Complex):** Helps immune cells recognize invaders.
 - **MHC Class I:** Helps cytotoxic T cells recognize infected cells.
 - **MHC Class II:** Helps helper T cells guide immune responses.

MHC Class I vs MHC Class II



MHC and Mate Selection: Why Does It Matter?

Some animals (and even humans) prefer mates with **different MHC genes** from their own. Why?

- A child with **diverse MHC genes** will have a **stronger immune system**.
- Some species (like sand lizards) can detect MHC differences **through smell** and choose mates accordingly.

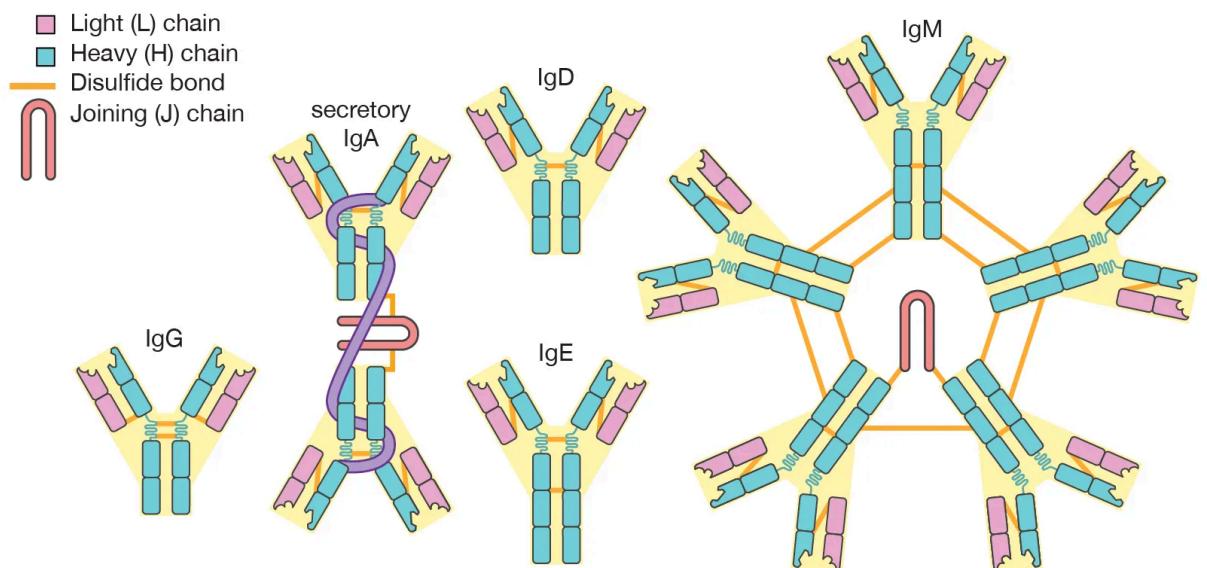
Does This Happen in Humans?

Research suggests that humans **might** prefer mates with different MHC genes. Some studies show that people are more attracted to the smell of someone with **different MHC genes**, but cultural factors also play a role in mate choice.

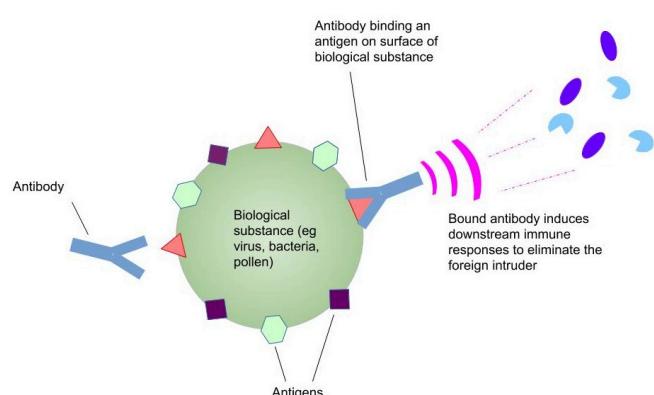
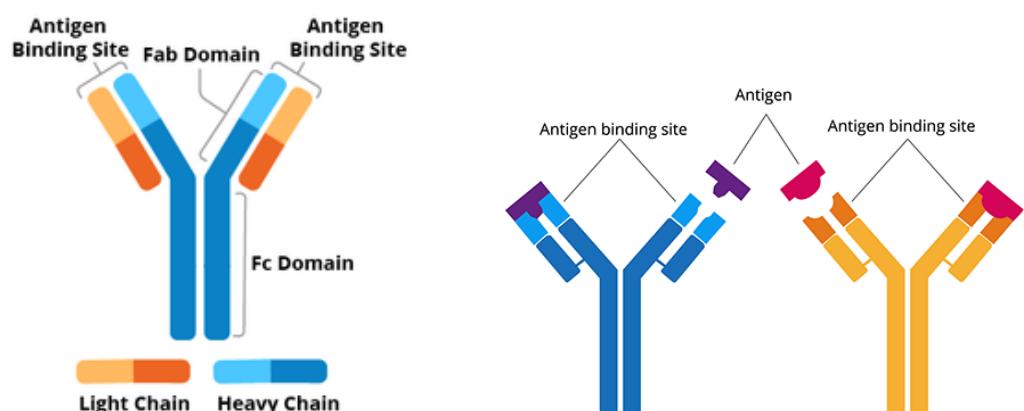
4. What Are Antibodies?

Antibodies are special proteins made by B cells to fight infections. Different types of antibodies have different jobs:

- IgG: The most common, helps fight infections.
- IgA: Found in tears, saliva, and mucus (guards entry points).
- IgM: The first antibody made when infection starts.
- IgE: Helps fight parasites and causes allergies.
- IgD: Helps B cells get ready to fight.



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Main Functions of Antibodies

1. Neutralization – Antibodies block bacteria, viruses, and toxins from attacking body cells.
 2. Phagocytosis – They help immune cells "eat" and destroy germs.
 3. Antibody-Dependent Cellular Cytotoxicity (ADCC) – They mark infected cells so immune cells can kill them.
 4. Complement Activation – Antibodies activate a group of proteins (complement system) to break open germs.
 5. Mucosal & Neonatal Immunity – Some antibodies protect areas like the lungs, gut, and help transfer immunity from mothers to babies.
 6. IgE Activation – A special antibody (IgE) helps fight parasites and triggers allergic reactions by activating mast cells, eosinophils, and basophils.
-

How Do Antibodies Work?

- They stick to germs so they can't infect body cells.
- They call for backup, signaling immune cells to attack.
- They help clear out toxins from the body.

Antibodies are superheroes of the immune system, working to keep us safe from infections!



5. How Does the Immune System Remember Germs?

Once the immune system fights off a germ, it remembers it. If the same germ comes back, the immune system acts quickly to destroy it before making us sick again. This is why vaccines work—they train the immune system to recognize germs without making us sick.

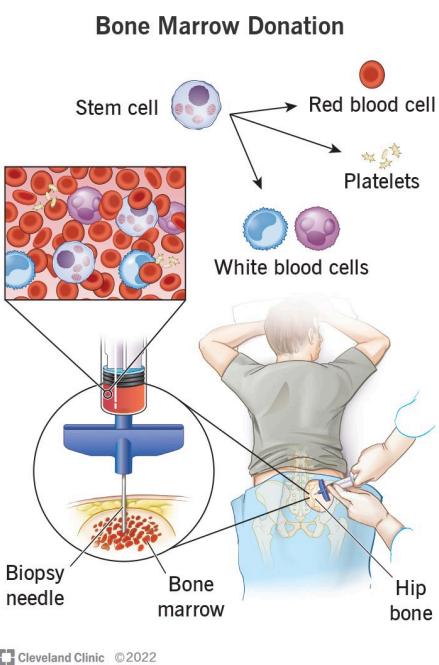
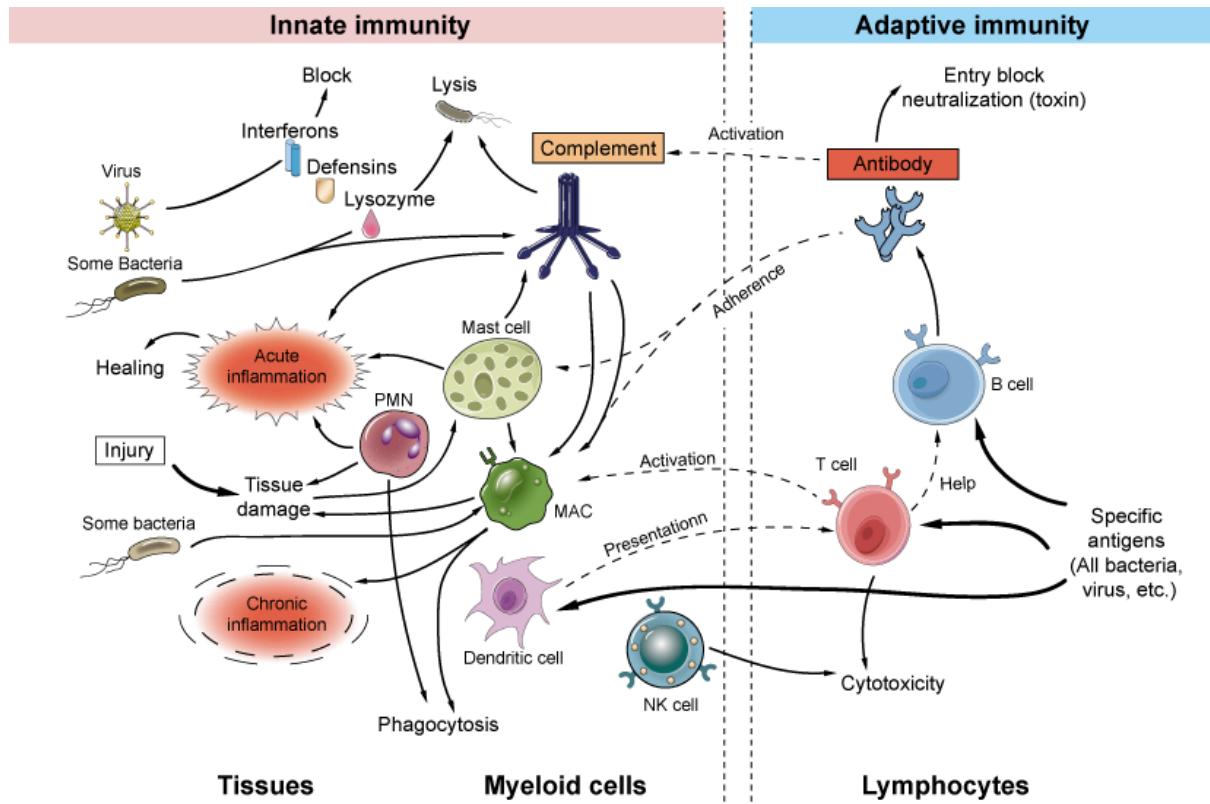
6. What Happens When the Immune System Goes Wrong?

- **Autoimmune Diseases:** The immune system mistakenly attacks the body (e.g., type 1 diabetes, rheumatoid arthritis).
- **Allergies:** The immune system overreacts to harmless things like pollen or peanuts.
- **Immune Deficiencies:**
 - Some people are born with weak immune systems (genetic immune diseases).
 - Diseases like **HIV** destroy immune cells, making people prone to infections.

7. How Do We Strengthen Our Immune System?

- Eat healthy foods (fruits, vegetables, and proteins).
- Get enough sleep.
- Exercise regularly.

- Wash hands to prevent infections.
- Get vaccines to help the immune system recognize dangerous germs.



Bone marrow donation, or bone marrow harvesting, is the procedure healthcare providers use to obtain blood-forming cells (stem cells) for bone marrow transplant. To do the procedure, healthcare providers use large hollow needles that pull bone marrow from donors' hips (pelvic bones). Donating bone marrow doesn't hurt and may cure someone who has blood cancer or a blood disorder.

How Does the Immune System Adapt to a Bone Marrow Transplant?

A **bone marrow transplant (BMT)** replaces damaged or diseased bone marrow with healthy stem cells from a donor. Since bone marrow produces blood cells, including immune cells, the

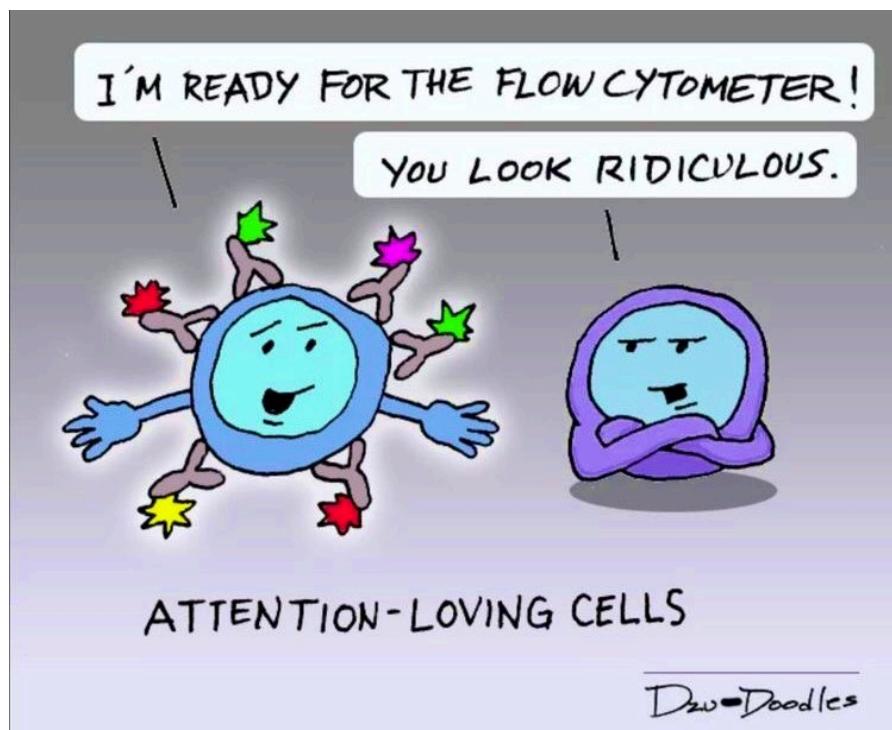
recipient's immune system must adapt to the new donor cells. This process involves several key steps:

- 1. Eliminating the Old Immune System** – Before the transplant, patients undergo chemotherapy and/or radiation to destroy their existing bone marrow, reducing the risk of the body rejecting the new stem cells.
- 2. Engraftment & Immune Rebuilding** – The donated stem cells settle in the recipient's bone marrow and begin producing new blood cells, including immune cells. This process, called *engraftment*, takes a few weeks.
- 3. Graft-versus-Host Disease (GVHD) Risk** – In cases of mismatched donor transplants, the donor's immune cells may attack the recipient's body, leading to **GVHD**. Doctors manage this with immunosuppressive drugs to help the immune system tolerate the new cells.
- 4. Long-Term Adaptation** – Over months to a year, the immune system rebuilds itself, recognizing the new cells as "self" while still fighting infections. Vaccinations may be needed to restore immunity lost during the transplant process.

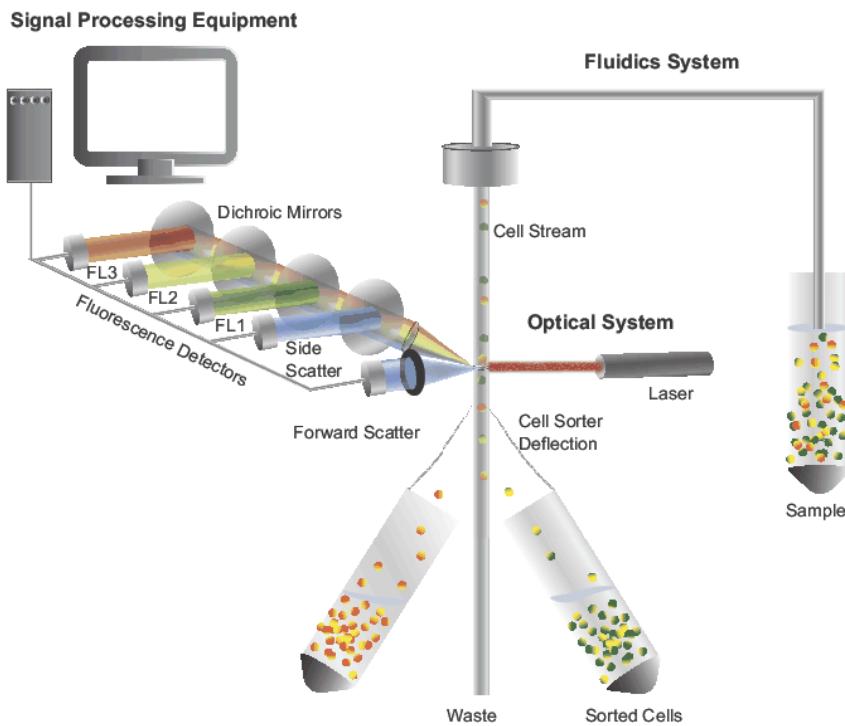
Leukemia is a cancer of the blood-forming tissues, including **bone marrow** and the lymphatic system, characterized by the abnormal and rapid production of white blood cells. These abnormal cells crowd out healthy blood cells, impairing the body's ability to fight infection, carry oxygen, and control bleeding.

How do we study Leukemia ?

FLOW CYTOMETER



<https://www.youtube.com/watch?v=gacNWEL4CzI>



Simplified Explanation of Flow Cytometry

Flow cytometry is a powerful technology that rapidly analyzes individual cells in a liquid sample using lasers and fluorescent markers. It measures how cells scatter light and detect fluorescence to classify different cell types. The data is recorded and analyzed by a computer. Scientists use flow cytometry in immunology, cancer research, virology, and infectious disease monitoring to study immune responses and sort cells for further research.

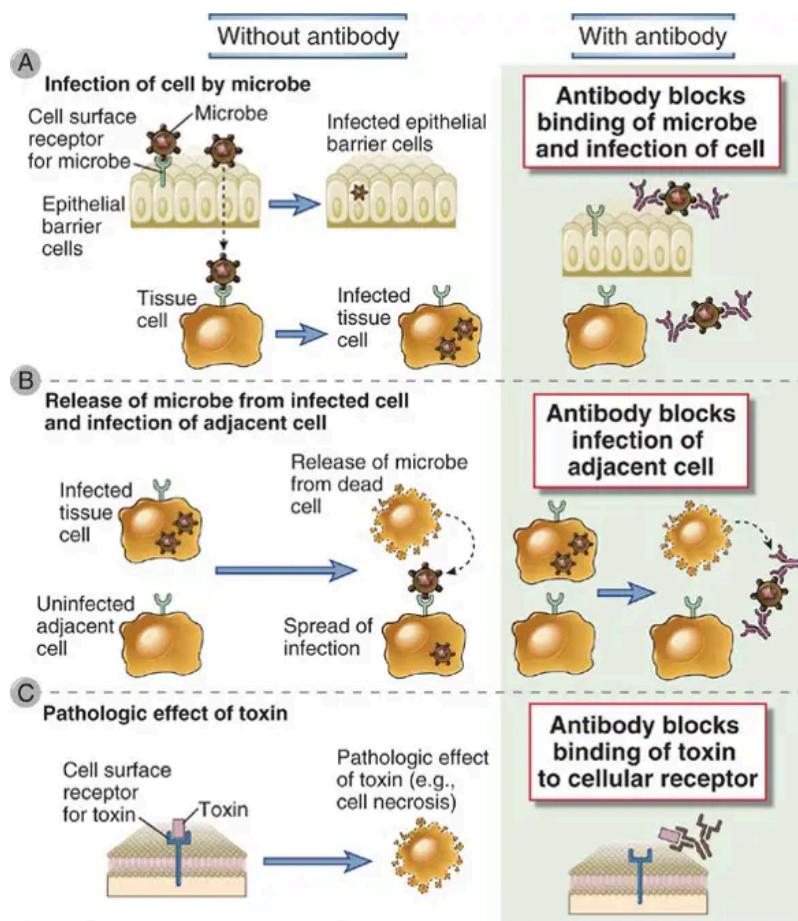
How It Works

1. Lasers & Light Detection – Cells pass through lasers, which scatter light to indicate size and complexity. Fluorescent markers help detect specific cell characteristics.
2. Fluorescent Reagents – These include antibody-based stains, DNA dyes, and viability markers, allowing scientists to label and analyze cells.
3. Data Collection & Analysis – The system captures signals and converts them into digital data, enabling researchers to study cell populations in detail.

Advancements & Applications

Modern flow cytometers use multiple lasers and advanced fluorescent dyes, allowing for 30+ parameters in a single experiment. Data analysis has also evolved, using advanced algorithms like PCA, SPADE, and tSNE to interpret complex information. Flow cytometry continues to revolutionize cell biology, disease diagnostics, and treatment development.

<https://www.youtube.com/watch?v=VhcZTGv0CU>



Abbas et al: Cellular and Molecular Immunology, 7e.
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How Antibodies Work

1. Neutralization of Germs and Toxins

Antibodies stop germs (bacteria, viruses, parasites, and fungi) from infecting body cells. They do this by:

- Blocking attachment – Antibodies stick to germs, preventing them from latching onto body cells.
- Clumping germs together – This makes it easier for the body to flush them out.

For example, certain antibodies stop HIV from binding to cells by blocking the virus's attachment protein.

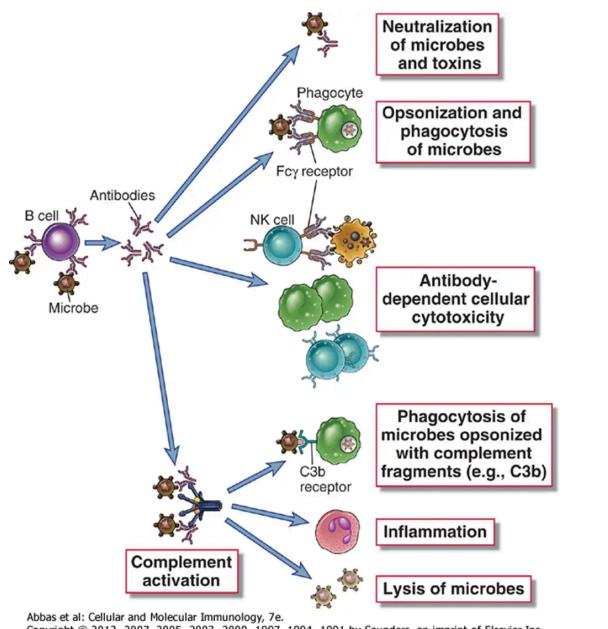
2. Phagocytosis (Eating Germs)

- Antibodies help immune cells "eat" germs in a process called opsonization.
- Special immune cells (macrophages and neutrophils) grab and swallow germs coated with antibodies.

- Inside these immune cells, germs are destroyed using enzymes and toxic chemicals.
-

3. Complement System: Breaking Germs Apart

- IgM and IgG antibodies can activate the complement system, a group of proteins that:
 - Punch holes in germs, killing them.
 - Mark germs for removal by other immune cells.
 - Transport germs to the liver or spleen, where they are safely removed.



4. Antibody-Dependent Cellular Cytotoxicity (ADCC)

- Antibodies act like bridges, connecting infected cells to killer immune cells (like NK cells).
 - NK cells then destroy the infected cells by breaking them open or making them self-destruct.
-

5. Special Antibody Functions: Protecting Mucosal Surfaces & Babies

- Some antibodies can move across body barriers to protect areas like the lungs and intestines. This is called transcytosis.
 - IgA is the main antibody in mucus, protecting against germs in the lungs, gut, and urinary tract.
 - IgG antibodies from the mother cross the placenta to protect the baby before birth.
-

Antibodies are multi-purpose protectors! They block germs, help immune cells destroy them, and even pass immunity from mothers to babies. They are an essential part of keeping us healthy! 

Immunopathology

Immunopathology is the study of diseases caused by problems in the immune system. These problems happen when:

1. The immune system overreacts (hypersensitivity).
 2. The immune system attacks the body by mistake (autoimmunity).
 3. The immune system fails to protect against infections (immunodeficiency).
-

1. Hypersensitivity (Overactive Immune Response)

Sometimes, the immune system reacts too strongly to harmless things, causing allergic reactions and tissue damage. There are four types of hypersensitivity reactions:

Type I – Immediate Allergic Reaction

- Happens within minutes (e.g., pollen allergies, food allergies).
- IgE antibodies attach to immune cells, which release chemicals like histamine.
- Can cause mild allergies or severe reactions like anaphylaxis, which requires epinephrine (EpiPen).

Role of IgE in Asthma

Immunoglobulin E (IgE) plays a central role in allergic asthma, a condition where the immune system overreacts to harmless substances (allergens) like pollen, dust mites, or pet dander.

How IgE Contributes to Asthma

1. **Sensitization to Allergens** – When an allergen enters the body, **B cells** produce IgE antibodies specific to that allergen.
2. **Binding to Mast Cells & Basophils** – IgE attaches to **mast cells** and **basophils**, priming them for future allergic reactions.
3. **Triggering an Asthma Attack** – On repeated exposure to the allergen, IgE signals mast cells to release **histamine**, **leukotrienes**, and **cytokines**, leading to:
 - **Airway inflammation**
 - **Bronchoconstriction (narrowing of airways)**
 - **Increased mucus production**
4. **Chronic Inflammation** – Continuous IgE activation contributes to **long-term airway remodeling**, making asthma symptoms persistent and severe.

Targeting IgE in Asthma Treatment

Monoclonal antibodies like **Omalizumab (anti-IgE therapy)** help block IgE function, reducing asthma severity and preventing attacks in patients with allergic asthma.

Type II – Antibody Attacks Own Cells

- Happens when IgG and IgM antibodies attack the body's own cells.
- Leads to red blood cell destruction and diseases like autoimmune anemia.

Type III – Immune Complex Disease

- Happens when antibody-antigen clumps (immune complexes) get stuck in tissues, causing inflammation.
- Examples: Lupus and serum sickness.

Type IV – Delayed Immune Response

- Takes 2 or more days to develop.
 - T cells overreact, leading to tissue damage.
 - Example: Poison ivy rash.
-

2. Autoimmunity (Immune System Attacks the Body)

- Normally, the immune system ignores the body's own cells.
- In autoimmune diseases, the immune system mistakenly attacks the body's own tissues.
- Examples:
 - Type 1 Diabetes – Attacks insulin-producing cells.
 - Graves' Disease – Attacks the thyroid gland.
 - Celiac Disease – Attacks the intestines.

3. Inflammation (Body's Defense or Overreaction?)

- Inflammation is helpful when fighting infections (causes redness, swelling, pain).
- But chronic inflammation can damage the body and cause diseases like:
 - Asthma (inflammation in the lungs).
 - Rheumatoid arthritis (inflammation in joints).
 - Psoriasis (skin inflammation).

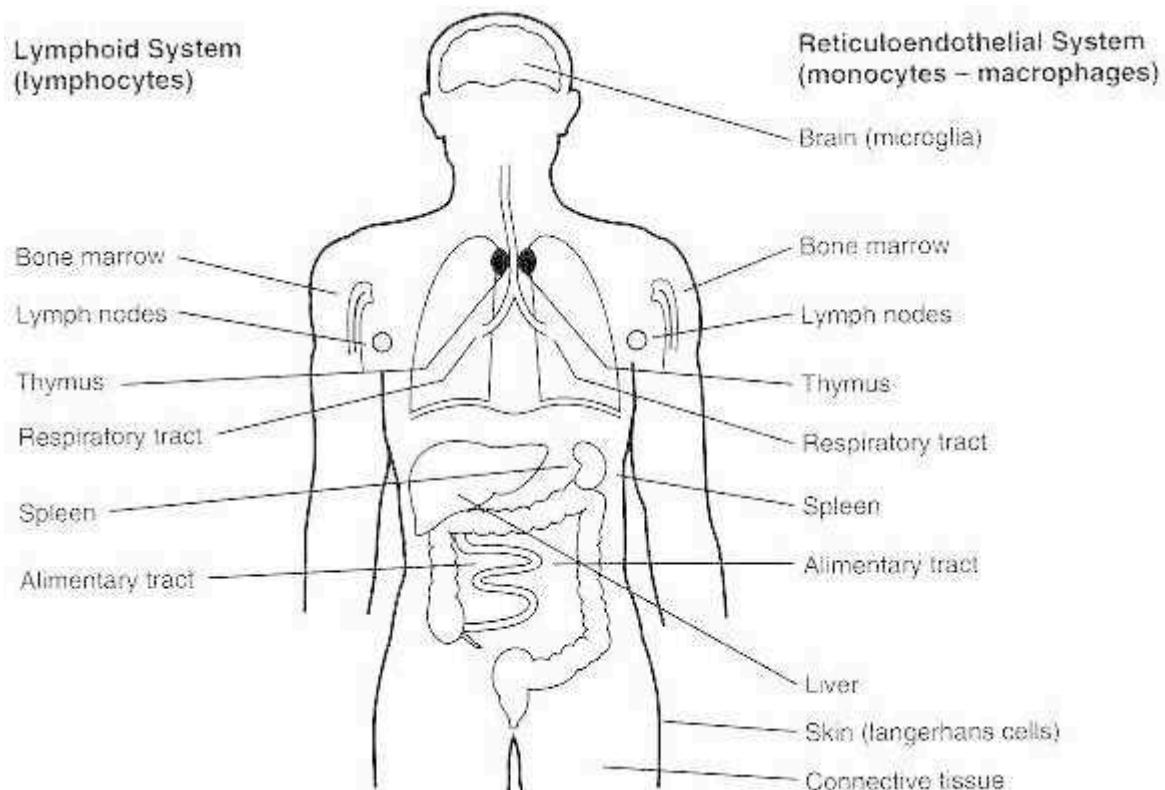
4. Immunodeficiency (Weak or Missing Immune System)

- Primary Immunodeficiency – Genetic disorders where the immune system doesn't work properly (e.g., SCID).

- Secondary Immunodeficiency – Caused by infections (like HIV/AIDS), malnutrition, or medications that weaken the immune system.
 - HIV/AIDS – Destroys helper T cells, making the body unable to fight infections.
-

Final Thought

A balanced immune system is key to good health. If it overreacts, it causes allergies or autoimmune diseases. If it fails, infections take over. Understanding immunopathology helps in treating these conditions effectively! 🦠💪

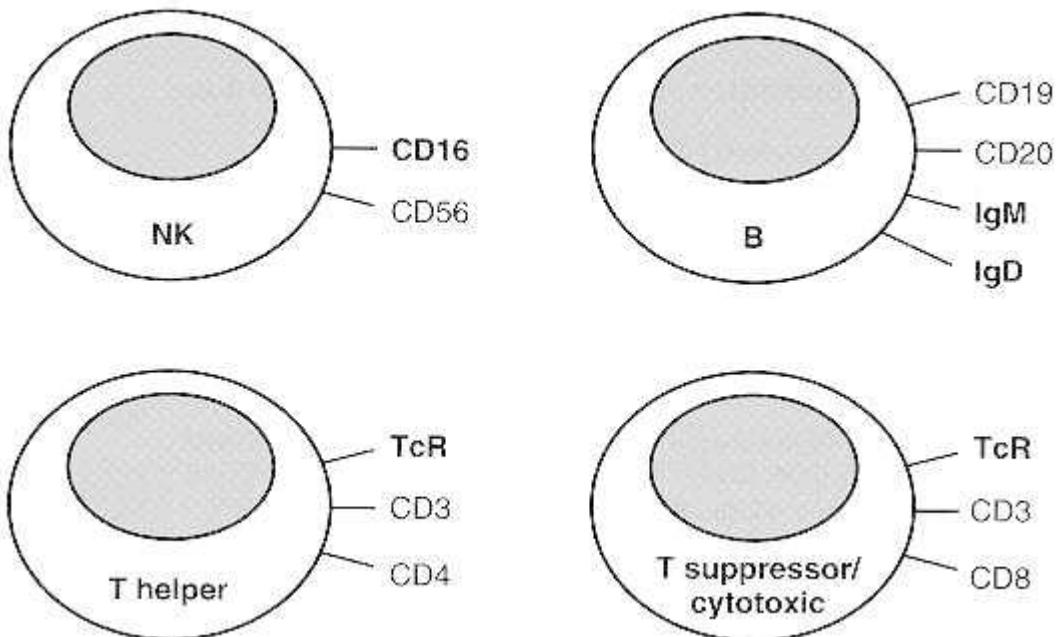


Key Immune Cells

- **Leukocytes (White Blood Cells)** are the main cells in the immune system. They provide either innate (born-with) or adaptive (learned) immunity. There are two main types:
 - **Myeloid cells:** These include neutrophils (for killing pathogens), eosinophils (for defending against parasites), basophils, and monocytes/macrophages (for eating and killing invaders).
 - **Lymphoid cells:** These include T cells (for cell-mediated immunity), B cells (for antibody production), and natural killer (NK) cells (for killing virus-infected or tumor cells).

T and B Lymphocytes

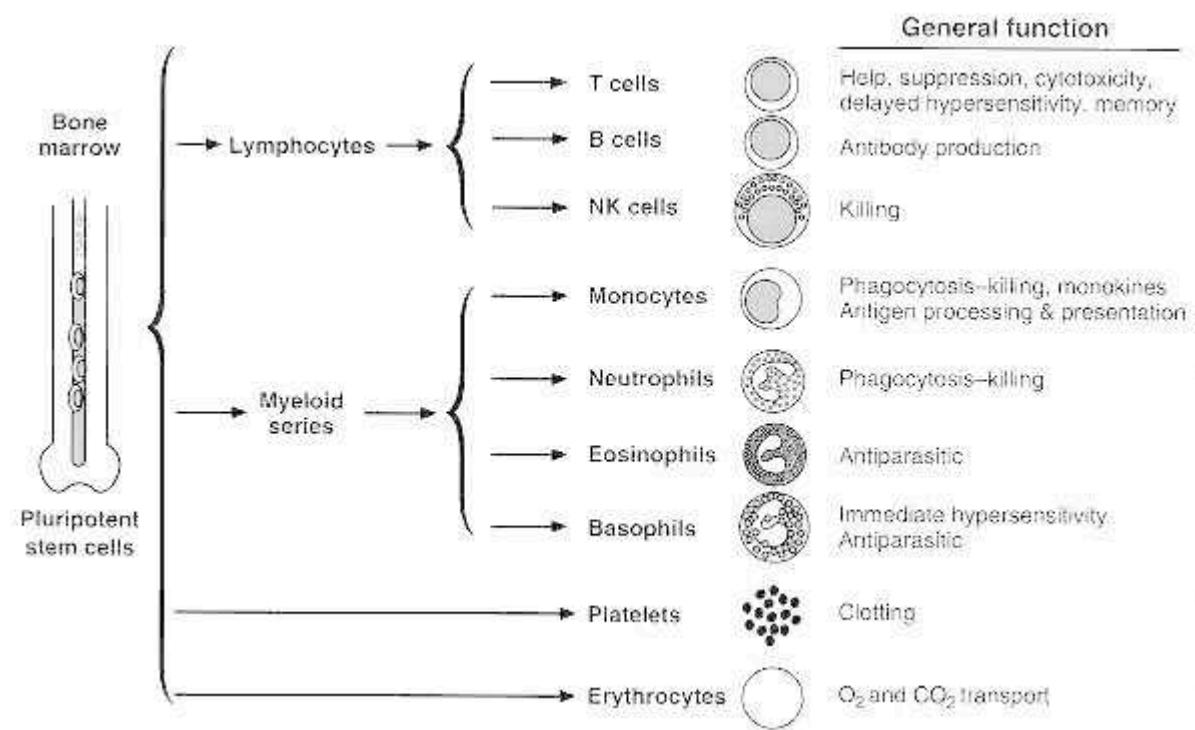
- **T Cells:** Regulate immune responses and kill infected cells. They can be further divided into helper T cells (Th cells) and cytotoxic T cells (Tc cells).
- **B Cells:** Produce antibodies to neutralize pathogens. When activated, they become plasma cells that secrete antibodies.



Molecules that serve as receptors are shown in bold type.

Immunoglobulins (Antibodies)

Antibodies are proteins that bind to antigens (foreign molecules) to neutralize them. There are five main types (IgG, IgA, IgM, IgD, and IgE), each with a different function in immune defense.



Major Histocompatibility Complex (MHC)

MHC molecules help T cells recognize infected cells. There are two types:

- **MHC class I** molecules present antigens from inside the cell (e.g., from viruses).
- **MHC class II** molecules present antigens from outside the cell (e.g., from bacteria).

T Cell Activation

For T cells to work, they need to recognize an antigen presented by MHC molecules. This process is supported by other proteins on the surface of antigen-presenting cells and T cells.

TABLE 1-1 Major Features and Functions of Mononuclear Leukocytes

	T Cells	B Cells	NK Cells	Monocytes/ Macrophages
Antigen recognition	+	+	-	-
Antigen presentation	-	+	-	+
Antibody production	-	+	-	-
Cellular immunity	+	-	-	+
Immune regulation	+	+	+	+
Phagocytosis	-	-	-	+
Cytotoxicity	+	-	+	+
Receptors	TcR	IgM & IgD	CD16 (Fc _y R)	CD11b (Mac-1)
Other surface markers	CD3, CD4, CD8	CD19-21	CD56	CD14
Mononuclear cells in blood (%)	~75%	~10%	10%	5% (monocytes)

Maternal Immune Contributions

Mothers transfer important immune factors to their infants through the placenta and breast milk, helping to protect infants until their own immune systems fully develop.

Evolution of the Immune System

The human immune system has evolved from basic defense mechanisms found in ancient animals. These innate defenses include physical barriers, chemical agents like acids and bases, and cells that can actively seek and destroy harmful microorganisms. Over time, the immune system has become more specialized, regulated, and complex. It has developed proteins like antibodies, cell receptors, and cytokines that help control and fine-tune immune responses. One key evolution is the ability to distinguish between the body's own cells and foreign invaders, as well as remember past encounters with pathogens.

Simplified Overview of Immune System Cells

Myeloid Cells

- **Neutrophils:** These are the first cells to respond to infection, moving to the site of infection to ingest and kill pathogens. They are produced in the bone marrow and are the most abundant type of white blood cell in circulation. They act quickly but only stay in the blood for a few hours before being removed or moving to the infection site.
- **Adherence and Chemoattraction:** Neutrophils stick to blood vessel walls using certain proteins, and they are guided to infection sites by chemical signals released by pathogens or the body. These signals help neutrophils move and get activated.
- **Opsonization:** Foreign particles are coated with molecules that help neutrophils recognize and ingest them. This process involves antibodies and proteins from the complement system, aiding neutrophils in capturing and killing invaders.
- **Microbicidal Mechanisms:** Neutrophils produce chemicals that kill pathogens inside the cell. They use oxygen to create reactive molecules that can destroy microbes.
- **Eosinophils:** These cells kill parasites and play a role in allergic reactions. They contain proteins that help break down parasites.
- **Basophils:** These cells help defend against parasites and participate in allergic inflammation by releasing chemicals like histamine when triggered by allergens.
- **Monocytes and Macrophages:** Macrophages are large cells that act similarly to neutrophils but are more long-lasting. They help fight infections by ingesting pathogens and presenting antigens to other immune cells to start an immune

response.

Neutrophils produced from myeloid precursors

↓ GM-CSF, G-CSF

Mature neutrophils released into blood

↓ L-selectin on neutrophils

Neutrophils adhere to vascular endothelium

↓ L-selectin on neutrophils

Neutrophils migrate between endothelial cells

↓ CD18/CD11b on neutrophils

Neutrophil chemotaxis

↓ C5a, TNF- α , IL-8 and leukotrienes

Neutrophils phagocytize microorganisms

↓ C3b, C3bi, IgG antibodies

Neutrophils kill microorganisms

↓ Respiratory burst, toxic O radicals

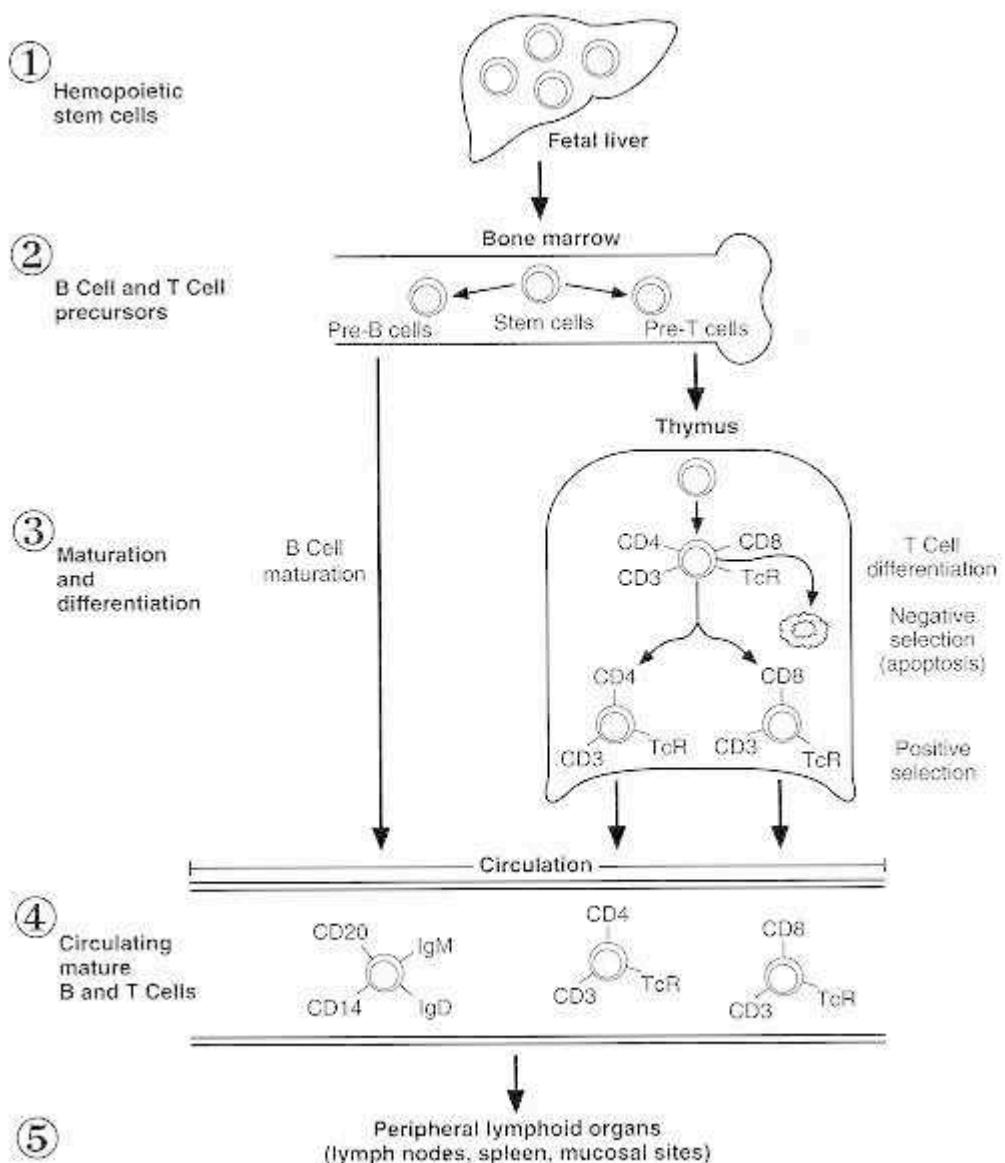
Neutrophils degrade microorganisms

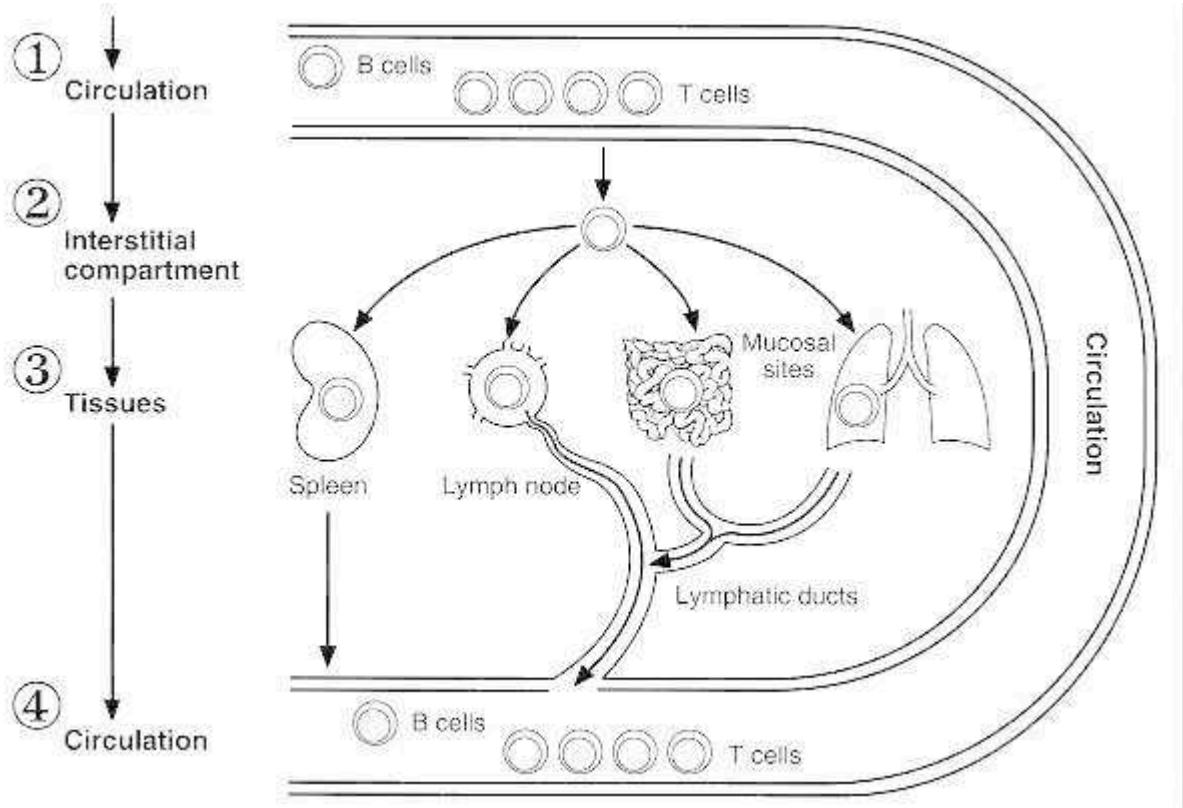
Lymphoid Cells

Lymphoid cells are essential for specific immunity. They include T cells, B cells, and natural killer (NK) cells, each with unique roles.

- **T Lymphocytes:** T cells are involved in the immune response to protein-based antigens. They originate in the bone marrow, mature in the thymus, and are responsible for immunologic memory. T cells are divided into helper (Th) cells, cytotoxic (CTL) cells, and suppressor cells.
 - **Maturation:** T cells mature in the thymus and either become CD4+ (helper) or CD8+ (cytotoxic) cells. They recognize antigens presented by MHC molecules.
 - **Th1 and Th2 Subsets:** Th1 cells support cell-mediated immunity, while Th2 cells help in antibody production by activating B cells.
 - **Cytotoxic T Cells:** These cells kill infected or tumor cells. They are MHC class I-restricted and recognize viral peptides on infected cells.

- **Suppressor T Cells:** These cells prevent excessive immune responses, maintaining self-tolerance.
- **Delayed Hypersensitivity:** Th1 cells activate macrophages to fight infections, contributing to delayed immune reactions.
- **B Lymphocytes:** B cells are responsible for producing antibodies. They mature in the bone marrow and, upon encountering an antigen, differentiate into plasma cells that secrete antibodies.
 - **Isotype Switching:** B cells change the type of antibodies they produce (e.g., from IgM to IgG) to better fight specific pathogens, with help from Th2 cells.

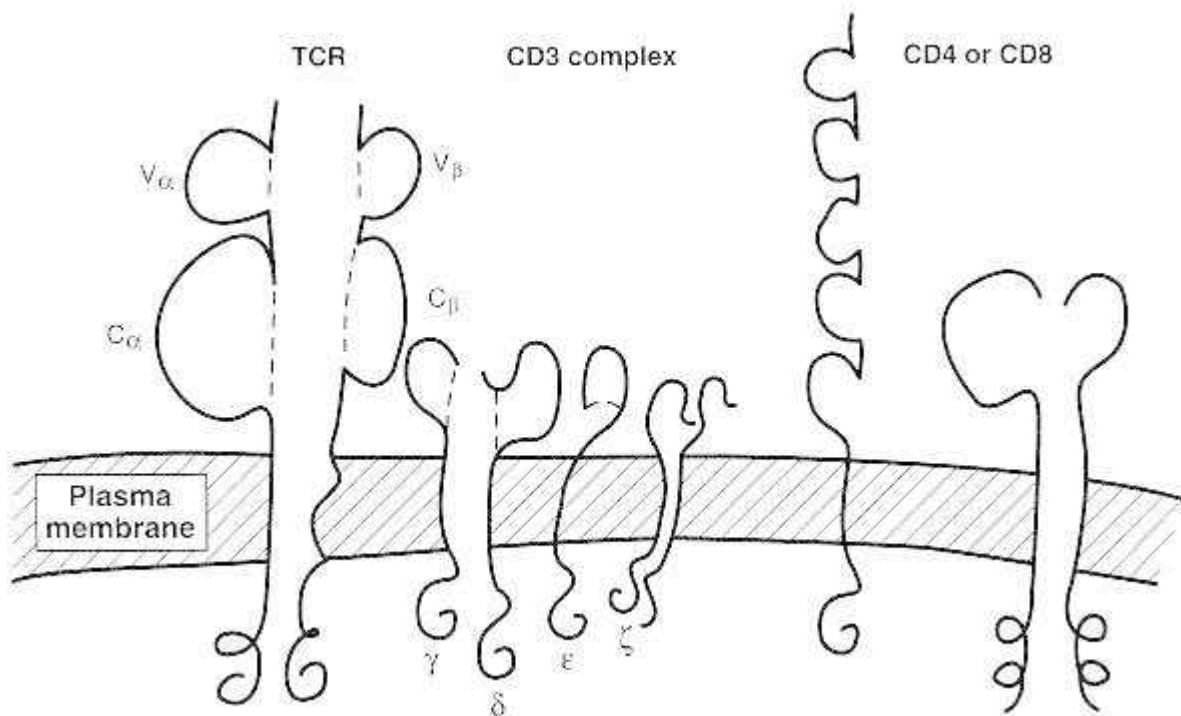




Lymphocyte circulation pathways. T cells are principally recirculating; B cells are principally sequestered in peripheral lymphoid organs.

Natural Killer (NK) Cells: NK cells provide early defense by killing infected cells or tumors. Unlike T cells, they do not require prior exposure to the pathogen and are not restricted by MHC molecules.

This simplified explanation highlights the key functions of the immune system cells involved in detecting and responding to pathogens, along with their roles in immunity and inflammation.



The TcR-CD3 complex on helper (CD4+) or cytotoxic/suppressor (CD8+) T cells. The TcR receives peptide fragments from antigen presenting cells. CD3 is a signaling molecule.

Role of MHC in T Cell Development

MHC (Major Histocompatibility Complex) molecules play a crucial role in the development of T cells by presenting antigens to them. T cells are produced in the bone marrow and migrate to the thymus for further maturation. While in the thymus, T cells are exposed to various proteins, especially those derived from MHC molecules. During this process, T cells are "educated" to distinguish between self and foreign antigens.

1. Negative and Positive Selection:

- **Negative Selection:** T cells that bind strongly to self-antigens (self-MHC molecules) are eliminated. This prevents the immune system from attacking the body's own tissues.
- **Positive Selection:** T cells that can recognize foreign antigens presented by self-MHC molecules are selected to survive and mature. This ensures that the immune system can respond to pathogens effectively while avoiding self-reactivity.

2. MHC Restriction:

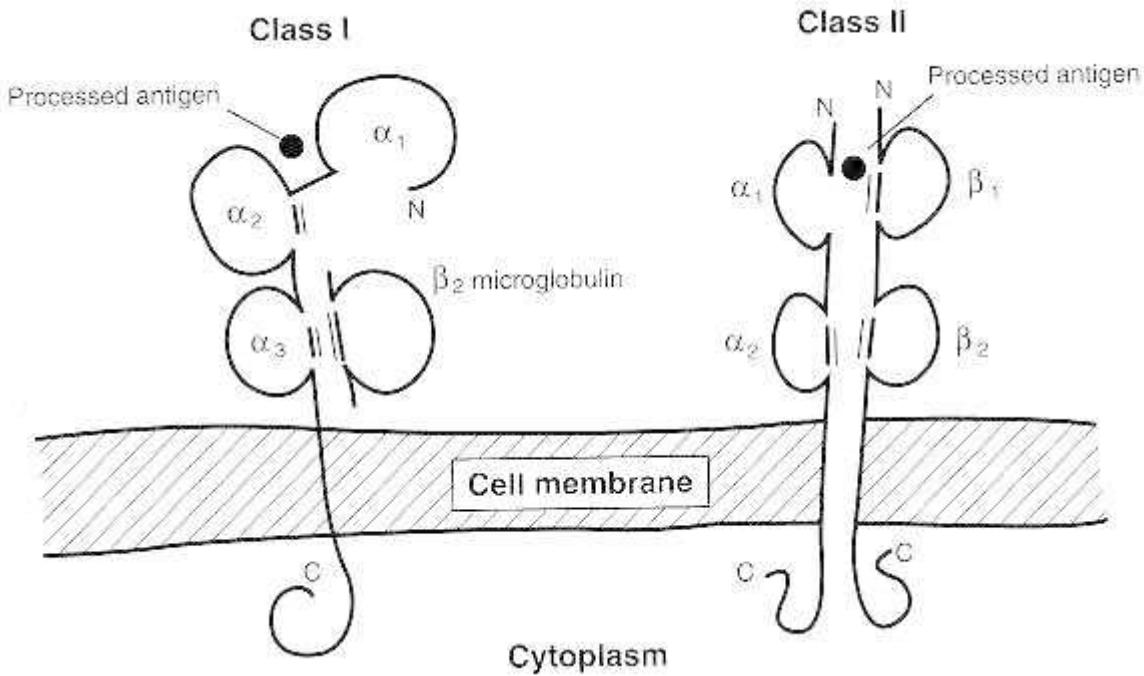
T cells are considered "MHC-restricted" because they recognize antigens only if those antigens are presented by the correct MHC molecule. This means a T cell will respond to a foreign antigen only if it is bound to the appropriate MHC molecule on the surface of another cell.

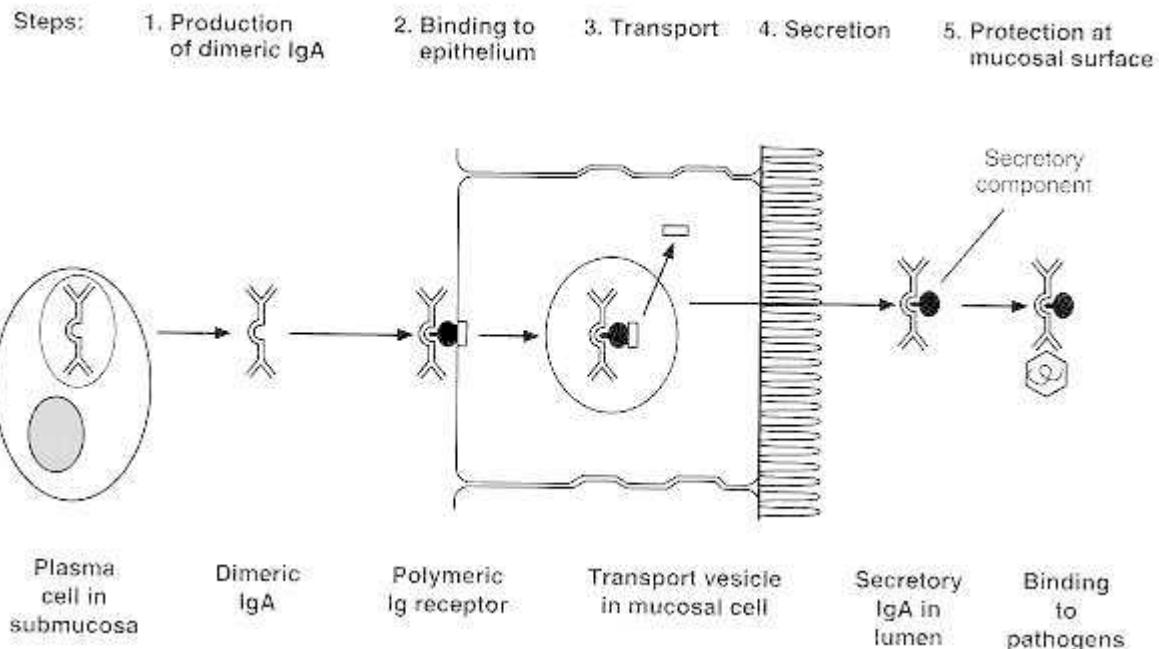
3. MHC Class I and Class II Molecules:

- **MHC Class I molecules** present antigens to CD8+ T cells (cytotoxic T cells). These T cells recognize antigens from inside the cell, such as viral infections, and respond by killing infected cells.
- **MHC Class II molecules** present antigens to CD4+ T cells (helper T cells). These T cells are involved in regulating other immune cells, like B cells and cytotoxic T cells, and are essential for coordinating the immune response.

Through this selection process, T cells exit the thymus either as **CD4+** or **CD8+** cells, which are then capable of responding to antigen presentation by MHC Class II or MHC Class I molecules, respectively. Both CD4+ and CD8+ T cells express the **T cell receptor (TcR)** and **CD3** molecules, which help in antigen recognition and signaling during immune responses.

In summary, MHC molecules are key in educating T cells to distinguish between self and non-self antigens, ensuring the immune system can respond to threats while maintaining self-tolerance.





Simplified Explanation of Genomics & Bioinformatics in Infectious Disease Research

1. How Genomics & Bioinformatics Help Understand Infectious Diseases

Genomics (the study of genes) and bioinformatics (using computers to analyze biological data) are **helping scientists study diseases** caused by bacteria (e.g., *Mycobacterium tuberculosis*) and parasites (e.g., *Plasmodium falciparum*, which causes malaria).

These tools help in:

- **Tracking disease outbreaks** and how infections spread.
- **Understanding how bacteria and viruses evolve** and resist treatments.
- **Finding new ways to diagnose diseases** quickly.
- **Developing better vaccines and medicines.**

By combining **genetic data from pathogens, animal models, and patient health records**, doctors can improve treatments and predict drug interactions.

2. Genomics & Bioinformatics in Africa

- **Africa has the highest number of infectious disease cases but the lowest research output** in genomics.
- Diseases like **tuberculosis (TB), dengue fever, malaria, and filariasis** need more research to develop better treatments.
- More **training and funding** are needed to improve disease research in Africa.

3. Applications of Genomics & Bioinformatics in Disease Research

- **Tuberculosis (TB):**
 - Scientists use **genetic analysis** to track how *M. tuberculosis* spreads and develops resistance to antibiotics.
 - Studies show that specific **genetic mutations** make TB bacteria resistant to drugs like rifampicin and isoniazid.
 - New genomics-based tools (like TB-Profiler) help detect **drug-resistant TB faster**.
 - **Dengue Virus (DENV):**
 - Dengue virus spreads through **mosquito bites** and affects over **350 million people yearly**.
 - Bioinformatics helps study **how dengue evolves**, spreads, and how to develop **better vaccines**.
 - Scientists also use **phylogenetic analysis** (studying the virus's genetic family tree) to track dengue's origins.
 - **Malaria & Parasitic Diseases:**
 - *Plasmodium falciparum* causes malaria, especially in **young children and pregnant women in Africa**.
 - Genetic studies help understand **how malaria parasites resist drugs** and **how the immune system fights them**.
 - Bioinformatics is used to identify **new drug and vaccine targets**.
-

4. Using Genomics to Detect Drug Resistance

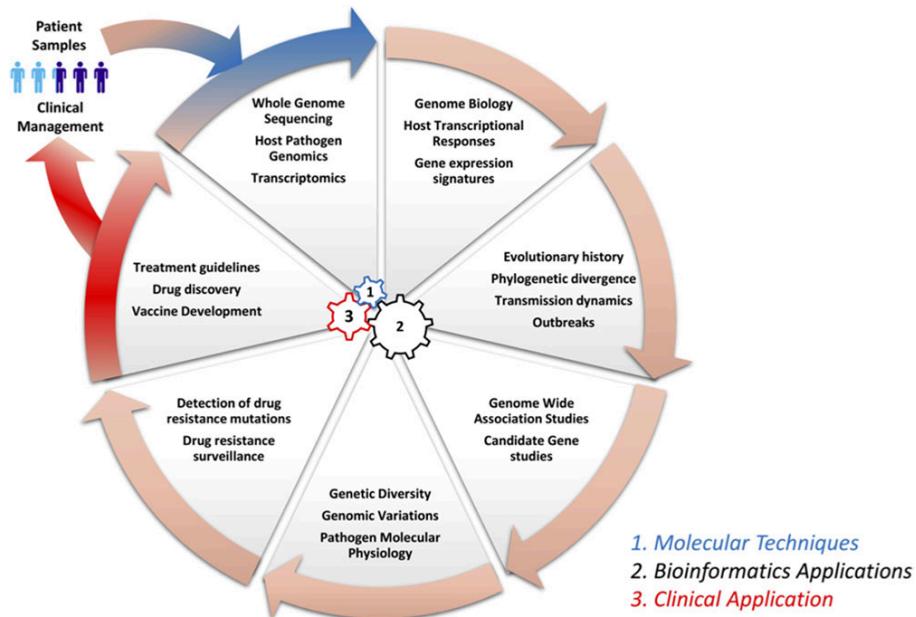
- Scientists study **bacterial and viral genomes** to find mutations that cause **drug resistance**.
 - Whole Genome Sequencing (WGS) helps detect **new resistant strains** of TB, malaria, and dengue.
 - New bioinformatics tools (e.g., Mykrobe Predictor, TB-Profiler) can predict **drug resistance within minutes**.
-

5. The Future of Bioinformatics in Disease Research

- **Personalized treatments** – Using genetic data to tailor treatments for each patient.
 - **Faster and more accurate diagnostics** – Using genetic markers to detect diseases early.
 - **Better vaccine development** – Studying genetic variations to make vaccines more effective.
 - **Tracking and controlling outbreaks** – Using bioinformatics to predict and stop disease spread.
-

Final Thought

Genomics and bioinformatics are **transforming disease research**, helping doctors and scientists fight deadly infections. **More investment in research, training, and technology** can improve **how we track, diagnose, and treat infectious diseases worldwide!** 



<https://www.malariagen.net/resource/34/>

Simplified Explanation of the Pf7 Malaria Dataset

The **Pf7 dataset** is a large-scale collection of **genetic data from over 20,000 samples of *Plasmodium falciparum***, the parasite that causes malaria. It was developed by the **MalariaGEN network** to help scientists study malaria genetics, drug resistance, and parasite evolution. This dataset is nearly **three times larger** than its previous version (Pf6, 2021) and includes data from **33 countries**.

Scientists use **whole genome sequencing (WGS)** and **genetic variation analysis** to:

- Track how the malaria parasite evolves and spreads.
- Identify **drug resistance mutations** to improve treatment strategies.
- Study **genetic differences** in the parasite across different regions.

Older Data Tools:

- **Pf3k Exploration Tool** – Contains **2,512 samples from 14 countries** (now outdated).
- **P. vivax Data Tool** – Contains **228 samples from 13 countries** (still useful).
- **Pf Community Project Tool** – Includes **3,488 samples from 23 countries** (now outdated).
- **P. falciparum Genetic Crosses Tool** – Analyzes **98 samples from genetic studies** (still relevant).

The dataset includes information on **82 contributing studies**, sample collection details, and **genetic markers linked to resistance against 10 malaria drugs**. All data are available for **open-access research**, and tools like the Pf7 app and Python-based resources help researchers analyze the data without downloading it. This dataset is a key resource for **malaria control, drug development, and vaccine research** worldwide. 

Key Bioinformatics Tools & Databases

- **Microbiome Analysis:** Tools like **Greengenes, SILVA, and Human Oral Microbiome Database (HOMD)** help identify bacteria in the body.
- **Pathogen Detection:** Tools like **MG-RAST, PathSeq, and ezVIR** analyze sequencing data to find known and unknown viruses, bacteria, and fungi in patient samples.
- **Drug Resistance Studies:** Databases like **CARD, ARDB, and ResFinder** help identify genes that make bacteria resistant to antibiotics.
- **Pathogenicity & Virulence:** Tools like **PathogenFinder and PATRIC** help predict whether a newly discovered bacterium is harmful.