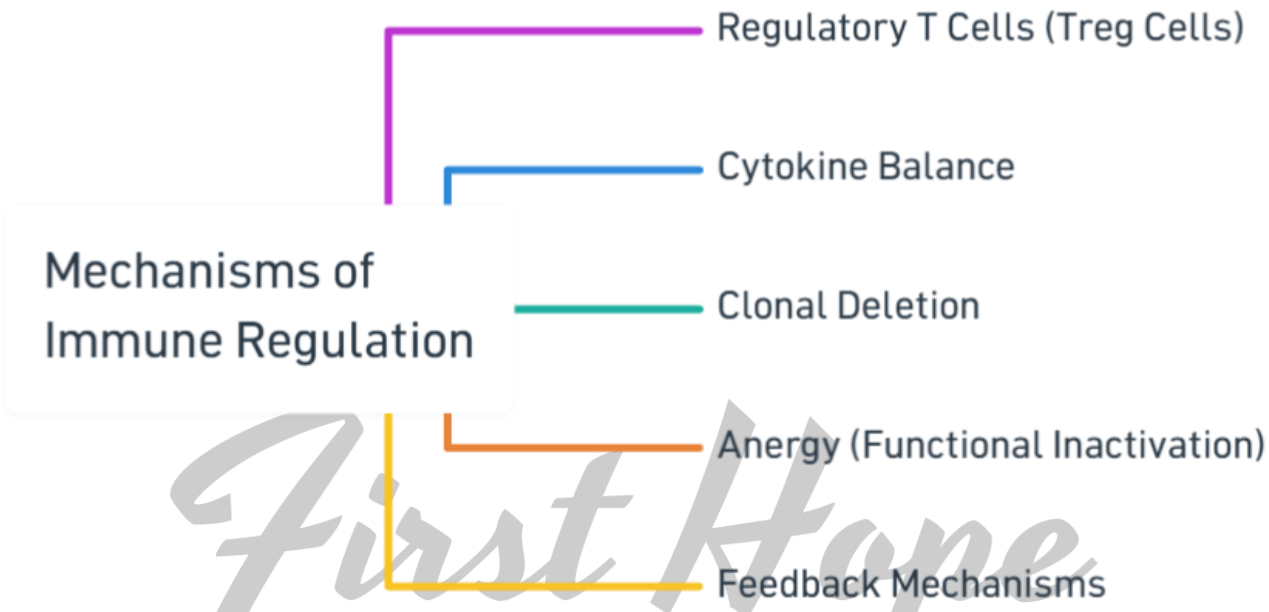
# Immune Regulation and Tolerance

## Immune Regulation (Overview)

- Immune regulation refers to the mechanisms that **control and balance the immune response**.
- It ensures that the immune system responds effectively to pathogens but does not damage the body's own tissues.

### Mechanisms of Immune Regulation




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#### A. Regulatory T Cells (Treg Cells)

- Specialized T cells that suppress immune responses.
- Maintain **self-tolerance** and prevent autoimmune diseases.
- Secrete inhibitory cytokines like **IL-10** and **TGF-β**.

#### B. Cytokine Balance

- Cytokines can either stimulate or suppress immune responses.
- Proper balance is necessary to avoid excessive inflammation.

#### C. Clonal Deletion

- Self-reactive lymphocytes are destroyed during development (in thymus and bone marrow).

#### D. Anergy (Functional Inactivation)

- Lymphocytes become inactive when antigen is recognized without proper co-stimulation.

#### E. Feedback Mechanisms

- Activated immune cells can produce signals that limit further activation.

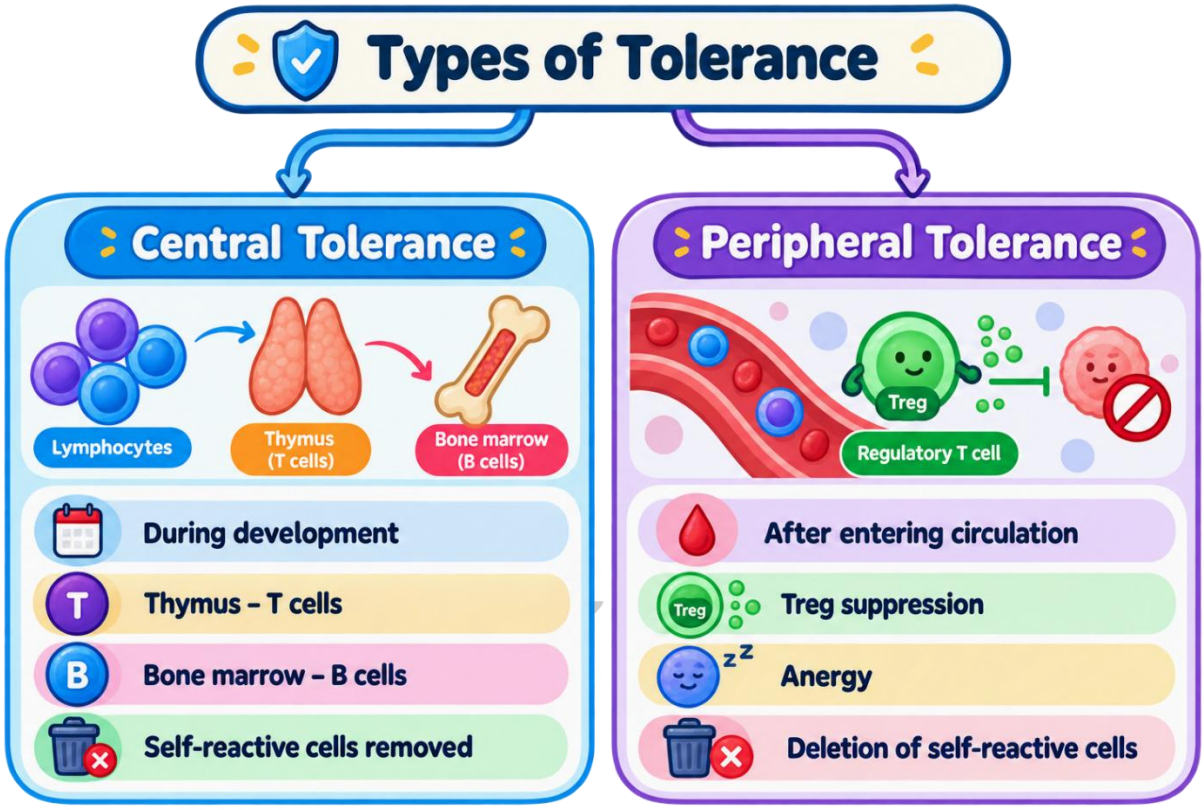
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# Immunological Tolerance

## Definition

- The ability of the immune system to **not respond to self-antigens**.
- Prevents autoimmune diseases.

## Types of Tolerance




### 1. Central Tolerance

- **Occurs during development of lymphocytes in:**
  - Thymus (T cells)
  - Bone marrow (B cells)
- Self-reactive cells are eliminated.

### 2. Peripheral Tolerance

- Occurs after lymphocytes enter circulation.
- **Mechanisms:**
  - Suppression by Treg cells
  - Anergy
  - Deletion of self-reactive cells

## Breakdown of Tolerance

- Failure of tolerance leads to **autoimmune diseases**.

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- Example: rheumatoid arthritis, type 1 diabetes.

## Importance of Tolerance

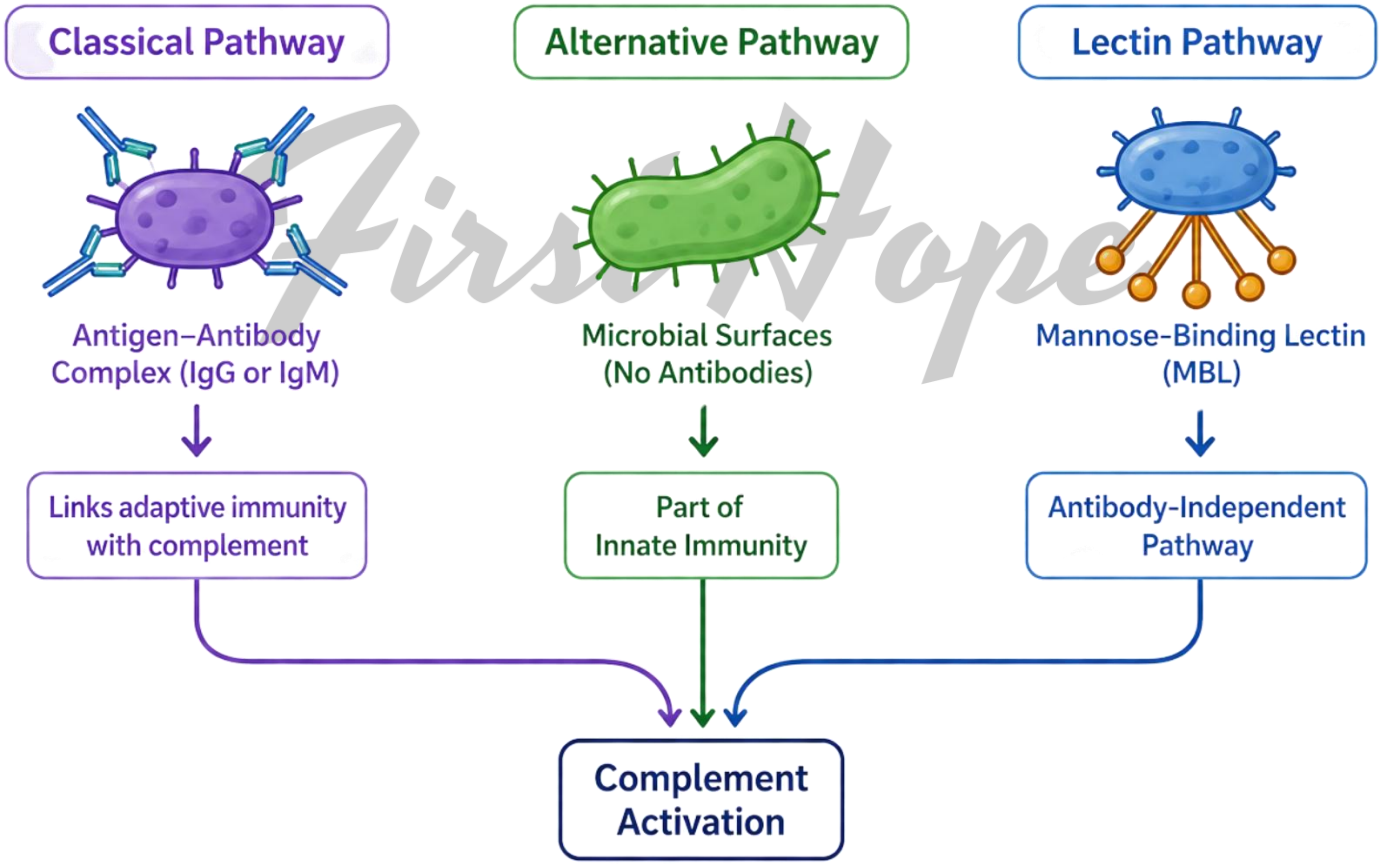
- Prevents autoimmune diseases
- Maintains immune system balance
- Ensures proper immune functioning

# Complement System

## Definition

- A group of **plasma proteins** that enhance (complement) immune responses.
- Part of **innate immunity** but also supports adaptive immunity.

## Types (Pathways) of Complement Activation




### 1. Classical Pathway

- Triggered by antigen-antibody complexes (IgG or IgM).
- Links adaptive immunity with complement system.

### 2. Alternative Pathway

- Activated directly by microbial surfaces.
- Does not require antibodies.

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- Part of innate immunity.

### 3. Lectin Pathway

- Initiated by binding of **mannose-binding lectin (MBL)** to pathogens.
- Antibody-independent pathway.

## Common Outcome of All Pathways

- Formation of Membrane Attack Complex (MAC).
- Leads to lysis (destruction) of pathogens.

## Biological Functions of Complement System

### A. Opsonization

- C3b coats pathogens, making them easier to phagocytose.

### B. Cell Lysis

- Formation of **Membrane Attack Complex (MAC)** destroys pathogens.

### C. Inflammation

- C3a and C5a act as inflammatory mediators.
- Attract immune cells (chemotaxis).

### D. Immune Complex Clearance

- Helps remove antigen-antibody complexes from circulation.

### E. Chemotaxis

- Attracts phagocytes to site of infection.

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# Cytokines

## Definition

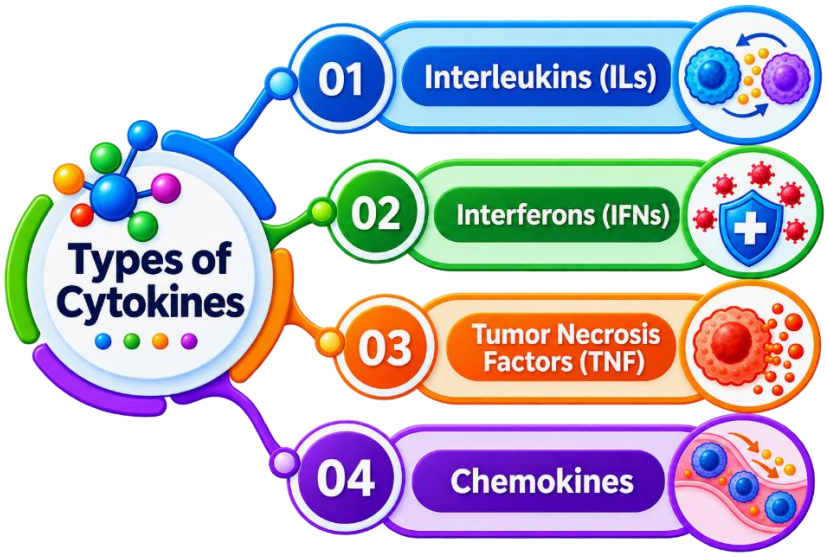
- Cytokines are small **signaling proteins** released by immune cells.
- They regulate the intensity and duration of immune responses.

## Characteristics of Cytokines

- Act in very small amounts
- Bind to specific receptors
- Can have multiple effects (pleiotropy)
- Act on nearby or distant cells

## Types of Cytokines

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1. **Interleukins (ILs)**
   - Communication between leukocytes.
   - Example: IL-2 stimulates T cell growth.
2. **Interferons (IFNs)**
   - Protect against viral infections.
   - Example: IFN-α, IFN-β inhibit viral replication.
3. **Tumor Necrosis Factors (TNF)**
   - Involved in inflammation and cell death.
   - Example: TNF-α.
4. **Chemokines**
   - Induce movement of immune cells towards infection site.

## Role of Cytokines in Immune Response

### A. Cell Activation and Proliferation

- Stimulate growth and differentiation of immune cells.

### B. Regulation of Immune Response

- Can enhance or suppress immune activity.

### C. Inflammation

- Promote inflammatory responses.

### D. Antiviral Defense

- Interferons inhibit viral replication.

### E. Cell Communication

- Coordinate interaction between different immune cells.

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