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PHARMACEUTICAL BIOTECHNOLOGY

UNIT 3

TOPIC :

- Types of immunity- humoral immunity, cellular immunity

  a) Structure of Immunoglobulins

Immunity

- Immunity is the ability of the body to recognize, resist, and destroy harmful substances such as bacteria, viruses, toxins, and parasites.
- These harmful substances are called antigens.
- The body protects itself through the immune system.
- The branch of science that deals with the study of the immune system is called Immunology.

Organs of Immune System

- Bone marrow
- Thymus
- Spleen
- Lymph nodes

Cells of Immune System

- Monocytes
- Macrophages
- Mast cells
- Dendritic cells
- Natural Killer (NK) cells
- Neutrophils
- Eosinophils
- Basophils
- T-lymphocytes
- B-lymphocytes

Types of Immunity

1. Innate Immunity
2. Acquired (Adaptive) Immunity

1. Innate Immunity

- Innate immunity is the natural defense system present from birth that provides immediate protection against pathogens.

Characteristics

- Present from birth
- Acts immediately
- Non-specific
- No immunological memory
- First line of defense

Components of Innate Immunity

1. Physical Barriers

These prevent the entry of pathogens into the body.

- **Skin** – Tough protective barrier
- **Mucus** – Traps microbes
- **Cilia** – Remove microbes from respiratory tract
- **Tears and Saliva** – Contain lysozyme enzyme
- **Stomach Acid (HCl)** – Kills pathogens

2. Chemical Barriers

Chemical substances that destroy pathogens.

- **Lysozyme** – Breaks bacterial cell wall
- **Acidic pH** – Present in skin and stomach
- **Interferons** – Prevent viral infection
- **Complement Proteins** – Destroy microbes

3. Cellular Components

Cell	Main Function
Neutrophils	First cells to arrive, perform phagocytosis
Macrophages	Engulf pathogens and initiate inflammation
Dendritic Cells	Present antigens to T-cells
NK Cells	Kill virus-infected and tumor cells
Mast Cells	Release histamine during inflammation
Basophils	Involved in allergic reactions
Eosinophils	Destroy parasites

Mechanism of Innate Immunity

Step 1: Pathogen Entry

Pathogens enter the body through skin or mucosal surfaces.

Step 2: Recognition

Pattern Recognition Receptors (PRRs) identify Pathogen-Associated Molecular Patterns (PAMPs).

Step 3: Early Cellular Response

- Neutrophils → Phagocytosis
- Macrophages → Release cytokines
- Mast cells → Release histamine

Step 4: Inflammation

Produces:

- Redness (Rubor), Heat (Calor), Swelling (Tumor)
- Pain (Dolor)

Step 5: Recruitment of Immune Cells

- NK cells destroy infected cells
- Eosinophils attack parasites
- Basophils participate in allergy

Step 6: Antigen Capture

Dendritic cells capture antigens.

Step 7: Migration

Dendritic cells migrate to lymph nodes.

Step 8: Activation of Adaptive Immunity

Activation of T-cells and B-cells occurs.

2. Acquired (Adaptive) Immunity

- Acquired immunity is a type of immunity that develops after exposure to an antigen and provides a specific response against that antigen.

Characteristics

- Specific against particular antigen
- Develops after exposure
- Has memory
- Mediated by B-cells and T-cells
- Faster response upon re-exposure

Classification of Acquired Immunity

A. On the Basis of Cells Involved

1. Humoral Immunity
2. Cellular Immunity

B. On the Basis of Source

1. Active Immunity
2. Passive Immunity

Humoral Immunity

- Humoral immunity is a type of adaptive immunity in which B-lymphocytes produce antibodies that circulate in body fluids (blood and lymph) to fight pathogens.

Functions

- Protects against extracellular pathogens
- Neutralizes toxins
- Produces antibodies

Role of B-Cells

- Produced and matured in bone marrow.
- Possess B-Cell Receptors (BCRs).
- Recognize specific antigens.

Activation of B-Cells

1. Antigen binds to BCR.
2. B-cell engulfs antigen.
3. Antigen fragments are presented on **MHC-II** molecules.
4. Helper T-cell recognizes antigen-MHC-II complex.
5. Cytokines activate B-cell.
6. B-cell proliferates and differentiates into:

Plasma Cells

- Produce large amounts of antibodies.

Memory B-Cells

- Long-lived cells.
- Provide rapid response upon re-exposure.

Cellular Immunity

- Cellular immunity is a type of adaptive immunity in which T-lymphocytes directly attack and destroy infected, abnormal, or foreign cells without using antibodies.

Functions

- Protects against intracellular pathogens
- Eliminates virus-infected cells
- Destroys cancer cells

Role of T-Cells

- Produced in bone marrow.
- Mature in thymus.
- Require Antigen Presenting Cells (APCs) for activation.

Antigen Presenting Cells (APCs)

- Dendritic cells, Macrophages, B-cells

Antigen Presentation

APCs present antigen fragments with MHC molecules.

- **MHC-I → Cytotoxic T-cells ($CD8^+$)**
- **MHC-II → Helper T-cells (CD_4^+)**

Types of T-Cells

1. Cytotoxic T-Cells ($CD8^+$)

- Kill infected cells
- Kill cancer cells
- Recognize antigen through MHC-I

2. Helper T-Cells (CD_4^+)

- Release cytokines
- Activate B-cells, Activate macrophages
- Activate cytotoxic T-cells

3. Regulatory T-Cells (Treg)

- Suppress excessive immune response
- Prevent autoimmunity

4. Memory T-Cells

- Long-lived cells
- Provide rapid response during future infections

Active Immunity

- Active immunity develops when the body's own immune system produces antibodies and memory cells in response to an antigen.

Features

- Long-lasting protection
- Memory present
- Slow onset

Types

1. Natural Active Immunity

Develops after natural infection.

Example: Immunity after recovering from chickenpox.

2. Artificial Active Immunity

Develops after vaccination.

Examples:

- Polio vaccine
- COVID-19 vaccine

Passive Immunity

Passive immunity is the immunity in which ready-made antibodies are transferred to an individual.

Features

- Immediate protection
- No memory cells
- Temporary protection

Types

1. Natural Passive Immunity

Antibodies are transferred from mother to baby.

- Through placenta → IgG
- Through breast milk → IgA

2. Artificial Passive Immunity

Ready-made antibodies are injected.

Examples:

- Anti-rabies serum

- Anti-snake venom

Immunoglobulins (Antibodies)

- Immunoglobulins (Ig) are glycoproteins produced by B-lymphocytes (plasma cells) in response to an antigen.
- They are Y-shaped proteins that specifically recognize and bind to antigens, helping to neutralize or eliminate them.
- Immunoglobulins are highly specific to antigens and form an important part of Humoral Immunity.

Structure of Antibody (Immunoglobulin)

An antibody is a Y-shaped glycoprotein composed of four polypeptide chains:

- Two Heavy (H) Chains
- Two Light (L) Chains

These chains are connected by disulfide bonds.

1. Heavy Chains (H Chains)

Characteristics

- Two identical heavy chains
- Molecular weight ≈ 50 kDa each
- Form the core structure of antibody
- Determine the class (type) of immunoglobulin

Types of Heavy Chains

Heavy Chain	Antibody Class
γ (Gamma)	IgG
α (Alpha)	IgA
μ (Mu)	IgM
ε (Epsilon)	IgE
δ (Delta)	IgD

2. Light Chains (L Chains)

Characteristics

- Two identical light chains
- Molecular weight ≈ 25 kDa each

- Attached to heavy chains

Types

1. Kappa (κ)
2. Lambda (λ)

Regions of Antibody

1. Fab Region (Fragment Antigen Binding)

Features

- Located at the two arms of Y-shaped antibody
- Contains antigen-binding sites
- Responsible for antigen recognition

Functions

- Binds specifically to antigens
- Each antibody has two Fab regions

2. Fc Region (Fragment Crystallizable)

Features

- Located at the stem of Y
- Formed by constant regions of heavy chains

Functions

- Activates complement system
- Binds to Fc receptors on immune cells

3. Variable Region (V Region)

Features

- Present at the tips of Fab arms
- Sequence varies among antibodies

Functions

- Recognizes specific antigens
- Responsible for antigen specificity

4. Constant Region (C Region)

Features

- Remains similar within an antibody class

Functions

- Determines antibody class
- Responsible for effector functions

5. Hinge Region

Features

- Located between Fab and Fc regions
- Rich in proline and cysteine amino acids

Functions

- Provides flexibility

Disulfide Bonds in Antibodies

➢ Disulfide bonds (-S-S-) are strong covalent bonds that stabilize antibody structure.

Types of Disulfide Bonds

1. Interchain Disulfide Bonds

Present between different chains:

- Heavy–Heavy chains
- Heavy–Light chains

Function

Hold antibody chains together.

2. Intrachain Disulfide Bonds

Present within the same polypeptide chain.

Function

Maintain three-dimensional structure of antibody.

Types of Immunoglobulins

Based on the type of heavy chain, antibodies are classified into five major classes:

1. IgG

2. IgA
3. IgM
4. IgE
5. IgD

1. IgG (Gamma Immunoglobulin)

Characteristics

- Most abundant antibody in blood
- Constitutes about 70–75% of total immunoglobulins
- Monomeric in structure
- Smallest antibody capable of crossing placenta

Functions

- Neutralizes toxins and viruses
- Opsonization of pathogens
- Activates complement system
- Provides long-term immunity
- Protects fetus through placental transfer

Clinical Importance

- Main antibody of secondary immune response
- Provides passive immunity to newborn

2. IgA (Alpha Immunoglobulin)

Characteristics

- Found mainly in body secretions
- Usually exists as a dimer
- Major antibody of mucosal surfaces

Location

- Saliva
- Tears
- Mucus
- Colostrum
- Breast milk
- Respiratory tract

- Gastrointestinal tract

Functions

- Prevents attachment of pathogens
- Protects mucosal surfaces
- Neutralizes bacteria and viruses

Clinical Importance

Acts as the first line of defense at mucosal surfaces.

3. IgM (Mu Immunoglobulin)

Characteristics

- Largest antibody
- Exists as a pentamer
- First antibody produced during primary immune response

Functions

- Strong activator of complement system
- Agglutinates microorganisms
- Provides early protection during infection

Clinical Importance

Presence of IgM indicates:

- Recent infection
- Acute infection

4. IgE (Epsilon Immunoglobulin)

Characteristics

- Present in very low concentration in blood
- Strong affinity for mast cells and basophils
- Exists as a monomer

Functions

- Mediates allergic reactions
- Defends against parasitic infections
- Triggers histamine release

Effects of Histamine Release

- Vasodilation

- Increased vascular permeability
- Bronchoconstriction

Associated Disorders

- Asthma
- Hay fever
- Anaphylaxis
- Allergic rhinitis

5. IgD (Delta Immunoglobulin)

Characteristics

- Least abundant immunoglobulin
- Exists as a monomer
- Found mainly on naïve B-cells

Functions

- Acts as B-cell receptor (BCR)
- Participates in antigen recognition
- Helps activate B-cells
- Assists B-cell differentiation

Comparison of Immunoglobulins

Feature	IgG	IgA	IgM	IgE	IgD
Structure	Monomer	Dimer	Pentamer	Monomer	Monomer
Percentage in Blood	70–75%	10–15%	5–10%	Very Low	Very Low
Main Function	Long-term immunity	Mucosal immunity	Primary response	Allergy & parasites	B-cell receptor
Complement Activation	Yes	No	Strongest	No	No
Crosses Placenta	Yes	No	No	No	No
First Produced	No	No	Yes	No	No

One-Line Revision

- **IgG** → Most abundant, crosses placenta.
- **IgA** → Mucosal antibody, found in secretions.
- **IgM** → First antibody produced, pentamer.
- **IgE** → Allergy and parasitic defense.
- **IgD** → B-cell receptor and activation.