The Lymphatic System and Immunity

Lymphatic System Organization

Lymphatic System Definitions
- Pathogens—Organisms that cause disease
- Lymphatic System—Cells, tissues, and organs that play a central role in the body’s defenses against pathogens
- Lymphatic system consists of vessels (lymphatics) filled with lymph connected to lymphatic organs

Lymphatic System Organization

The Components of the Lymphatic System

Lymphatic System Organization

Functions of the Lymphatic System
- Produce, maintain, distribute lymphocytes
  - Lymphocytes attack invading organisms, abnormal cells, foreign proteins
- Maintain blood volume
- Help eliminate local variations in interstitial fluid concentration

Lymphatic System Organization

Lymphatic Vessels
- Lymph flows inside
- Begin as lymphatic capillaries in the tissues
- Lymph empties into venous system
  - At thoracic duct
  - At right lymphatic duct

Lymphatic System Organization

Lymphatic Capillaries

Lymphatic System Organization

Lymphatic Capillaries

Lymphatic System Organization

The Lymphatic Ducts and the Venous System

Lymphatic System Organization
Three Classes of Lymphocytes

- **T cells**
  - Thymus dependent
- **B cells**
  - Bone marrow derived
- **NK cells**
  - Natural killer

**Lymphatic System Organization**

Types of T Lymphocytes

- **Cytotoxic T cells**
  - Provide *cell-mediated* immunity
  - Attack foreign and virus-infected cells
- **Regulatory T cells**
  - Helper T cells
  - Suppressor T cells

**B Lymphocytes**

- Can become *plasma cells*
  - Specific to a particular *antigen*
  - Produce *antibodies* that react with that antigen
  - Antibodies are *immunoglobulins*
- Responsible for *humoral or antibody-mediated immunity*

**NK Lymphocytes**

- Provide *immunological surveillance*
- Attack cells
  - Foreign cells
  - Virally-infected cells
  - Cancerous cells

**Lymphatic System Organization**

Lymphocyte Life Cycle

- Continuously migrate between lymphoid tissues and the blood
- Production and development (called *lymphopoiesis*) involves:
  - Bone marrow
  - Thymus
  - Peripheral lymphoid tissues

**The Origins of Lymphocytes**
Lymphatic System Organization
Lymphoid Nodules
- Consists of loose connective tissue containing densely packed lymphocytes
- *Tonsils* are lymphoid nodules in the pharynx wall

Lymphatic System Organization
The Tonsils

Lymphatic System Organization
Lymphoid Organs
- Important lymphoid organs include:
  - Lymph nodes
  - Thymus
  - Spleen
- Located in areas that are vulnerable to pathogens

Lymphatic System Organization
Lymph Nodes
- Encapsulated masses of lymphoid tissue containing lymphocytes
- Monitor and filter lymph
- Remove antigens
- Initiate immune response

Lymphatic System Organization
The Structure of a Lymph Node

Lymphatic System Organization
The Thymus
- Lies behind sternum
- T cells divide and mature there
- Shrinks after puberty
- Produces *thymosins*
  - Hormones that regulate T cell development

Lymphatic System Organization
The Thymus

Lymphatic System Organization
The Spleen
• **White pulp**
  - Resembles lymphoid nodules
  - Removes antigens
  - Initiates immune response

• **Red pulp**
  - Contains red blood cells
  - Recycles damaged or out-dated RBCs
  - Stores iron from recycled RBCs

### Lymphatic System Organization

#### The Spleen

Overview of Body’s Defenses
- Non-specific defenses
  - Protect against any threat
- Specific defenses
  - Protect against particular threats
  - Responds to *antigens*

### Nonspecific Defenses

- Physical Barriers
  - Skin, hair, & skin secretions
  - Digestive epithelia, & secretions

- Phagocytes
  - Microphages (neutrophils, eosinophils)
  - Macrophages

- Immunological Surveillance
  - NK cells
  - Find, kill cancer and virus-infected cells

### Nonspecific Defenses

- *Interferons*
  - Small proteins released by virus-infected cells
  - *Cytokines* that trigger release of anti-viral proteins that inhibit virus production
Nonspecific Defenses
• Complement System
  • Complex system of proteins
    • Initiate chain reaction (positive feedback)
    • Destroy target cell membranes
    • Stimulate inflammation, attract phagocytes

Nonspecific Defenses
• Inflammatory Response
  • Coordinated non-specific response to tissue injury

Nonspecific Defenses
• Fever
  • Temperature greater than 99ºF
  • Inhibits pathogens
  • Accelerates metabolism

Nonspecific Defenses
Events in Inflammation

Specific Defenses: Immunity
Types of Immunity
• Innate immunity
  • Genetically determined
  • Present at birth
• Acquired immunity
  • Active
    • Follows exposure to antigen
  • Passive
    • From transfer of antibodies from outside source

Specific Defenses: Immunity
Types of Immunity

Specific Defenses: Immunity
Properties of Specific Immunity
• Provided by lymphocytes
• Four general characteristics
  • Specificity
  • Versatility
  • Memory
  • Tolerance

Specific Defenses: Immunity
Properties of Specific Immunity
• Specificity
- T and B cell membrane receptors recognize a unique antigen
- **Versatility**
  - Responsive to millions of antigens
- **Memory**
  - Memory cells recall earlier encounters with an antigen
- **Tolerance**
  - Ignores body’s own antigens

**Specific Defenses: Immunity**

**Overview of the Immune Response**
- Purpose is to inactivate or destroy:
  - Pathogens
  - Abnormal cells
  - Foreign molecules
- Based on activation of lymphocytes by *specific* antigens by antigen recognition

**Specific Defenses: Immunity**

**T Cell Activation**
- Antigens processed by macrophages
- Fragments form complex with *MHC proteins* on cell surface
- T cell recognizes MHC complex, or
- Viral antigens on infected body cells
- Activated T cells differentiate further

**Specific Defenses: Immunity**

**Roles for Activated T Cells**
- **Cytotoxic** (killer) T cells
  - Provide *cell-mediated immunity*
- **Memory** T cells
  - Remember the activating antigen
- **Suppressor** T cells
  - Suppress other T and B cells
- **Helper** T cells
  - Secrete regulatory *cytokines*

**Specific Defenses: Immunity**

**Key Note**
Cell-mediated immunity depends on direct contact between cytotoxic T cells and foreign, abnormal, or infected cells. T cell activation usually involves antigen presentation by a phagocytic cell. Cytotoxic T cells destroy target cells with cytokines, lymphotoxins, or perforin.
Specific Defenses: Immunity

B Cells and Antibody-Mediated Immunity
- B cells are first sensitized by exposure to “their” antigen
- Helper T cells for that antigen then activate those B cells
- Activated B cells divide to form:
  - Plasma cells
    - Produce antibodies against that antigen
  - Memory cells

Specific Defenses: Immunity

Antibody Structure and Function
- Two pairs of parallel polypeptide chains
- Four Fixed segments
  - Provides basic structure
- Four Variable segments
  - Provides specific antigen-binding structure
- Antigen-antibody complex forms
  - Antigen determinant site binds to antibody

Specific Defenses: Immunity

Antibody Structure

Specific Defenses: Immunity

Classes of Antibodies
- Immunoglobulin G (IgG)
  - Resistance to pathogens
- Immunoglobulin M (IgM)
  - First antibody secreted
- Immunoglobulin A (IgA)
  - Found in glandular secretions
- Immunoglobulin E (IgE)
  - Stimulates inflammation
- Immunoglobulin D (IgD)
  - Found on surface of B cells

Specific Defenses: Immunity

How Antibodies Can Eliminate Antigens
- Neutralization
- Precipitation
- Agglutination
- Complement activation
- Attraction of phagocytes
• Stimulation of phagocytosis
• Stimulation of inflammation

**Specific Defenses: Immunity**

**Key Note**
Antibody-mediated immunity depends on specific antibodies from plasma cells derived from activated B cells by (1) antigen recognition, through binding to surface antibodies, and (2) stimulation by a helper T cell activated by the same antigen. The antibodies bind to the target antigen and either inhibit it, destroy it, remove it from solution, or promote its phagocytosis.

**Specific Defenses: Immunity**

**Primary and Secondary Immune Response**
• *Primary response*—Antibodies produced by plasma cells after first exposure to antigen
• *Secondary response*—Maximum antibody levels produced by subsequent exposure to the same antibody

**Specific Defenses: Immunity**

**The Primary and Secondary Immune Responses**

**Key Note**
Immunization produces a primary response to a specific antigen. If the same antigen is encountered at a later date, it triggers a powerful secondary response that usually prevents infection and disease.

**Specific Defenses: Immunity**

**Hormones of the Immune System**
• *Interleukins (IL)*
  • Sensitize T cells
  • Stimulate B cells
  • Enhance non-specific defenses
• *Interferons*
  • Slow the spread of viruses locally
• *Tumor necrosis factors (TNF)*
  • Slows growth, kills tumor cells
• Phagocytic regulators

**Specific Defenses: Immunity**

**Key Note**
Viruses replicate inside cells, whereas bacteria usually live outside. Antibodies work outside of cells, so they are primarily effective
against bacteria rather than viruses. T cells, NK cells, and interferons are the primary defenses against viral infection.

Patterns of Immune Response
A Summary of the Immune Response and Its Relationship to Nonspecific Defenses

Patterns of Immune Response

Immune Disorders

- Autoimmune disorders
  - Mistaken attack on body’s own tissues
- Immunodeficiency disease
  - Disease (e.g., AIDS) or a congenital block of immunity
- Allergies
  - Inappropriate or excessive response to allergens
- Age-related loss of effectiveness

Patterns of Immune Response

Types of Allergies

- Immediate hypersensitivity (Type I)
- Cytotoxic reaction (Type II)
- Immune complex disorders (Type III)
- Delayed hypersensitivity (Type IV)

The Integumentary System

- Provides physical barriers to pathogen entry; macrophages in dermis resist infection and present antigens to trigger immune response; mast cells trigger inflammation, mobilize cells of lymphatic system
- Provides IgA antibodies for secretion onto integumentary surfaces

The Skeletal System

- Lymphocytes and other cells involved in the immune response are produced and stored in bone marrow
- Assists in repair of bone after injuries; macrophages fuse to become osteoclasts

The Muscular System

- Protects superficial lymph nodes and the lymphatic vessels in the abdominopelvic cavity; muscle contractions help propel lymph along lymphatic vessels
- Assists in repair after injuries

The Nervous System

- Microglia present antigens that stimulate specific defenses; glial cells secrete cytokines; innervation stimulates antigen-presenting
cells

- Cytokines affect hypothalamic production of CRH and TRH

**The Endocrine System**

- Glucocorticoids have anti-inflammatory effects; thymosins stimulate development and maturation of lymphocytes; many hormones affect immune function
- Thymus secretes thymosins; cytokines affect cells throughout the body

**The Cardiovascular System**

- Distributes WBCs; carries antibodies that attack pathogens; clotting response helps restrict spread of pathogens; granulocytes and lymphocytes produced in bone marrow
- Fights infections of cardiovascular organs; returns tissue fluid to circulation

**The Respiratory System**

- Alveolar phagocytes present antigens and trigger specific defenses; provides oxygen required by lymphocytes and eliminates carbon dioxide generated during their metabolic activities
- Tonsils protect against infection at entrance to respiratory tract

**The Digestive System**

- Provides nutrients required by lymphatic tissues; digestive acids and enzymes provide nonspecific defense against pathogens
- Tonsils and lymphoid nodules of the intestine defend against infection and toxins absorbed from the digestive tract; lymphatics carry absorbed lipids to venous system

**The Urinary System**

- Eliminates metabolic wastes generated by cellular activity; acid pH of urine provides nonspecific defense against urinary tract infection
- Provides specific defenses against urinary tract infections

**The Reproductive System**

- Lysoenzymes and bactericidal chemicals in secretions provide nonspecific defense against reproductive tract infections
- Provides IgA antibodies for secretion by epithelial glands