Lymphatic System and Immunity
Lymphatic System

- Immunity- ability to resist infection and disease through the activation of specific defenses
- These defenses can be found in the lymphatic system
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

- Lymphatic Fluid
- Lymphatic Vessels
- Lymphocytes
- Lymphatic organs

Diagram showing various lymphatic nodes and vessels in the human body.
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 Organization in Detail

Lymphatic fluid – Lymph (lympha=clear water) fluid flow through lymphatic vessels

Similar in its makeup to Plasma found in blood
Lymphatic Organization in Detail

Lymph Capillaries in the Tissue Spaces

- Lymph capillary
- Arteriole
- Tissue fluid
- Tissue cells
- Tissue spaces
- Venule
- Lymphatic vessel
Lymphatic Organization in Detail

- Lymph collected by capillaries are collected into two ducts
  - Thoracic duct - collects from left side head, neck, and chest, left upper extremity, and entire body below ribs
  - Right Lymphatic duct – collects from upper right side of body
Lymphatic Organization in Detail
Lymphatic Organization in Detail

- Lymphocytes – Cells of lymphatic system; provide defense against specific pathogens or toxins
  - Live months, even decades
  - Produced in bone marrow and lymphatic tissues
  - Found blood and tissues
Lymphatic System Organization

Three Classes of Lymphocytes

• T cells
  • Thymus dependent
• B cells
  • Bone marrow derived
• NK cells
  • Natural killer
It was on a short-cut through the hospital kitchens that Albert was first approached by a member of the Antibiotic Resistance.
Types of Lymphocytes

- T-Cells - directly attack foreign cells or body cells infected by viruses
  - Majority circulating lymphocytes are T-Cells
Types of Lymphocytes

- B-Cells – produce antibodies which react with antigens (pathogens i.e. bacteria)
  - Antibodies join with antigens begin destruction of target
Types of Lymphocytes

- NK cells – natural killer cells
  - Attack foreign cells, normal cells infected with viruses, cancer cells
Lymphocytes in detail

- Constantly moving throughout the body (not stationary)
- Move through blood, bone marrow, spleen, lymphatic vessels etc.
- Fun fact: 80% live for four years; some last 20 years or more
Lymphocytes in detail

Scanty peripheral cytoplasm

Size relation to erythrocytes

A B cell covered with bacteria.

T Cells (in red) attacking a cancer cell
Lymphoid Organs

• Important lymphoid organs include:
  • Lymph nodes
  • Thymus
  • Spleen
• Located in areas that are vulnerable to pathogens
Lymphatic Organization in Detail

- Lymph Nodes – small, round organs, range from small to big
Lymphatic Organization in Detail

- Function of lymph nodes
  - Filter lymph before returned to blood stream
  - 99 percent of pathogens (bacteria, toxins etc.) are removed
  - Located in ideal spots to protect vital organs of body
Lymphatic Organization in Detail

- Preauricular
- Submental
- Tonsilar
- Submandibular
- Anterior Cervical
- Posterior Cervical
- Supraclavicular
Thymus
Bone marrow
Spleen
Lymph nodes
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

- Thyroid gland
- Trachea
- Heart
- Diaphragm
- RIGHT LUNG
- LEFT LUNG
- Right lobe
- Septae
- Lobule
- Left lobe
- Thymus
- Cortex
- Medulla
- Blood vessels

(c) Lobule

Figure 14-7
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

(a) Diagram showing the location of the spleen and its proximity to other organs such as the liver, pancreas, aorta, and diaphragm, as well as the stomach and kidneys.

(b) Close-up view of the spleen highlighting the gastric area, splenic vein, splenic artery, renal area, and white pulp.

(c) Microscopic view of the spleen showing red pulp and white pulp with veins, capsule, and arteries.
The Appendix

- Has an immune function, especially early in life.
- Assists with the maturation of B lymphocytes, and in the production of antibodies known as immunoglobulin A.
- Researchers have also shown that it’s involved in the production of molecules that help direct the movement of lymphocytes to various other locations in the body.
Body Defenses and the Lymphatic System

Overview of Body’s Defenses

- Non-specific defenses
  - Protect against any threat
- Specific defenses
  - Protect against particular threats
  - Responds to *antigens*
Body Defenses and the Lymphatic System

- Non-Specific resistance – inherited; provides general response to wide variety of pathogens
  - Consist of Skin and Mucous membranes, antimicrobial substances, phagocytosis, inflammation, fever
Body Defenses and the Lymphatic System (Non-Specific)

- **Skin**
  - Physical Barrier and constant shedding removes microbes from surface
- **Other Physical Barriers**
  - Hair & skin secretions
  - Digestive epithelia, & secretions
Body Defenses and the Lymphatic System (Non-Specific)

- Mucous Membranes – release a fluid called mucus
  - Helps trap microbes
  - Ex: Nose and Hairs; Upper Respiratory tract and Cilia; urethra and flow of urine
Body Defenses and the Lymphatic System (Non-Specific)

- **Chemical Factors**
  - Oil glands on skin produce sebum; forms layer over skin
    - pH of 3 - 5
  - Perspiration contains lysozomes capable breaking down cell walls in some bacteria
  - Gastric Juice in stomach pH of 1.2-3.0
Body Defenses and the Lymphatic System (Non-Specific)

- **Antimicrobial Substances**
  - **Interferons** - IFN’s produced by body cells already infected by a virus
    - This protein binds to uninfected cell and prevents virus from taking over

### INTERFERONS
Increase resistance of cells to viral infection; slow the spread of disease

Interferons released by activated lymphocytes, macrophages, or virus-infected cells
## Body Defenses and the Lymphatic System (Non-Specific)

- **Antimicrobial Substances**
  - Complement - group of 20 proteins found in blood
    - Play a role in certain immune and allergic reactions. Destroy target cell membranes.
    - Stimulate inflammation; attract phagocytes

<table>
<thead>
<tr>
<th>COMPLEMENT SYSTEM</th>
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<tbody>
<tr>
<td>Attacks and breaks down cell walls; attracts phagocytes; stimulates inflammation</td>
<td><img src="https://via.placeholder.com/150" alt="Diagram" /></td>
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</table>

<table>
<thead>
<tr>
<th>Complement</th>
<th><img src="https://via.placeholder.com/150" alt="Pathogen" /></th>
</tr>
</thead>
<tbody>
<tr>
<td>Lysed pathogen</td>
<td></td>
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</tbody>
</table>
Body Defenses and the Lymphatic System (Non-Specific)

- Phagocytosis – *phagein* = to eat *cyto* = cell
  - One type of Macrophage
  - Microphages (neutrophils, eosinophils)
Body Defenses and the Lymphatic System (Non-Specific)

- **Inflammation**
  - A defensive response of body due to tissue damage
  - Symptoms – redness, pain, heat, and swelling
  - Attempt to restore tissue homeostasis

| INFLAMMATORY RESPONSE | 1. Blood flow increased  
|-----------------------|--------------------------|
| Multiple effects      | 2. Phagocytes activated  
|                       | 3. Capillary permeability increased  
|                       | 4. Complement activated  
|                       | 5. Clotting reaction walls off region  
|                       | 6. Regional temperature increased  
|                       | 7. Specific defenses activated  

Mast cell
Nonspecific Defenses

Events in Inflammation

- Area becomes red, swollen, warm, and painful
- Dilation of blood vessels, increased blood flow, increased vessel permeability
- Mast cells release histamine and heparin
- Attraction of phagocytes, especially neutrophils
  - Release of cytokines
  - Removal of debris by neutrophils and macrophages; stimulation of fibroblasts
  - Activation of specific defenses
- Clot formation (temporary repair)
- Pathogen removal, clot erosion, scar tissue formation

Figure 14-10

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Body Defenses and the Lymphatic System (Non-Specific)

- Fever – abnormally high body temperature (above 99 degrees F)
  - Inhibits microbial growth and speeds up body reactions (metabolism) that help repair

<table>
<thead>
<tr>
<th>FEVER</th>
<th>Body temperature rises above 37.2°C in response to pyrogens</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobilizes defenses; accelerates repairs; inhibits pathogens</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>80</td>
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<tr>
<td></td>
<td>60</td>
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Specific Defenses: Immunity

Types of Immunity

INNATE IMMUNITY
Genetically determined—no prior exposure or antibody production involved

ACTIVE IMMUNITY
Produced by antibodies that develop in response to antigens (Immune response)

A. Naturally acquired active immunity
Develops after exposure to antigens in environment

B. Induced active immunity
Develops after administration of antigen to prevent disease

ACQUIRED IMMUNITY
Produced by prior exposure or antibody production

PASSIVE IMMUNITY
Produced by transfer of antibodies from another person

A. Natural passive immunity
Conferred by transfer of maternal antibodies across placenta or in breast milk

B. Induced passive immunity
Conferred by administration of antibodies to combat infection

SPECIFIC RESISTANCE (IMMUNITY)
Responds to threats on an individualized basis

Figure 14-11
Body Defenses and the Lymphatic System (Specific)

- Immunity – specific resistance
- Involves specific type of cell or molecule (antibody) to destroy particular antigen
  - Ex. If antigen 1 enters body then antibody 1 is produced to fight it
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
Body Defenses and the Lymphatic System (Specific)

- Types of Immunity
  - Innate and Acquired
  - Innate – present at birth
    - Based on genetics
Body Defenses and the Lymphatic System (Specific)

- Acquired Immunity – immunity gained as result of contact with antigen

- 4 types
  - Naturally acquired active immunity – body comes in contact with microbes and produces antibodies and T – Cells ex. Chickenpox
  - Naturally acquired passive immunity – transfer of antibodies from an immunized donor to non-immunized patient ex. Mother to fetus
Body Defenses and the Lymphatic System (Specific)

- Artificially acquired active immunity – results from vaccination (killed or damaged microbe)
- Artificially acquired passive immunity – injection of antibodies from outside sources
What is an antigen?? What is an antibody?? How do they interact??

- Antigen – foreign substance that illicit an immune response from the body
  - Ex. Virus, Bacterium, food, drugs, Pollen, Organs
Body Defenses and the Lymphatic System (Specific)

- Antibody – Protein produced by body in response to presence of an antigen
  - Capable of combining with SPECIFIC SITES on antigen known as antigenic determinant sites
  - 5 classes of Antibodies all having specific guidelines (immuglobulins)
Figure 14-12

Direct physical and chemical attack

SPECIFIC DEFENSES (Immune response)

ANTIGENS
- Bacteria
- Viruses

Attack by circulating antibodies

CELL–MEDIATED IMMUNITY
- Phagocytes activated
- T cells activated

Communication and feedback

ANTIBODY–MEDIATED IMMUNITY
- B cells activated
Body Defenses and the Lymphatic System (Specific)

- Cellular vs. Humoral Immunity
- T – Cells and Cellular Immunity
  - Before T – Cells move into action must become sensitized to invaders
  - Macrophage engulfs antigen and breaks it down
    - Parts of antigen are presented on macrophage surface
    - T – Cells contact this stimulated cell and begin immune response
Body Defenses and the Lymphatic System (Specific)

- T - Cells
- Millions of different T-cells in body all ready to stop any antigen at any time
  - Cannot anticipate
Body Defenses and the Lymphatic System (Specific)

- T – Cells and cellular immunity
  - Once sensitized, T – Cells differentiate into parts
  - 1. Cytotoxic T Cells – Destroy antigens directly and indirectly
  - 2. Helper T- Cells – coordinate both specific and non- specific attacks
Body Defenses and the Lymphatic System (Specific)

- 3. Suppressor T Cells - suppress responses of T and B cells
  - React late to keep immune system from overreacting

- 4. Memory T-Cells – Programmed to remember antigen so if it invades again, ready for a much QUICKER REACTION
  - Last for years
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.
Body Defenses and the Lymphatic System (Specific)

- B-Cells and Antibody mediated Immunity
- Activated by Helper T-Cells specific to that antigen
- Once activated, do two things
  1. Cells begin to divide to form Plasma cells and Memory cells
  2. Increase antibody production
**Step 1: Sensitization**

- **Inactive B cell**
- **Class II MHC**
- **Antigens**
- **Antibodies**
- **Antigen binding**
- **Sensitized B cell**

**Step 2: Activation**

- **Class II MHC**
- **T cell receptor**
- **Antigen binding**
- **Helper T cell**
- **Sensitized B cell**
- **Activated B cells**

**Step 3: Division and Differentiation**

- **Stimulation by cytokines**
- **Plasma cells**
- **ANTIBODY PRODUCTION**
- **Memory B cells (inactive)**
- **Antigen**
- **B cell**
- **T cell**

*Figure 14-14*
Body Defenses and the Lymphatic System (Specific)

- **Antibody structure**
  - Consist of constant segments and variable segments
  - Constant stay same among different antibodies
  - Variable segments cause differences among antibodies
Specific Defenses: Immunity

Antibody Structure

Figure 14-15
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.
Primary and Secondary Responses to Antigen Exposure

- **Primary response** – initial response to antigen. Antibodies produced by plasma cells after first exposure to antigen.
- **Secondary response** – antigen appears again.
  - Longer and more powerful
  - Maximum antibody levels produced by subsequent exposure to the same antibody
Specific Defenses: Immunity

The Primary and Secondary Immune Responses

Figure 14-16
Specific Defenses: Immunity

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.
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.
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 (e.g. Celiac Disease, Lupus, MS)
- Immunodeficiency disease
  - Disease (e.g., AIDS, Lymphoma, Sickle Cell) or a congenital block of immunity
- Allergies
  - Inappropriate or excessive response to allergens (food, pollen, etc.)
- Age-related loss of effectiveness
Allergies

- Inappropriate or excessive immune responses to antigens

  - Ex. 1  Cytotoxic T-Cells destroy normal cells while attacking antigen
  - Ex. 2  Antigen/Antibody complexes may trigger large inflammatory response
Allergies

- Four categories of allergies with the most common being Type I or Immediate Hypersensitivity
  - Rapid and severe reaction to an allergen
  - First time allergen is present the antibodies are produced but there is little reaction
  - Second time is major inflammation, smooth muscles contracting (airway small)