The Lymphatic System and Immunity

PowerPoint® Lecture Outlines
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Slides 1 to 87
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 lymphatic vessels filled with lymph connected to lymphatic organs
Lymphatic System Organization

The Components of the Lymphatic System

- Tonsil
- Cervical lymph nodes
- Right lymphatic duct
- Thymus
- Thoracic duct
- Lumbar lymph nodes
- Lymphatics of upper limb
- Axillary lymph nodes
- Thoracic (left lymphatic) duct
- Lymphatics of mammary gland
- Spleen
- Lymphoid nodules of intestines
- Pelvic lymph nodes
- Inguinal lymph nodes
- Lymphatics of lower limb
 Functions of the Lymphatic System

1. Produce, maintain, distribute lymphocytes
   - Lymphocytes attack invading organisms, abnormal cells, foreign proteins
2. Maintain blood volume
3. Help keep local interstitial fluid concentrations level
Lymphatic System Organization

Lymphatic Vessels

- *Lymph* fluid that flows inside

- Begin as *lymphatic capillaries* in the tissues

- Lymph empties into circulatory system
  - At *thoracic duct*
  - At *right lymphatic duct*
Lymphatic System Organization

Lymphatic Capillaries

Figure 14-2(a)
Lymphatic System Organization

Lymphatic Capillaries

(b)

Figure 14-2(b)

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Lymphatic System Organization

The Lymphatic Ducts and the Venous System

Figure 14-3
Three Classes of Lymphocytes

1. *T* cells
   - Thymus dependent

2. *B* cells
   - Bone marrow derived

3. *NK* cells
   - Natural Killer
Types of T Lymphocytes

1. *Cytotoxic* T cells
   - Provide *cell-mediated* immunity
   - Attack foreign and virus-infected cells

2. *Regulatory* T cells
   - *Helper* T cells
   - *Suppressor* T cells
Lymphatic System Organization

B Lymphocytes

1. Can become *plasma cells*
   - Specific to a particular *antigen*
   - Produce *antibodies* that react with that antigen
   - Antibodies are *immunoglobulins*

2. Responsible for *humoral* or *antibody-mediated immunity*
Lymphatic System Organization

NK Lymphocytes

1. Provide *immunological surveillance*

2. Attack cells
   - Foreign cells
   - Virally-infected cells
   - Cancerous cells
Lymphocyte Life Cycle

• Continuously migrate between lymphoid tissues and the blood
• Production and development (called lymphopoiesis) involves:
  • Bone marrow
  • Thymus
Lymphatic System Organization

The Origins of Lymphocytes

Figure 14-4
**Lymphoid Nodules** (like lymph nodes only different!)

- Consists of loose connective tissue containing densely packed lymphocytes
- Found in food and air passages
- *Tonsils* are lymphoid nodules in the pharynx wall
  1. Pharyngeal (aka adenoids)
  2. Palatine
  3. Lingual
The Tonsils

Figure 14-5

Pharyngeal tonsil
Palate
Palatine tonsil
Lingual tonsil
Lymphoid Organs

- Important lymphoid organs include:
  1. Lymph nodes
  2. Thymus
  3. Spleen

- Located in areas that are vulnerable to pathogens
Lymphatic System Organization

Lymph Nodes

1. What are they? Masses of lymphoid tissue containing lymphocytes

2. What do they do?
   • Monitor and filter lymph
   • Remove antigens
   • Initiate immune response
Lymphatic System Organization

The Structure of a Lymph Node

Figure 14-6

Afferent lymphatic vessel
Capsule
Germinal centers
Cortex
Medulla
Sinuses
Efferent lymphatic vessel
Lymph node artery and vein

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The Thymus

1. Where? Lies behind sternum
2. What happens there? T cells divide and mature there
3. Shrinks after puberty
4. Produces *thymosins*
   • Hormones that regulate T cell development
Lymphatic System Organization

The Thymus

Figure 14-7
The Thymus

Figure 14-7(a)
The Thymus

Right lobe

Left lobe

Septae

Thymus

Lobule

Figure 14-7(b)
Lymphatic System Organization

The Thymus

Figure 14-7(c)
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
The Spleen

Diagram showing the location of the spleen, with labels for the Aorta, Pancreas, Liver, Rib, Diaphragm, Stomach, Gastric area, SPLEEN, Renal area, and Kidneys. The spleen is shown in both superior and inferior views.

Figure 14-8
Lymphatic System Organization

The Spleen

Figure 14-8(a)
Lymphatic System Organization

The Spleen

Figure 14-8(b)
Overview of Body’s Defenses

1. **Non-specific defenses** (7 types)
   - Protect against any threat

2. **Specific defenses**
   - Protect against particular threats
   - Responds to *antigens*
Nonspecific Defenses

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

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Nonspecific Defenses

2. Phagocytes

- Microphages (neutrophils, eosinophils)
- Macrophages

![Diagram of Phagocytes](image)

PHAGOCYTES
Remove debris and pathogens

- Fixed macrophage
- Neutrophil
- Free macrophage
- Eosinophil
- Monocyte

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3. Immunological Surveillance

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

**Figure 14-9 (3 of 7)**
4. Interferons

- Small proteins released by virus-infected cells
- *Cytokines* that trigger release of anti-viral proteins that inhibit virus production
5. **Complement System**

- Complex system of proteins
  - Initiate chain reaction (positive feedback)
  - Destroy target cell membranes
  - Stimulate inflammation, attract phagocytes
6. Inflammatory Response

- Coordinated non-specific response to tissue injury

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

Figure 14-9 (6 of 7)
7. Fever

- Temperature greater than 99°F
- Inhibits pathogens
- Accelerates metabolism
Nonspecific Defenses

Events in Inflammation

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

Figure 14-10
Specific Defenses: Immunity

Types of Immunity

1. **Innate immunity**
   - Genetically determined
   - Present at birth

2. **Acquired immunity**
   - Active
     - Follows exposure to *antigen*
   - Passive
     - From transfer of antibodies from outside source
Specific Defenses: Immunity

Types of Immunity

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

**ACQUIRED IMMUNITY**
Produced by prior exposure or antibody production

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

- Naturally acquired active immunity
  - Develops after exposure to antigens in environment
- Induced active immunity
  - Develops after administration of antigen to prevent disease

**PASSIVE IMMUNITY**
Produced by transfer of antibodies from another person

- Natural passive immunity
  - Conferred by transfer of maternal antibodies across placenta or in breast milk
- Induced passive immunity
  - Conferred by administration of antibodies to combat infection

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

Figure 14-11
Specific Defenses: Immunity

Properties of Specific Immunity

• Four general characteristics
  1. Specificity
  2. Versatility
  3. Memory
  4. Tolerance
Properties of Specific Immunity

1. **Specificity**
   - T and B cell membrane receptors recognize a unique antigen

2. **Versatility**
   - Responsive to millions of antigens

3. **Memory**
   - Memory cells recall earlier encounters with an antigen

4. **Tolerance**
   - Ignores body’s own antigens
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 (Immune response)

ANTIGENS
- Bacteria
- Viruses

Direct physical and chemical attack

CELL–MEDIATED IMMUNITY
- Phagocytes activated
- T cells activated

Communication and feedback

ANTIBODY–MEDIATED IMMUNITY
- B cells activated

Attack by circulating antibodies
ANTIGENS

Bacteria

Viruses
SPECIFIC DEFENSES (Immune response)

ANTIGENS

Bacteria

Viruses
SPECIFIC DEFENSES (Immune response)

ANTIGENS
- Bacteria
- Viruses

CELL-MEDIATED IMMUNITY
- Phagocytes activated
- T cells activated
SPECIFIC DEFENSES (Immune response)

ANTIGENS
- Bacteria
- Viruses

CELL–MEDIATED IMMUNITY
- Phagocytes activated
- T cells activated

Communication and feedback

ANTIBODY–MEDIATED IMMUNITY
- B cells activated
**SPECIFIC DEFENSES (Immune response)**

**CELL–MEDIATED IMMUNITY**
- Phagocytes activated
- T cells activated

**ANTIBODY–MEDIATED IMMUNITY**
- B cells activated

Direct physical and chemical attack

**ANTIGENS**
- Bacteria
- Viruses
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

Figure 14-12
Specific Defenses: Immunity

T CELLS & CELL MEDIATED IMMUNITY

1. **T Cell Activation** (*T cells are usually activated before B cells*)

- T cells don’t recognize antigens by themselves; usually recognize them when they are bound to receptors on other cell membranes
- T cells have specific receptors that detect these antigens
- Activated T cells differentiate further
2. Differentiated Activated T Cells

1. Cytotoxic (killer) T cells
   - Provide cell-mediated immunity
   - Track down and attack bacteria, fungi, protozoa, or foreign transplanted tissues that contain the target antigen
   - How? Produce toxins and other chemical compounds that get rid of antigen by:
     - disrupting metabolism, genetically modifying target cell genes, or rupturing target cell membrane
2. **Helper T cells**

- **Secrete cytokines** *(chemical messengers like hormones)*
- **2 jobs:**
  1. Coordinate specific and non-specific defenses
  2. Stimulate both cell-mediated and antibody-mediated immunity

Once activated Helper T cells will divide to produce more Helper T cells and Memory cells. They also have a function in B cell activation (coming up later…)
Specific Defenses: Immunity

3. Memory T cells
   • Remember the activating antigen
   • “in reserve”
   • When same antigen appears a second time, memory cells differentiate into cytotoxic T cells and helper T cells

4. Suppressor T cells
   • Suppress other T and B cells
   • Limit the degree of the immune response
Infected cell

Viral or bacterial antigen

Inactive cytotoxic T cell

Class I MHC protein

T cell receptor

ACTIVATION AND CELL DIVISION

Active cytotoxic T cells

Memory T cells (inactive)

Lymphotoxin release

Cytokine release

Perforin release

Destruction of cell membrane

Stimulation of apoptosis

Disruption of cell metabolism

Lysed cell

DESTRUCTION OF TARGET CELL

Figure 14-13
1 of 5
Infected cell

Viral or bacterial antigen

Class I MHC protein

Inactive cytotoxic T cell

T cell receptor

Figure 14-13
2 of 5
Infected cell

Viral or bacterial antigen

Inactive cytotoxic T cell

Class I MHC protein

T cell receptor

ACTIVATION AND CELL DIVISION

Active cytotoxic T cells

Memory T cells (inactive)
Infected cell

Viral or bacterial antigen

Class I MHC protein

Inactive cytotoxic T cell

T cell receptor

ACTIVATION AND CELL DIVISION

Active cytotoxic T cells

Memory T cells (inactive)

Lymphotoxin release

Cytokine release

Perforin release

Stimulation of apoptosis

Disruption of cell metabolism

Destruction of cell membrane

Stimulation of apoptosis

Figure 14-13
4 of 5
**Figure 14-13**

5 of 5

Infected cell

- Viral or bacterial antigen
- Class I MHC protein
- T cell receptor

**ACTIVATION AND CELL DIVISION**

- Active cytotoxic T cells
- Memory T cells (inactive)

- Lymphotixin release
- Cytokine release
- Perforin release
- Disruption of cell metabolism
- Stimulation of apoptosis
- Destruction of cell membrane
- Stimulation of apoptosis

**DESTRUCTION OF TARGET CELL**

Lysed cell
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.
B CELLS & ANTIBODY-MEDIATED IMMUNITY

1. B cells are first sensitized by exposure to “their” antigen
2. Helper T cells for that antigen then activate those B cells
3. Activated B cells divide to form:
   • Plasma cells
     • Produce antibodies against that antigen
   • Memory B cells
**STEP 1** Sensitization

- Antigens
- Class II MHC
- Antibodies

Inactive B cell

Antigens bound to antibody molecules

Antigen binding

Sensitized B cell

**STEP 2** Activation

- Class II MHC
- T cell receptor
- Antigen

B cell

T cell

Stimulation by cytokines

**STEP 3** Division and differentiation

- Plasma cells
- Activated B cells
- Memory B cells (inactive)

ANTIBODY PRODUCTION

B cell

T cell

Figure 14-14
Figure 14-14

STEP 1 Sensitization

Antigens

Class II MHC

Antibodies

Inactive B cell

Antigens bound to antibody molecules

Antigen binding

Sensitized B cell
**Antigens Sensitization**

Inactive B cell

- Antigens
- Class II MHC
- Antibodies

**Antigens bound to antibody molecules**

**Antigen binding**

**Sensitized B cell**

**STEP 2 Activation**

Class II MHC

T cell receptor

**Antigen**

B cell

T cell

**Helper T cell**

**Sensitized B cell**

Figure 14-14
**Figure 14-14**

**STEP 1** Sensitization
- Antigens
- Class II MHC
- Antibodies
- Inactive B cell
  - Antigens bound to antibody molecules
  - Antigen binding
  - Sensitized B cell

**STEP 2** Activation
- Class II MHC
- T cell receptor
- Antigen
- B cell
- T cell
- Stimulation by cytokines
- Sensitized B cell
- Helper T cell
- Activated B cells
- Memory B cells (inactive)

**STEP 3** Division and differentiation
- Activated B cells
- Memory B cells (inactive)
**STEP 1  Sensitization**

- Antigens
- Class II MHC
- Antibodies

Inactive B cell

Antigens bound to antibody molecules

Antigen binding

Sensitized B cell

**STEP 2  Activation**

- Class II MHC
- T cell receptor

Antigen

B cell

T cell

Stimulation by cytokines

**STEP 3  Division and differentiation**

- Plasma cells
- Activated B cells
- Memory B cells (inactive)

**ANTIBODY PRODUCTION**

Figure 14-14
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

Figure 14-15

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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
How Antibodies Can Eliminate Antigens

1. **Neutralization** -- bind to viruses or bacteria making them incapable of attaching to a cell

2. **Precipitation** -- 1 antibody can bind 2 antigens together and create a large complex. When it is insoluble in a body fluid (like bacterial toxin) it settles out

3. **Agglutination** -- formation of large complexes; clumping of RBC’s when incompatible blood types are mixed
Specific Defenses: Immunity

4. Complement System activation
5. Attraction of phagocytes
6. Stimulation of phagocytosis
7. Stimulation of inflammation
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

- **First exposure**
- **Primary response**
- **Second exposure**
- **Secondary response**

Figure 14-16

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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.
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*. 
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
  • Result of some kind of infection (e.g., AIDS) or a congenital block of immunity; meaning immune system doesn’t develop properly

• Allergies
  • Inappropriate or excessive response to allergens

• Age-related loss of effectiveness
Patterns of Immune Response

Types of Allergies

1. *Immediate hypersensitivity* (Type I)
   • Hay fever causes inflammatory response

2. *Cytotoxic reaction* (Type II)
   • Blood transfusion

3. *Immune complex disorders* (Type III)
   • Inflammation in blood vessels and kidneys due to decreased phagocytosis

4. *Delayed hypersensitivity* (Type IV)
   • Inflammatory response that occurs 2-3 days after exposure to an antigen (poison ivy)
Patterns of Immune Response

Anaphylaxis:

- Type I
- Changes in capillary permeability produces swelling in the dermis
- Hives
- Smooth muscle in respiratory passages contracts
- Vasodilation causes BP to drop which leads to Anaphylactic Shock
The Lymphatic System in Perspective

FIGURE 14-18
Functional Relationships Between the Lymphatic System and Other Systems
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.
• 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

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