Chapter 12
The Lymphatic System and Body Defenses

Slides 12.1 – 12.22

Lecture Slides in PowerPoint by Jerry L. Cook
The Lymphatic System

- Tonsils
- Thymus
- Lymph nodes
- Lymphatic vessels
- Liver
- Spleen
- Peyer’s patch on small intestine
- Appendix
- Bone marrow
The Lymphatic System

- Functions
  - Transport fluids (lymph) back to the blood
  - Play essential roles in body defense and resistance to disease
Lymph

- Materials returned to the blood
  - Water
  - Blood cells
  - Proteins
Lymph

- Harmful materials that enter lymph vessels
  - Bacteria
  - Viruses
  - Cancer cells
  - Cell debris
Lymphatic Vessels

Figure 12.1
I. Lymphatic Vessels

- Transport of Lymph
  - No pump
  - One way system towards the heart using
    - Milking action of skeletal muscle
    - Rhythmic contraction of smooth muscle in vessel walls
I. Lymphatic Vessels

- Characteristics
  - Collects lymph from lymph capillaries
  - Carries lymph to and away from lymph nodes
  - Returns fluid to circulatory veins near the heart at the
    - Right lymphatic duct
    - Thoracic duct

Figure 12.2
Drained by right lymphatic duct

Drained by thoracic duct
II. Lymph Nodes

- **Function**
  - Filter lymph (about 4 liters per day) before it is returned to the blood
Lymph Nodes

Regional lymph nodes:
- Cervical nodes
- Axillary nodes
- Inguinal nodes

Entrance of right lymphatic duct into right subclavian vein

Internal jugular vein

Entrance of thoracic duct into left subclavian vein

Thoracic duct

Aorta

Spleen

Cisterna chyli (receives lymph drainage from the digestive organs)

Lymphatics

Figure 12.3
Lymph Node Structure

- Most are kidney-shaped, less than 1 inch long
- Cortex
  - Outer part, contains follicles – collections of lymphocytes
- Medulla
  - Inner part, contains phagocytic macrophages
Enlarged mesenteric lymph nodes in a case of AIDS and *Mycobacterium avium*-complex (MAC) infection.
Activation of Lymphocytes

1. Lymphocytes destined to become T cells migrate to the thymus and develop immunocompetence there. B cells develop immuno-competence in the bone marrow.

2. After leaving the thymus or bone marrow as naive immunocompetent cells, lymphocytes “seed” the infected connective tissues (especially lymphoid tissue in the lymph nodes), where the antigen challenge occurs and the lymphocytes become fully activated.

3. Activated (mature) lymphocytes circulate continuously in the bloodstream and lymph and throughout the lymphoid organs of the body.

Figure 12.9
Cells of the Immune System

- Lymphocytes
  - Provide immune response to antigens
  - Originate in the red bone marrow
  - B lymphocytes become immunocompetent (mature) in the bone marrow
  - T lymphocytes become immunocompetent in the thymus
Cells of the Immune System

- Macrophages
  - Engulf and destroy foreign substances
  - Begin as monocytes
  - Leave lymphatic tissue to enter surrounding tissue
Flow of Lymph Through Nodes
Flow of Lymph Through Nodes

- Enters the convex side through afferent lymphatic vessels
- Exits through efferent lymphatic vessels
- Fewer efferent than afferent vessels causes flow to be slowed
Other Lymphoid Organs

- Tonsils (in pharyngeal region)
- Thymus (in thorax; most active during youth)
- Spleen (curves around left side of stomach)
- Peyer’s patches (in intestine)
The Spleen
III. The Spleen

- Located on the left side of the abdomen
- Filters blood and destroys worn out blood cells
- Forms blood cells in the fetus
- Acts as a blood reservoir
The Thymus

[Image of a human body with labeled Thymus and Spleen]
IV. The Thymus

- Located low in the throat, overlying the heart
- Functions at peak levels only during childhood
- Produces hormones to program lymphocytes (T cells)
V. Mucosa-Associated Lymphatic Tissue (MALT)

- Includes:
  - Peyer’s patches
  - Tonsils & Adenoids
  - Other small accumulations of lymphoid tissue

- Acts as a sentinel to protect respiratory and digestive tracts
Look at the tonsils! They protect you from bad germs.
The Tonsils
Tonsils/Adnoids

- Small masses of lymphoid tissue around the nasopharynx (adnoids) and oropharynx (tonsils)
- Trap and remove bacteria and other foreign materials
- Tonsillitis is caused by congestion with bacteria
Peyer’s Patches

- Found in the wall of the small intestine
- Resemble tonsils in structure
- Capture and destroy bacteria in the intestine
Absence of Peyer’s Patches in HIV Infection

slide courtesy of Timothy Schacker, UM
• Video: Introduction to how the immune system works
Antigens (Nonself)

- Any substance capable of exciting the immune system and provoking an immune response
ANTIGENS

bacterium

virus

antigen
Self-Antigens

- Human cells have many surface proteins
- Our immune cells do not attack our own proteins
Characteristics

- Soluble proteins secreted by B cells (plasma cells)
- Carried in blood plasma
- Capable of binding to a specific antigen
Antibody Structure

- Four amino acid chains linked by disulfide bonds
- Contains specific antigen-binding sites
Antibody Classes

- Five major immunoglobulin classes
  - IgM – can fix complement

Activated complement proteins attach to pathogen's membrane in step-by-step sequence, forming a membrane attack complex (a MAC attack).

MAC pores in the membrane cause cell lysis.
Antibody Classes

- Five major immunoglobulin classes
- IgA – found mainly in mucus
Antibody Classes

- Five major immunoglobulin classes
  - IgD – important in activation of B cell
Antibody Classes

- Five major immunoglobulin classes
  - IgG – smallest, and most numerous form. Can cross the placental barrier.
Antibody Classes

- Five major immunoglobulin classes
  - IgE – involved in allergies
Antibody Function

Figure 12.14
Humoral Immune Response

Primary Response (initial encounter with antigen)

Secondary Response (can be years later)

Antigen

Proliferation to form a clone

Clone of cells identical to ancestral cells

Plasma cells

Secreted antibody molecules

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Humoral Immune Response

Figure 12.10
Humoral Immune Response

Primary Response
(initial encounter with antigen)

B lymphoblasts
Proliferation to form a clone

Secondary Response
(can be years later)

Clone of cells identical to ancestral cells

Antigen
Antigen binding to a receptor on a specific B lymphocyte (B lymphocytes with non-complementary receptors remain inactive)

Plasma cells
Secretd antibody molecules

Figure 12.10
Humoral Immune Response

Figure 12.10
Humoral Immune Response

Primary Response
(initial encounter with antigen)

Antigen binding to a receptor on a specific B lymphocyte
(B lymphocytes with non-complementary receptors remain inactive)

B lymphoblasts

Proliferation to form a clone

Plasma cells

Secreted antibody molecules

Secondary Response
(can be years later)

Clone of cells identical to ancestral cells

Plasma cells

Secreted antibody molecules
Humoral Immune Response

**Primary Response**
- Initial encounter with antigen
- Antigen binding to a receptor on a specific B lymphocyte
- B lymphoblasts proliferate to form a clone
- Proliferation of B lymphocytes with non-complementary receptors remain inactive
- Plasma cells secrete antibody molecules

**Secondary Response**
- Can be years later
- Clone of cells identical to ancestral cells
- Plasma cells secrete antibody molecules

Figure 12.10
Humoral Immune Response

Primary Response (initial encounter with antigen)
- Antigen binding to a receptor on a specific B lymphocyte (B lymphocytes with non-complementary receptors remain inactive)

B lymphoblasts
- Proliferation to form a clone

Plasma cells
- Secreted antibody molecules

Secondary Response (can be years later)
- Clone of cells identical to ancestral cells

Plasma cells
- Secreted antibody molecules

Memory B cell
- Subsequent challenge by same antigen

Figure 12.10
Humoral Immune Response

**Primary Response**
(initial encounter with antigen)

- **Antigen** binding to a receptor on a specific B lymphocyte (B lymphocytes with non-complementary receptors remain inactive)

- **B lymphoblasts**
  - Proliferation to form a clone

- **Plasma cells**
  - Secreted antibody molecules

**Secondary Response**
(can be years later)

- **Clone of cells identical to ancestral cells**

- **Plasma cells**
  - Secreted antibody molecules

- **Memory B cells**

**Subsequent challenge by same antigen**

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Figure 12.10

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*Slide 12.32*
Secondary Response

Figure 12.11

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Cellular (Cell-Mediated) Immune Response

Figure 12.15
Cellular (Cell-Mediated) Immune Response

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Cellular (Cell-Mediated) Immune Response

Figure 12.15
Cellular (Cell-Mediated) Immune Response

- Recruit other cells to fight the invaders
- Interact directly with B cells

Figure 12.15
Cellular (Cell-Mediated) Immune Response

Figure 12.15
Cellular (Cell-Mediated) Immune Response

- Specialize in killing infected cells
- Insert a toxic chemical (perforin)

Figure 12.15
Cellular (Cell-Mediated) Immune Response

Figure 12.15
Cellular (Cell-Mediated) Immune Response

Figure 12.15
Cellular (Cell-Mediated) Immune Response

Figure 12.15
Summary of the Immune Response

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**Humoral (Antibody-Mediated) Immune Response**
- Antigen (1st exposure) engulfed by macrophage.
- Macrophage becomes antigen-presenting cell.
- Antigen-presenting cell stimulates helper T cell.
- Helper T cell stimulates B cell.
- B cell gives rise to plasma cells.
- Plasma cells secrete antibodies.
- Antibodies defend against extracellular pathogens by binding to antigens and making them easier targets for phagocytes and complement.

**Cell-Mediated Immune Response**
- Antigens displayed by infected cells activate cytotoxic T cell.
- Cytotoxic T cell gives rise to active cytotoxic T cells.
- Active cytotoxic T cells defend against intracellular pathogens and cancer by binding to and lysing the infected cells or cancer cells.

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Figure 12.16
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Figure 12.12

- Acquired immunity
  - Naturally acquired
  - Artificially acquired
Figure 12.12
Figure 12.12

Acquired immunity

Naturally acquired

Active Infection; contact with pathogen

Artificially acquired

Active Vaccine; dead or attenuated pathogens
Figure 12.12

Diagram showing the branches of acquired immunity.

- **Active Infection**: Contact with pathogen.
- **Passive Antibodies**: Pass from mother to fetus via placenta; or to infant in her milk.
- **Active Vaccine**: Dead or attenuated pathogens.
Acquired immunity

Naturally acquired

Active
Infection; contact with pathogen

Passive
Antibodies pass from mother to fetus via placenta; or to infant in her milk

Artificially acquired

Active
Vaccine; dead or attenuated pathogens

Passive
Injection of immune serum (gamma globulin)

Figure 12.12