Chapter 23

The Lymphatic System

Lecture Presentation by
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Introduction

• The lymphatic system consists of:
  • Lymph
  • Lymphatic vessels
  • Lymphoid organs
An Overview of the Lymphatic System

- Lymph consists of:
  - Interstitial fluid
  - Lymphocytes
  - Macrophages

- Lymphatic vessels:
  - Pass through lymphoid tissue
  - Pass through lymphoid organs
An Overview of the Lymphatic System

- Lymphoid Organs or Tissue
  - Primary organs or tissue
    - Thymus
    - Bone marrow
  - Secondary organs or tissue
    - Tonsils
    - Nodes
      - Axillary, lumbar, pelvic, inguinal
    - Spleen
    - Mucosa-associated lymphoid tissue
Figure 23.1 Lymphatic System

- Lymphatics of upper limb
- Axillary lymph nodes
- Thoracic duct
- Thoracic (left lymphatic) duct
- Lymphatics of mammary gland
- Spleen
- Mucosa-associated lymphoid tissue (MALT)
- Pelvic lymph nodes
- Inguinal lymph nodes
- Lumbar lymph nodes
- Cisterna chyli
- Right lymphatic duct
- Thymus
- Cervical lymph nodes
- Tonsil
- Lymphatics of lower limb
An Overview of the Lymphatic System

- Functions of the Lymphatic System
  - Produce, maintain, and distribute lymphocytes
  - Maintain normal blood volume and the normal composition of the interstitial fluid
  - Provide an alternative route for the transport of
    - Hormones
    - Nutrients
    - Waste
An Overview of the Lymphatic System

• Functions of the Lymphatic System
  
  • Primary lymphoid structures (central structures)
    • Causes differentiation of lymphocytes resulting in
      • **T cells**, **B cells**, and **NK cells**
  
  • Secondary lymphoid structures (peripheral structures)
    • Considered to be the “front line” of defense
    • Consist of lymphocytes and more B cells to battle infectious agents

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An Overview of the Lymphatic System

• Functions of the Lymphatic System
  • The maintenance of normal blood volume and chemical composition of the interstitial fluid
    • The blood pressure in capillaries is about 35 mm Hg
      • This pressure forces solutes and waste out of the plasma into the interstitial fluid area
    • Some interstitial fluid enters the lymphatic system
    • The lymphatic system eventually connects with the venous system

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A three-dimensional view of the association of blood capillaries and lymphatic capillaries. Arrows show the direction of blood, interstitial fluid, and lymph movement.
An Overview of the Lymphatic System

• Functions of the Lymphatic System
  • Provides an alternative route for the transport of:
    • Hormones
    • Nutrients
      • For example: some lipids are absorbed by the digestive tract and carried to the bloodstream via the lymphatic vessels
    • Waste products
Sectional view through a cluster of lymphatic capillaries.

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Structure of Lymphatic Vessels

• Small lymphatic vessels are called:
  • Lymphatic capillaries

• Large-diameter lymphatic vessels are called:
  • Lymphatic ducts
Structure of Lymphatic Vessels

- Lymphatic Capillaries
  - Comparisons to the vascular capillaries
    - Lymphatic capillaries are larger in diameter
    - Lymphatic capillaries have thinner walls
    - Lymphatic capillaries have an irregular outline
    - Lymphatic capillaries have anchoring filaments that connect to the surrounding connective tissue to keep the capillaries open
    - Lymphatic capillaries have greater permeability
A diagrammatic view of loose connective tissue showing small blood vessels and a lymphatic vessel. Arrows indicate the direction of lymph flow.

Histology of a lymphatic vessel. Lymphatic valves resemble those of the venous system. Each valve consists of a pair of flaps that permit fluid movement in only one direction.
Figure 23.3ac Lymphatic Vessels and Valves

A diagrammatic view of loose connective tissue showing small blood vessels and a lymphatic vessel. Arrows indicate the direction of lymph flow.

The cross-sectional view emphasizes the structural differences between blood vessels and lymphatic vessels.
Structure of Lymphatic Vessels

• Valves of Lymphatic Vessels
  • Comparing larger lymphatics to veins
    • Lymphatic vessels have thinner walls
    • Lymphatic vessels have larger lumens
    • Lymphatic vessels do not have easily identifiable tunics
    • Larger lymphatic vessels have valves just like most veins have
Histology of a lymphatic vessel. Lymphatic valves resemble those of the venous system. Each valve consists of a pair of flaps that permit fluid movement in only one direction.
Structure of Lymphatic Vessels

• Valves of Lymphatic Vessels
  • Pressure in the lymphatic vessels is lower than the pressure in the veins
  • Valves prevent the backflow of lymph
  • Skeletal muscles contract to help propel lymph
  • Inhalation decreases thoracic pressure, which helps to move lymph toward the venous system (subclavians)
Major Lymph-Collecting Vessels

• Two Sets of Lymphatic Vessels
  • Superficial lymphatics
    • Found in the subcutaneous layer
    • Found in the mucous lining of the digestive, respiratory, urinary, and reproductive tracts
    • Found in the serous lining of the pleural, pericardial, and peritoneal cavities
  • Deep lymphatics
    • Collect lymph from skeletal muscles and tissues of the neck, limbs, trunk, and visceral organs
Major Lymph-Collecting Vessels

• The superficial and deep lymphatic vessels converge to form **lymphatic trunks**
  • There are five major lymphatic trunks
    • Lumbar trunks
    • Intestinal trunks
    • Bronchomediastinal trunks
    • Subclavian trunks
    • Jugular trunks
The collecting system of lymph vessels, lymph nodes, and major lymphatic collecting ducts and their relationship to the brachiocephalic veins.
Major Lymph-Collecting Vessels

• The Thoracic Duct
  • Drains into the left subclavian vein
    • Drains lymph inferior to the diaphragm
    • Drains lymph from
      • Left arm
      • Left side of the torso
      • Left side of the neck
      • Left side of the head
      • Abdomen
      • Both legs
The collecting system of lymph vessels, lymph nodes, and major lymphatic collecting ducts and their relationship to the brachiocephalic veins.
The thoracic duct collects lymph from tissues inferior to the diaphragm and from the left side of the upper body. The right lymphatic duct drains the right half of the body superior to the diaphragm.
Major Lymph-Collecting Vessels

• The Thoracic Duct
  • Begins with a saclike structure called the *cisterna chyli*
  • Collects lymph from
    • Left and right lumbar trunks
    • Intestinal trunks
    • Left bronchomediastinal trunk
    • Left subclavian trunk
    • Left jugular trunk
Major Lymph-Collecting Vessels

- The Right Lymphatic Duct
  - Drains into the right subclavian vein
    - Drains lymph from
      - Right arm
      - Right side of the torso
      - Right side of the neck
      - Right side of the head
The collecting system of lymph vessels, lymph nodes, and major lymphatic collecting ducts and their relationship to the brachiocephalic veins.
Major Lymph-Collecting Vessels

- Right Lymphatic Duct
  - Collects lymph from
    - The right bronchomediastinal trunk
    - The right subclavian trunk
    - The right jugular trunk
Lymphocytes

• Lymphocytes are the primary cells of the lymphatic system
  • They respond to:
    • Invading bacteria and viruses
    • Abnormal body cells such as cancer cells
    • Foreign proteins such as toxins released by some bacteria
Lymphocytes

• Types of Lymphocytes
  • T cells (Thymus-dependent cells)
  • B cells (bone marrow–derived cells)
  • NK cells (natural killer cells)
Lymphocytes

• T Cells
  • Originate in the bone marrow but travel to the thymus gland and become activated (immunocompetent) by thymosin
  • Different types of T cells
    • Cytotoxic T cells
    • Helper T cells
    • Suppressor T cells
    • Memory T cells
Lymphocytes

• T Cells
  • Different types of T cells
    • Cytotoxic T cells
      • Attack foreign cells and viruses
    • Helper T cells
      • Enhance antibody production
    • Suppressor T cells
      • Inhibit antibody production
  • Memory T cells
    • Become activated if the same antigen appears in the body at a later date
Lymphocytes

• **B Cells**
  - Originate and become immunocompetent in the bone marrow
  - Can differentiate to form
    - **Plasmocytes**
      - Produce antibodies that react with antigens
      - Antibodies are also called immunoglobulins
    - **Memory B cells**
      - Become activated if the same antigen appears at a later date
Lymphocytes

• **NK Cells**
  • Attack foreign cells
  • Attack normal cells that are infected with viruses
  • Attack cancer cells
  • NK cells are often called *immunological surveillance cells*
Lymphocyte formation, or **lymphopoiesis**, involves the red bone marrow, thymus, and peripheral lymphoid tissues. Of these, the red bone marrow plays the primary role in the maintenance of normal lymphocyte populations. Pluripotential stem cells in the red bone marrow produce lymphoid stem cells with two distinct fates.

**Red Bone Marrow**

One group of lymphoid stem cells remains in the bone marrow, producing daughter cells that mature into NK (natural killer) cells and B cells under the influence of interleukin-7.

**Thymus**

The second group of lymphoid stem cells migrates to the thymus, where subsequent divisions produce daughter cells that mature into T cells under the influence of thymic hormones.

**Peripheral Tissues**

All three types of lymphocytes circulate throughout the body, detecting and responding to toxins and pathogens that threaten homeostasis. Each type of lymphocyte makes a specific contribution to immunity.
Lymphocytes

• Lymphocytes and the Immune Response
• There are two response mechanisms
  • Cell-mediated immunity
    • T cells directly attach the pathogen
  • Antibody-mediated immunity
    • Pathogen is attacked by antibodies produced by B cells
Lymphocytes

• Lymphocytes and the Immune Response
  • The following is a sequence of events involved in the immune response to a bacterial antigen (for example)
    • Macrophages will phagocytize the foreign substance
    • Macrophages will present the antigen to specific T cells
      • This is called antigen presentation
    • T cells begin to divide to produce cytotoxic T cells, helper T cells, and memory T cells
Lymphocytes and the Immune Response (continued)

- The cytotoxic T cells will kill the bacterial agent directly
- The helper T cells will activate the B cells
- B cells will begin producing antibodies against the bacterial antigens
- Antibodies will bind to the bacterial antigens
- This antigen–antibody combination will attract an “army” of leukocytes
- These leukocytes will kill the bacteria
Lymphocytes

• Distribution and Life Span of Lymphocytes
  • Ratio of T cells to B cells
    • In the blood = 8:1
    • In the spleen = 1:1
    • In the bone marrow = 1:3
  • Life span
    • Most live 4 to 20 years
Lymphocytes

- Lymphopoiesis: Lymphocyte Production
  - The pluripotential stem cells produce two sets of lymphoid stem cells each with a different fate
  - One set of lymphoid stem cells will:
    - Migrate to the thymus gland
    - Upon exposure to thymosin, the lymphocytes will mature to form T cells
    - Mature T cells will reside in peripheral tissue or circulate throughout the body
Lymphocytes

• Lymphopoiesis: Lymphocyte Production (continued)
  • The other set of lymphoid stem cells will
    • stay in the bone and differentiate to form B cells and NK cells
      • B cells produce antibodies
      • NK cells act as immunological surveillance cells
    • Both will reside in peripheral tissues or circulate throughout the body
Lymphocyte formation, or \textit{lymphopoiesis}, involves the red bone marrow, thymus, and peripheral lymphoid tissues. Of these, the red bone marrow plays the primary role in the maintenance of normal lymphocyte populations. Pluripotential stem cells in the red bone marrow produce lymphoid stem cells with two distinct fates.

**Red Bone Marrow**

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**Thymus**

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**Peripheral Tissues**

All three types of lymphocytes circulate throughout the body, detecting and responding to toxins and pathogens that threaten homeostasis. Each type of lymphocyte makes a specific contribution to immunity.

- **Immunological surveillance**: NK (natural killer) cells attack foreign cells, body cells infected by viruses, and cancer cells. They secrete chemicals that lyse the plasmalemma of the abnormal cells.

- **Antibody-mediated immunity**: When stimulated, B cells can differentiate into \textit{plasmocytes} (plasma cells), which produce and secrete antibodies. These antibodies attach to pathogens, abnormal cells, or other specific targets. This attachment starts a chain reaction that leads to the destruction of the target.

- **Cell-mediated immunity**: One type of mature T cell, called \textit{cytotoxic T cells}, is responsible for cell-mediated immunity. These cells attack and destroy foreign cells or body cells infected by viruses.
Lymphoid Tissues

• Lymphoid Tissue Characteristics
  • Tissue dominated by lymphocytes
  • Lymphocytes are loosely aggregated within connective tissue

• Lymphoid Nodule Characteristics
  • Lymphocytes aggregated within a supporting framework of reticular fibers
  • Nodules have a germinal center, which contains the lymphocytes
The location of the tonsils and the histological organization of a single tonsil

- Pharyngeal tonsil
- Palate
- Palatine tonsil
- Lingual tonsil

- Pharyngeal epithelium
- Germinal centers within nodules
Lymphoid Tissues

- Types of Nodules
  - Mucosa-associated lymphoid tissue (MALT)
  - Tonsils
    - Pharyngeal tonsil
    - Palatine tonsils
    - Lingual tonsils
  - Aggregated lymphoid nodules (Peyer’s patches and appendix)
Lymphoid Tissues

• **Mucosa-associated lymphoid tissue (MALT)**
  • Lymphoid nodules associated with the digestive tract

• **Tonsils**
  • There are five sets of tonsils
    • One pharyngeal tonsil
    • Two palatine tonsils
    • Two lingual tonsils

• **Aggregated lymphoid nodules** (Peyer’s patches and appendix)
  • Lymphoid nodules associated with the small intestine

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Lymphoid Organs

- Lymphoid organs include:
  - Lymph nodes
  - Thymus gland
  - Spleen

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Figure 23.1 Lymphatic System

- Tonsil
- Cervical lymph nodes
- Right lymphatic duct
- Thymus
- Thoracic duct
- Cisterna chyli
- Lumbar lymph nodes
- Lymphatics of upper limb
- Axillary lymph nodes
- Thoracic (left lymphatic) duct
- Lymphatics of mammary gland
- Spleen
- Mucosa-associated lymphoid tissue (MALT)
- Pelvic lymph nodes
- Inguinal lymph nodes
- Lymphatics of lower limb
Lymphoid Organs

- Lymph Nodes
  - 1 to 25 mm in diameter
  - Scattered throughout the body but high concentrations can be found in the following areas:
    - Cervical region
    - Axillary region
    - Breasts
    - Abdominal region
    - Inguinal region
Lymphoid Organs

• Structure of a Lymph Node
  • Lymph nodes consist of
    • **Capsule** with **afferent** vessels
    • Subcapsular space
    • Outer cortex
    • Germinal center
    • Medulla
    • Medullary cords
    • **Hilum** with **efferent** vessels
Figure 23.8 Structure of a Lymph Node

- Lymph vessel
- Lymph nodes
- Efferent vessel
- Lymph node artery and vein
- Hilum
- Medullary sinus
- Outer cortex (B cells)
- Subcapsular space
- Capsule
- Medullary cord (B cells and plasmocytes)
- Afferent vessel
- Deep cortex (T cells)
- Cortex
- Trabeculae
- Medulla
- Capsule
- Dividing B cell
- Germinal center
- Outer cortex
- Subcapsular space
- Capsule
- Dendritic cells
- Nuclei of B cells
- Capillary
Lymphoid Organs

• Distribution of Lymphoid Tissues and Lymph Nodes
  • Lymphoid tissue and lymph nodes are in high concentrations where the body is more susceptible to injury or invasion
Lymphoid Organs

• Distribution of Lymphoid Tissues and Lymph Nodes
  • **Cervical lymph nodes**
    • Found in the head and neck region
  • **Axillary lymph nodes**
    • Found in the axillary region
    • Filter lymph from the trunk and arms
    • In women, filters lymph from the mammary glands
  • **Popliteal lymph nodes**
    • Filter lymph from the legs
Superficial lymphatic vessels and nodes that drain the upper limb and chest of a male.
Superficial and deeper lymphatic vessels and nodes of the upper limb and chest of a female
Figure 23.11 Lymphatic Drainage of the Lower Limb

- Superficial inguinal lymph nodes
- Deep inguinal lymph nodes
- Great saphenous vein
- Popliteal lymph nodes
Lymphoid Organs

• Distribution of Lymphoid Tissues and Lymph Nodes
  • Inguinal lymph nodes
    • Filter lymph from the lower limbs and trunk
  • Thoracic lymph nodes
    • Filter lymph from the lungs, respiratory passageways, and mediastinal structures
  • Abdominal lymph nodes
    • Filter lymph from the urinary and reproductive systems
Figure 23.13a Lymphatic Drainage of the Inguinal Region

An anterior view of a dissection of the inguinal lymph nodes and vessels

- Inguinal ligament
- Femoral artery
- Deep inguinal lymph nodes
- Great saphenous vein
Figure 23.1 Lymphatic System

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- Lumbar lymph nodes
- Thymus
- Cisterna chyli
- Thoracic duct
- Right lymphatic duct
- Cervical lymph nodes
- Tonsil
Lymphoid Organs

• Distribution of Lymphoid Tissues and Lymph Nodes
  • **Intestinal lymph nodes**
    • Filter lymph from the digestive tract
  • **Mesenterial lymph nodes**
    • Filter lymph from the digestive tract
Figure 23.14 Lymph Nodes in the Large Intestine and Associated Mesenteries

- Transverse colon
- Superior mesenteric lymph nodes
- Ascending colon
- Ileocolic lymph nodes
- Ileum
- Cecum
- Appendicular lymph nodes
- Appendix
- Transverse mesocolic lymph nodes
- Superior mesenteric artery
- Distal portion of duodenum
- Inferior mesenteric artery
- Inferior mesenteric lymph nodes
- Descending colon
- Sigmoid colon
- Rectum
Lymphoid Organs

• The Thymus
  • Lies posterior to the manubrium of the sternum
  • Reaches its greatest size by age 1 or 2
  • Reaches maximum size by puberty
  • Diminishes in size after puberty
  • Consists of two thymic lobes (left and right)
  • Consists of numerous lobules (about 2 mm in width) separated by septa
  • Consists of a cortex and a medulla
Lymphoid Organs

• The Thymus (continued)
  • The cortex consists of:
    • Stem cells that differentiate to form T cells
    • Mature T cells migrate to the medulla
  • The medulla consists of:
    • T cells that remain inactive until they enter circulation
    • Thymic corpuscles (function is unknown)
The location of the thymus on gross dissection; note the relationship to other organs in the chest.
Anatomical landmarks on the thymus.
Histology of the thymus. Note the fibrous septa that divide the thymic tissue into lobules resembling interconnected lymphoid nodules.
Histology of the unusual structure of thymic corpuscles. The small cells in view are lymphocytes in various stages of development.
Lymphoid Organs

• The Spleen
  • Largest lymphoid organ (12 cm in length)
  • Located on the left edge of the stomach
  • Attached to the stomach via the gastroplenic ligament
Figure 23.1 Lymphatic System

- Lymphatics of upper limb
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- Tonsil
Lymphoid Organs

• The Spleen
  • Consists of the following areas or regions
    • Diaphragmatic surface
    • Visceral surface
      • The visceral surface contains the hilum
b External appearance of the visceral surface of the intact spleen showing major anatomical landmarks. This view should be compared with that of part (a).
Lymphoid Organs

• Histology of the Spleen
  • The spleen consists of:
    • Capsule
    • Red pulp
      • Contains large quantities of red blood cells
    • White pulp
      • Forms lymphoid nodules
Histological appearance of the spleen. Areas of white pulp are dominated by lymphocytes. Areas of red pulp contain a preponderance of red blood cells.
Aging and the Lymphatic System

• As we age:
  • T cells become less responsive to antigens
  • B cells then become less responsive as well
  • Thymus gland diminishes in size