The Lymphatic and Immune Systems

Chapter 21
The Lymphatic and Immune Systems

• Lymphatic system
  – Main function is to return excess tissue fluid to blood vascular system
  – **Lymphatic vessels** collect tissue fluid

• Immune system
  – Protects our bodies from foreign organisms
  – Confers immunity to disease
  – Main components
    • Lymphocytes, lymphoid tissue, and lymphoid organs
The Lymphatic System

• **Lymphatic vessels** collect tissue fluid from loose connective tissue
  – Carry fluid to great veins in the neck
  – Fluid flows only toward the heart
  – Once tissue fluid is within lymphatic vessels it is termed **lymph**

• Functions of lymphatic vessels – collect excess tissue fluid and blood proteins

• Return tissue fluid and blood proteins to bloodstream
Orders of Lymphatic Vessels

• **Lymph capillaries** – smallest lymph vessels
  – First to receive lymph

• **Lymphatic collecting vessels** – collect from lymph capillaries
  – **Lymph nodes** are scattered along collection vessels

(a) Structural relationship between a capillary bed of the blood vascular system and lymphatic capillaries
Orders of Lymphatic Vessels

• Lymph nodes
  – Scattered along collecting vessels

• Lymph trunks
  – Collect lymph from collecting vessels

• Lymph ducts
  – Empty into veins of the neck
Lymphatic Capillaries

• Located near blood capillaries

• Receive tissue fluid from CT
  – Increased volume of tissue fluid
    • Minivalve flaps open and allow fluid to enter

• High permeability allows entrance of
  – Tissue fluid and protein molecules
  – Bacteria, viruses, and cancer cells
Lymphatic Capillaries

• **Lacteals**—specialized lymphatic capillaries
  – Located in the villi of the small intestines
    • Receive digested fats
    • Fatty lymph—**chyle**
Distribution and Features of Lymphatic Capillaries

(a) Structural relationship between a capillary bed of the blood vascular system and lymphatic capillaries

(b) Lymphatic capillaries are blind-ended tubes in which adjacent endothelial cells overlap each other, forming flaplike minivalves.
Lymphatic Collecting Vessels

• Accompany blood vessels

• Composed of the same three tunics as blood vessels

• Contain *more valves* than veins do
  – Helps direct the flow of blood

• Lymph propelled by
  – Skeletal muscles bulging
  – Nearby arteries pulsing
  – Tunica media of the lymph vessels

• Lymph flow is unaided by heartbeat
Lymph Nodes

• Cleanse the lymph of pathogens
• Human body contains around 500
• Superficial lymph nodes located in
  – Cervical, axillary, and inguinal regions
• Deep nodes are
  – Tracheobronchial, aortic, and iliac lymph nodes
General Distribution of Lymphatic Collecting Vessels and Regional Lymph Nodes

- **Internal jugular vein**
- **Entrance of right lymphatic duct into vein**
- **Entrance of thoracic duct into vein**
- **Thoracic duct**
- **Cisterna chyli**
- **Lymphatic collecting vessels**

**Regional lymph nodes**
- **Cervical nodes**
- **Axillary nodes**
- **Inguinal nodes**

- Drained by the right lymphatic duct
- Drained by the thoracic duct
Microscopic Anatomy of a Lymph Node

• Fibrous capsule—surrounds lymph nodes

• Trabeculae—connective tissue strands

• Lymph vessels
  – Afferent lymphatic vessels
  – Efferent lymphatic vessels
Microscopic Anatomy of a Lymph Node

(a) Longitudinal view of the internal structure of a lymph node and associated lymphatics

- Afferent lymphatic vessels
- Cortex
  - Lymphoid follicle
  - Germinal center
  - Subcapsular sinus
- Efferent lymphatic vessels
- Hilum
- Medulla
  - Medullary cord
  - Medullary sinus
- Capsule
- Trabeculae
Microscopic Anatomy of a Lymph Node

(b) Photomicrograph of part of a lymph node (14X)
Microscopic Anatomy of a Lymph Node

Figure 21.3c

(c) Reticular tissue within the medullary sinus (540X)
Lymph Trunks

• Lymphatic collecting vessels converge

• Five major lymph trunks
  – Lumbar trunks
    • Receives lymph from lower limbs
  – Intestinal trunk
    • Receives chyle from digestive organs
  – Bronchomediastinal trunks
    • Collects lymph from thoracic viscera
Lymph Trunks

• Five major lymph trunks (continued)
  – Subclavian trunks
    • Receive lymph from upper limbs and thoracic wall
  – Jugular trunks
    • Drain lymph from the head and neck
The Lymphatic Trunks

(a) Major lymphatic trunks and ducts in relation to veins and surrounding structures, anterior view
The Lymphatic Trunks

(b) Thoracic duct (colored green) along the posterior thoracic wall
Lymph Ducts

• Cisterna chyli
  – Located at the union of lumbar and intestinal trunks

• Thoracic duct
  – Ascends along vertebral bodies
  – Empties into venous circulation
    • Junction of left internal jugular and left subclavian veins
    • Drains three quarters of the body
Right Lymphatic Duct

- Empties into right internal jugular and subclavian veins
The Immune System

• Recognizes specific foreign molecules
• Destroys pathogens effectively
• Key cells—*lymphocytes*
• Also includes lymphoid tissue and lymphoid organs
• Lymphoid organs
  – Lymph nodes, spleen, thymus, tonsils, aggregated lymphoid nodules, and appendix
Lymphocytes

- Infectious organisms attacked by inflammatory response
  - Macrophages, then lymphocytes

- Are effective fighters of infectious organisms
  - Each lymphocyte recognizes a specific foreign molecule
    - *Antigens* are any molecules inducing a response from a lymphocyte
Lymphocytes

• B lymphocytes and T lymphocytes are the two main classes of lymphocytes

• Cytotoxic T lymphocytes
  – Attack foreign cells directly
    • Binds to antigen-bearing cells
    • Perforates cell membrane
    • Signals cell to undergo apoptosis
    • Destroy virus infected cells and some cancer cells
Lymphocytes

- B lymphocytes
  - Become plasma cells
  - Secrete antibodies
    - Mark cells for destruction by macrophages
  - Respond primarily to bacteria and bacterial toxins
Lymphocyte Function

(a) Action of cytotoxic T lymphocyte

1. T lymphocyte binds to target cell, secretes proteins that lyse the cell’s membrane, and signals the cell to die.

(b) Differentiation and activity of B lymphocyte

1. B lymphocyte gives rise to plasma cell, which secretes antibodies.

2. Antibodies bind to antigens on bacteria, marking the bacteria for destruction.

3. Antibody-coated bacteria are avidly phagocytized.
Lymphocyte Activation

• Lymphocytes originate in bone marrow
• Some travel to the thymus gland
  – T lymphocytes
• Some stay in bone marrow
  – B lymphocytes
• Able to recognize a unique antigen
  – Gain immunocompetence
  • Travels through blood stream
    – Meets and binds to a specific antigen
Lymphocyte Activation

• During activation
  – Lymphocyte is presented its antigen by
    • A macrophage
    • Or a dendritic cell
Lymphocyte Activation

- Both T and B lymphocytes produce clones of
  - **Effector lymphocytes**
    - Respond immediately, then die
  - **Memory cells**
    - Wait until the body encounters the antigen again
    - Basis of acquired immunity
    - Prevent subsequent infections of the same illness
Lymphocytes destined to become T cells migrate (in blood) to the thymus and develop immunocompetence there. B cells develop immunocompetence in red bone marrow.

- **Red bone marrow**: site of lymphocyte origin
- **Primary lymphoid organs**: site of development of immunocompetence as B or T cells
- **Secondary lymphoid organs**: site of antigen encounter, and activation to become effector and memory B or T cells

Immunocompetent but still naive lymphocytes leave the thymus and bone marrow. They “seed” the lymph nodes, spleen, and other lymphoid tissues where they encounter their antigen.

Antigen-activated immunocompetent lymphocytes (effector cells and memory cells) circulate continuously in the bloodstream and lymph and throughout the lymphoid organs of the body.
Lymphoid Tissue

• Most important tissue of the immune system

• Two general locations
  – Mucous membranes of
    • Digestive, urinary, respiratory, and reproductive tracts
      – Mucosa-associated lymphoid tissue (MALT)
    • Lymphoid organs (except thymus)
Lymphoid Tissue

Lymphoid tissue from mucosa of small intestine (14x)

Figure 21.7
Lymphoid Organs

• Primary lymphoid organs
  – Bone marrow
  – Thymus

• Secondary lymphoid organs
  – Lymph nodes, spleen, tonsils
  – Aggregated lymphoid nodules
  – Appendix
Lymphoid Organs

- Designed to gather and destroy infectious microorganisms and to store lymphocytes
Thymus

• Immature lymphocytes develop into T lymphocytes
• Secretes thymic hormones
• Most active in childhood
• Functional tissue atrophies with age
• Composed of cortex and medulla
  – Medulla contains Hassall’s corpuscles (thymic corpuscles)
• Differs from other lymphoid organs
  – Functions strictly in lymphocyte maturation
  – Arises from epithelial tissue
Thymus

(a) Thymus located in the superior mediastinum

(b) Micrograph of thymic tissue showing part of a lobule
Lymph Nodes

• Function
  – Lymph percolates through lymph sinuses
  – Most antigenic challenges occur in lymph nodes
  – Antigens destroyed and activate B and T lymphocytes
Spleen

• Largest lymphoid organ

• Two main *blood-cleansing functions*
  – Removal of blood-borne antigens
  – Removal and destruction of old or defective blood cells

• Site of hematopoiesis in the fetus
Spleen

• Destruction of antigens
• Site of B cell maturation into plasma cells
• Phagocytosis of bacteria and worn-out RBCs, WBCs and platelets
• Storage of platelets
Spleen

• White pulp
  – Thick sleeves of lymphoid tissue
  – Blood-borne antigens are destroyed as they activate the immune response
  – Provides the immune function of the spleen

• Red pulp
  – Surrounds white pulp
  – Composed of
    • Venous sinuses
    • Splenic cords
    • Responsible for disposing of worn out RBCs
Spleen

(a) Diagram of the spleen, anterior view

(b) Diagram of spleen histology

Capsule
Trabecula
Splenic cords
Venous sinuses
Arterioles and capillaries
Red pulp
White pulp
Central artery
Splenic artery
Splenic vein
Spleen

(c) Photograph of the spleen in its normal position in the abdominal cavity, anterior view

(d) Photomicrograph of spleen tissue (7×). The white pulp, a lymphoid tissue with many lymphocytes, is surrounded by red pulp containing abundant erythrocytes.
Tonsils

• Simplest lymphoid organs

• Four groups of tonsils
  – Palatine, lingual, pharyngeal, and tubal tonsils

• Arranged in a ring to gather and remove pathogens

• Underlying lamina propria consists of MALT
Palatine Tonsil

Figure 21.11
Aggregated Lymphoid Nodules & Appendix

• MALT—abundant in walls of intestines
• Fight invading bacteria
• Generate a wide variety of memory lymphocytes
  – Aggregated lymphoid nodules (Peyer’s patches)
    • Located in the distal part of the small intestine
  – Appendix—tubular offshoot of the cecum
Aggregated Lymphoid Nodule

Aggregated lymphoid nodules (Peyer’s patch)

Smooth muscle in the intestinal wall
Disorders of the Lymphatic and Immune Systems

• Chylothorax
  – Leakage of fatty lymph into the thorax

• Lymphangitis
  – Inflammation of a lymph vessel

• Mononucleosis
  – Viral disease caused by Epstein-Barr virus
  – Attacks B lymphocytes
Disorders of the Lymphatic and Immune Systems

• Hodgkin’s disease
  – Malignancy of lymph nodes

• Non-Hodgkin’s lymphoma
  – Uncontrolled multiplication and metastasis of undifferentiated lymphocytes
The Lymphatic and Immune Systems Throughout Life

• Lymphatic vessels and lymph nodes
  – Develop from lymphatic sacs

• Thymus originates as an outgrowth of the endoderm

• Spleen, lymph nodes, and MALT
  – Arise from mesodermal mesenchyme