The Lymphoid System

23

PowerPoint® Lecture Presentations prepared by
Steven Bassett
Southeast Community College
Lincoln, Nebraska

© 2012 Pearson Education, Inc.
Introduction

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

- Lymph consists of:
  - Interstitial fluid
  - Lymphocytes
  - Macrophages
An Overview of the Lymphoid System

• Functions of the Lymphoid System
  • Primary lymphoid structure (thymus gland)
    • Causes differentiation of lymphocytes resulting in:
      • T cells, B cells, and NK cells
  • Secondary lymphoid structures (lymph nodes and tonsils)
    • Consist of lymphocytes and more B cells to battle infectious agents
An Overview of the Lymphoid System

• Functions of the Lymphoid System (continued)
  • Maintains normal blood volume
  • Maintains chemical composition of the interstitial fluid
  • Provides an alternative route for the transport of:
    • Hormones
    • Nutrients
    • Waste products
An Overview of the Lymphoid System

- Functions of the Lymphoid System (details)
  - 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 lymphoid system
  - The lymphoid system eventually connects with the venous system
Figure 23.2a Lymphatic Capillaries

A three-dimensional view of the association of blood capillaries and lymphatic capillaries. Arrows show the direction of blood, interstitial fluid, and lymph movement.
Sectional view through a cluster of lymphatic capillaries
Figure 23.1 Lymphoid 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

© 2012 Pearson Education, Inc.
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**
Figure 23.3ac  Lymphatic Vessels and Valves

Lymphatic vessel
Vein
Artery

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

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

• Comparisons of lymphatic vessels 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)
Structure of Lymphatic Vessels

• Major Lymph-Collecting Vessels
  • There are two sets of lymph vessels (superficial lymphatics and deep lymphatics)
• 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
Structure of Lymphatic Vessels

• Major Lymph-Collecting Vessels (continued)
  • There are two sets of lymph vessels (superficial lymphatics and deep lymphatics)
  • **Deep lymphatics**
    • Collect lymph from skeletal muscles and tissues of the neck, limbs, and trunk
Structure of Lymphatic Vessels

• Major Lymph-Collecting Vessels (continued)
  • 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
Structure of Lymphatic Vessels

• Major Lymph-Collecting Vessels (continued)
  • The lymphatic trunks drain into **lymphatic ducts**
  • Lymphatic ducts drain into the subclavians
The collecting system of lymph vessels, lymph nodes, and major lymphatic collecting ducts and their relationship to the brachiocephalic veins.
Structure of Lymphatic Vessels

• The Lymphatic Ducts
  • There are two lymphatic ducts (thoracic duct and right lymphatic duct)
  • **Thoracic duct** (drains into the left subclavian vein)
    • Drains lymph inferior to the diaphragm
    • Drains lymph from the left arm, left side of the torso, left side of the neck, and left side of the head
  • **Right lymphatic duct** (drains into the right subclavian vein)
    • Drains lymph from the right arm, right side of the torso, right side of the neck, and right side of the head
Structure of Lymphatic Vessels

• The Lymphatic Ducts
  • **Thoracic duct**
    • Begins with a saclike structure called the *cisterna chyli*
    • Collects lymph from the left and right lumbar trunks, intestinal trunks, left bronchomediastinal trunk, left subclavian trunk, and left jugular trunk
  • **Right lymphatic duct**
    • Collects lymph from the right bronchomediastinal trunk, right subclavian trunk, and right jugular trunk
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.
Figure 23.5 Major Lymphatic Vessels of the Trunk

- Thoracic aorta
- Thoracic duct
- Pleura
- Cut edge of diaphragm (removed)
- Thoracic aorta entering aortic hiatus
- First lumbar vertebra
- Right renal artery
- Cisterna chyli
- Abdominal aorta
Lymphocytes

- Lymphocytes are the primary cells of the lymphoid 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** (attack foreign cells and viruses)
    - **Helper T cells** (coordinates the immune response)
    - **Suppressor T cells** (coordinate the immune response)
    - **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 and memory B cells

• **Plasmocytes**
  - Produce antibodies that react with antigens
  - Antibodies are 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
Lymphocytes

• **Cell-mediated immunity**
  • Since the attack is a direct cell-to-cell attack, it is known as cellular immunity

• **Antibody-mediated immunity**
  • Since blood is the main transport for the antibodies, it is known as humoral immunity
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 are activated by the antigen
    • Macrophages will phagocytize the foreign substance
    • Macrophages will present the antigen to specific T cells
    • T cells begin to divide to produce cytotoxic T cells, helper T cells, and memory T cells
Lymphocytes

- 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
Defenses against bacterial pathogens are usually initiated by active macrophages.
Lymphocytes

• Lymphopoiesis: Lymphocyte Production
  • The pluripotential stem cells produce two sets of lymphoid stem cells
  • One set of lymphoid stem cells will do the following:
    • 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
Figure 23.7 Derivation and Distribution of Lymphocytes

The second group of stem cells migrates to the thymus, where subsequent divisions produce daughter cells that mature into T cells. One group remains in the bone marrow, producing daughter cells that mature into B cells and NK cells that enter peripheral tissues.

Mature T cells leave the circulation to take temporary residence in peripheral tissues. All three types of lymphocytes circulate throughout the body in the bloodstream.

© 2012 Pearson Education, Inc.
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
  • Nodules have a [germinal center](#), which contains the lymphocytes
Lymphoid Tissues

• Types of Nodules
  • Mucosa-associated lymphoid tissue (MALT)
  • 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
Figure 23.8c Histology of Lymphoid Tissues

The location of the tonsils and the histological organization of a single tonsil

- Pharyngeal tonsil
- Palatine tonsil
- Lingual tonsil

Pharyngeal epithelium

Germinal centers within nodules

Pharyngeal tonsil

LM × 50

© 2012 Pearson Education, Inc.
Lymphoid Organs

- Lymphoid organs include:
  - Lymph nodes
  - Thymus gland
  - Spleen
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
Figure 23.1 Lymphoid 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

• 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 23.9 Structure of a Lymph Node

Lymph node artery and vein
Hilum
Lymph nodes
Lymph vessel
Lymph nodes
Trabeculae
Medulla
Cortex
Subcapsular space
Deep cortex (T cells)
Capsule
Medullary cord (B cells and plasmocytes)
Afferent vessel
Efferent vessel
Lymph node artery and vein
Hilum
Medullary sinus
Outer cortex (B cells)
Germinal center
Outer cortex
Capsule
Subcapsular space
Dividing B cell
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
  • Axillary lymph nodes
  • Popliteal lymph nodes
  • Inguinal lymph nodes
  • Thoracic lymph nodes
  • Abdominal lymph nodes
  • Intestinal lymph nodes
  • Mesenterial lymph nodes
Figure 23.10 Lymphatic Drainage of the Head and Neck

- Periauricular lymph node
- Retroauricular lymph node
- Occipital lymph node
- Parotid lymph node
- Superficial cervical lymph node
- Deep cervical lymph node
- Sternocleidomastoid muscle
- Orbicularis oculi muscle
- Infraorbital lymph node
- Parotid salivary gland
- Buccal lymph node
- Mandibular lymph node
- Submental lymph node
- Submandibular lymph node
Figure 23.11a  Lymphatic Drainage of the Upper Limb

- Deltoid muscle
- Deltopectoral lymph node
- Pectoralis major muscle
- Axillary lymph nodes
- Cephalic vein
- Basilic vein
- Supratrochlear lymph node

Superficial lymphatic vessels and nodes that drain the upper limb and chest of a male.
Figure 23.11b Lymphatic Drainage of the Upper Limb

**Pectoralis major muscle (cut)**

- Subclavian lymph node
- Axillary vein
- Axillary lymph nodes

**Central lymph node**

- Parasternal lymph node

**Subscapular lymph node**

- Pectoral lymph node

**Mammary gland**

**b** Superficial and deeper lymphatic vessels and nodes of the upper limb and chest of a female
Figure 23.12 Lymphatic Drainage of the Lower Limb

- Superficial inguinal lymph nodes
- Deep inguinal lymph nodes
- Great saphenous vein
- Popliteal lymph nodes
Figure 23.14a 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

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

© 2012 Pearson Education, Inc.
A superficial and deeper view of the inguinal region of a male showing the distribution of lymph nodes and lymphatics.

- **Deep Inguinal and Iliac Lymph Nodes**
  - External iliac artery
  - External iliac vein
  - Inguinal ligament
  - Femoral artery
  - Femoral vein
  - Great saphenous vein
  - Deep inguinal lymph nodes

- **Superficial Inguinal Lymph Nodes**
  - Anterior superior iliac spine
  - Superficial inguinal lymph nodes
  - Fascia
  - Lymphatic vessels

**b** A superficial and deeper view of the inguinal region of a male showing the distribution of lymph nodes and lymphatics.
Figure 23.15  Lymph Nodes in the Large Intestine and Associated Mesenteries

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

• The Thymus
  • Lies posterior to the manubrium of the sternum
  • Reaches its greatest 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
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)
Figure 23.16a Anatomy and Histological Organization of the Thymus

The location of the thymus on gross dissection; note the relationship to other organs in the chest.
Figure 23.16bc  Anatomy and Histological Organization of the Thymus

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.

Histology of the thymus. Note the fibrous septa that divide the thymic tissue into lobules resembling interconnected lymphoid nodules.
Lymphoid Organs

• The Spleen
  • Largest lymphoid organ (12 cm in length)
  • Located on the left edge of the stomach
  • Consists of the following areas or regions
    • Diaphragmatic surface
    • Visceral surface (gastric area and renal area)
    • The visceral surface consists of the hilum
The shape of the spleen roughly conforms to the shapes of adjacent organs. This transverse section through the trunk shows the typical position of the spleen within the abdominopelvic cavity (inferior view).
Figure 23.17b  Anatomy and Histological Organization of the Spleen

**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

• The Spleen (continued)
  • The spleen consists of:
    • **Capsule**
    • **Red pulp** (contains large quantities of blood)
    • **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 Lymphoid System

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