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 excess tissue fluid and blood proteins from loose connective tissue and return tissue fluid and blood proteins to bloodstream
  - 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**

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
- **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
    - ‘Mini’ valve 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

- Lymphatic system
- Lymph duct
- Lymph trunk
- Lymph node
- Lymphatic capillary
- Blood capillaries

- Lymphatic collecting vessels, with valves
- Filaments anchored to connective tissue
- Fibroblast in loose connective tissue
- Endothelial cell
- Flaplike minivalve

- Tissue fluid
- Tissue cell
- Blood capillaries
- Lymphatic capillaries

- Arterial system
- Venous system

Figure 21.1

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

- Cervical nodes
- Entrance of right lymphatic duct into vein
- Internal jugular vein
- Entrance of thoracic duct into vein
- Thoracic duct
- Cisterna chyli
- Lymphatic collecting vessels
- Axillary nodes
- Aorta
- 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

- Cortex
- Lymphoid follicles
- Germinal center
- Subcapsular sinus
- Effective lymphatic vessels
- Hilum
- Medulla
- Medullary cord
- Medullary sinus

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

Figure 21.3a

Figure 21.2

Figure 21.3b
**Microscopic Anatomy of a Lymph Node**

- **Follicles**
- **Trabecula**
- **Subcapsular sinus**
- **Capsule**
- **Medullary cords**
- **Medullary sinuses**

*(b) Photomicrograph of part of a lymph node (140X)*

**Figure 21.3b**

- **Macrophage**
- **Reticular cells on reticular fibers**
- **Lymphocytes**
- **Medullary sinus**
- **Reticular fiber**

*(c) Reticular tissue within the medullary sinus (540X)*

**Figure 21.3c**

**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
  - **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*

**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 include:
  - Lymph nodes, spleen, thymus, tonsils, aggregated lymphoid nodules, and appendix

Role of 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

B lymphocytes

- Become plasma cells
- Secret antibodies
- Mark cells for destruction by macrophages
- Respond primarily to bacteria and bacterial toxins

Lymphocyte Function

- T lymphocyte binds to target cell, secretes proteins that lyse the cell's membrane, and signals the cell to die.
- B lymphocyte gives rise to plasma cell, which secretes antibodies.
- Antibodies bind to antigens on bacteria, marking the bacteria for destruction.
- Antibody-coated bacteria are avidly phagocytosed.

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

- 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

Lymphoid Tissue is...

- The 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 Organs...

- Designed to gather and destroy infectious microorganisms and to store lymphocytes
  - Primary lymphoid organs
    - Bone marrow
    - Thymus
  - Secondary lymphoid organs
    - Lymph nodes, spleen, tonsils
    - Aggregated lymphoid nodules
    - Appendix
Lymphoid Organs
...include:
- Tonsils (in pharyngeal region)
- Thymus (in thorax; most active during youth)
- Spleen (curves around left side of stomach)
- Aggregated lymphoid nodule (in intestine)
- Appendix

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

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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
- 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

**Tonsils**

- Simplest lymphoid organs
- Four groups of tonsils
  - Palatine, lingual, pharyngeal, and tubal tonsils (just behind the openings of the auditory tubes into the pharynx)
- Arranged in a ring to gather and remove pathogens
- Underlying lamina propria consists of MALT (Mucosa-associated lymphoid tissue)

**Palatine Tonsil**

Germinal centers in lymphoid follicles

**Aggregated Lymphoid Nodules and Appendix**

- abundant MALT in walls of intestines
- Fights invading bacteria
- Generates 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**

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