Chapter 22:
The Lymphatic System

*What are the major components of the lymphatic system?*
Components of the Lymphatic System

1. Lymph:
   - a fluid similar to plasma
   - does not have plasma proteins
2. Lymphatic vessels (lymphatics):
   - network that carries lymph from peripheral tissues to the venous system
3. Lymphocytes, phagocytes, and other immune system cells
4. Lymphoid tissues and lymphoid organs:
   - found throughout the body

Organization of the Lymphatic System
What are the major functions of the lymphatic system?

Function of the Lymphatic System

- Collection of fluid and solutes lost by the capillaries
  - 3.6L/day
- Distribution
  - Hormones
  - Nutrients
  - Waste products
- Protects us against disease
  - Production, maintenance and distribution of lymphocytes
1. Lymphatic Vessels

Role of Lymphatic Vessels

- About 3.6L/day of fluid is lost from the capillaries each day
  - This fluid is termed lymph fluid
    - Similar to plasma but with little proteins
- This fluid is returned to the venous system by the lymphatic vessels
- Also transports hormones, nutrients, and waste products in the process
Lymphatic Vessels

- Formed from buds coming off the veins
- Lymphatic system begins with smallest vessels:
  - lymphatic capillaries (terminal lymphatics)

Distribution of Lymphatic Vessels

- Wide-spread originating from most capillary beds
- Absent from:
  - Bone
  - Teeth
  - Bone marrow
  - Nervous system
    - Function is replaced by cerebral spinal fluid
Lymphatic Capillaries

- Differ from blood capillaries in 4 ways:
  - start as pockets rather than tubes
  - Originate in the capillary beds
  - have larger diameters
  - have thinner walls
  - flat or irregular in section
Construction of Lymphatic Capillaries

- Endothelial cells loosely bound together with overlap
- Overlap acts as one-way valve:
  - Called minivalves
  - Allows fluids, solutes, viruses, and bacteria to enter
    - Can allow entry of cancer cells
  - Prevents return to intercellular space

Lymphatic Vessels and Valves
Lacteals

- Are special lymphatic capillaries in small intestine
  - Very large diameter
- Transport lipids from digestive tract

Lymph Flow

- From lymphatic capillaries have minivalves
- Larger lymphatic vessels containing one-way valves like seen in veins
- Larger lymphatic vessels have smooth muscle that contracts rhythmically
- Movement also aided by respiratory and muscular pump
Lymphatic Ducts and the Venous System

Superficial and Deep Lymphatics

- Join to form large lymphatic trunks
- Trunks empty into 2 major collecting vessels:
  - thoracic duct
  - right lymphatic duct
The lower portion of the Thoracic Duct

• Receives the lymph flow from structures inferior to the diaphragm
• Expands into cisterna chyli
• Cisterna chyli receives lymph from:
  – right and left lumbar trunks
  – intestinal trunk

The upper portion of the Thoracic Duct

• Receives lymph flow from structures on the left side but superior to the diaphragm
• Collects lymph from:
  – left bronchiomediastinal trunk
  – left subclavian trunk
  – left jugular trunk
• Thoracic duct empties into left subclavian vein
Lymphatic Ducts and the Venous System

The Right Lymphatic Duct

- Receives lymph flow from structures on the right side but superior to the diaphragm
- Collects lymph from:
  - right jugular trunk
  - right subclavian trunk
  - right bronchiomediastinal trunk
- Empties into right subclavian vein
Lymphatic Ducts and the Venous System

Lymphedema

- Blockage of lymph drainage from a limb
- Causes severe swelling
- Interferes with immune system function
2. Lymphocytes

- Lymphatic system cells respond to:
  - environmental pathogens
  - toxins
  - abnormal body cells, such as cancers
Lymphocytes

- Make up 20–30% of circulating leukocytes
- Most are stored, not circulating

Lymphopoiesis

- Lymphocyte production involves:
  - bone marrow
  - thymus
  - peripheral lymphoid tissues
Lymphoid Stem Cells

- Group 1:
  - remain in bone marrow
  - produce B cells and natural killer cells
Lymphoid Stem Cells

- Group 2:
  - migrate to thymus
  - produce T cells in environment isolated by blood-thymus barrier

Differentiation

- B cells differentiate:
  - with exposure to hormone interleukin-7
- T cells differentiate:
  - with exposure to several thymic hormones
3 Classes of Circulating Lymphocytes

1. T cells:
   - thymus-dependent
2. B cells:
   - bone–marrow derived
3. NK cells:
   - natural killer cells

T Cells

- Make up 80% of circulating lymphocytes
3 Main Types of T Cells

1. Cytotoxic T cells
2. Helper T cells
3. Suppressor T cells

Cytotoxic T Cells

- Attack cells infected by viruses
- Produce cell-mediated immunity
Helper T Cells

- Stimulate function of T cells and B cells

Suppressor T Cells

- Inhibit function of T cells and B cells
B Cells

• Make up 10–15% of circulating lymphocytes
• Differentiate into plasma cells

Plasma Cells

• Produce and secrete antibodies (immunoglobin proteins)
Natural Killer (NK) Cells

- Also called large granular lymphocytes
- Make up 5–10% of circulating lymphocytes
- Responsible for immunological surveillance
- Attack:
  - foreign cells
  - virus-infected cells
  - cancer cells

T Cells and B Cells

- Migrate throughout the body:
  - to defend peripheral tissues
- Retain their ability to divide:
  - is essential to immune system function
3. Lymphoid Tissues

Characteristics of Lymphoid Tissues

- Connective tissues dominated by lymphocytes
- Strategically located to intercept and react with foreign material (antigens)
  - Located where risk of infection is greatest
Types of Lymphoid Tissues

Diffuse Lymphatic Tissue
Lymphoid Nodules
Lymphoid Organs

Diffuse Lymphatic Tissue
- Simple in construction
- Loosely scattered lymphocytes located in areolar connective tissue
- Not enclosed by a capsule
- Location of lymphocytes is not static
- Located beneath the epithelia of most tissues
  - Most common in GI, respiratory, genitourinary tracts
Lymphoid Nodule

- Areolar tissue with densely packed lymphocytes
- Germinal center contains dividing lymphocytes
Distribution of Lymphoid Nodules

- Lymph nodes
- Spleen
- Respiratory tract (tonsils)
- Along digestive and urinary tracts

Mucosa-Associated Lymphoid Tissue (MALT)

- Lymphoid tissues associated with the digestive system:
  - aggregated lymphoid nodules:
    - clustered deep to intestinal epithelial lining
    - mass of fused lymphoid nodules
      - Appendix:
      - Peyer's patches
The 5 Tonsils

- In wall of pharynx:
  - left and right palatine tonsils
  - pharyngeal tonsil (adenoid)
  - 2 lingual tonsils

- Contains crypts that trap infectious material
Lymphoid Organs

- Lymph nodes
- Thymus
- Spleen

Lymphoid Organs

- Typically constructed of large collections of lymphatic nodules
- Are separated from surrounding tissues by a fibrous connective-tissue capsule
  - Helps contain infectious material
Lymph Nodes

- Range from 1–25 mm diameter
- Function as a filter for the lymph fluid
- 600 bean-shaped lymph nodes scattered throughout the body
  - Large numbers in the cervical, axillary, and inguinal regions
Lymph Glands

- Large lymph nodes at groin and base of neck
- Swell in response to inflammation

Function of Lymph Nodes

- A filter:
  - purifies lymph before return to venous circulation
    - Lymph fluid will pass through at least one node before returning to the circulation
- Removes:
  - debris
  - pathogens
  - 99% of antigens
Flow of Lymph Fluid

• Enters the node through afferent lymphatic vessel
• Passes next to subcapsular sinus:
  – Contains macrophages
    • Engulfs cellular debris and infectious material
  – Contains dendritic cells
    • Involved in initiation of immune response
      – Antigen presentation
• Passes into the outer cortex:
  – Contains lymphoid nodules housing B cells
    • Germinal center contains dividing B cells and lymphatic dendritic cells
      – Lymphatic Dendritic cells assist in maturation of B cells
• Passes into the deep cortex:
  – Dominated by T cells
    • Involved in cell-mediated immunity
• Passes into the medulla:
  – Contains B cells and Plasma cells
    • Involved in antibody production (humoral immunity)
  – Are arranged in elongated masses called medullary cords
• Exits the node by the efferent lymphatic vessel

Flow of Lymph Fluid (cont.)
Lymphadenopathy

- Chronic or excessive enlargement of lymph nodes may indicate infections, endocrine disorders, or cancer
The Thymus

- Located in mediastinum
- Deteriorates after puberty:
  - diminishing effectiveness of immune system

Divisions of the Thymus

- Thymus is divided into 2 thymic lobes
- Septa divide lobes into smaller lobules
A Thymic Lobule

- Contains a dense outer cortex
- And a pale central medulla

Lymphocytes

- Divide in the cortex
- T cells migrate into medulla
- Mature T cells leave thymus by medullary blood vessels
Reticular Epithelial Cells in the Cortex

- Surround lymphocytes in cortex
- Maintain blood-thymus barrier
- Secrete thymic hormones (Thymosins) that stimulate:
  - stem cell divisions
  - T cell differentiation

Reticular Epithelial Cells in the Medulla

- Form concentric layers (Hassall’s corpuscles)
- The medulla has no blood–thymus barrier:
  - T cells can enter or leave bloodstream
3 Functions of the Spleen

1. Removal of abnormal blood cells and other blood components by phagocytosis
2. Storage of iron recycled from red blood cells
3 Functions of the Spleen

3. Initiation of immune responses by B cells and T cells:
   – in response to antigens in circulating blood

Structure of the Spleen

- Inside fibrous capsule:
  – red pulp:
    • which contains many red blood cells
  – white pulp:
    • resembles lymphoid nodules
Trabecular Arteries

• Branch of the splenic artery that radiate toward capsule
• Finer branches surrounded by white pulp
• Capillaries discharge red blood cells into red pulp