Lymphatic System

- Returns fluids that leaked from blood vessels back to blood
- Consists of three parts
  1. Network of **lymphatic vessels** (lymphatics)
  2. **Lymph** – fluid in vessels
  3. **Lymph nodes** – cleanse lymph

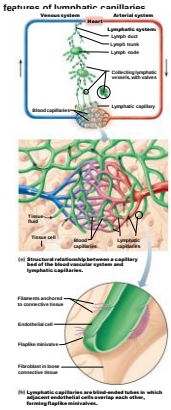
Lymphoid Organs and Tissues

- Provide structural basis of immune system
- House phagocytic cells and lymphocytes
- Structures include spleen, thymus, tonsils, lymph nodes, other lymphoid tissues

Lymphatic System: Functions

- **Lymphatic vessels** (lymphatics)
  - Return interstitial fluid and leaked plasma proteins back to blood
  - ~ 3L / day
  - Once interstitial fluid enters lymphatics, called lymph

Figure 20.1 Distribution and special features of lymphatic capillaries.



Lymphatic Vessels: Distribution and Structure

- One-way system; lymph flows toward heart
- Lymph vessels (lymphatics) include:
  - **Lymphatic capillaries**
  - **Collecting lymphatic vessels**
  - **Lymphatic trunks** and ducts

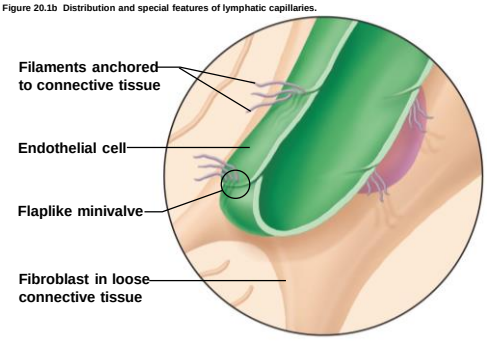
Lymphatic Capillaries

- Similar to blood capillaries, except
  - Very permeable (take up proteins, cell debris, pathogens, and cancer cells)
    - Endothelial cells overlap loosely to form one-way *minivalves*
    - Anchored by collagen filaments, preventing collapse of capillaries; increased ECF volume opens minivalves
  - Pathogens travel throughout body via lymphatics

Lymphatic Capillaries

- Absent from bones, teeth, bone marrow, and CNS
- **Lacteals**: specialized lymph capillaries present in intestinal mucosa
  - Absorb digested fat and deliver fatty lymph (**chyle**) to the blood

Figure 20.1b Distribution and special features of lymphatic capillaries.



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

Lymphatic Collecting Vessels

- Similar to veins, except
  - Have thinner walls, with more internal valves
  - Anastomose more frequently
- Collecting vessels in skin travel with superficial veins
- Deep vessels travel with arteries
- Nutrients supplied from branching **vasa vasorum**

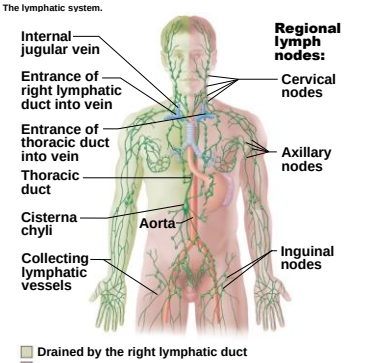
Lymphatic Trunks

- Formed by union of largest collecting ducts
  - Paired **lumbar**
  - Paired **bronchomediastinal**
  - Paired **subclavian**
  - Paired **jugular trunks**
  - Single **intestinal trunk**

Lymphatic Ducts

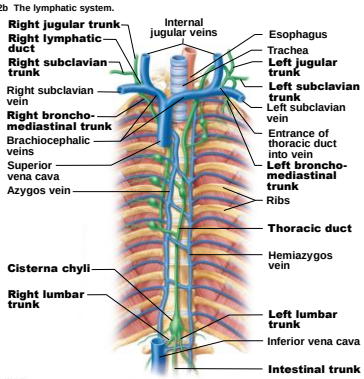
- Lymph delivered into one of two large ducts
  - **Right lymphatic duct** drains right upper arm and right side of head and thorax
  - **Thoracic duct** arises as **cisterna chyli;** drains rest of body
- Each empties lymph into venous circulation at junction of internal jugular and subclavian veins on its own side of body

Figure 20.2a The lymphatic system.



(a) General distribution of collecting lymphatic vessels and regional lymph nodes.

Figure 20.2b The lymphatic system.



(b) Major lymphatic trunks and ducts in relation to veins and surrounding structures. Anterior view of thoracic and abdominal wall.

Lymph Transport

- Lymph propelled by
  - Milking action of skeletal muscle
  - Pressure changes in thorax during breathing
  - Valves to prevent backflow
  - Pulsations of nearby arteries
  - Contractions of smooth muscle in walls of lymphatics

Lymphoid Cells

- **Lymphocytes** main warriors of immune system
  - Arise in red bone marrow
- Mature into one of two main varieties
  - **T cells** (T lymphocytes)
  - **B cells** (B lymphocytes)

Lymphocytes

- T cells and B cells protect against **antigens**
  - Anything body perceives as foreign
    - Bacteria and bacterial toxins, viruses, mismatched RBCs, cancer cells

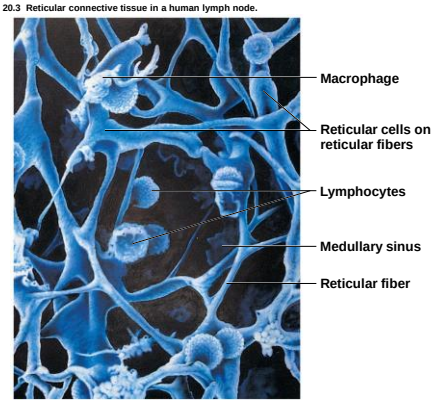
Lymphocytes

- T cells
  - Manage immune response
  - Attack and destroy infected cells
- B cells
  - Produce **plasma cells**, which secrete **antibodies**
    - Antibodies mark antigens for destruction by phagocytosis or other means

Other Lymphoid Cells

- **Macrophages** phagocytize foreign substances; help activate T cells
- **Dendritic cells** capture antigens and deliver them to lymph nodes; activate T cells
- **Reticular cells** produce reticular fiber **stroma** that supports other cells in lymphoid organs

Figure 20.3 Reticular connective tissue in a human lymph node.



Lymphoid Tissue

- Houses, and provides proliferation site for, lymphocytes
- Surveillance vantage point for lymphocytes and macrophages
- Largely **reticular connective tissue** – type of loose connective tissue
- Two main types
  - **Diffuse lymphoid tissue; Lymphoid follicles**

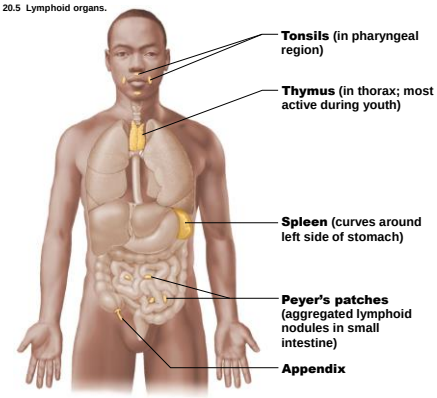
Lymphoid Tissue

- Diffuse lymphoid tissue of lymphoid cells and reticular fibers in ~ every body organ
  - Larger collections in lamina propria of mucous membranes

Lymphoid Tissue

- Lymphoid follicles (nodules) are solid, spherical bodies of tightly packed lymphoid cells and reticular fibers
  - **Germinal centers** of proliferating B cells
  - May form part of larger lymphoid organs
  - Isolated aggregations of Peyer's patches and in appendix

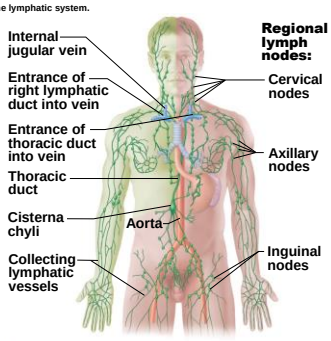
Figure 20.5 Lymphoid organs.



Lymph Nodes

- Principal lymphoid organs of body
- Embedded in connective tissue, in clusters along lymphatic vessels
- Near body surface in inguinal, axillary, and cervical regions of body

Figure 20.2a The lymphatic system.



(a) General distribution of collecting lymphatic vessels and regional lymph nodes.

Lymph Nodes

- Functions
  1. Filter lymph—macrophages destroy microorganisms and debris
  2. Immune system activation—lymphocytes activated and mount attack against antigens

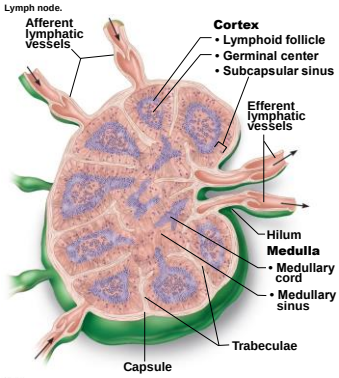
Structure of a Lymph Node

- Vary in shape and size but most bean shaped
- External fibrous **capsule**
- **Trabeculae** extend inward and divide node into compartments
- Two histologically distinct regions
  - **Cortex**
  - **Medulla**

Structure of a Lymph Node

- Cortex contains follicles with germinal centers, heavy with dividing B cells
- Dendritic cells nearly encapsulate follicles
- Deep cortex houses T cells in transit
- T cells circulate continuously among blood, lymph nodes, and lymph

Figure 20.4a Lymph node.

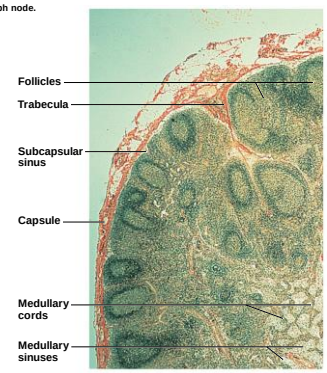


(a) Longitudinal view of the internal structure of a lymph node and associated lymphatics

Structure of a Lymph Node

- Medullary cords extend inward from cortex and contain B cells, T cells, and plasma cells
- **Lymph sinuses** contain macrophages

Figure 20.4b Lymph node.

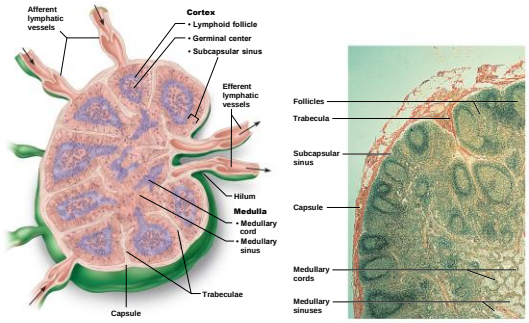


(b) Photomicrograph of part of a lymph node (72x)

Circulation in the Lymph Nodes

- Lymph
  - Enters convex side via **afferent lymphatic vessels;** travels through large **subcapsular sinus** and smaller sinuses to medullary sinuses; exits concave side at hilum via efferent vessels
- Fewer efferent vessels so flow somewhat stagnate; allows lymphocytes and macrophages time to function

Figure 20.4 Lymph node.



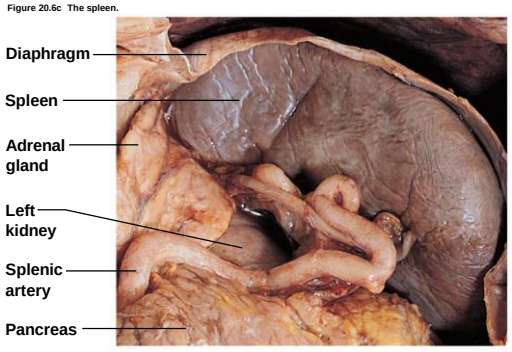
(a) Longitudinal view of the internal structure of a lymph node and associated lymphatics

(b) Photomicrograph of part of a lymph node (72x)

Spleen

- Largest lymphoid organ
- Served by splenic artery and vein, which enter and exit at the hilum
- Functions
  - Site of lymphocyte proliferation and immune surveillance and response
  - Cleanses blood of aged cells and platelets, macrophages remove debris

Figure 20.6c The spleen.



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

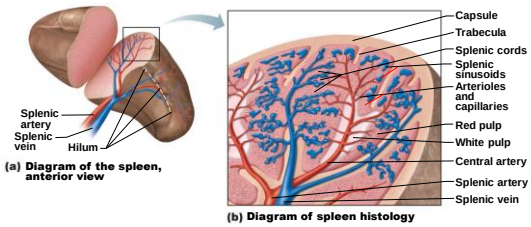
Spleen: Additional Functions

- Stores breakdown products of RBCs (e.g., iron) for later reuse
- Stores blood platelets and monocytes
- May be site of fetal erythrocyte production (normally ceases before birth)
- Encased by fibrous capsule; has trabeculae
- Contains lymphocytes, macrophages, and huge numbers of erythrocytes

Structure of the Spleen

- Two distinct areas
  - **White pulp** around central arteries
    - Mostly lymphocytes on reticular fibers; involved in immune functions
  - **Red pulp** in venous sinuses and splenic cords
    - Rich in RBCs and macrophages for disposal of worn-out RBCs and bloodborne pathogens
    - Composed of **splenic cords** and **sinusoids**

Figure 20.6a–b The spleen.



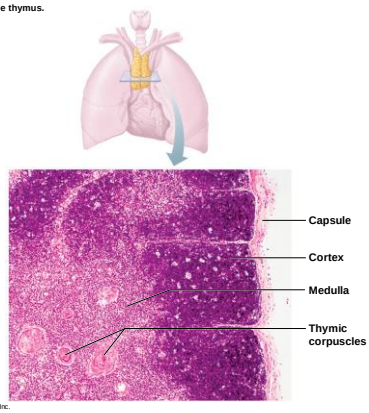
Thymus

- Important functions early in life
- Found in inferior neck; extends into mediastinum; partially overlies heart
- Increases in size and most active during childhood
- Stops growing during adolescence, then gradually atrophies
  - Still produces immunocompetent cells, though slowly

Thymus

- Thymic lobules contain outer cortex and inner medulla
- Most thymic cells are lymphocytes
  - Cortex contains rapidly dividing lymphocytes and scattered macrophages
- Medulla contains fewer lymphocytes and **thymic corpuscles** involved in regulatory T cell development (prevent autoimmunity)

Figure 20.7 The thymus.



Thymus

- Differs from other lymphoid organs in important ways
  - Has no follicles because it lacks B cells
  - Does not directly fight antigens
    - Functions strictly in T lymphocyte maturation
      - Keeps isolated via **blood thymus barrier**
- **Stroma** of epithelial cells (not reticular fibers)
  - Provide environment in which T lymphocytes become immunocompetent

Mucosa-associated Lymphoid Tissue (MALT)

- Lymphoid tissues in mucous membranes throughout body
- Protects from pathogens trying to enter body
- Largest collections of MALT in **tonsils, Peyer's patches, appendix**
- Also in mucosa of respiratory and genitourinary organs; rest of digestive tract

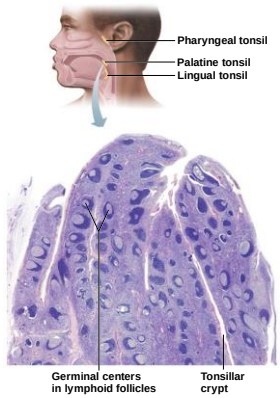
Tonsils

- Simplest lymphoid organs
- Form ring of lymphatic tissue around pharynx
  - **Palatine tonsils**—at posterior end of oral cavity
  - **Lingual tonsil**—grouped at base of tongue
  - **Pharyngeal tonsil**—in posterior wall of nasopharynx
  - **Tubal tonsils**—surrounding openings of auditory tubes into pharynx
- Gather and remove pathogens in food or air

Tonsils

- Contain follicles with germinal centers
- Are not fully encapsulated
- Overlying epithelium invaginates forming **tonsillar crypts**
  - Trap and destroy bacteria and particulate matter
  - Allow immune cells to build memory for pathogens

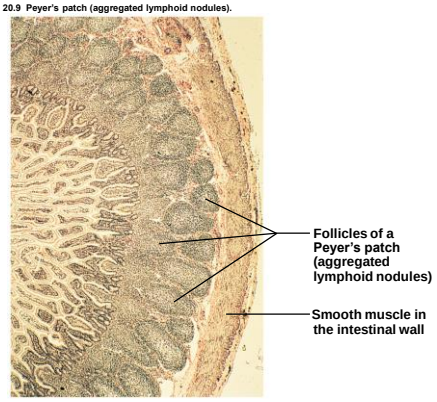
Figure 20.8 Histology of the palatine tonsil.



Aggregates of Lymphoid Follicles

- Peyer's patches
  - Clusters of lymphoid follicles
  - In wall of distal portion of small intestine
  - Similar structures are also found in the appendix
- Peyer's patches and appendix
  - Destroy bacteria, preventing them from breaching intestinal wall
  - Generate "memory" lymphocytes

Figure 20.9 Peyer's patch (aggregated lymphoid nodules).



Developmental Aspects

- Beginnings of lymphatic vessels and main clusters of lymph nodes by 5th week of embryonic development
  - Arise as **lymph sacs** from developing veins
  - Jugular lymph sacs arise → right lymphatic duct and thoracic duct
- Lymphatic organs (except thymus) arise from mesoderm

Developmental Aspects

- Lymphoid organs (except thymus) develop from mesodermal mesenchymal cells
- Thymus (endodermal origin) forms as an outgrowth of pharynx
- Except for spleen and tonsils, lymphoid organs poorly developed at birth
- After birth high numbers of lymphocytes; their development parallels maturation of immune system