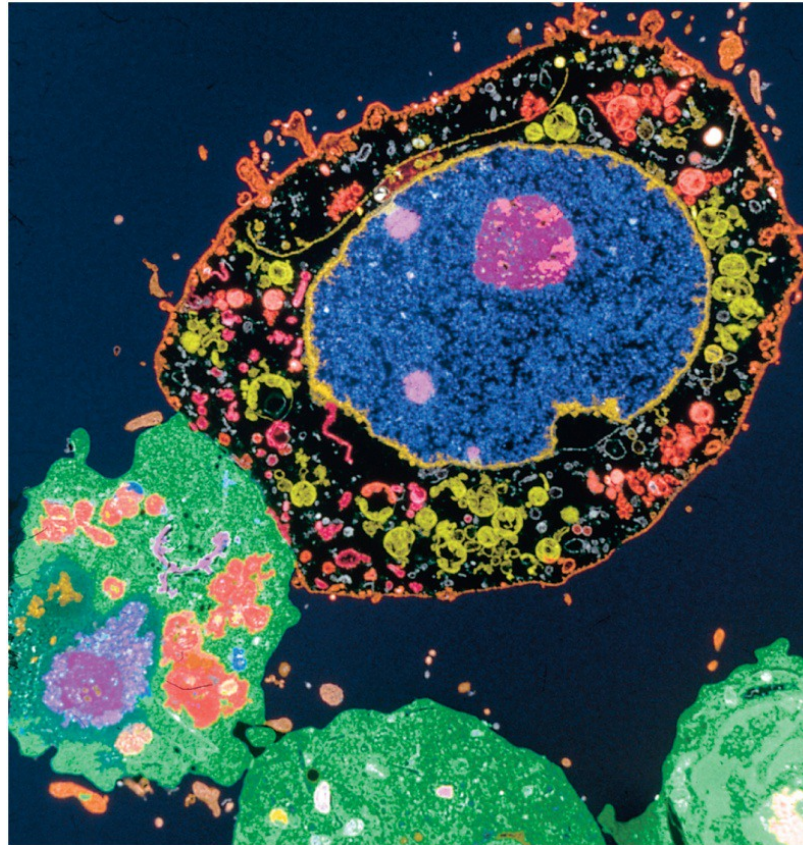


Lymphatic System Structure

Organs of the Lymphatic System



What are the three functions of the lymphatic system?



- **Fluid recovery** // fluid continually filters from blood capillaries into the interstitial spaces
 - blood capillaries only reabsorb 85% of the fluid crossing capillary bed
 - **15%** (2 – 4 L/day) of the water and about half of the plasma proteins enters lymphatic system /// returned to the blood via lymphatic vessels
- **Lipid absorption** // lacteals (i.e. lymphatic capillaries) in small intestine allow lipid to enter lymphatic system /// dietary lipids are unable to enter systemic circuit via continuous capillaries of villus
- **Immunity** // interstitial fluid enter lymphatic capillary to carry antigen presenting cells and pathogens to lymph nodes / T cells and B cells in lymph node initiate immune response
 - immune cells in lymph nodes stand guard against foreign matter
 - naive immunocompetent T and B cells also memory T and memory B cells are able to initiate the immune response
 - T and B cells carry out their function in three steps: **Recognize / React / Remember**
 - there are two forms of an immune response:
 - 1. Non-specific resistance
 - 2. Adaptive Immunity



Components of the Lymphatic System

- **Lymph //** the recovered fluid
- **lymphatic capillaries and lymphatic vessels //** pick up and transport the lymph
- **lymph nodes**
 - Organs inserted in pathway of lymphatic vessels
 - Filters lymph
 - Site of pathogen recognition
- **lymphatic tissues**
 - composed of aggregates of lymphocytes and macrophages that populate many organs in the body
 - “nomadic” cells with the ability to move throughout the tissue and organs of your body
 - these cells patrol for pathogens
- **lymphatic organs**
 - defense cells are especially concentrated in these organs
 - separated from surrounding organs by connective tissue capsules
 - Tonsils, spleen, thymus, lymph nodes

SYSTEMIC CIRCULATION

PULMONARY CIRCULATION

LYMPHATIC DUCTS (thoracic duct, right lymphatic duct) empty lymph into the junction of jugular and subclavian veins of the cardiovascular system.

Subclavian vein

LYMPHATIC VESSELS pass lymph to lymphatic ducts.

VALVE ensures one-way flow of lymph.

EFFERENT LYMPHATIC VESSELS carry lymph from lymph nodes.

LYMPH NODES filter lymph and remove foreign substances through filtering, phagocytosis, and immune reactions.

AFFERENT LYMPHATIC VESSELS carry lymph from lymphatic capillaries to lymph nodes.

LYMPHATIC CAPILLARIES absorb interstitial fluid and pass lymph to afferent lymphatic vessels

Lymph node

Lymphatic capillaries

Pulmonary blood capillaries

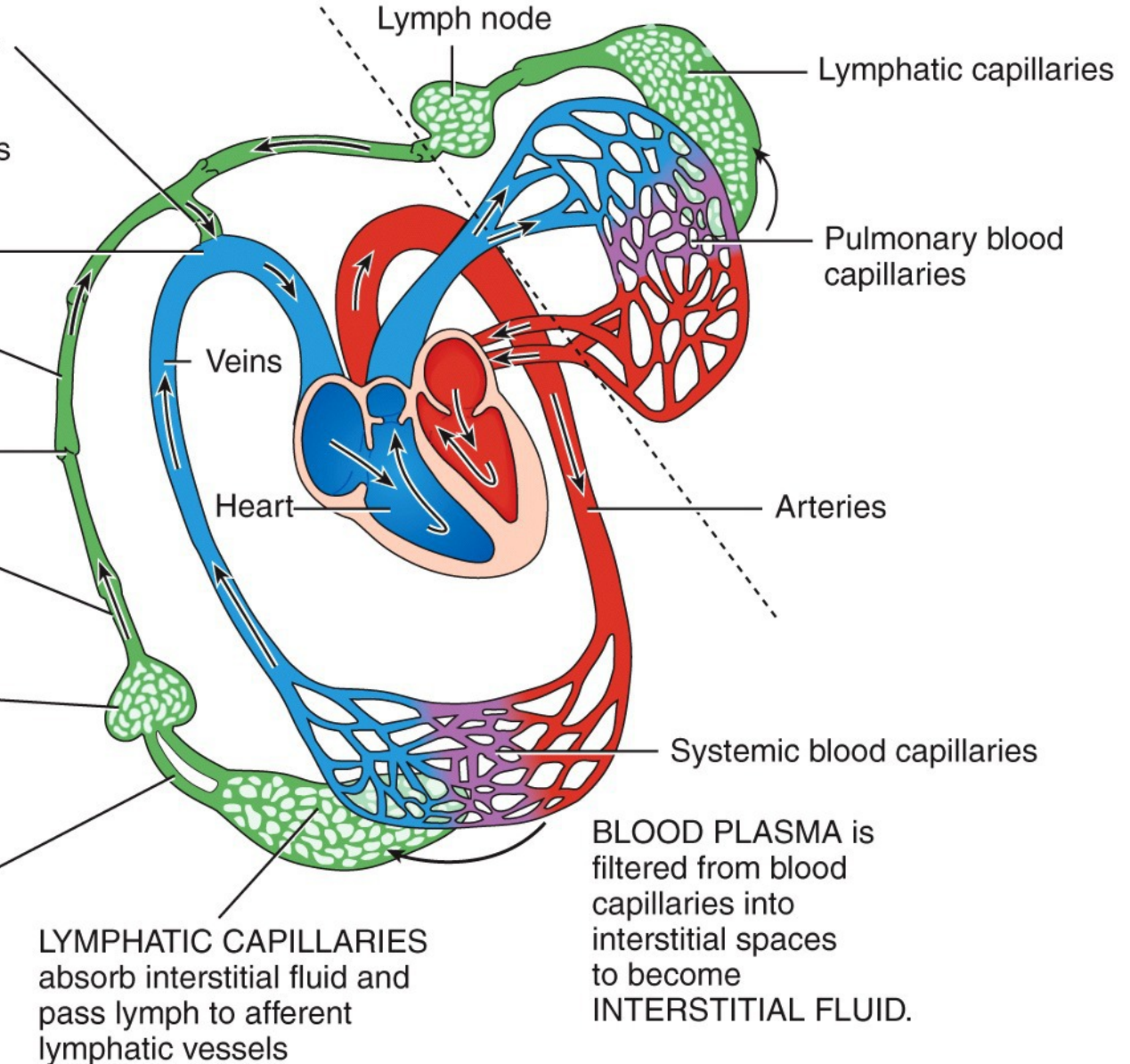
Veins

Heart

Arteries

Systemic blood capillaries

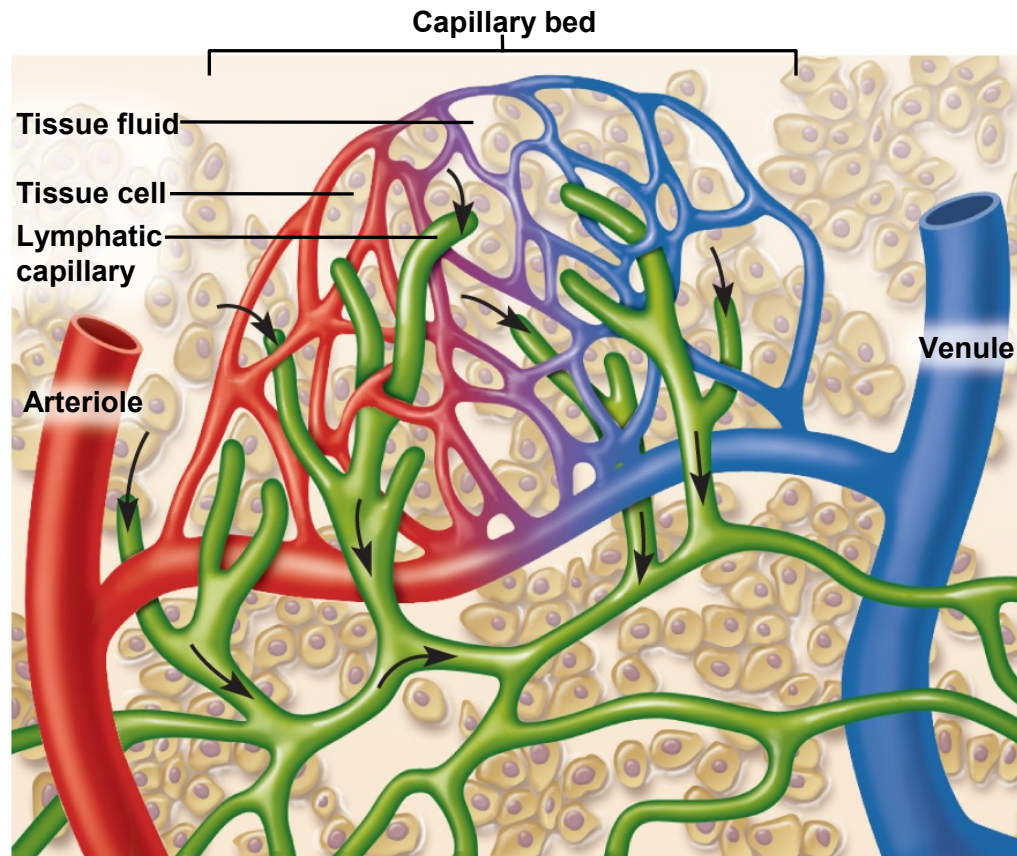
BLOOD PLASMA is filtered from blood capillaries into interstitial spaces to become **INTERSTITIAL FLUID**.



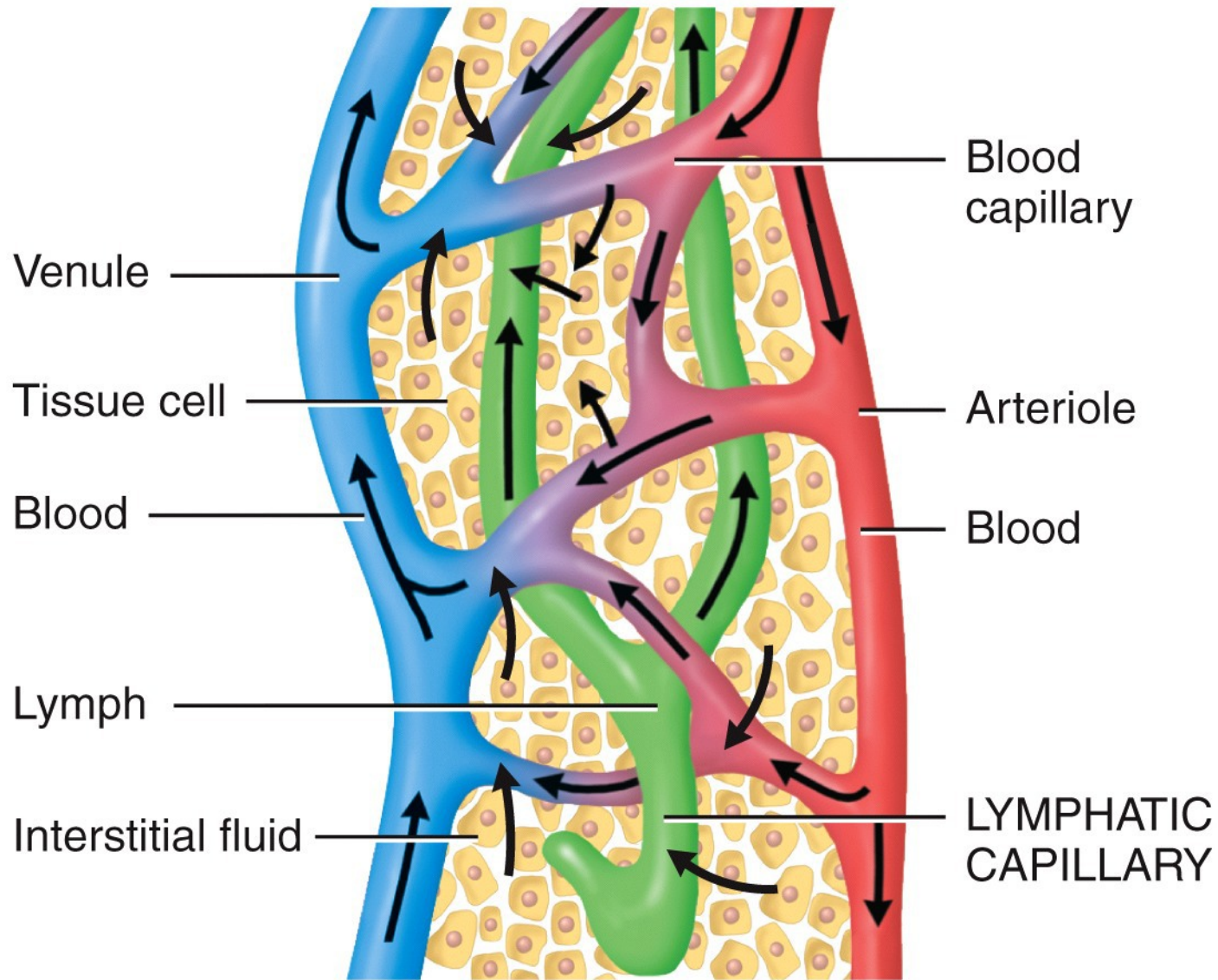
Lymph and Lymphatic Capillaries

- **Lymph** // clear, colorless fluid, similar to plasma, but much less protein // extracellular fluid drawn into lymphatic capillaries
- **Lymphatic capillaries** (terminal lymphatic)
 - penetrate nearly every tissue of the body // cartilage, cornea, bone and bone marrow
 - sacs of thin endothelial cells that loosely overlap each other
 - closed at one end
 - Lymphatic capillaries are tethered to surrounding tissue by protein filaments // gaps between cells are large enough to allow bacteria and cells entrance into lymphatic capillary
 - endothelium creates valve-like flaps that open when interstitial fluid pressure is high, and close when it is low

Structure of a Capillary Bed with Lymphatic Capillaries and Their Afferent Vessels



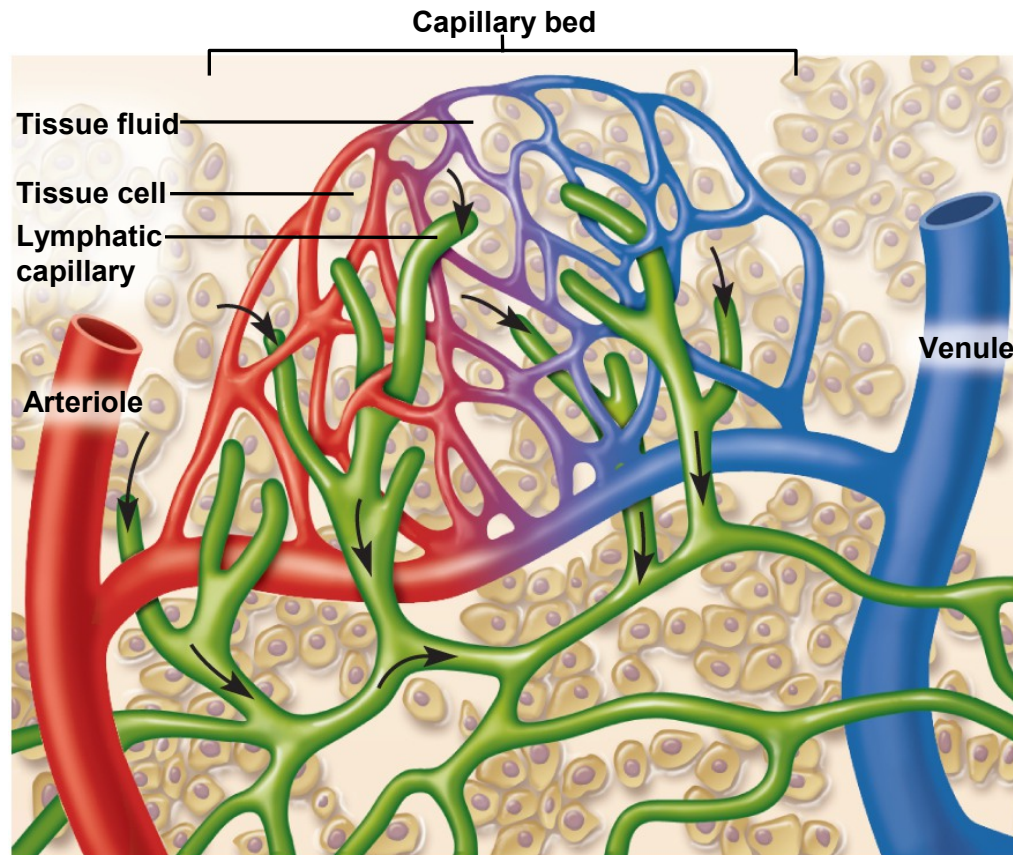
How much fluid is not recovered at the end of the capillary bed? (15%)



(a) Relationship of lymphatic capillaries to tissue cells and blood capillaries

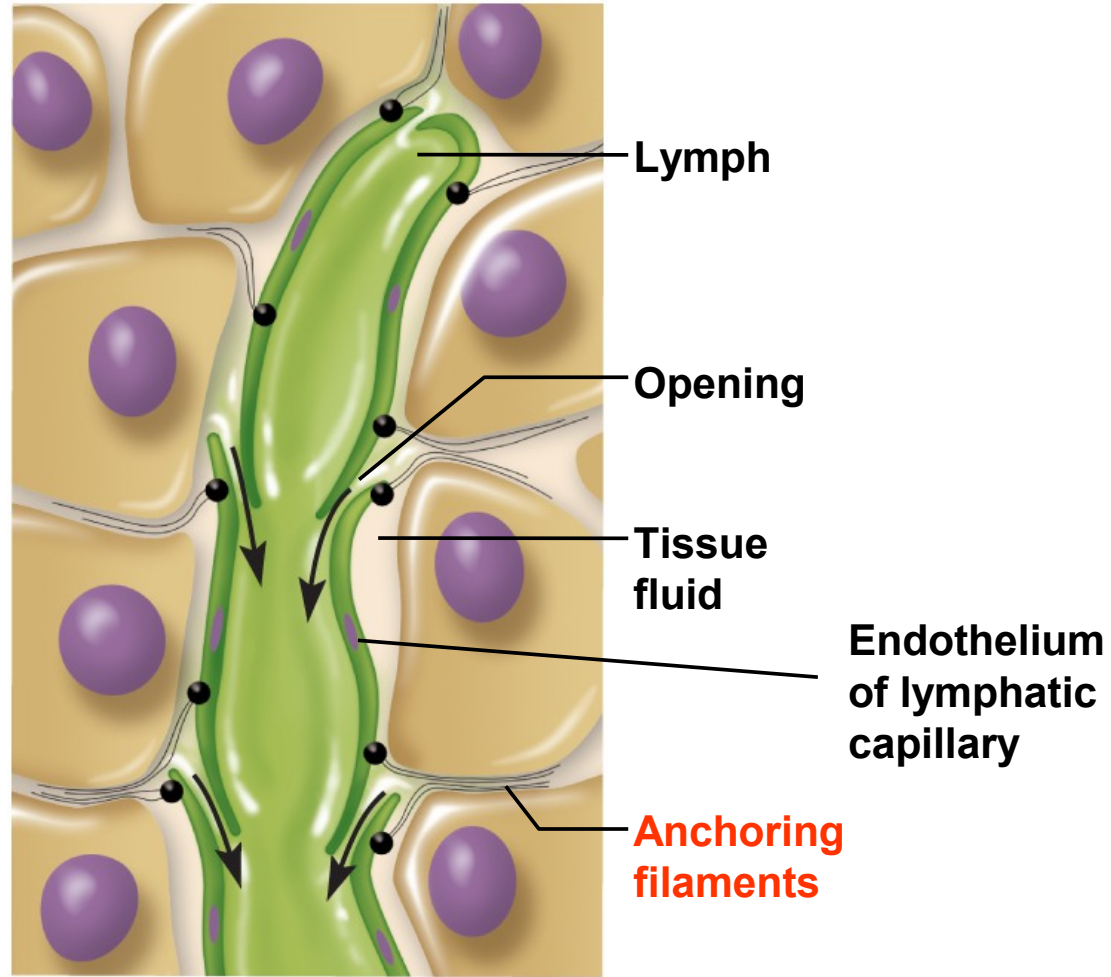


Structure of a Capillary Bed with Lymphatic Capillaries and Their Afferent Vessels



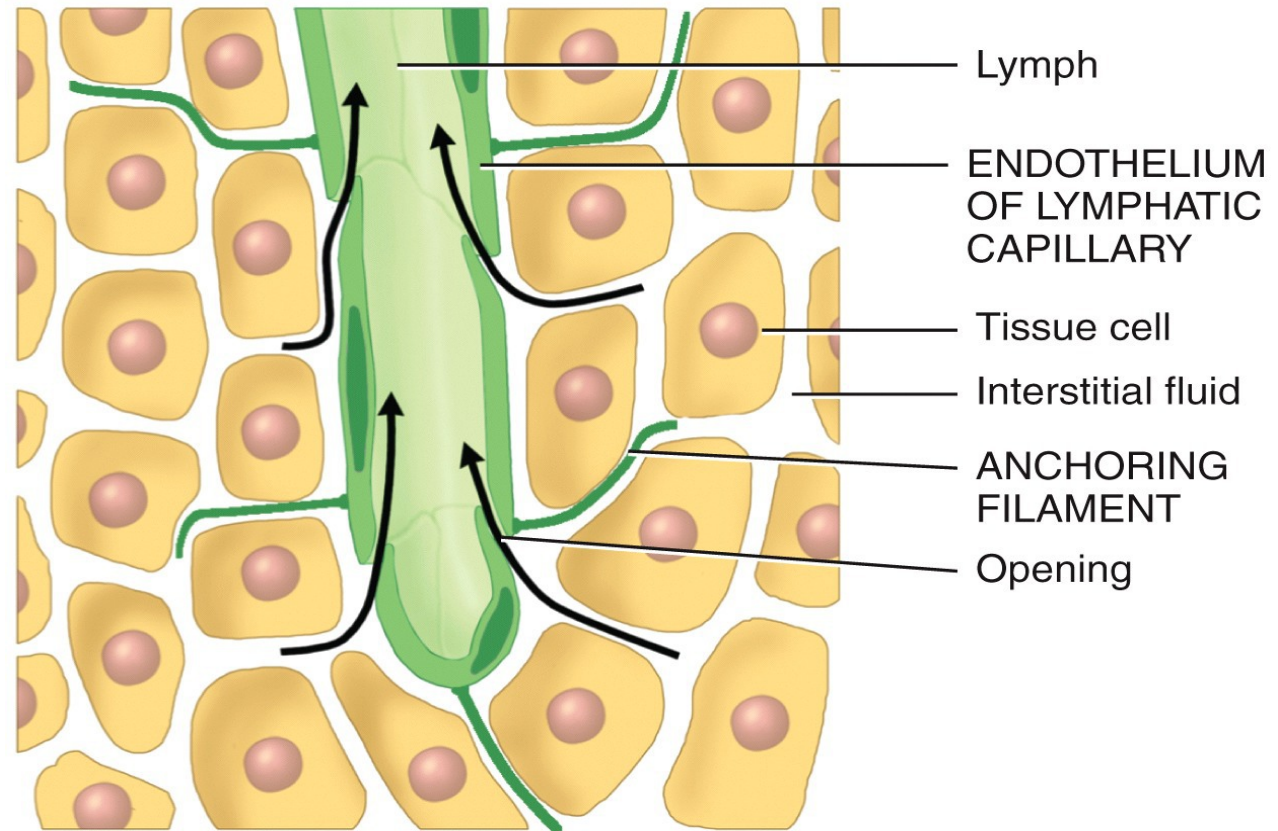
If there is a bacterial infection in a tissue space, then why is it important to redirect interstitial fluid to the lymph nodes?

Lymphatic Capillary





How is fluid directed to flow into lymphatic capillary and not into the veins?



(b) Details of a lymphatic capillary

Edema causes pressure within the tissue space to increase. As this pressure increases: 1) What will happen to the veins? Why? 2) What will happen to the lymphatic capillaries? Why? Where will interstitial fluid flow to?



Route of Lymph Flow



- lymphatic capillaries
- collecting vessels // course through many lymph nodes
- six lymphatic trunks // drain major portions of body
- two collecting ducts
 - **right lymphatic duct** – receives lymph from right arm, right side of head and thorax; empties into right subclavian vein
 - **thoracic duct** - larger and longer, begins as a prominent sac in abdomen called the **cisterna chyli**; receives lymph from below diaphragm, left arm, **left side** of head, neck, and thorax; empties into left subclavian vein
- subclavian veins right & left // Receive fluid from respective collecting ducts

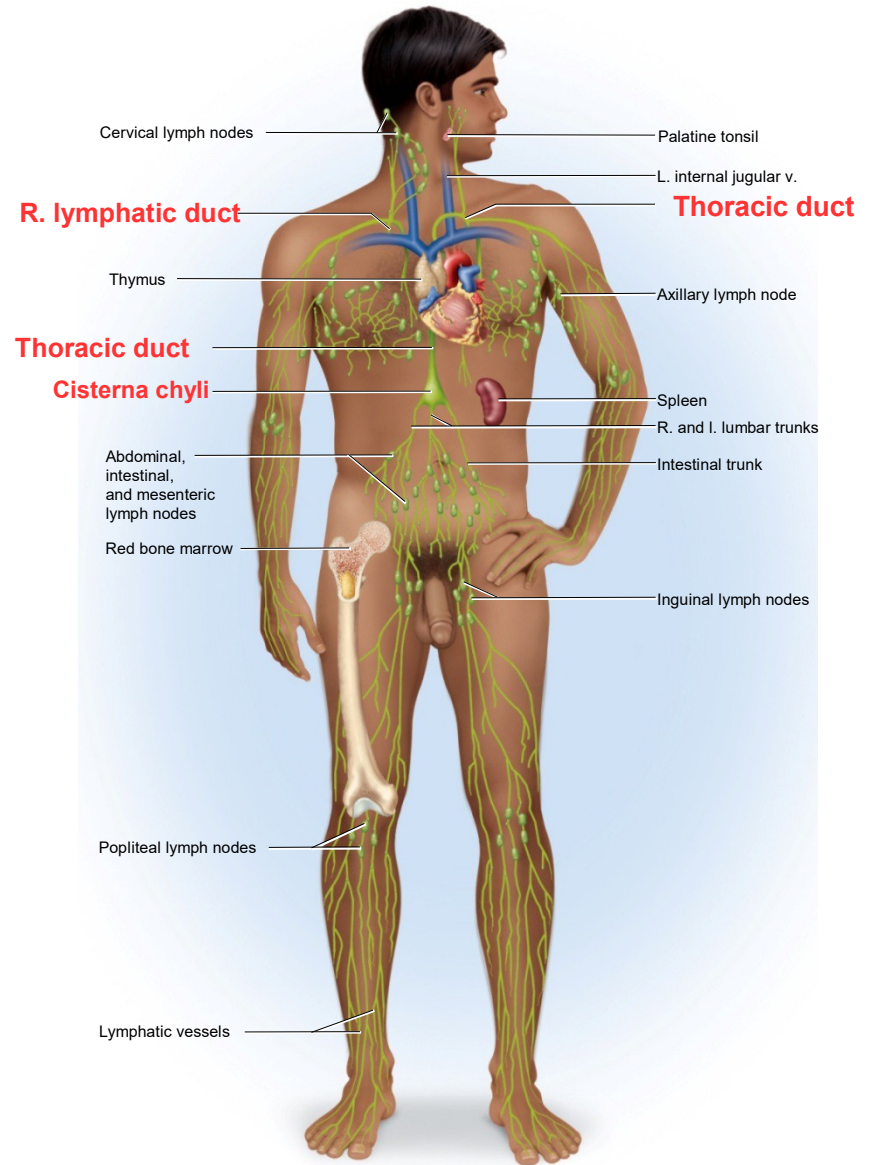
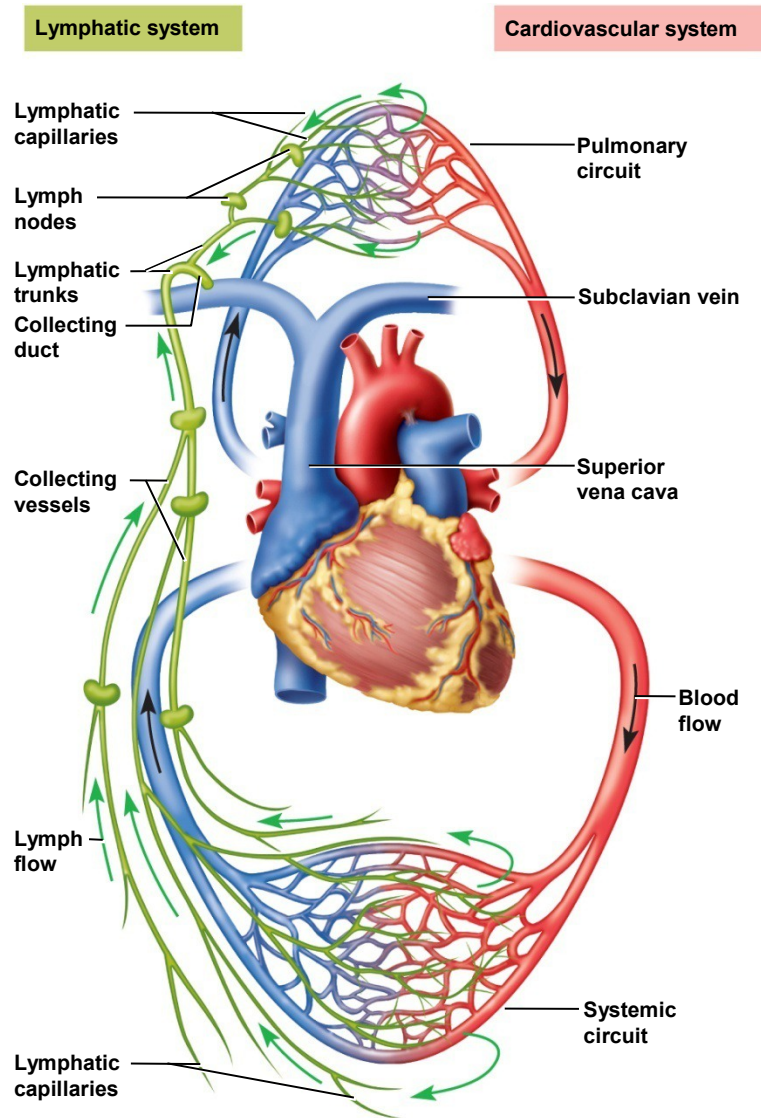


(b) Areas drained by
right lymphatic and
thoracic ducts

 Area drained by
right lymphatic duct

 Area drained by
thoracic duct

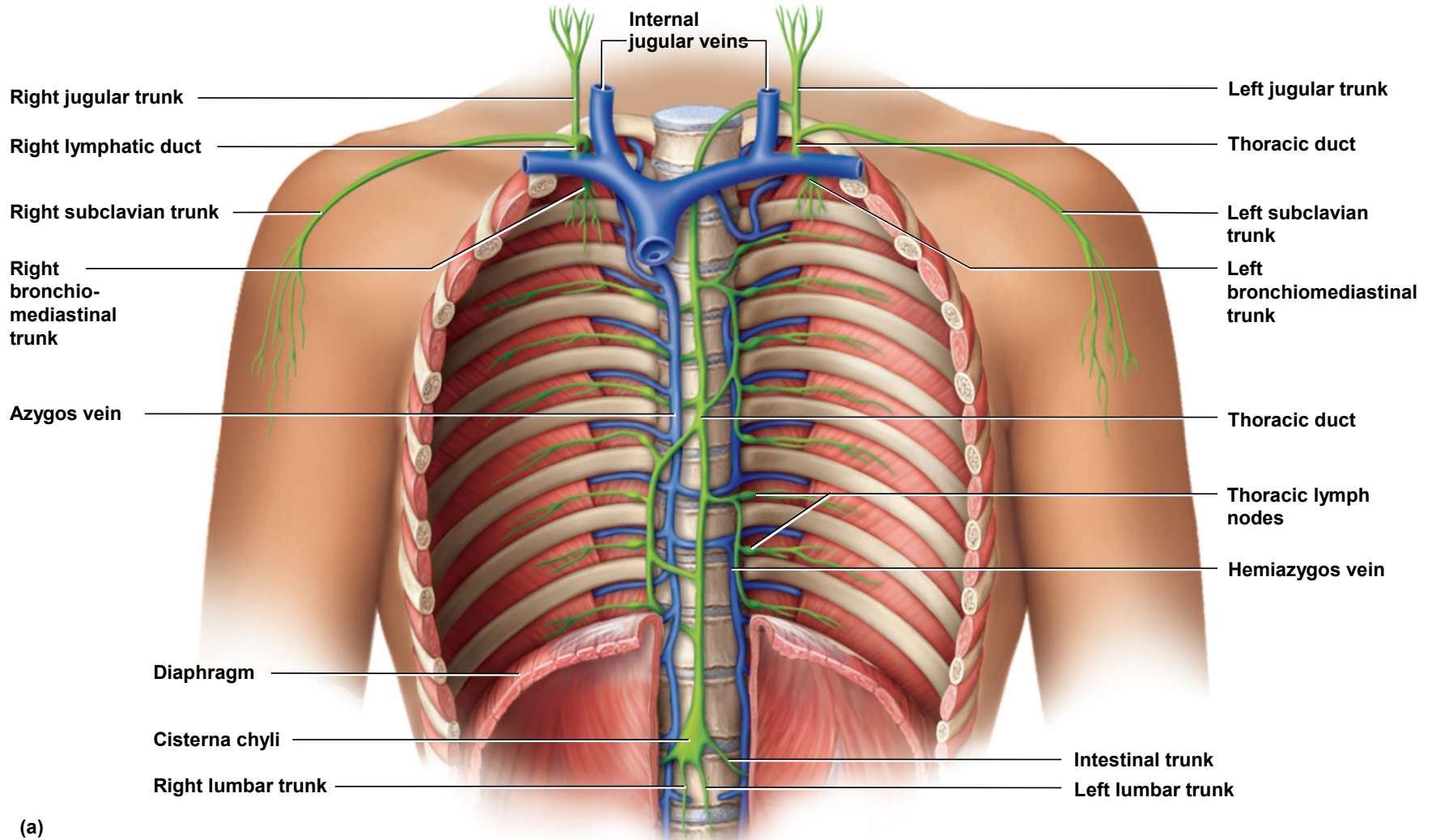
The Fluid Cycle



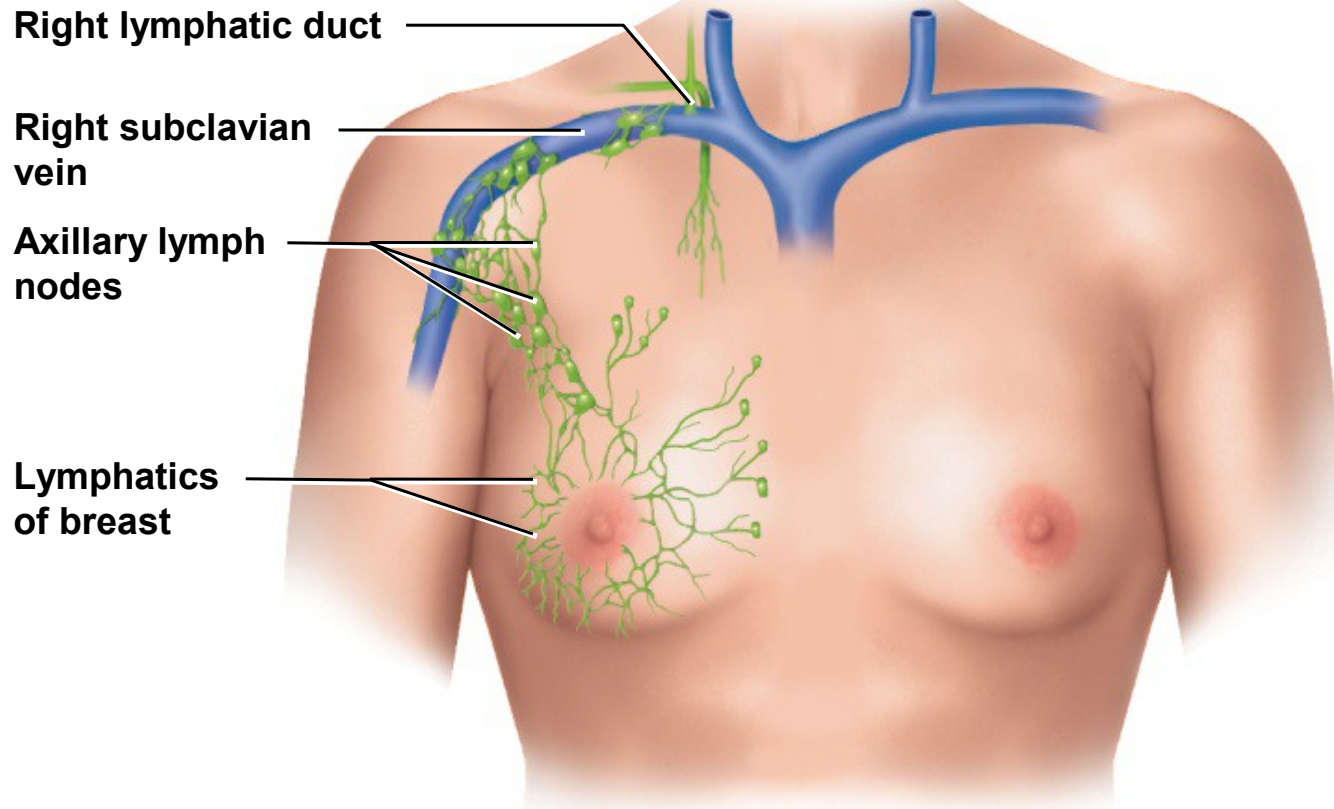
Lab Objectives

Drainage of Thorax

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Lymphatic Drainage of Mammary and Axillary Regions



lymphadenitis -
swollen, **painful** node
responding to foreign
antigen (bacteria)

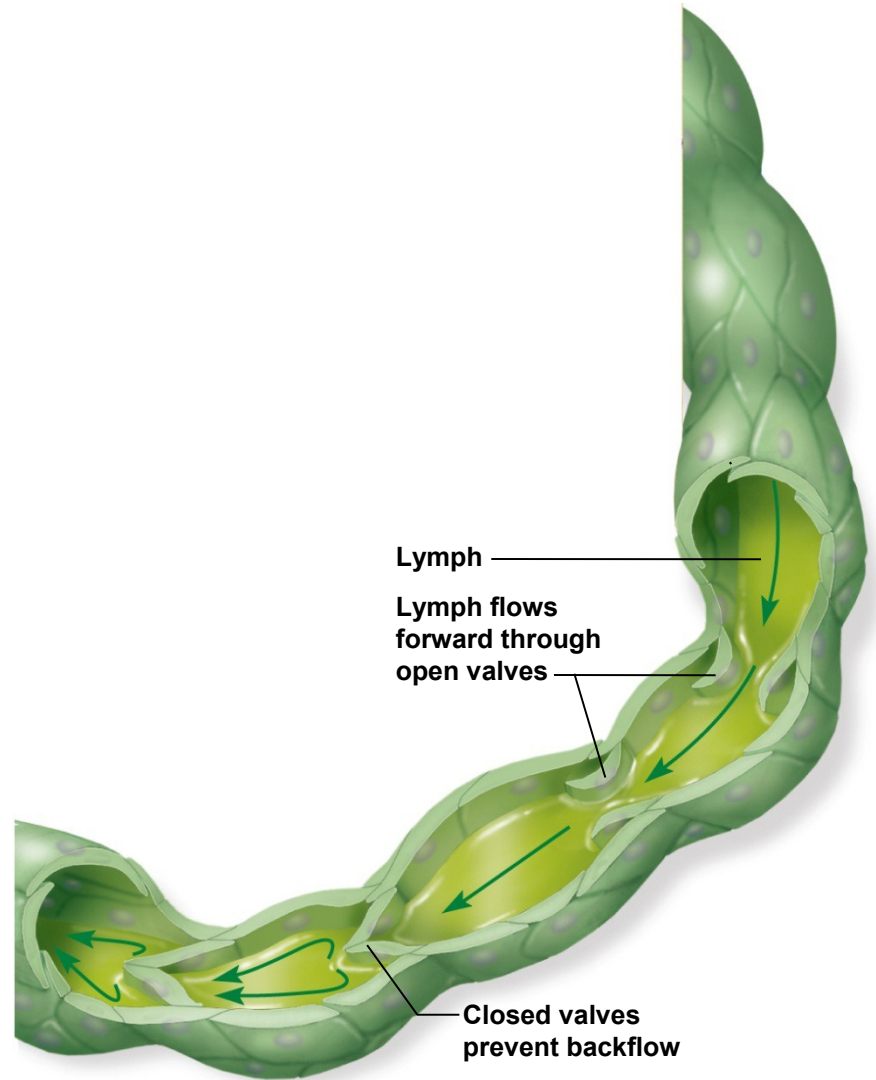
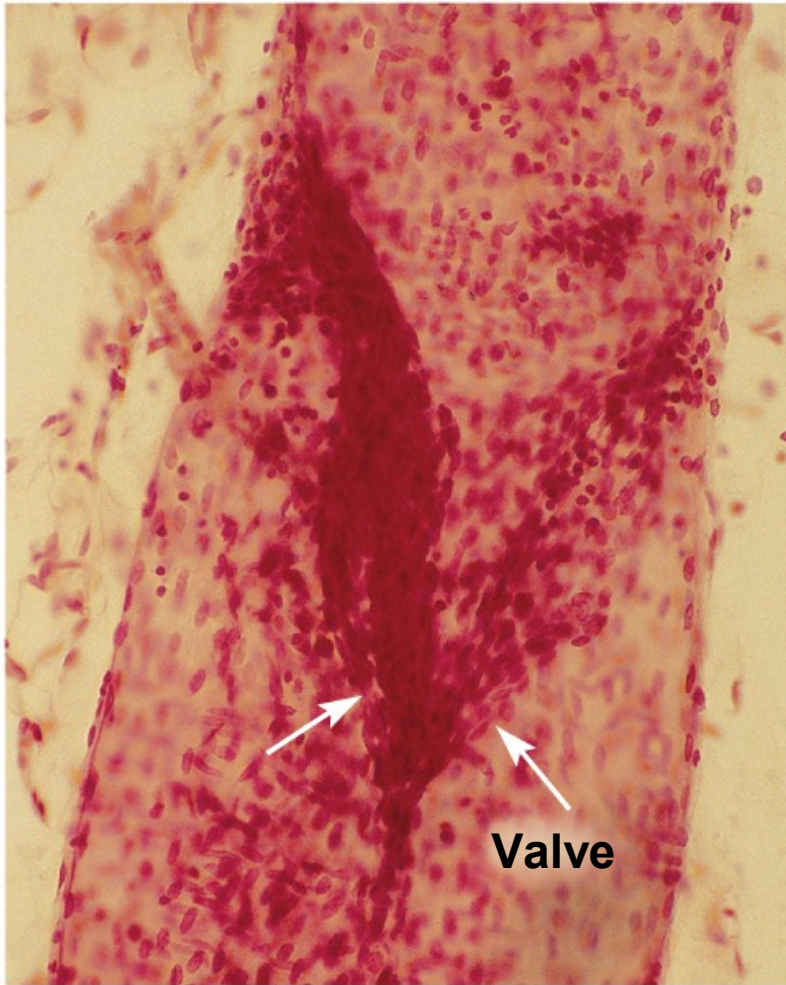
lymph nodes are
common sites for
metastatic cancer ///
swollen, firm and but
usually **painless**

What is the clinical significance?

Mechanisms of Lymph Flow

- lymph flows under forces similar to those that govern venous return, except **no pump** (heart)
- lymph flows at low pressure and slower speed than venous blood
- moved along by **rhythmic contractions** of lymphatic vessels /// stretching of vessels stimulates contraction
- flow **aided by skeletal muscle pump**
- arterial pulsation rhythmically squeeze lymphatic vessels
- thoracic pump aids flow from abdominal to thoracic cavity
- valves prevent backward flow
- rapidly flowing blood in subclavian veins, draws lymph into it
- exercise significantly increases lymphatic return

Valves in Lymphatic Vessel



Lymphatic Organs VS Lymphatic Tissue

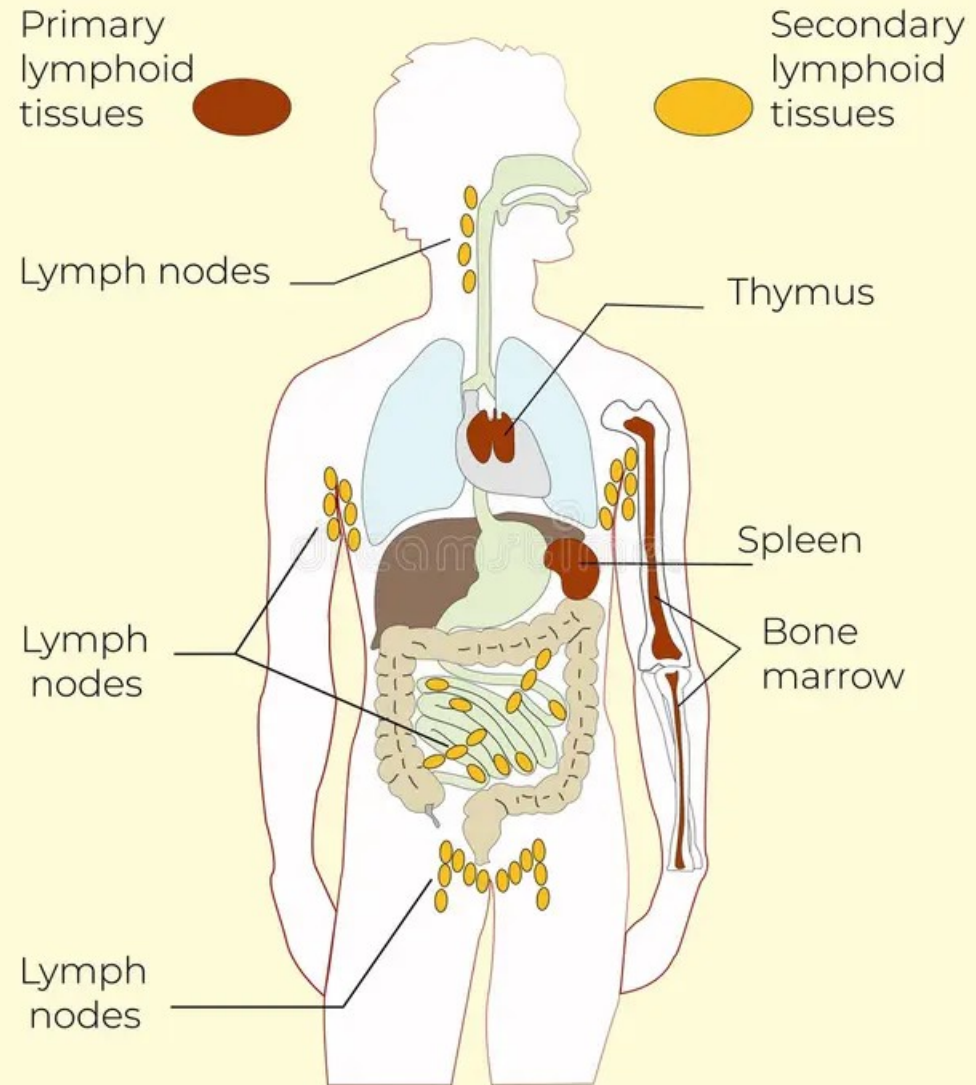


- Lymphatic organs are surrounded by a **connective tissue capsule** and contain a high concentration of WBC.
- Lymphatic tissues are clusters of WBC **not surrounded by connective**. These cells come together to defeat a pathogen and then break apart so they may patrol and seek other pathogens.

- Lymphatic organs are surrounded by a **connective tissue capsule** and contain a high concentration of WBC.

- Lymph nodes
- Tonsils
- Spleen
- Thymus

Lymphatic organs



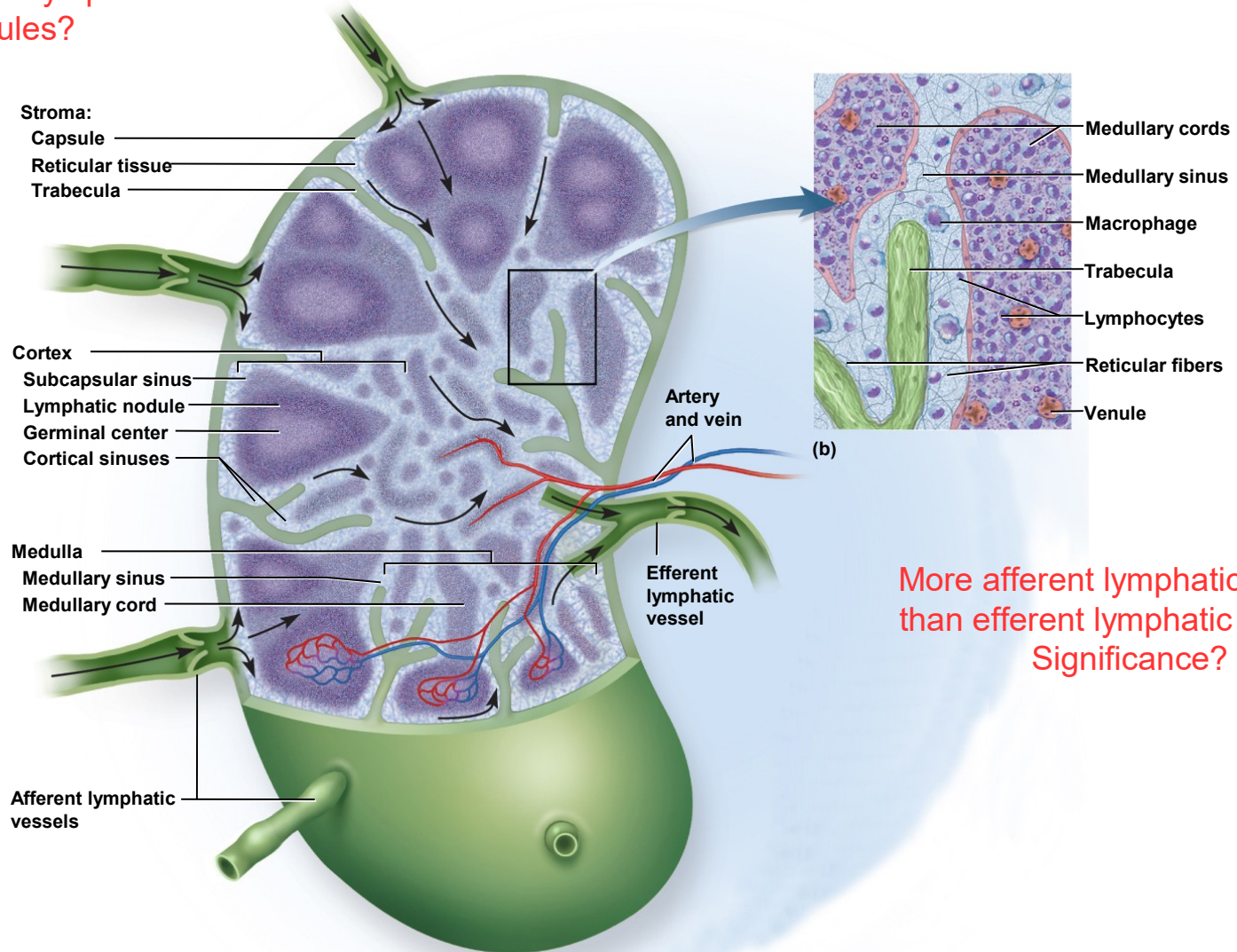
Lymph Nodes



- These are the most numerous lymphatic organs // about 450 in typical young adult
 - they have two functions:
 - cleanse the lymph with macrophage as lymph passes through nodes
 - Initiate an immune response to pathogens // nodes are sites where T and B cell “rest” while they wait to be activated by antigen presenting cells
- Elongated, bean shaped structure with **hilum**
- Enclosed with fibrous capsule // **trabeculae** that divide interior into compartments // stroma of reticular fibers and reticular cells

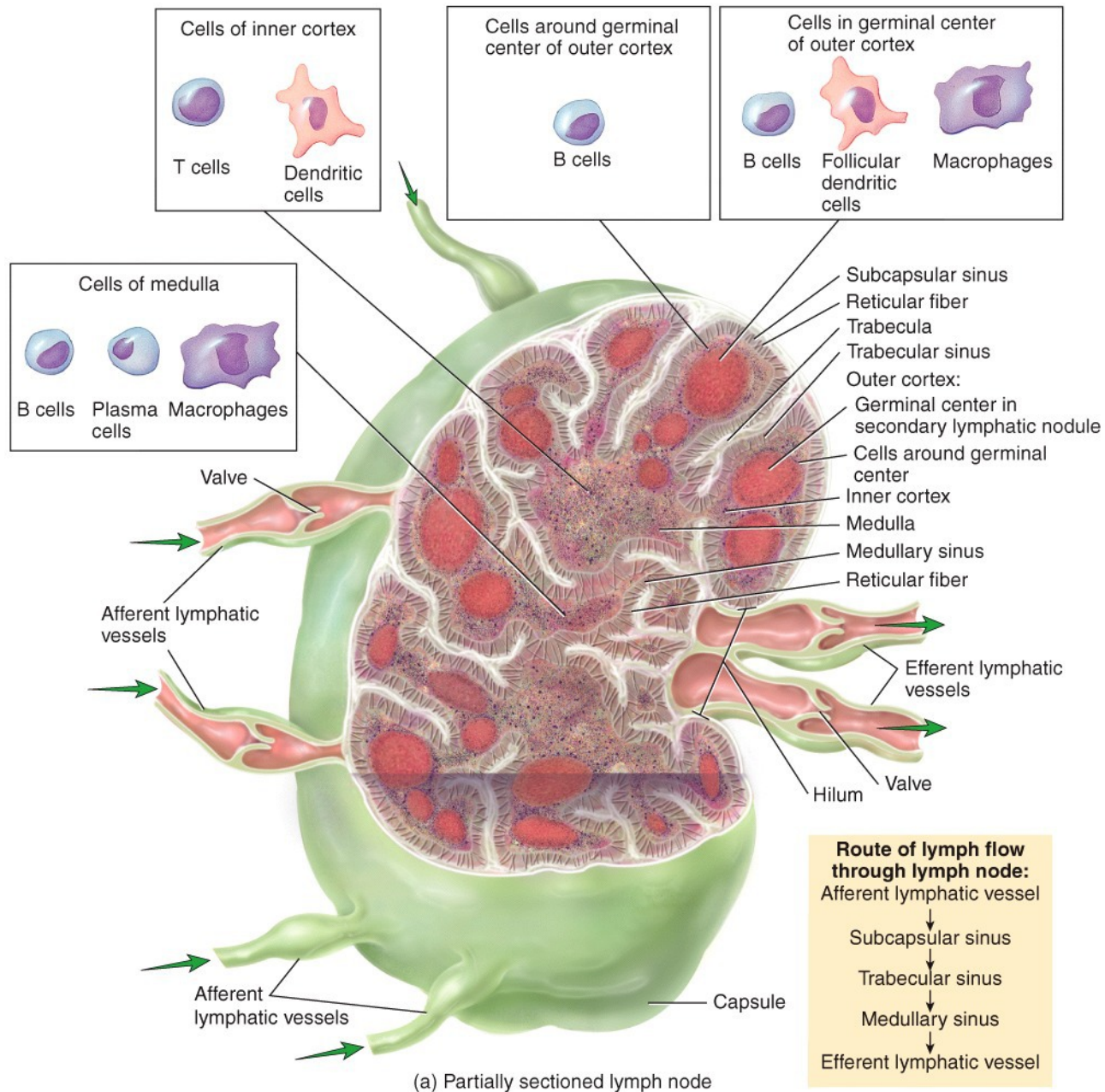
What type of WBC are
Found in the lymphatic
nodules?

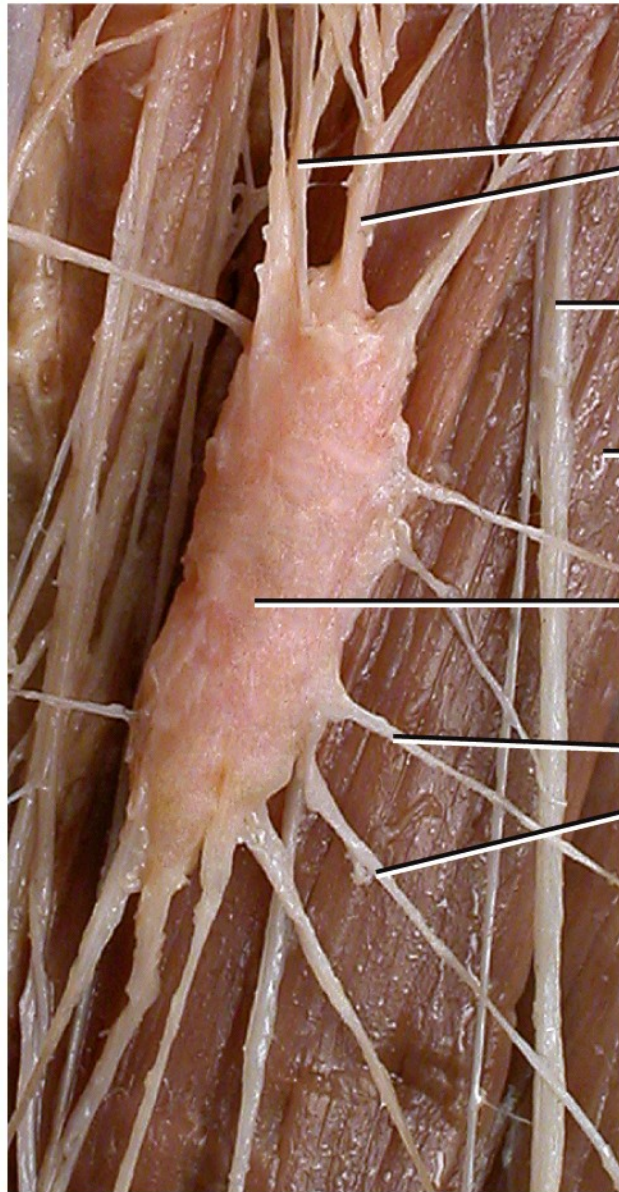
Lymph Node



More afferent lymphatic vessels
than efferent lymphatic vessels.
Significance?

Why is this a good example of the relationship
between structure and function?





Efferent lymphatic
vessels

Nerve

Skeletal muscle

Lymph node

Afferent lymphatic
vessels

(c) Anterior view of inguinal lymph node

Lymph Node Locations

(Lab Objectives)

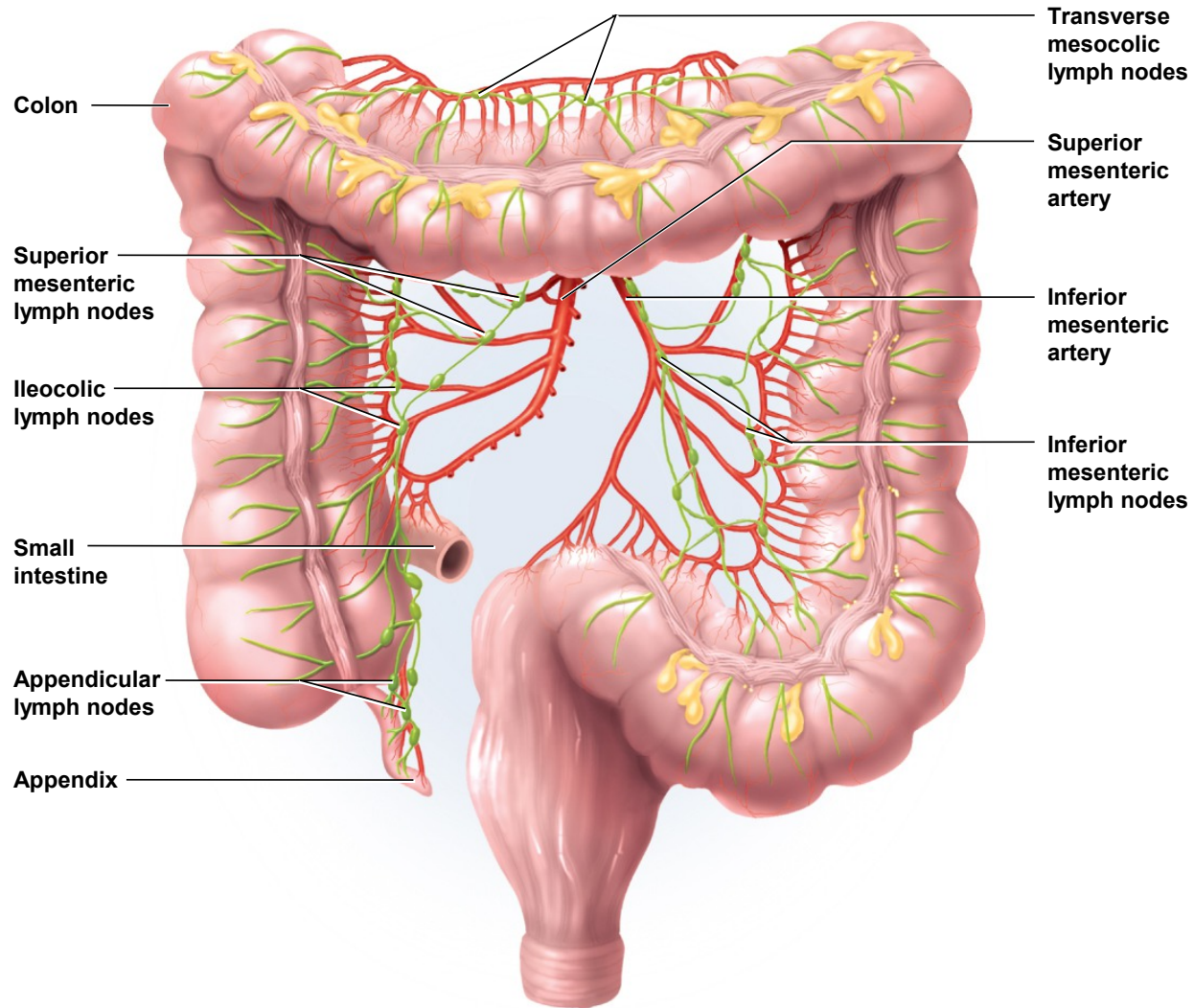
- **cervical lymph nodes**
 - deep and superficial group in the neck
 - monitor lymph coming from head and neck
- **axillary lymph nodes**
 - concentrated in armpit
 - receive lymph from upper limb and female breast
- **thoracic lymph nodes**
 - in thoracic cavity especially embedded in mediastinum
 - receive lymph from mediastinum, lungs, and airway

Lymph Node Locations

(Lab Objectives)

- **abdominal lymph nodes**
 - occur in posterior abdominopelvic wall
 - monitor lymph from the urinary and reproductive systems
- **intestinal and mesenteric lymph nodes**
 - found in the mesenteries, adjacent to the appendix and intestines
 - monitor lymph from the digestive tract
- **inguinal lymph nodes**
 - in the groin and receive lymph from the entire lower limb
- **popliteal lymph nodes**
 - occur on the back of the knee
 - receive lymph from the leg proper

Lymph Node Areas of Concentration

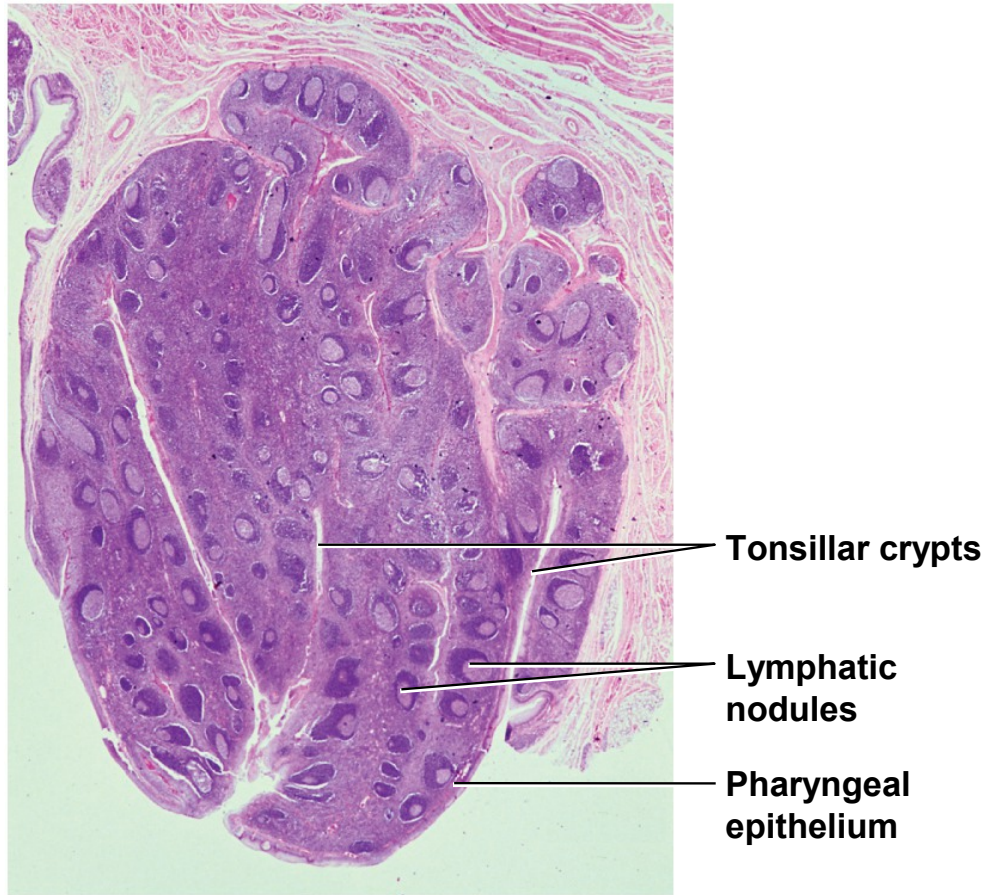


Tonsils



- patches of lymphatic tissue **located at the entrance to the pharynx**
 - guard against ingested or inhaled pathogens
 - covered with epithelium
 - have deep pits – **tonsillar crypts** lined with lymphatic nodules (clusters of macrophages and immune cells)
 - **tonsillitis** and **tonsillectomy**

Pharyngeal Tonsil



- covered by epithelium
- Food with pathogens enter tonsillar crypts and encounter lymphocytes

Tonsils

(Lab Objectives)

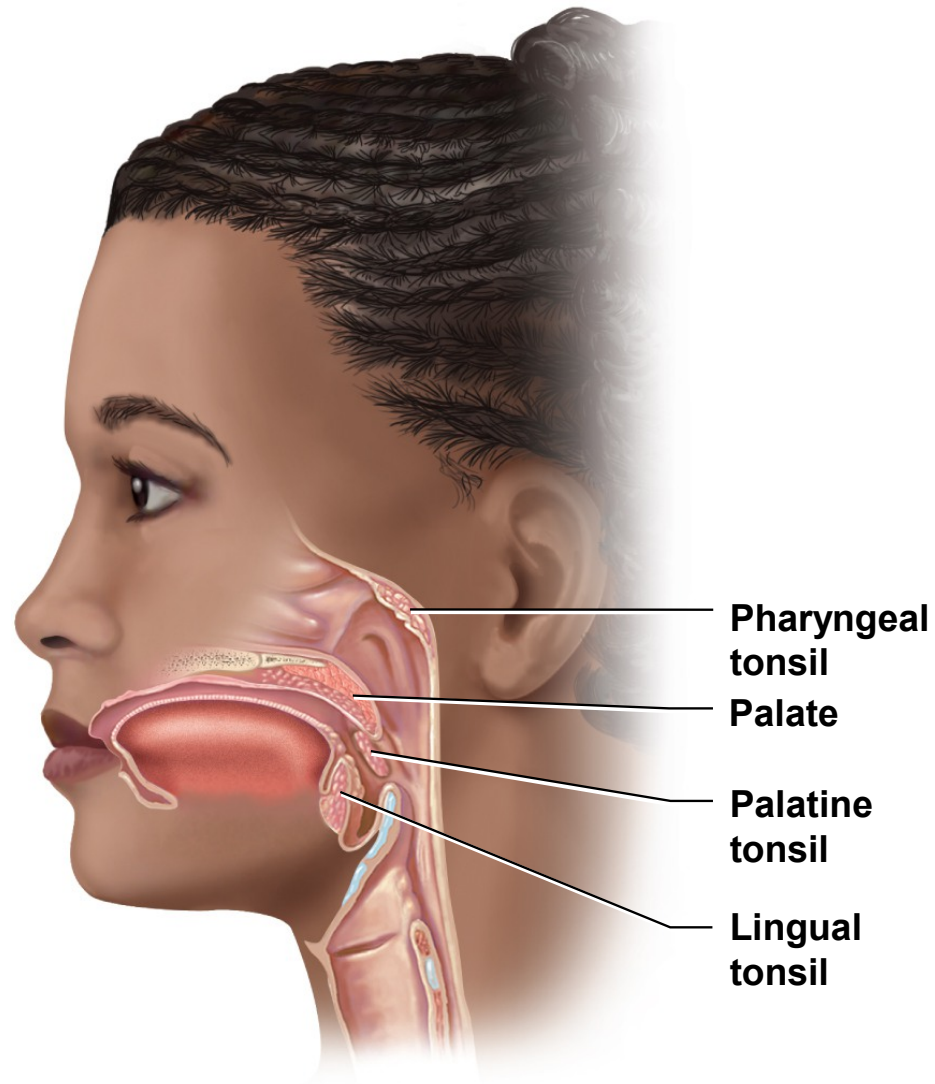
Three main sets of tonsils

palatine tonsils // pair at posterior margin of oral cavity // most often infected

lingual tonsils // pair at root of tongue

pharyngeal tonsil (adenoid) // single tonsil on wall of nasopharynx

The Tonsils



Spleen

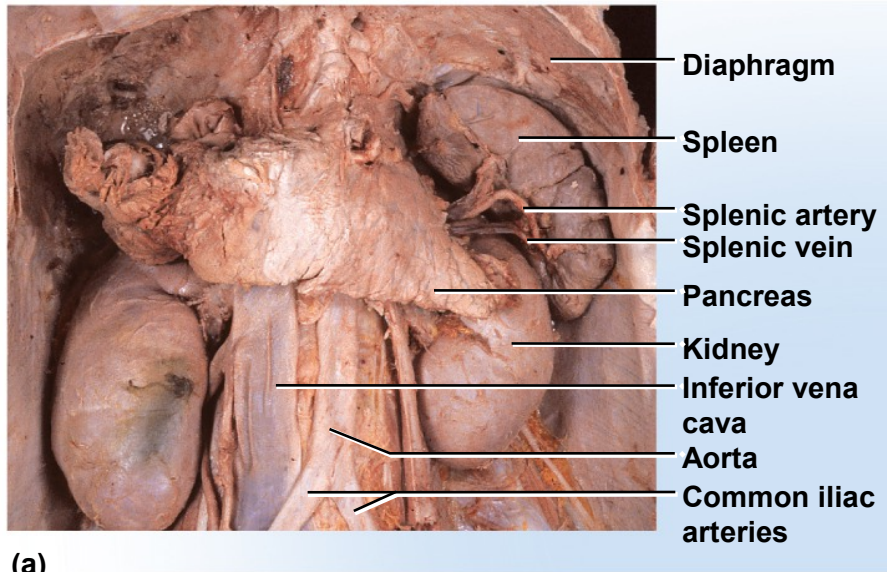


- the body's **largest lymphatic organ**
- **parenchyma** exhibits two types of tissue:
 - red pulp - sinuses filled with erythrocytes
 - white pulp – lymphocytes & macrophages surrounding small branches of splenic artery

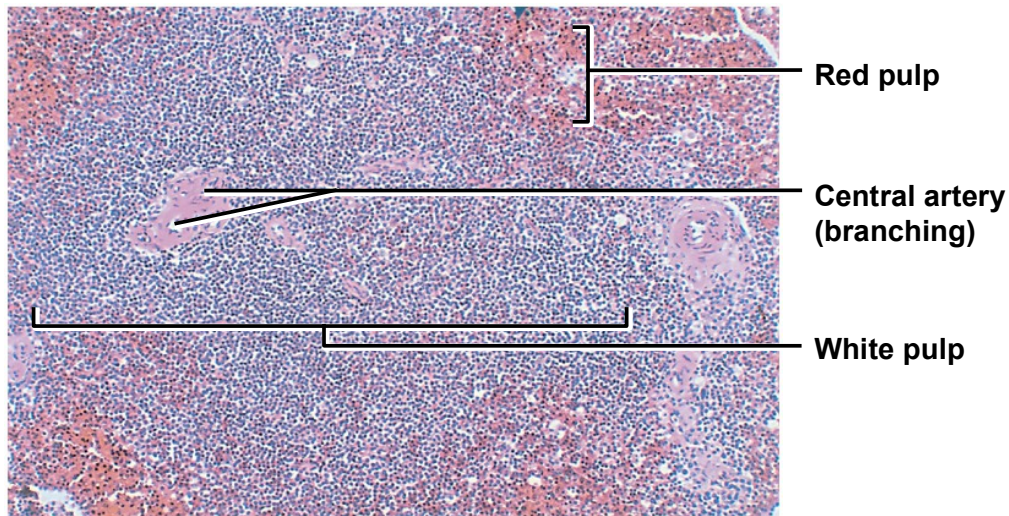
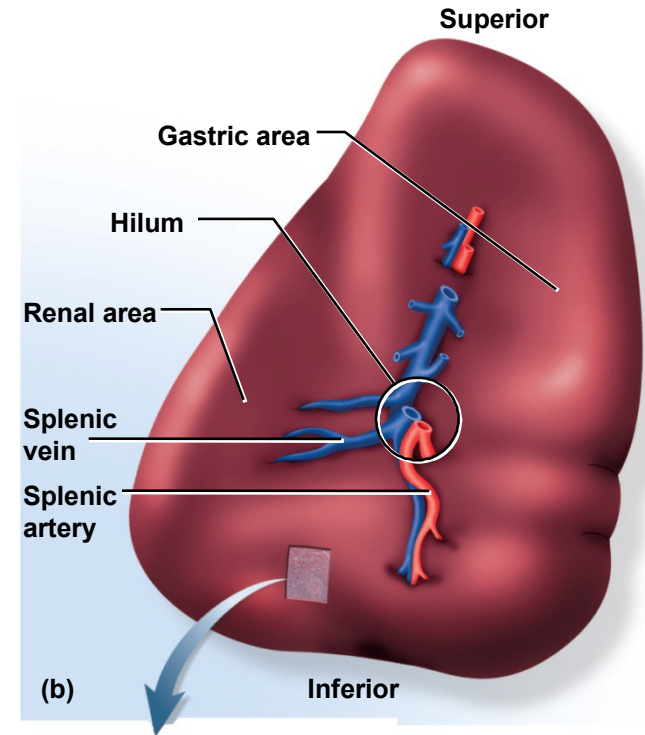
Spleen Functions



- Filters blood – remove bacteria / similar functions as lymph nodes / white pulp = WBC that monitor blood for foreign antigens / site for resting T and B cells in spleen / many macrophage
- blood production in fetus (may resume under certain conditions)
- blood reservoir
- 40% of circulating platelets stored in spleen
- ‘erythrocyte graveyard’ - RBC disposal
- spleen highly vascular and vulnerable to trauma and infection
- ruptured spleen /// often requires the removal of spleen - splenectomy



Spleen

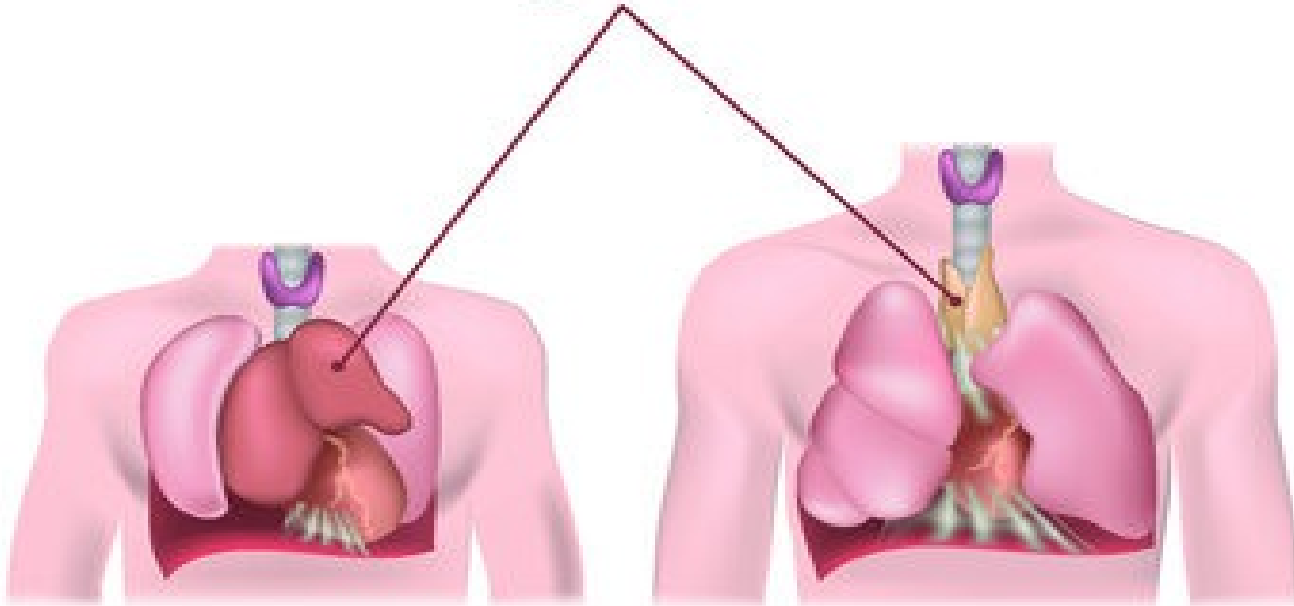


Thymus



- Contributes to the function of the **endocrine, lymphatic, and immune systems**
 - Bi-lobed organ located in superior mediastinum between the sternum and aortic arch // **site where T cells “mature” (born in bone marrow)**
 - secretes hormones regulating their activity
 - degeneration or involution with age
 - fibrous capsule gives off **trabeculae (septa)** that divide the gland into several lobes
 - lobes have cortex and medulla areas populated by T lymphocytes
 - **reticular epithelial cells** seal off cortex from medulla forming a functional **blood-thymus barrier**
 - produce signaling molecules **thymosin, thymopoietin, thymulin, interleukins, and interferon**

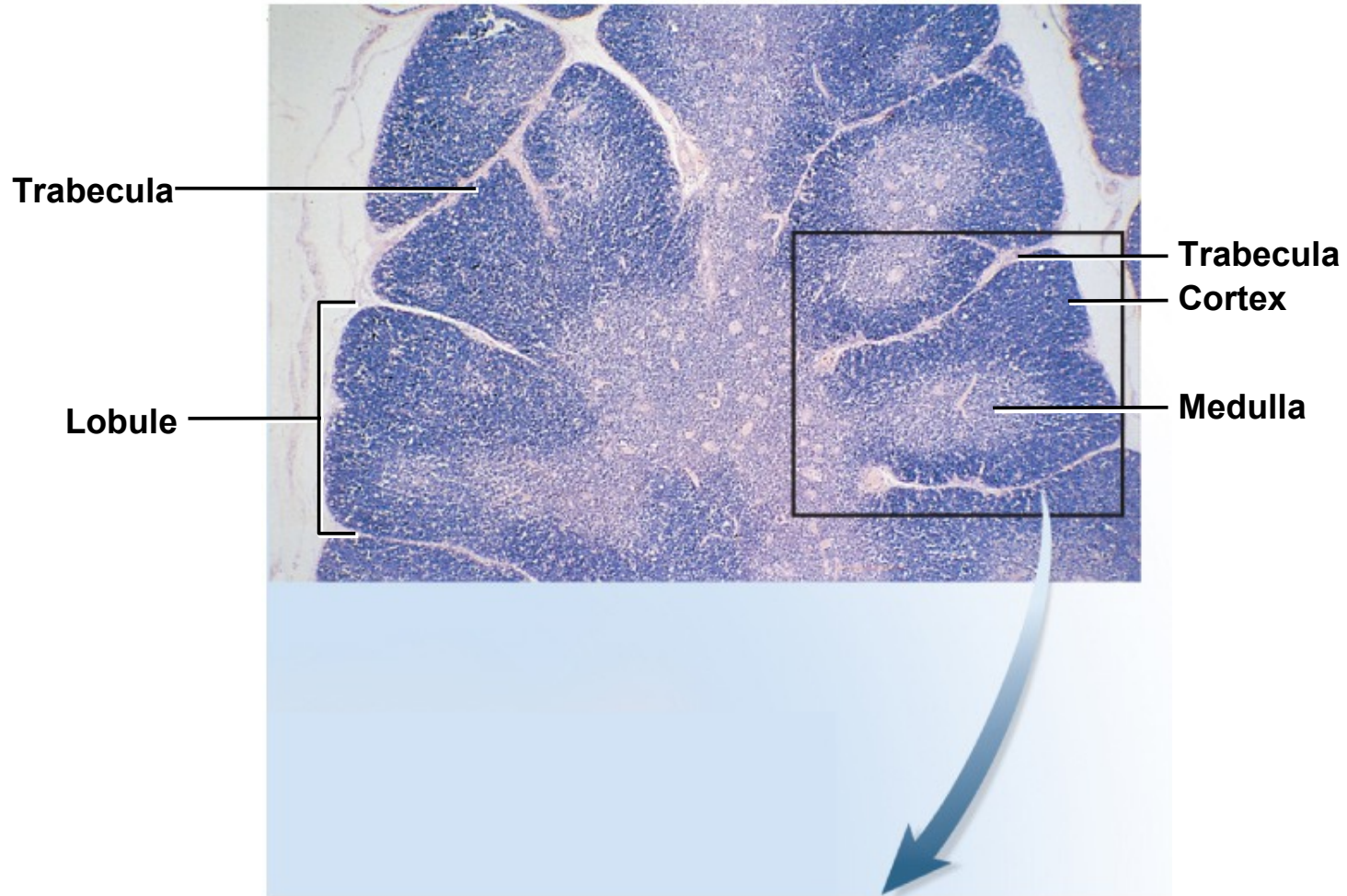
thymus



newborn

adult

Histology of Thymus





Lymphatic system & Immunity

Lymph nodes play a key role in protecting our body from pathogens // lymph nodes are resting sites for immune cells (T cells, B cells, macrophage)

Pathogens are ingested throughout our body by different types of WBC (the antigen presenting cells) and transported in the lymph fluid to the lymph nodes

As lymph is moved through a lymph node - fluid is inspected for signs of pathogens

Inside the lymph nodes, **antigen presenting cells** will display signs of pathogens to initiate an immune Responses

APC are required to activate helper T cells, cytotoxic T cells, and B cells