Chapter 15

The Lymphatic System and Immunity

Objectives

- Describe general functions of the lymphatic system and list the main lymphatic structures
- Compare nonspecific and specific immunity
- Name the major disorders associated with the lymphatic system

Objectives

- Discuss the major types of immune system molecules
- Discuss and contrast the development and functions of B and T cells

Objectives

- Describe the mechanisms of allergy, autoimmunity, and isoimmunity
- List the major types of immune deficiencies and explain their causes

The Lymphatic System

- Lymph—fluid in the tissue spaces that carries protein molecules and other substances back to the blood

Lymph Road Map

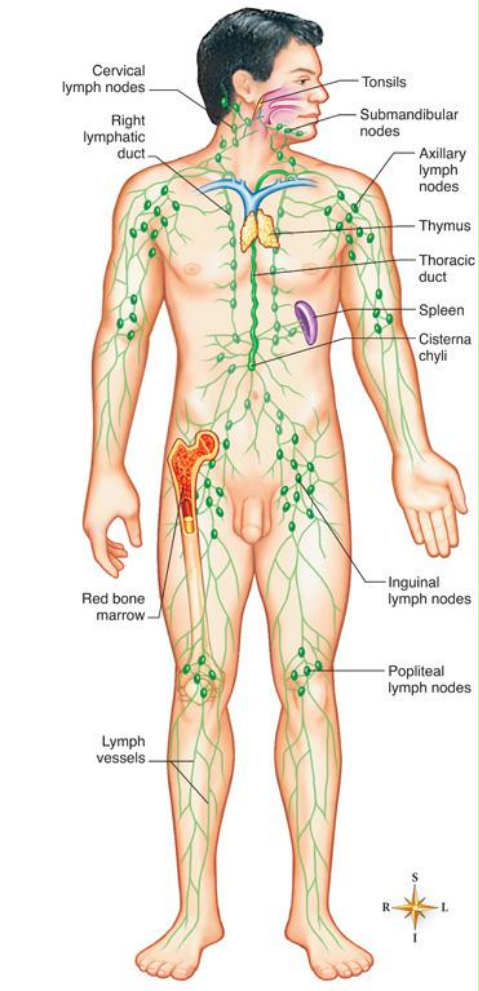
1. Blood plasma filters out
2. Liquid enters as interstitial fluid
3. Enters lymphatic capillaries
4. Venules

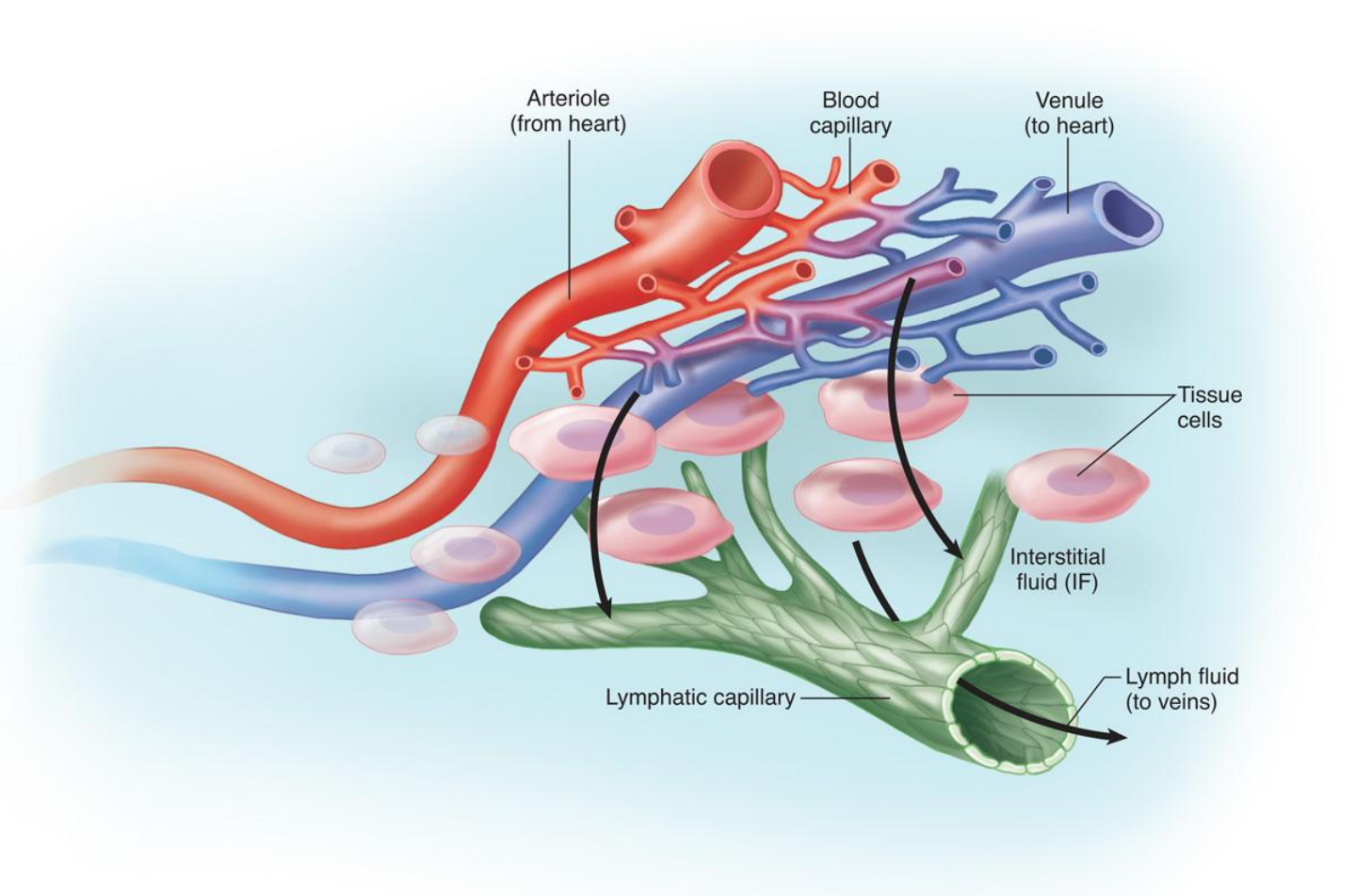
Lymph is filtered along way by organs and glands

5. Veins
6. Right lymphatic duct and thoracic duct
7. Blood veins in neck

The Lymphatic System

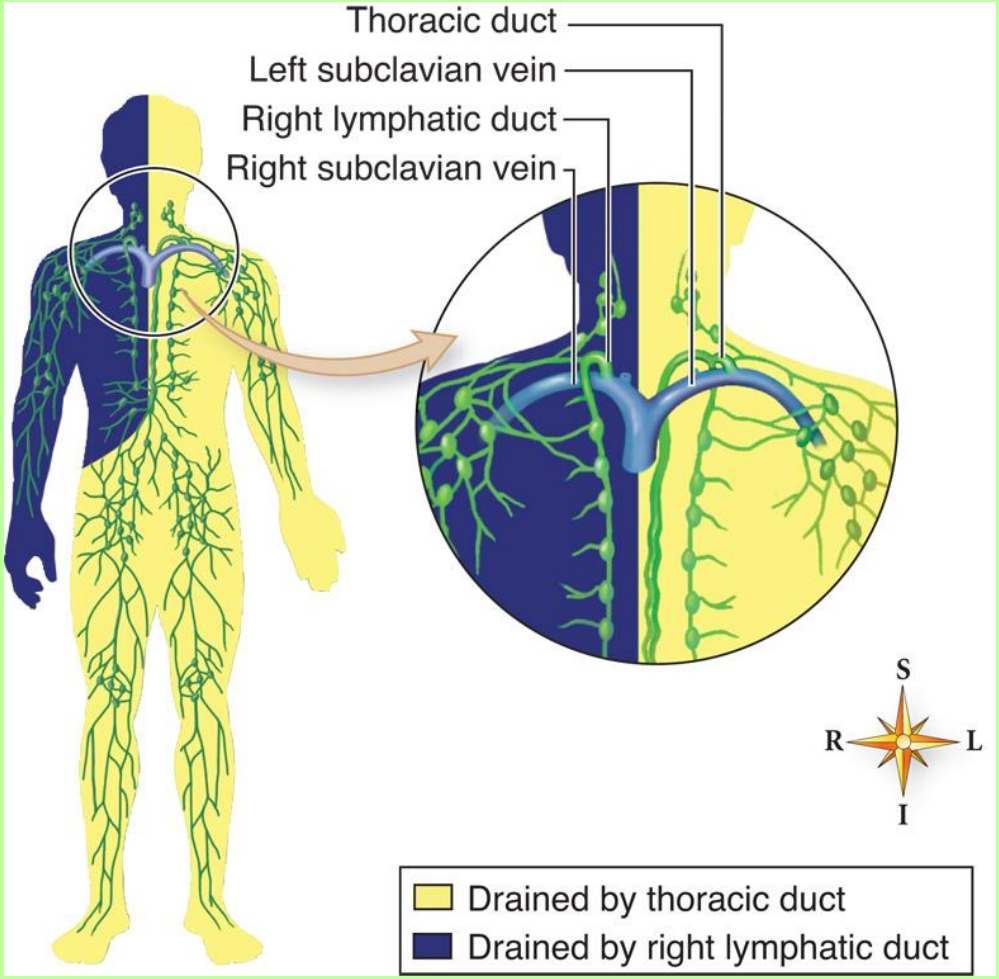
- Lymphatic vessels—permit only one-way movement of lymph
  - Lymphatic capillaries—tiny blind-ended tubes distributed in tissue spaces
    - Microscopic in size
    - Sheets consisting of one cell layer of simple squamous epithelium
    - Poor “fit” between adjacent cells results in porous walls
    - Called *lacteals* in the intestinal wall (for fat transportation)


Cervical lymph nodes
Tonsils
Submandibular nodes
Right lymphatic duct
Axillary lymph nodes
Thymus
Thoracic duct
Spleen
Cisterna chyli
Red bone marrow
Inguinal lymph nodes
Popliteal lymph nodes
Lymph vessels
S
R
L
I


Arteriole
(from heart)
Blood
capillary
Venule
(to heart)
Tissue
cells
Interstitial
fluid (IF)
Lymphatic capillary
Lymph fluid
(to veins)

The Lymphatic System

- Lymphatic vessels
  - Right lymphatic duct
    - Drains lymph from the right upper extremity and right side of head, neck, and upper torso
  - Thoracic duct
    - Largest lymphatic vessel
    - Has an enlarged pouch along its course, called *cisterna chyli*
    - Drains lymph from about three fourths of the body

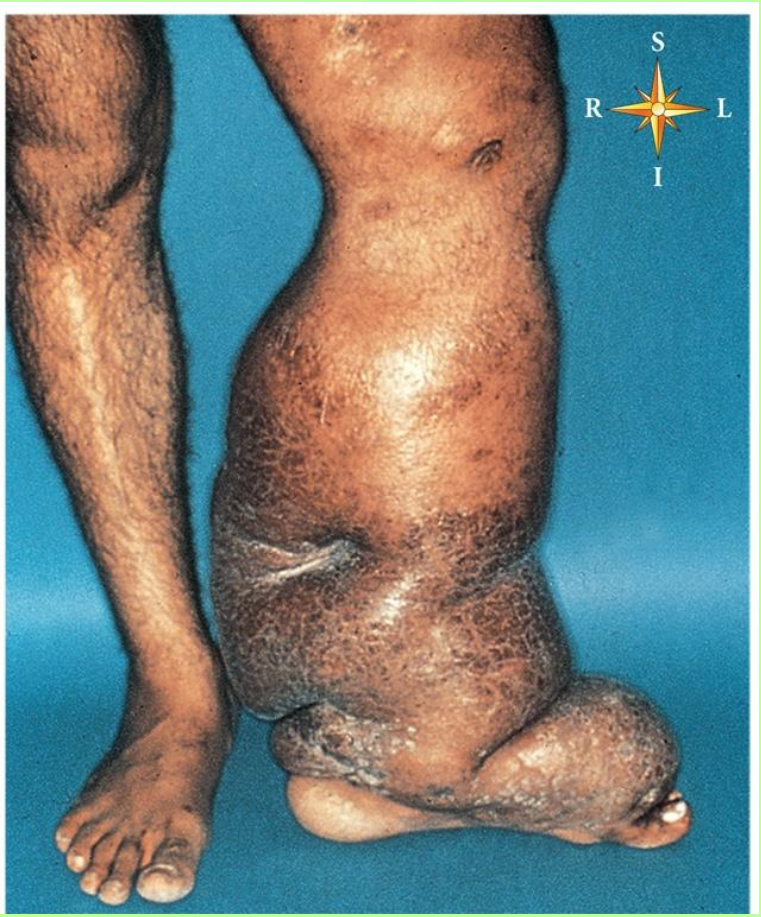

Thoracic duct
Left subclavian vein
Right lymphatic duct
Right subclavian vein
S
R
L
I
Drained by thoracic duct
Drained by right lymphatic duct

The Lymphatic System

- Lymphedema—swelling (edema) of tissues caused by blockage of lymphatic vessels
  - Lymphangitis—inflammation of lymphatic vessels, may progress to septicemia (blood infection)
  - Elephantiasis—severe lymphedema of limbs resulting from parasite infestation of lymphatic vessels

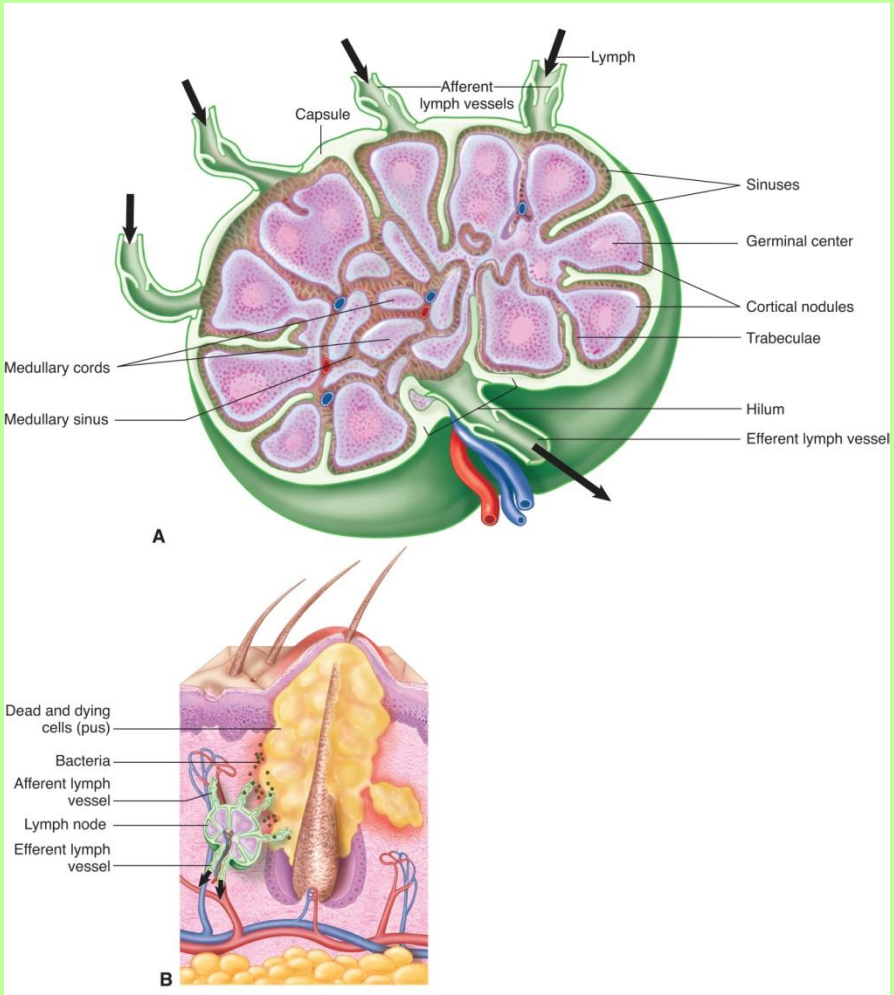

L
P
D
R

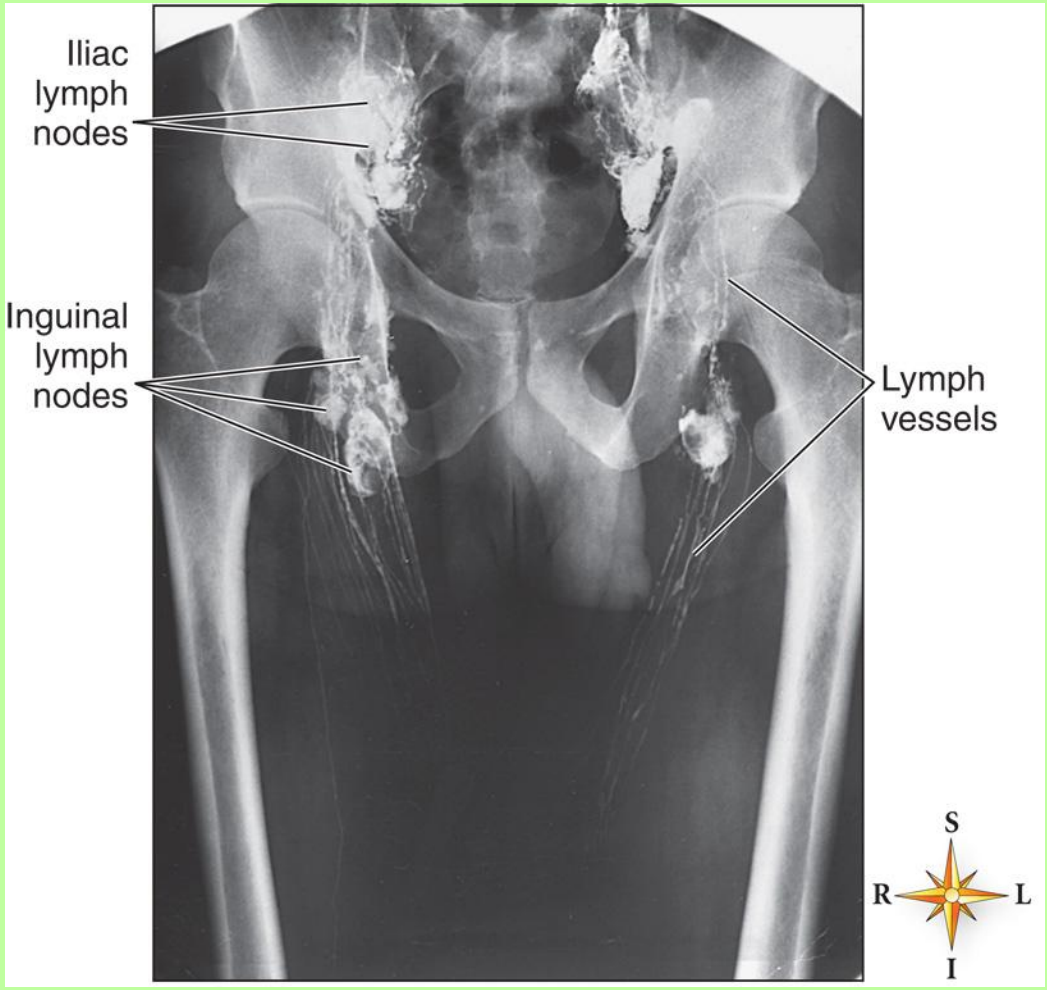

S
P
A
I

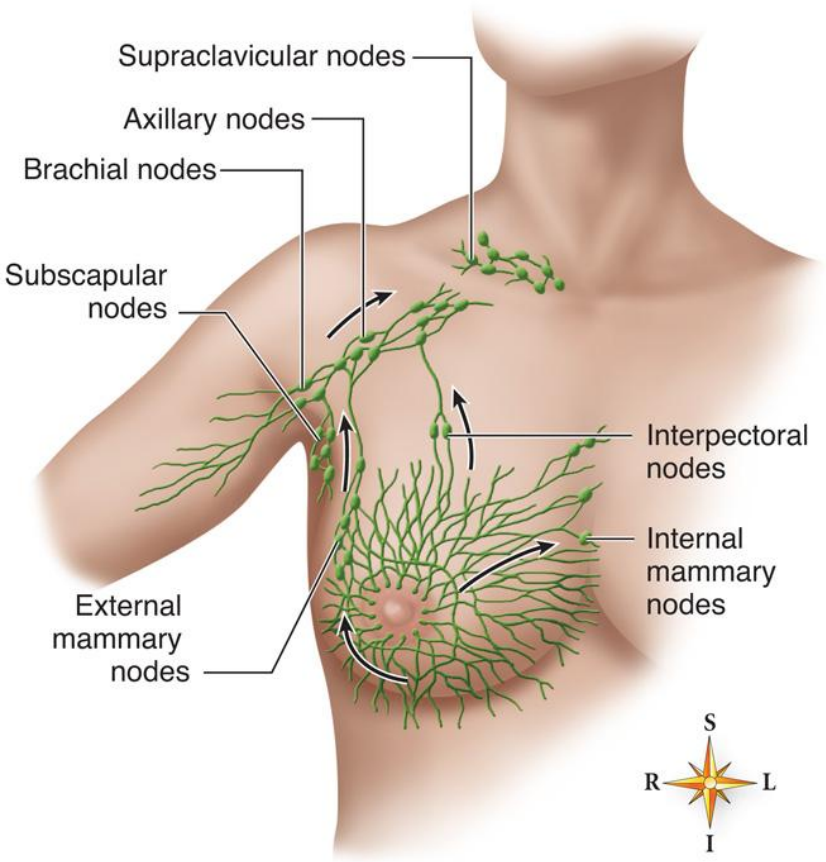

S
R
L
I

The Lymphatic System

- Lymph nodes
  - Filter lymph
  - Located in clusters along the pathway of lymphatic vessels
  - Lymphoid tissue—mass of lymphocytes and related cells inside a lymphoid organ; provides immune function and development of immune cells
  - Lymph nodes and other lymphoid organs have functions that include defense and WBC formation

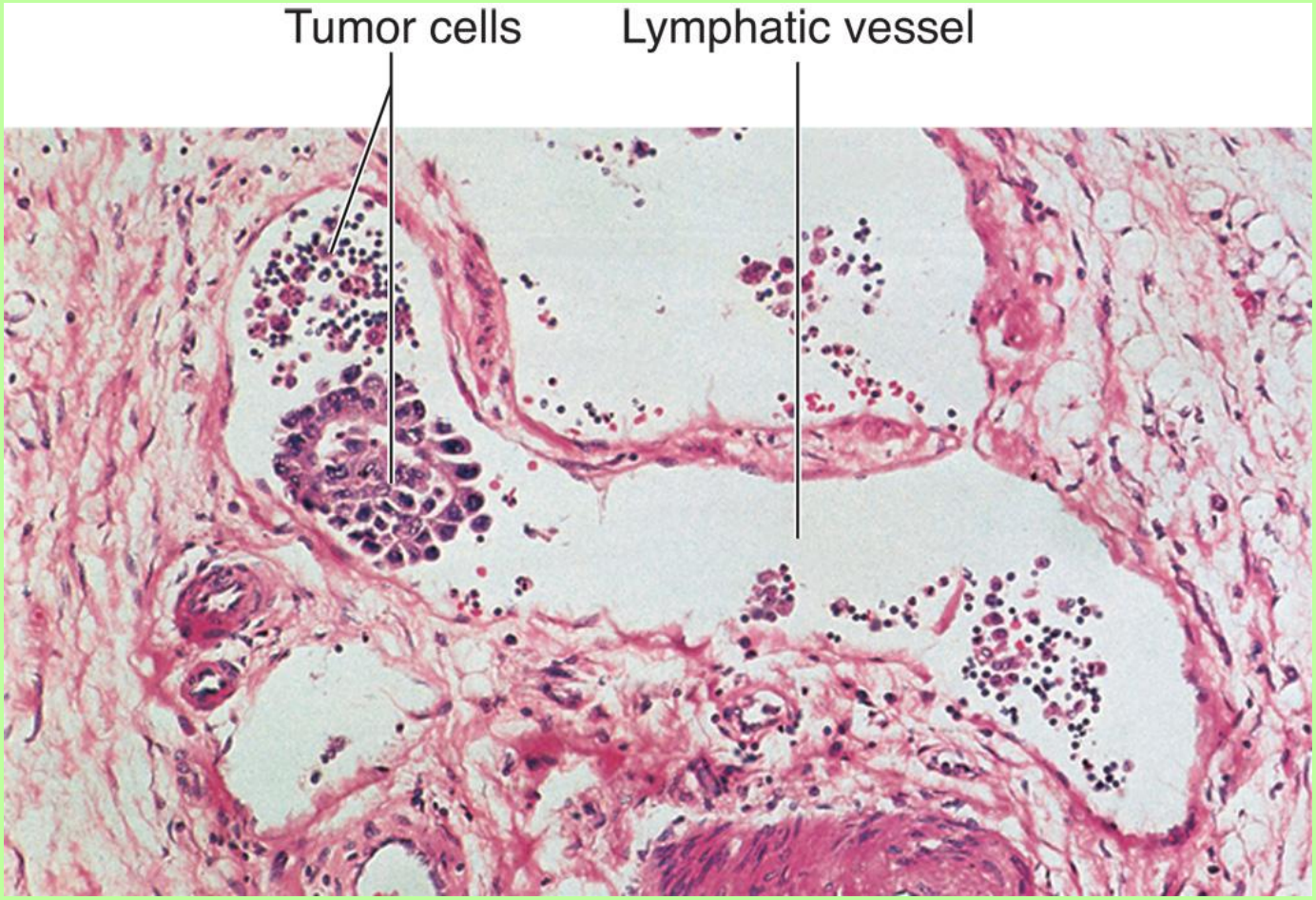

Lymph
Afferent lymph vessels
Capsule
Sinuses
Germinal center
Cortical nodules
Trabeculae
Medullary cords
Medullary sinus
Hilum
Efferent lymph vessel
A
Dead and dying cells (pus)
Bacteria
Afferent lymph vessel
Lymph node
Efferent lymph vessel
B


Iliac lymph nodes
Inguinal lymph nodes
Lymph vessels
S
R
L
I


Supraclavicular nodes
Axillary nodes
Brachial nodes
Subscapular nodes
Interpectoral nodes
Internal mammary nodes
External mammary nodes
S
R
L
I

The Lymphatic System

- Lymph nodes
  - Flow of lymph: to node via several afferent lymphatic vessels and drained from node by a single efferent lymphatic vessel
  - Lymphadenitis—swelling and tenderness of lymph nodes
  - Cancer cells can easily move through lymphatic vessels to other parts of the body in a process called *metastasis*


Tumor cells
Lymphatic vessel

The Lymphatic System

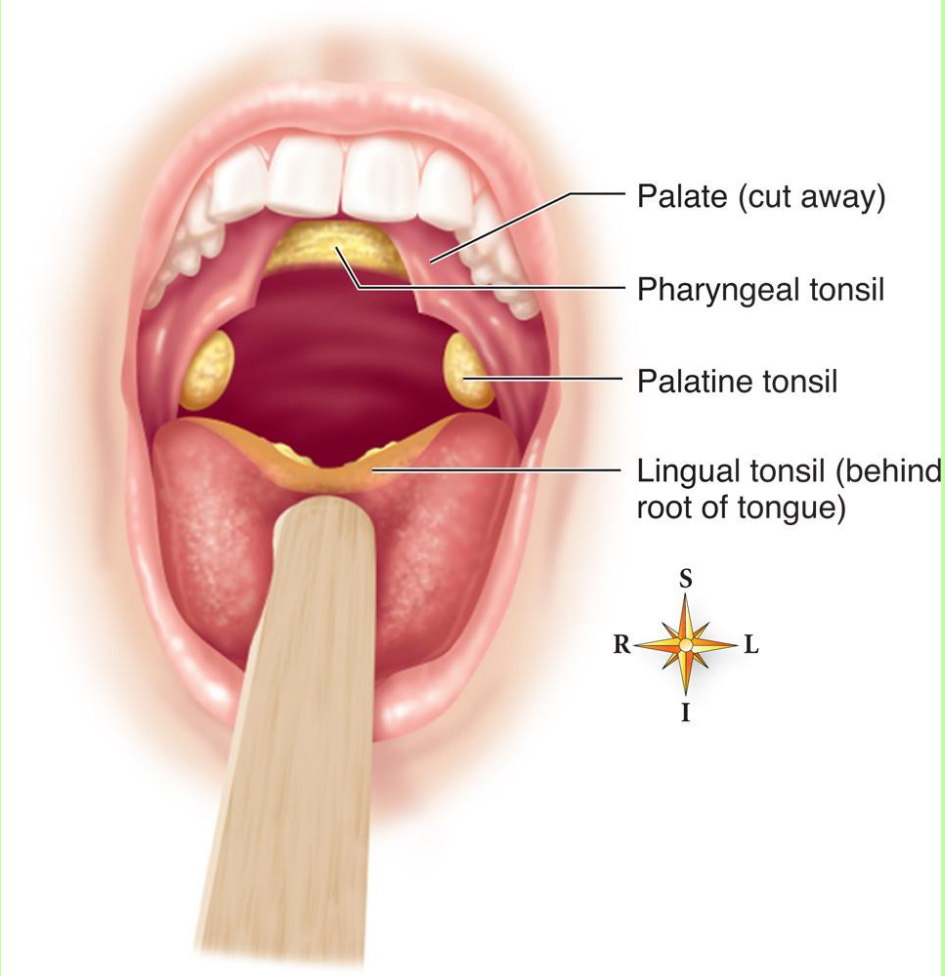
- Lymphoma—malignant tumor of lymph nodes
  - Two types: Hodgkin disease and non-Hodgkin lymphoma
- Thymus
  - Lymphoid tissue organ located in mediastinum
  - Total weight of about 35–40 g—a little more than an ounce

The Lymphatic System

- Thymus
  - Plays a vital and central role in immunity
  - Produces T lymphocytes or T cells
  - Secretes hormone called *thymosin*
  - Lymphoid tissue is largely replaced by fat in the process called *involution*

The Lymphatic System

- Tonsils
  - Composed of three masses of lymphoid tissue around the openings of the mouth and throat
    - Palatine tonsils (“the tonsils”)
    - Pharyngeal tonsils (adenoids)
    - Lingual tonsils
  - Subject to chronic infection
  - Enlargement of pharyngeal tonsils may impair breathing


Palate (cut away)
Pharyngeal tonsil
Palatine tonsil
Lingual tonsil (behind root of tongue)
S
R
L
I

The Lymphatic System

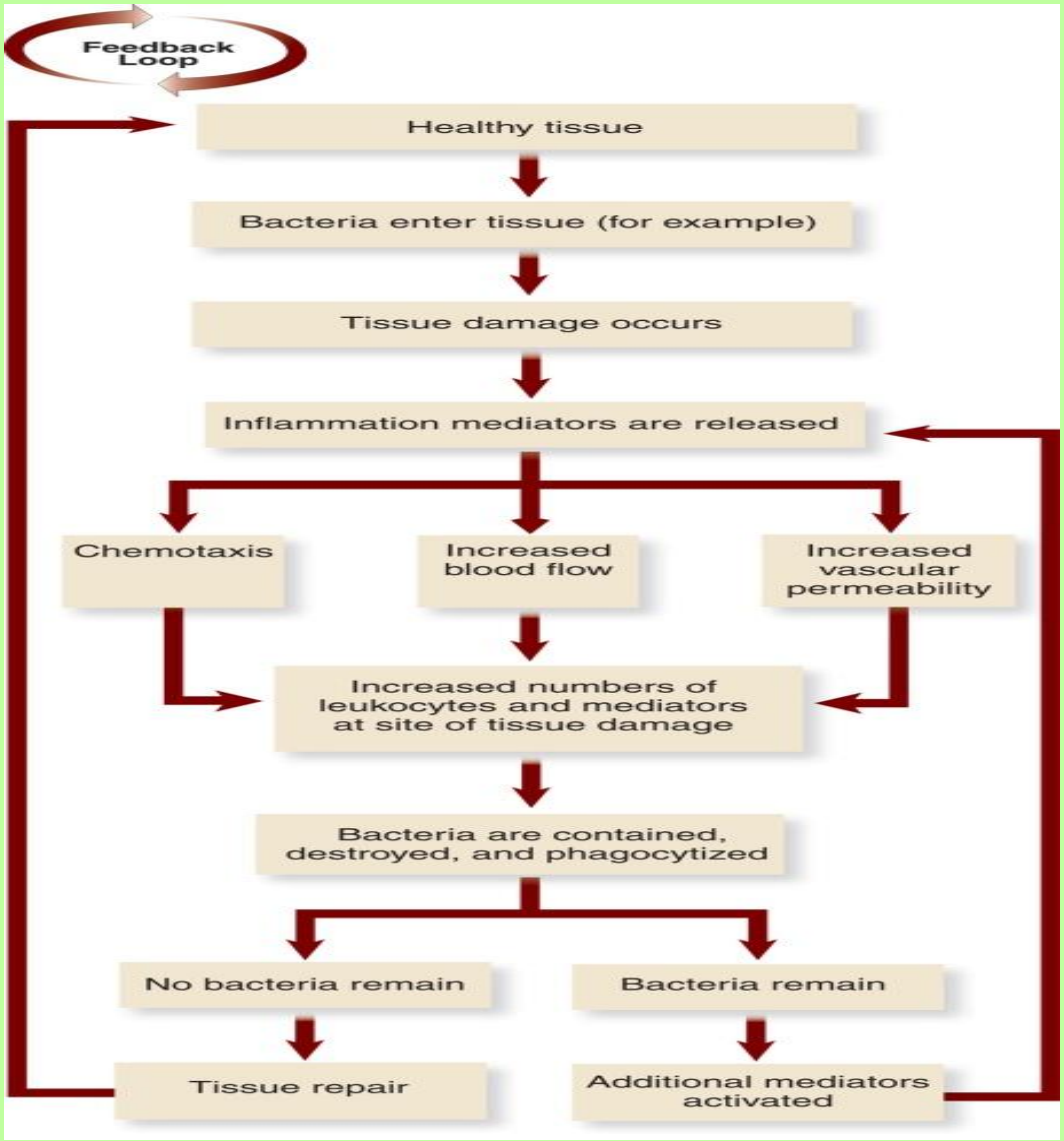
- Spleen
  - Largest lymphoid organ in body
  - Located in upper left quadrant of abdomen
  - Often injured by trauma to abdomen
  - Surgical removal called *splenectomy*
  - Functions include phagocytosis of bacteria and old RBCs; acts as a blood reservoir
  - Splenomegaly—enlargement of the spleen

The Immune System

- Protects body from pathological bacteria, foreign tissue cells, and cancerous cells
- Made up of defensive cells and molecules
- Nonspecific immunity
  - Skin—mechanical barrier to bacteria and other harmful agents

The Immune System

- Nonspecific immunity
  - Tears and mucus—wash eyes and trap and kill bacteria
  - Inflammation attracts immune cells to site of injury, increases local blood flow, increases vascular permeability; promotes movement of WBCs to site of injury or infection


Feedback Loop
Healthy tissue
Bacteria enter tissue (for example)
Tissue damage occurs
Inflammation mediators are released
Chemotaxis
Increased blood flow
Increased vascular permeability
Increased numbers of leukocytes and mediators at site of tissue damage
Bacteria are contained, destroyed, and phagocytized
No bacteria remain
Bacteria remain
Tissue repair
Additional mediators activated

The Immune System

- Specific immunity—ability of body to recognize, respond to, and remember harmful substances or bacteria
- Inherited or inborn immunity—inherited immunity to certain diseases from time of birth

The Immune System

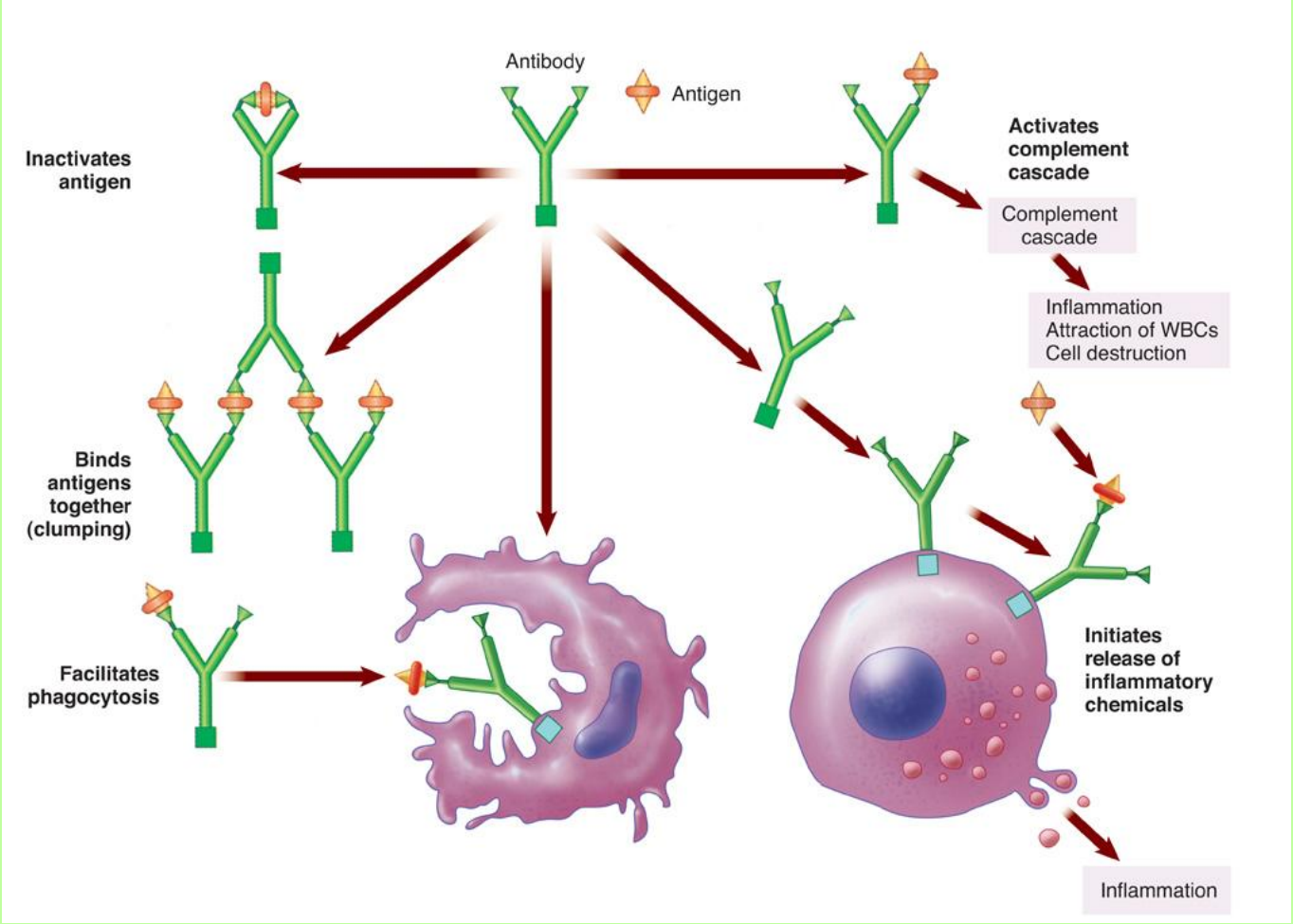
- Acquired immunity
  - Natural immunity—exposure to causative agent is not deliberate
    - Active—active disease produces immunity-measles
    - Passive—immunity passes from mother to fetus through placenta or from mother to child through mother's milk

The Immune System

- Acquired immunity
  - Artificial immunity—exposure to causative agent is deliberate
    - Active—vaccination results in immunity
    - Passive—protective material developed in another individual's immune system and given to previously nonimmune individual- i.e. antibodies in mother's milk

Immune System Molecules

- Antibodies
  - Protein compounds with specific combining sites
  - Combining sites attach antibodies to specific antigens (foreign proteins), forming antigen-antibody complex—called *humoral* or *antibody-mediated* immunity
  - Antigen-antibody complexes may:
    - Neutralize toxins
    - Clump or agglutinate enemy cells
    - Promote phagocytosis

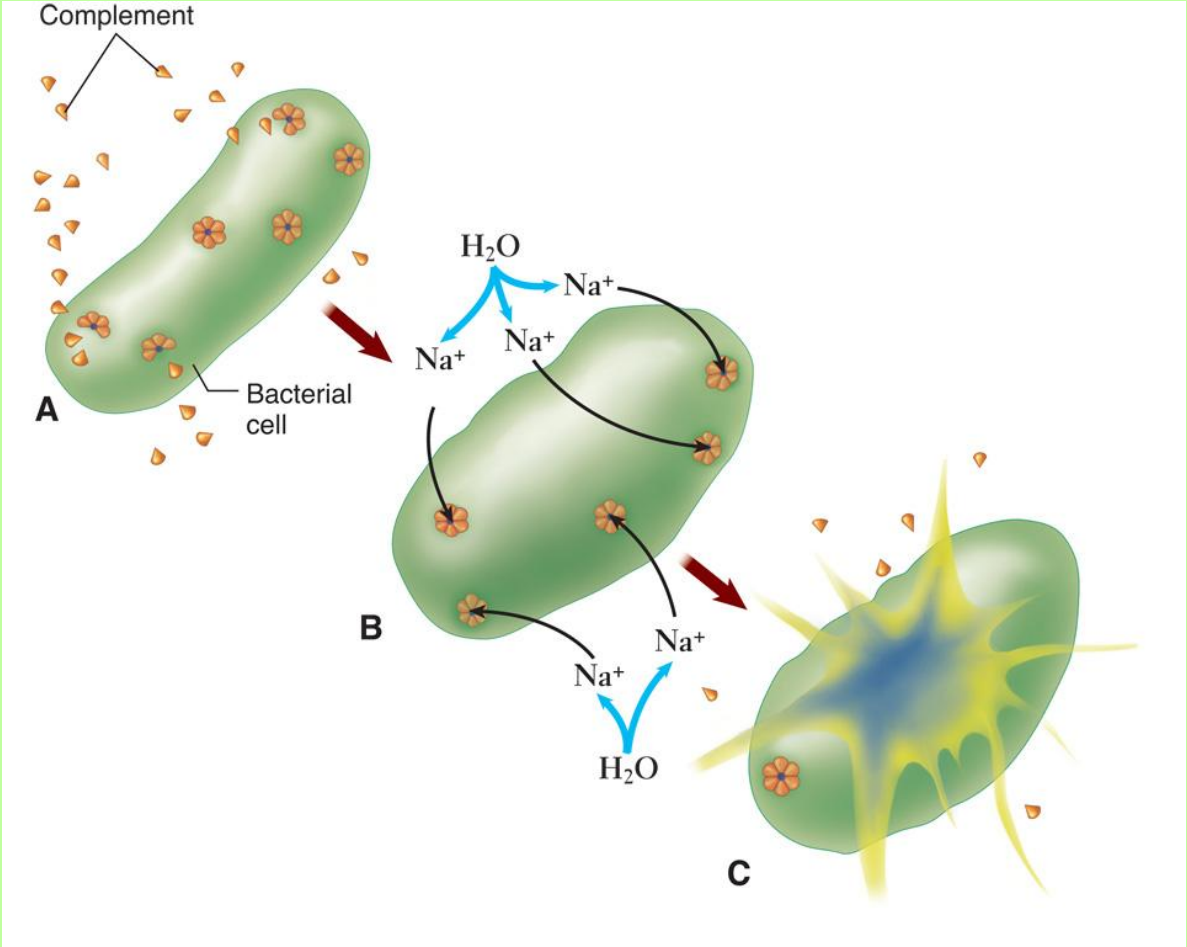

Antibody
Antigen
Inactivates antigen
Activates complement cascade
Complement cascade
Inflammation
Attraction of WBCs
Cell destruction
Binds antigens together (clumping)
Facilitates phagocytosis
Initiates release of inflammatory chemicals
Inflammation

Immune System Molecules

- Complement proteins
  - Group of proteins normally present in blood in inactive state
  - Complement cascade
    - Important mechanism of action for antibodies
      - Complement-binding sites on antibody are exposed after attaching to antigen
      - Complement triggers a series (cascade) of reactions that produce tiny protein rings that create holes in the surface of a foreign cell

Immune System Molecules

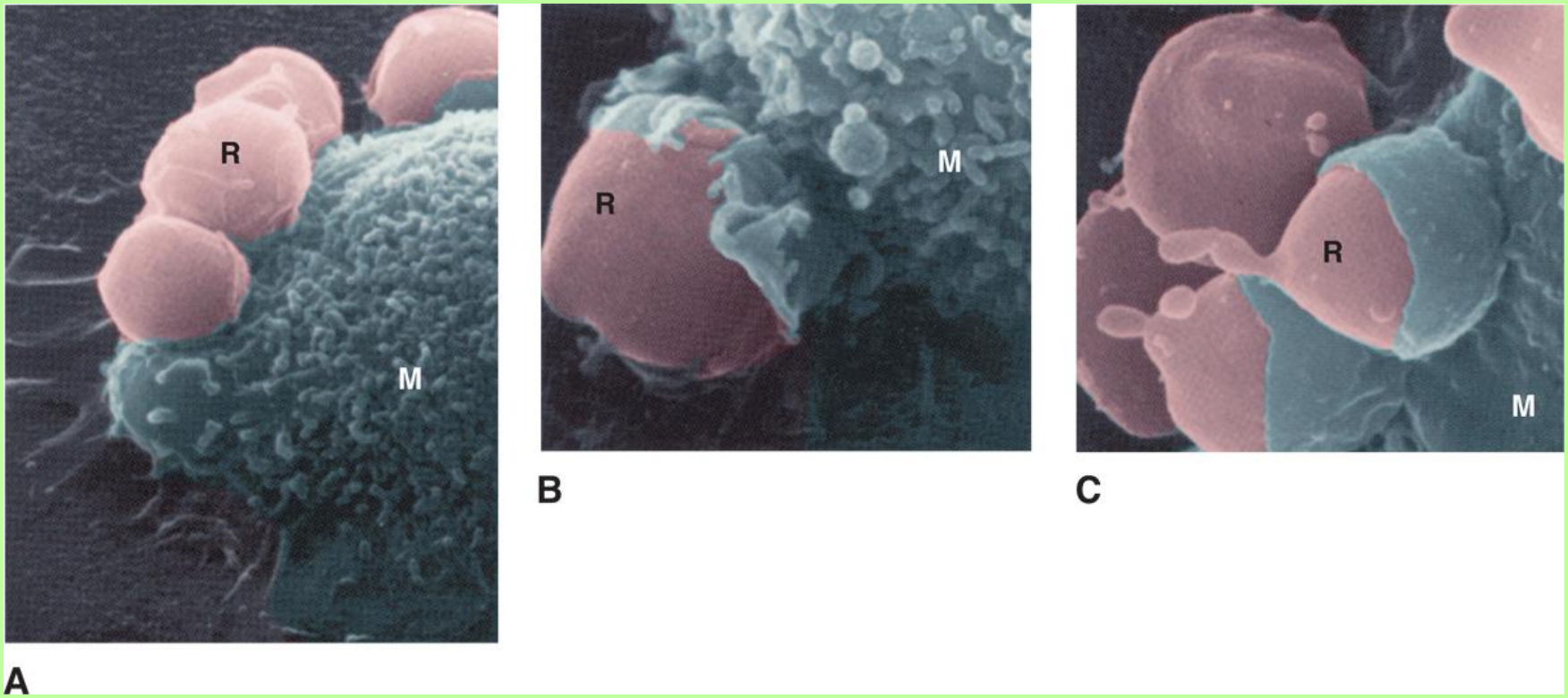
- Complement proteins
  - Complement cascade
    - Ultimately causes cell lysis by permitting entry of water through a defect created in the plasma membrane of the foreign cell
  - Complement proteins play many other roles in immunity, including the inflammatory response


Complement
Bacterial cell
A
H_2O
Na^+
Na^+
Na^+
B
Na^+
Na^+
H_2O
C

Immune System Cells

- Phagocytes
  - Types
    - Neutrophils—short-lived phagocytic cells
    - Monocytes—develop into phagocytic macrophages and migrate to tissues (Figure 15-15)
    - Dendritic cells (DCs)—often found at or near external surfaces

Phagocytosis

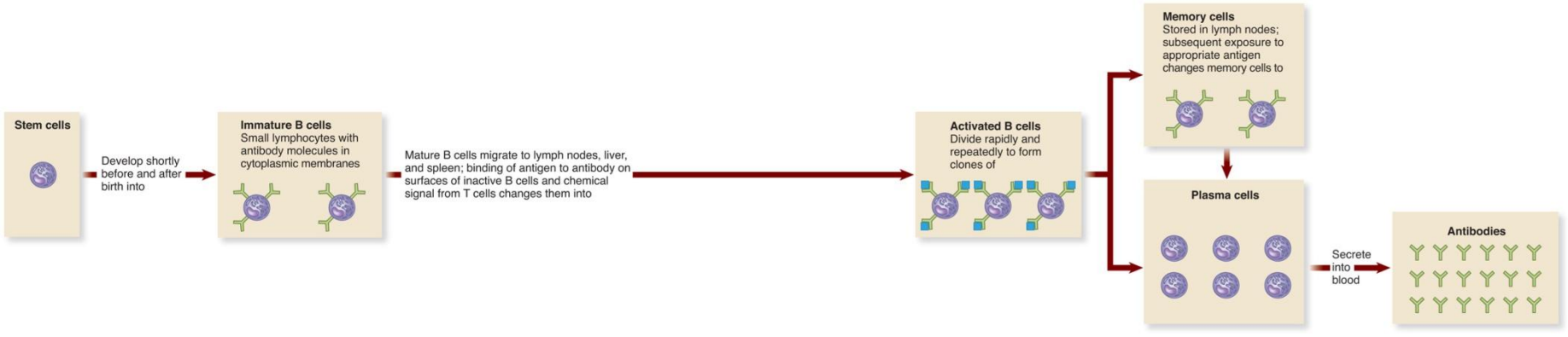


Immune System Cells

- Phagocytes
  - Ingest and destroy foreign cells or other harmful substances via phagocytosis
  - Macrophages and DCs act as antigen-presenting cells (APCs) by displaying ingested antigens on their outer surface to trigger specific immune cells

Immune System Cells

- Lymphocytes
  - Most numerous of immune system cells
  - Development of B cells—primitive stem cells migrate from bone marrow and go through two stages of development


Stem cells
Develop shortly before and after birth into
Immature B cells
Small lymphocytes with antibody molecules in cytoplasmic membranes
Mature B cells migrate to lymph nodes, liver, and spleen; binding of antigen to antibody on surfaces of inactive B cells and chemical signal from T cells changes them into
Activated B cells
Divide rapidly and repeatedly to form clones of
Memory cells
Stored in lymph nodes; subsequent exposure to appropriate antigen changes memory cells to
Plasma cells
Secrete into blood
Antibodies

Immune System Cells

- Lymphocytes
  - Development of B cells
    - First stage—stem cells develop into immature B cells
      - Takes place in the liver and bone marrow before birth and in the bone marrow only in adults
      - B cells are small lymphocytes with antibody molecules (which they have synthesized) in their plasma membranes
      - After they mature, inactive B cells migrate chiefly to lymph nodes

Immune System Cells

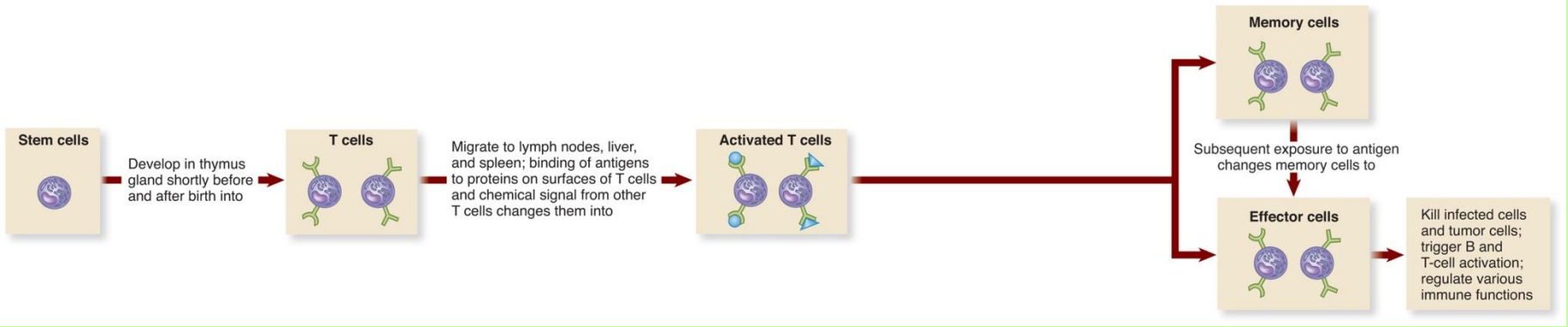
- Development of B cells
  - Second stage—inactive B cell develops into activated B cell
    - Initiated by inactive B cell's contact with antigens, which bind to its surface antibodies, plus signal chemicals from T cells
    - Activated B cell, by dividing repeatedly, forms two clones of cells—plasma (effector) cells and memory cells
    - Plasma cells secrete antibodies into blood; memory cells are stored in lymph nodes
    - If subsequent exposure to antigen that activated B cell occurs, memory cells become plasma cells and secrete antibodies

Immune System Cells

- Function of B cells—indirectly, B cells produce humoral immunity
  - Activated B cells develop into plasma cells
  - Plasma cells secrete antibodies into the blood
  - Circulating antibodies produce humoral immunity

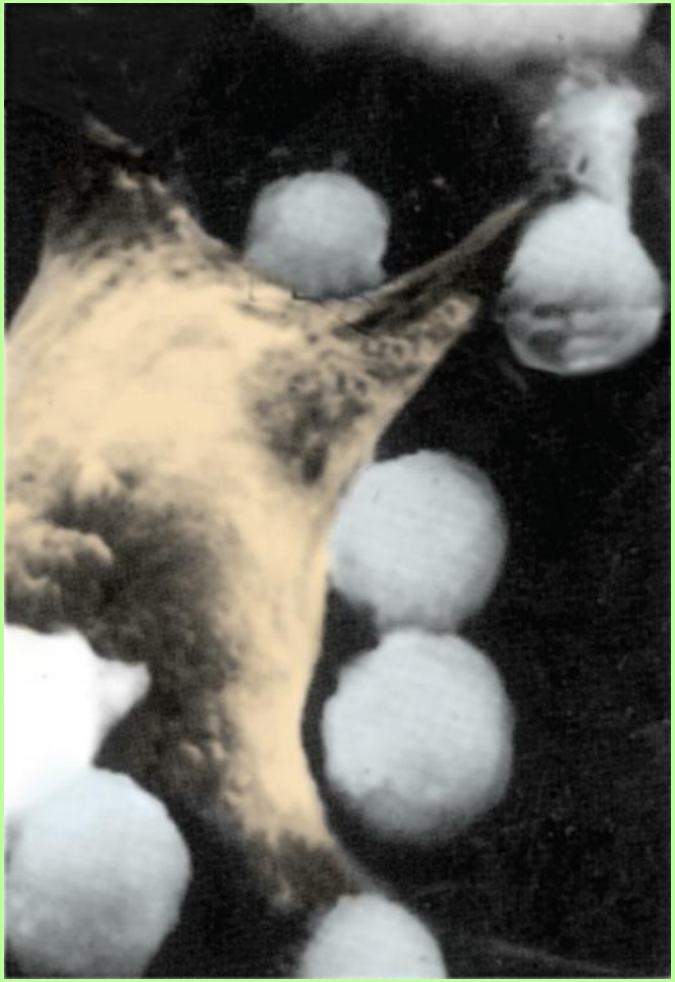
Immune System Cells

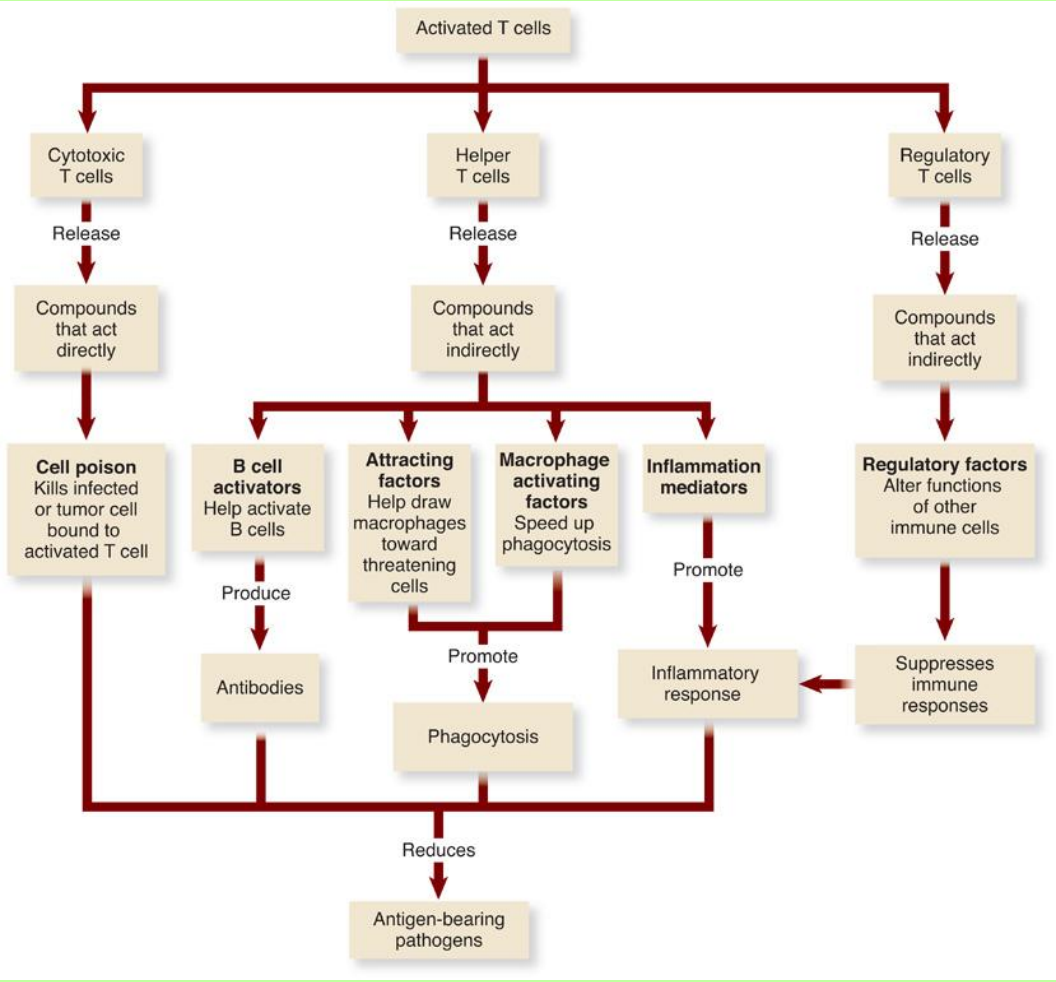
- Development of T cells—stem cells from bone marrow migrate to thymus gland
  - First stage—stem cells develop into T cells
    - Occurs in thymus during few months before and after birth
    - T cells migrate chiefly to lymph nodes
  - Second stage—T cells develop into activated T cells
    - Occurs when, and if, antigen binds to T cell's surface proteins and chemical signal received from another T cell
    - As with B cells, clones made up of effector cells and memory cells are formed


Stem cells
Develop in thymus gland shortly before and after birth into
T cells
Migrate to lymph nodes, liver, and spleen; binding of antigens to proteins on surfaces of T cells and chemical signal from other T cells changes them into
Activated T cells
Memory cells
Subsequent exposure to antigen changes memory cells to
Effector cells
Kill infected cells and tumor cells; trigger B and T-cell activation; regulate various immune functions

Immune System Cells

- Functions of T cells—produce cell-mediated immunity
  - Cytotoxic T cells—kill infected or tumor cells by releasing a substance that poisons infected or tumor cells
  - Helper T cells—release chemicals that attract and activate macrophages to kill cells by phagocytosis; produce chemicals that help activate B cells
  - Regulatory T cells—release chemicals to suppress immune responses




Activated T cells
Cytotoxic T cells
Helper T cells
Regulatory T cells
Release
Release
Release
Compounds that act directly
Compounds that act indirectly
Compounds that act indirectly
Cell poison
Kills infected or tumor cell bound to activated T cell
B cell activators
Help activate B cells
Attracting factors
Help draw macrophages toward threatening cells
Macrophage activating factors
Speed up phagocytosis
Inflammation mediators
Regulatory factors
Alter functions of other immune cells
Produce
Promote
Promote
Antibodies
Phagocytosis
Inflammatory response
Suppresses immune responses
Reduces
Antigen-bearing pathogens

Hypersensitivity of the Immune System

- Inappropriate or excessive immune response
- Allergy—hypersensitivity to harmless environmental antigens (allergens)
  - Immediate allergic responses usually involve humoral immunity
  - Delayed allergic responses usually involve cell-mediated immunity

Hypersensitivity of the Immune System

- Autoimmunity—inappropriate, excessive response to self-antigens
  - Causes autoimmune diseases
  - Systemic lupus erythematosus (SLE)—chronic inflammatory disease caused by numerous antibodies attacking a variety of tissues


S
R
L
I

Hypersensitivity of the Immune System

- Isoimmunity—excessive reaction to antigens from another human
  - May occur between mother and fetus during pregnancy
  - May occur in tissue transplants (causing rejection syndrome)

Immune System Deficiency

- Congenital immune deficiency or immunodeficiency (rare)
  - Results from improper lymphocyte development before birth
  - Severe combined immune deficiency (SCID)—caused by disruption of stem cell development

Immune System Deficiency

- Acquired immune deficiency
  - Develops after birth
  - Acquired immunodeficiency syndrome (AIDS)—caused by HIV infection of T cells