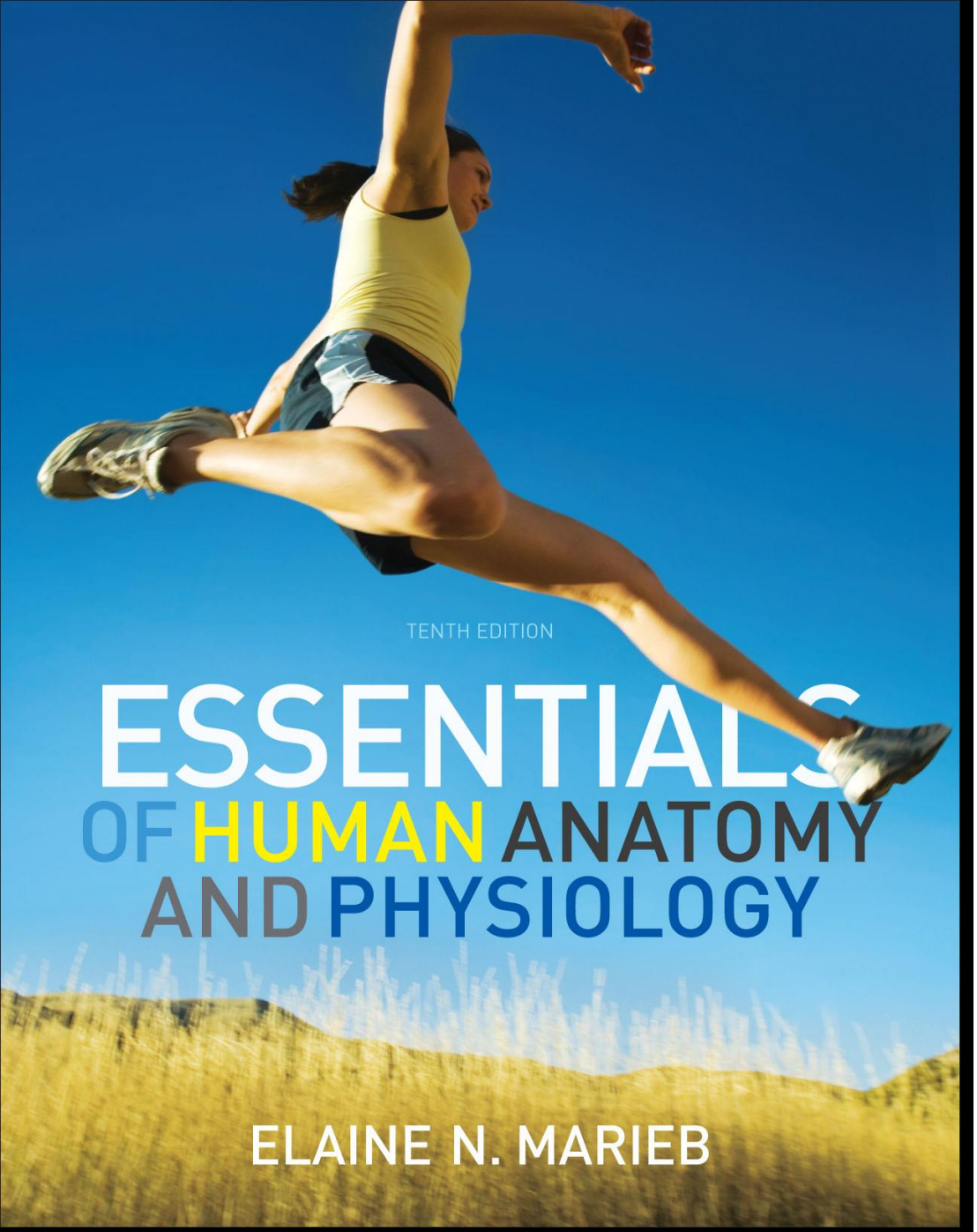

PowerPoint® Lecture Slides

Prepared by Patty Bostwick-Taylor,
Florence-Darlington Technical College

CHAPTER 12

The Lymphatic System and Body Defenses

The Lymphatic System

- Consists of two semi-independent parts
  - Lymphatic vessels
  - Lymphoid tissues and organs
- Lymphatic system functions
  - Transports escaped fluids back to the blood
  - Plays essential roles in body defense and resistance to disease

Lymphatic Characteristics

- **Lymph** —excess tissue fluid carried by lymphatic vessels
- Properties of lymphatic vessels
  - One way system toward the heart
  - No pump
  - Lymph moves toward the heart
    - Milking action of skeletal muscle
    - Rhythmic contraction of smooth muscle in vessel walls

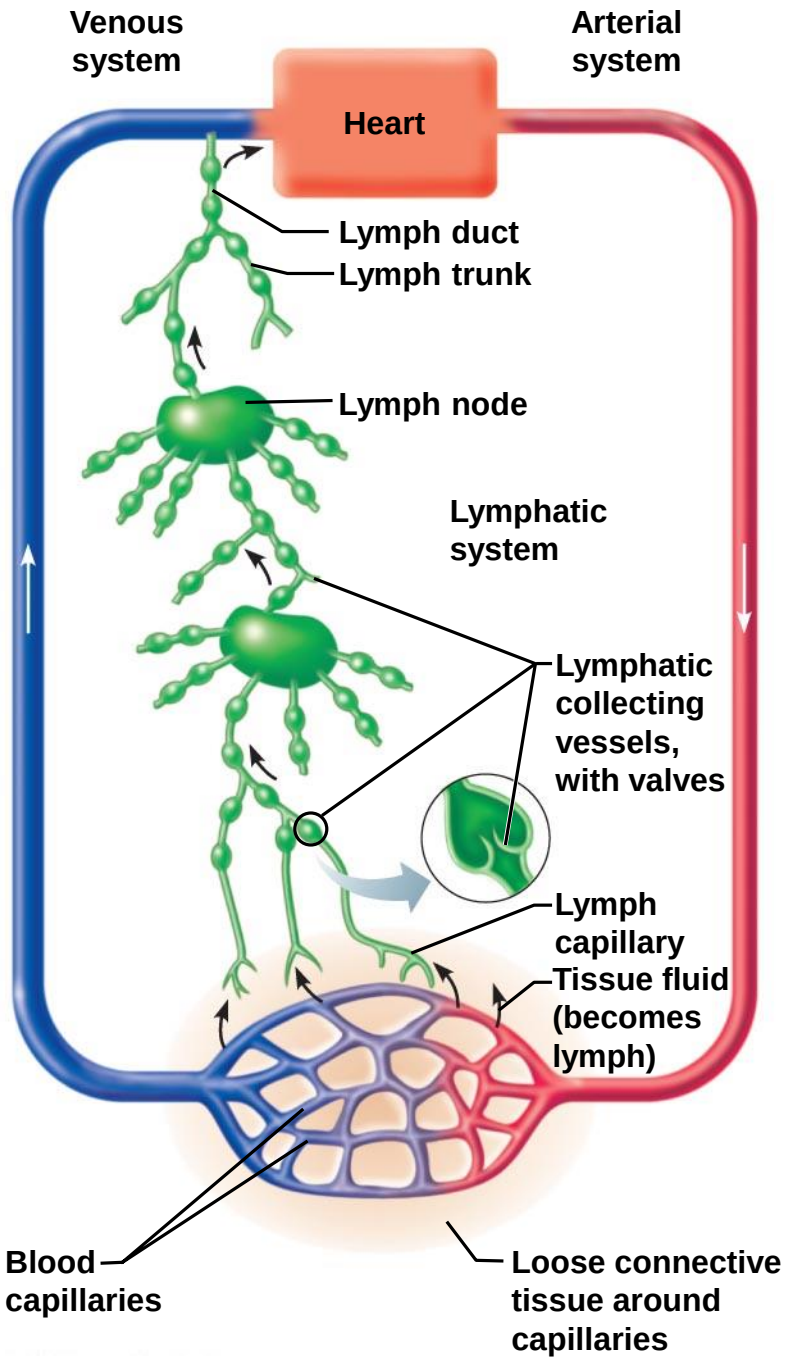

Figure 12.1

Lymphatic Vessels

- Lymph capillaries
  - Walls overlap to form flap-like minivalves
  - Fluid leaks into lymph capillaries
  - Capillaries are anchored to connective tissue by filaments
  - Higher pressure on the inside closes minivalves
  - Fluid is forced along the vessel

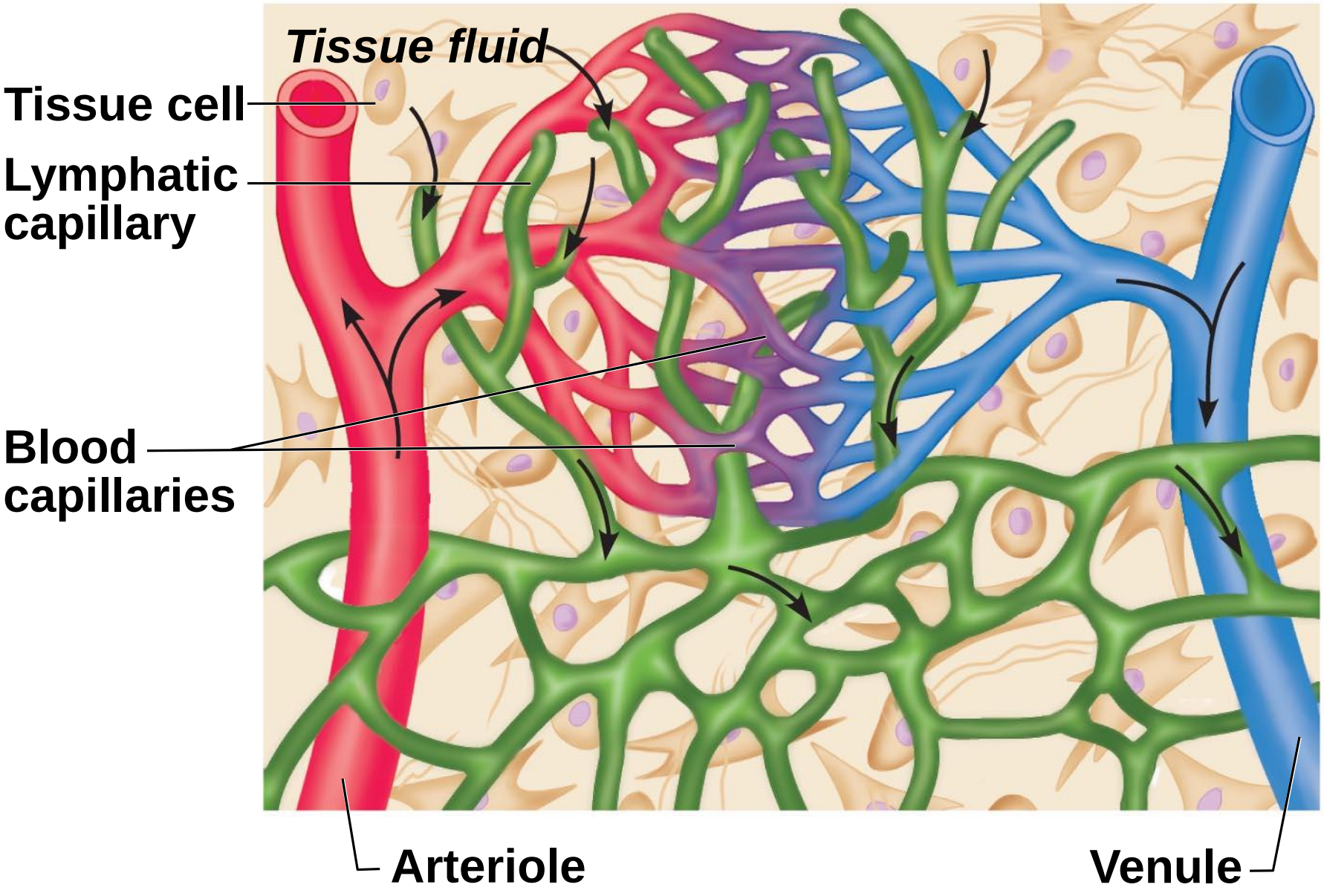

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Figure 12.2a

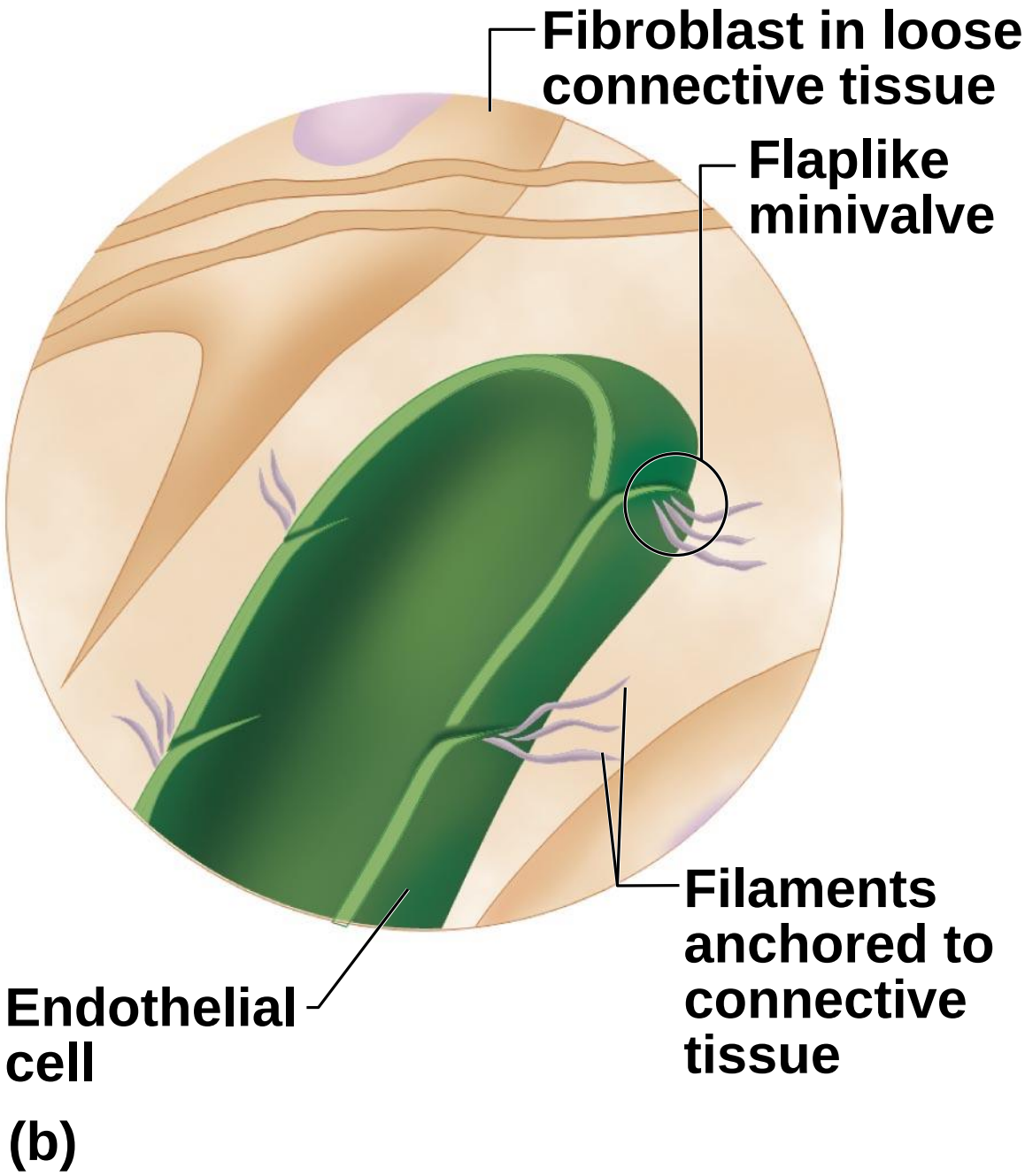


Figure 12.2b

Lymphatic Vessels

- Lymphatic collecting vessels
  - Collect lymph from lymph capillaries
  - Carry lymph to and away from lymph nodes
  - Return fluid to circulatory veins near the heart
    - Right lymphatic duct
    - Thoracic duct

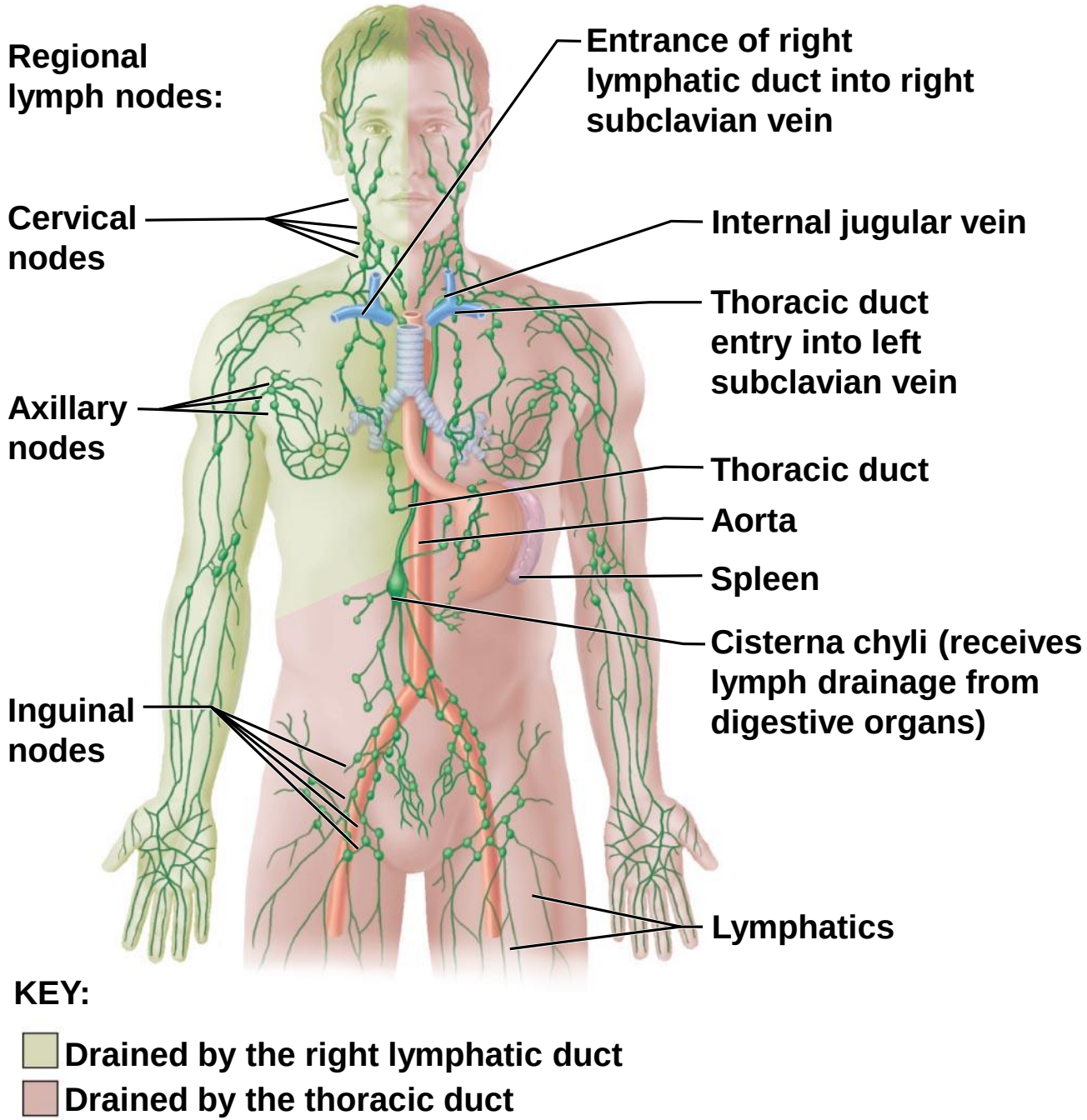


Figure 12.3

Lymph

- Harmful materials that enter lymph vessels
  - Bacteria
  - Viruses
  - Cancer cells
  - Cell debris

Lymph Nodes

- Filter lymph before it is returned to the blood
- Defense cells within lymph nodes
  - **Macrophages** —engulf and destroy foreign substances
  - **Lymphocytes** —provide immune response to antigens

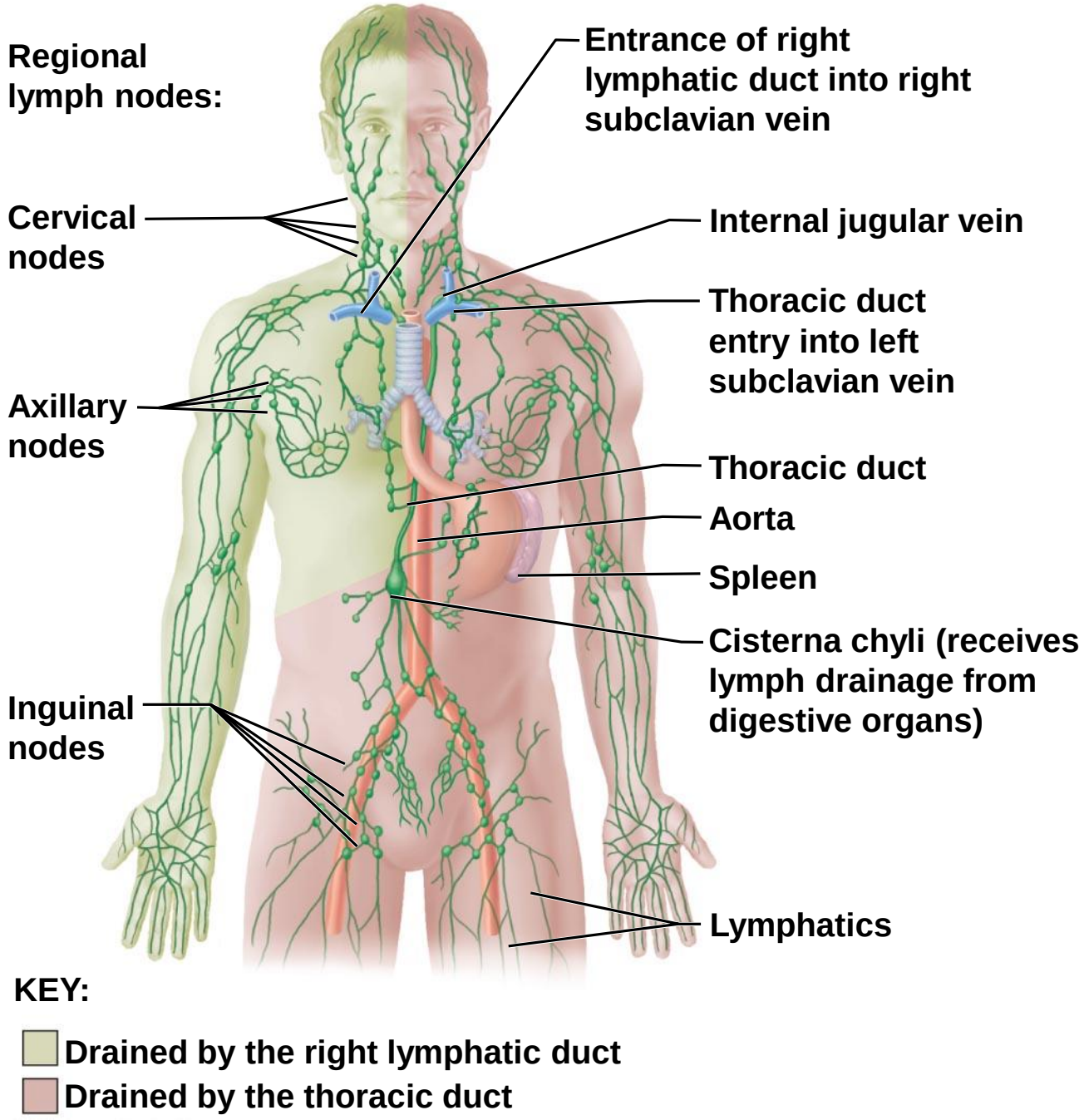


Figure 12.3

Lymph Node Structure

- Most are kidney-shaped and less than 1 inch long

- **Cortex**
  - Outer part
  - Contains **follicles**—collections of lymphocytes

- **Medulla**
  - Inner part
  - Contains **phagocytic macrophages**

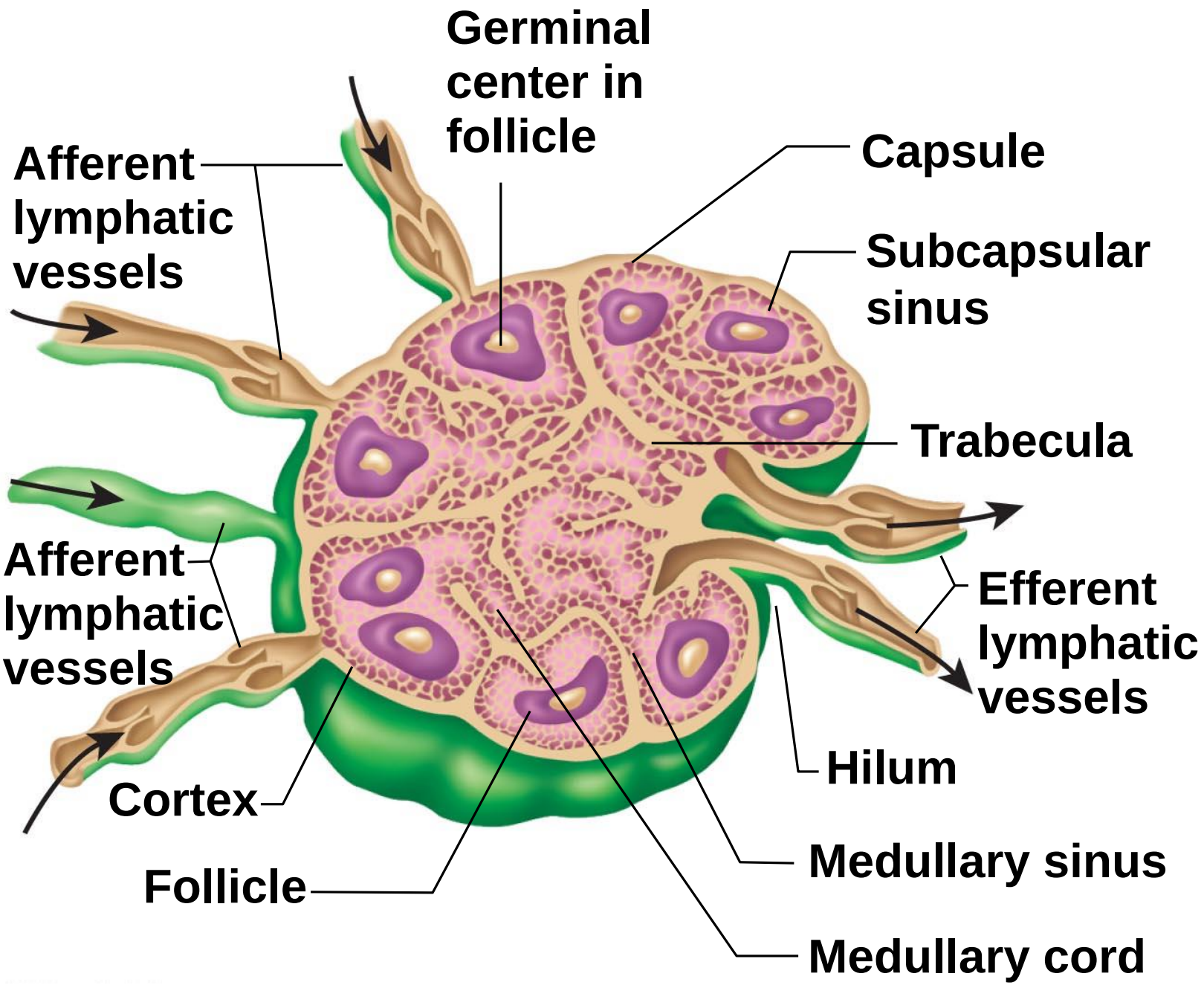


Figure 12.4

Flow of Lymph Through Nodes

- Lymph enters the convex side through afferent lymphatic vessels
- Lymph flows through a number of sinuses inside the node
- Lymph exits through efferent lymphatic vessels
- Fewer efferent than afferent vessels causes flow to be slowed

Other Lymphoid Organs

- Several other organs contribute to lymphatic function
  - Spleen
  - Thymus
  - Tonsils
  - Peyer’s patches

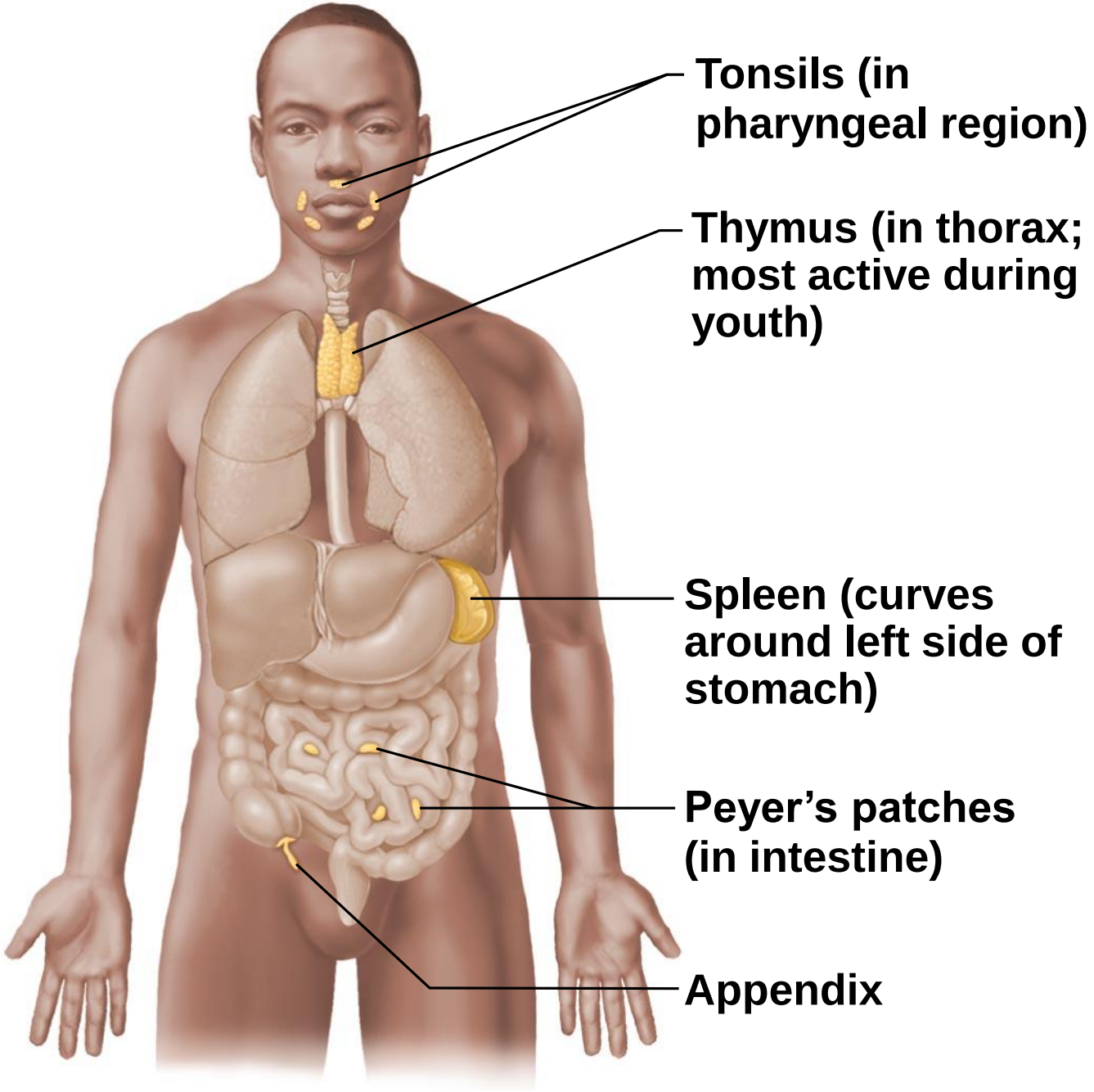


Figure 12.5

Spleen

- Located on the left side of the abdomen
- Filters blood
- Destroys worn out blood cells
- Forms blood cells in the fetus
- Acts as a blood reservoir

Thymus Gland

- Located low in the throat, overlying the heart
- Functions at peak levels only during childhood
- Produces hormones (like thymosin) to program lymphocytes

Tonsils

- Small masses of lymphoid tissue around the pharynx
- Trap and remove bacteria and other foreign materials
- Tonsillitis is caused by congestion with bacteria

Peyer's Patches

- Found in the wall of the small intestine
- Resemble tonsils in structure
- Capture and destroy bacteria in the intestine

Mucosa-Associated Lymphatic Tissue (MALT)

- Includes
  - Peyer's patches
  - Tonsils
  - Other small accumulations of lymphoid tissue

- Acts as a sentinel to protect respiratory and digestive tracts

Body Defenses

- The body is constantly in contact with bacteria, fungi, and viruses
- The body has two defense systems for foreign materials
  - **Innate** (**nonspecific**) defense system
  - **Adaptive** (**specific**) defense system
- **Immunity**—specific resistance to disease

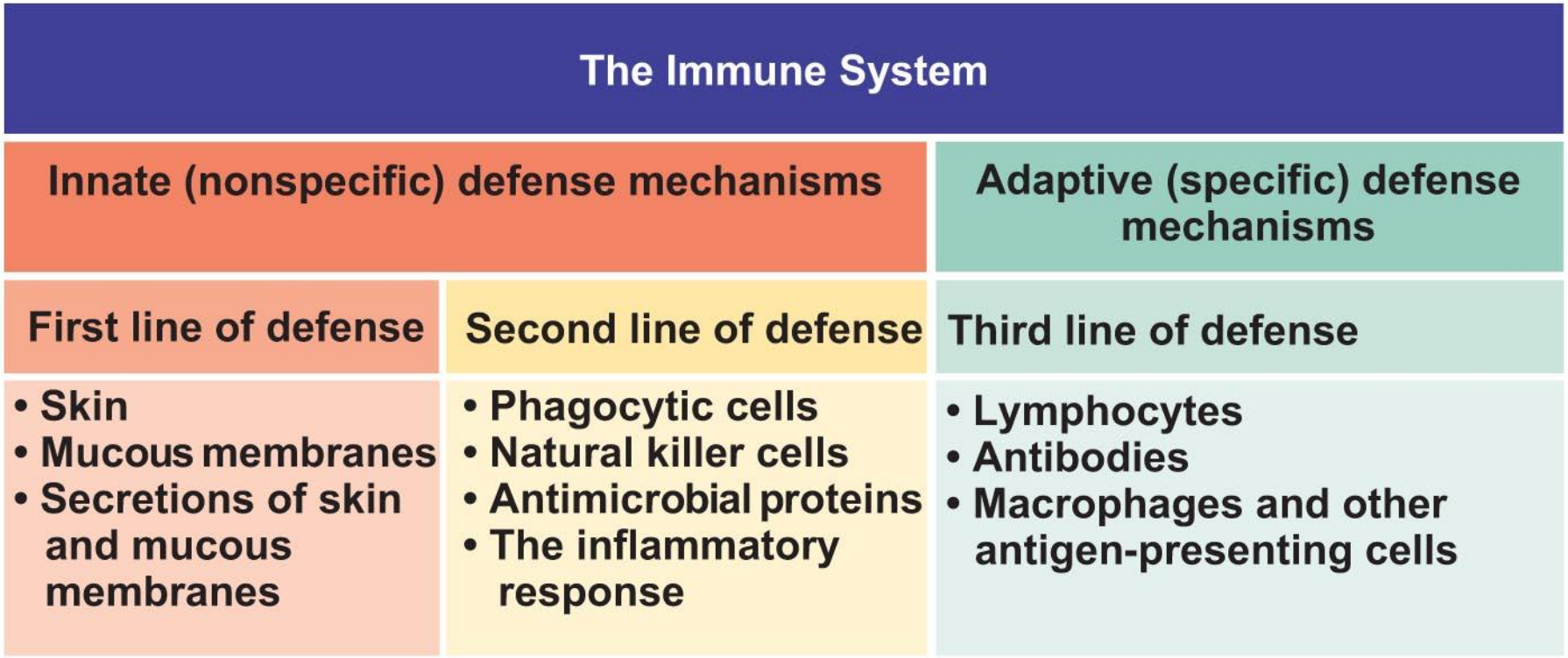


Figure 12.6

Body Defenses

- **Innate (nonspecific)** defense system
  - Mechanisms protect against a variety of invaders
  - Responds immediately to protect body from foreign materials
- **Adaptive (specific)** defense system
  - Specific defense is required for each type of invader

Innate (Nonspecific) Body Defenses

- Innate body defenses are mechanical barriers to pathogens such as
  - Body surface coverings
    - Intact skin
    - Mucous membranes
  - Specialized human cells
  - Chemicals produced by the body

Surface Membrane Barriers: First Line of Defense

- Skin and mucous membranes
  - Physical barrier to foreign materials
  - Also provide protective secretions
    - pH of the skin is acidic to inhibit bacterial growth
    - Sebum is toxic to bacteria
    - Vaginal secretions are very acidic

Surface Membrane Barriers: First Line of Defense

- Stomach mucosa
  - Secretes hydrochloric acid
  - Has protein-digesting enzymes
- Saliva and lacrimal fluid contain **lysozymes**, an enzyme that destroy bacteria
- Mucus traps microogranisms in digestive and respiratory pathways

Innate (Nonspecific) Defense System Cells and Chemicals: Second Line of Defense

- Natural killer cells
- Inflammatory response
- Phagocytes
- Antimicrobial proteins
- Fever

Innate (Nonspecific) Defense System Cells and Chemicals: Second Line of Defense

- Natural killer (NK) cells
  - Can lyse (disintegrate or dissolve) and kill cancer cells
  - Can destroy virus-infected cells
  - Release a chemical called **perforin** to target the cell's membrane and nucleus, causing disintegration

Innate (Nonspecific) Defense System Cells and Chemicals: Second Line of Defense

- Inflammatory response
  - Triggered when body tissues are injured
  - Four most common indicators of acute inflammation
    - Redness
    - Heat
    - Swelling
    - Pain

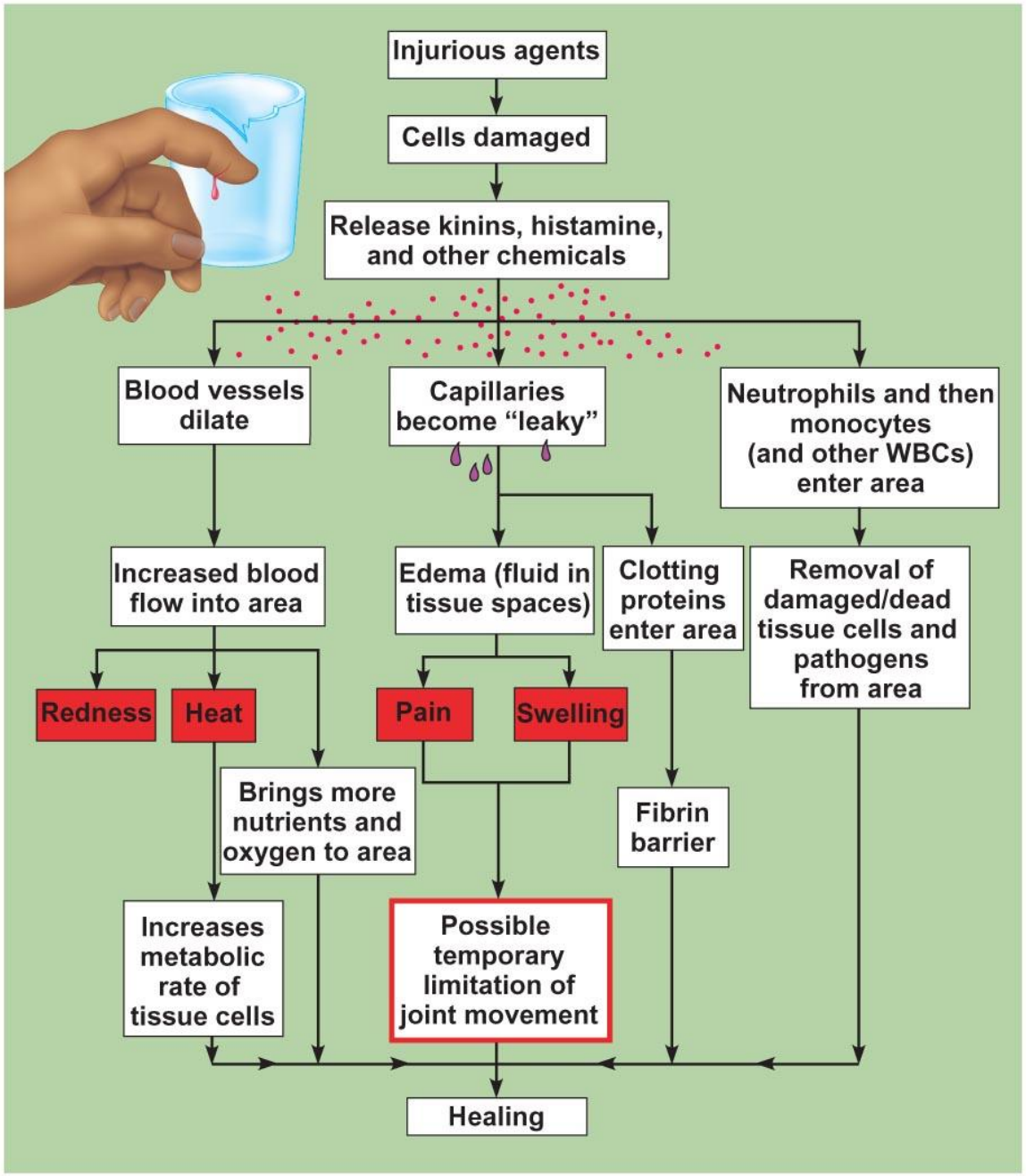


Figure 12.7

Innate (Nonspecific) Defense System Cells and Chemicals: Second Line of Defense

- Functions of the inflammatory response
  - Prevents spread of damaging agents
  - Disposes of cell debris and pathogens through phagocytosis
  - Sets the stage for repair

Innate (Nonspecific) Defense System Cells and Chemicals: Second Line of Defense

- Process of the inflammatory response:
  - Neutrophils migrate to the area of inflammation by rolling along the vessel wall
  - They squeeze through the capillary walls by **diapedesis** to sites of inflammation
  - Neutrophils gather in the precise site of tissue injury (**positive chemotaxis**) and consume any foreign material present.

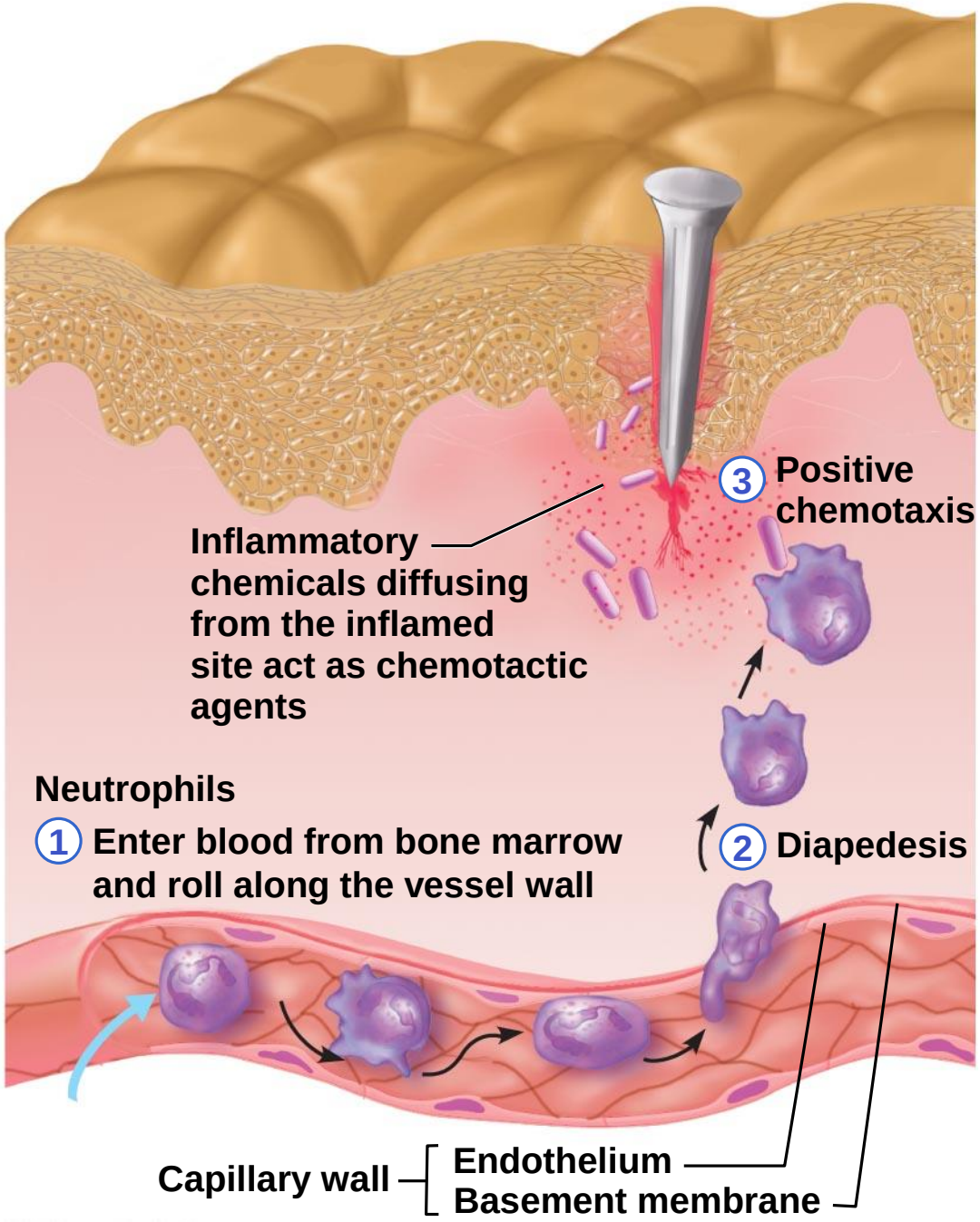


Figure 12.8

Innate (Nonspecific) Defense System Cells and Chemicals: Second Line of Defense

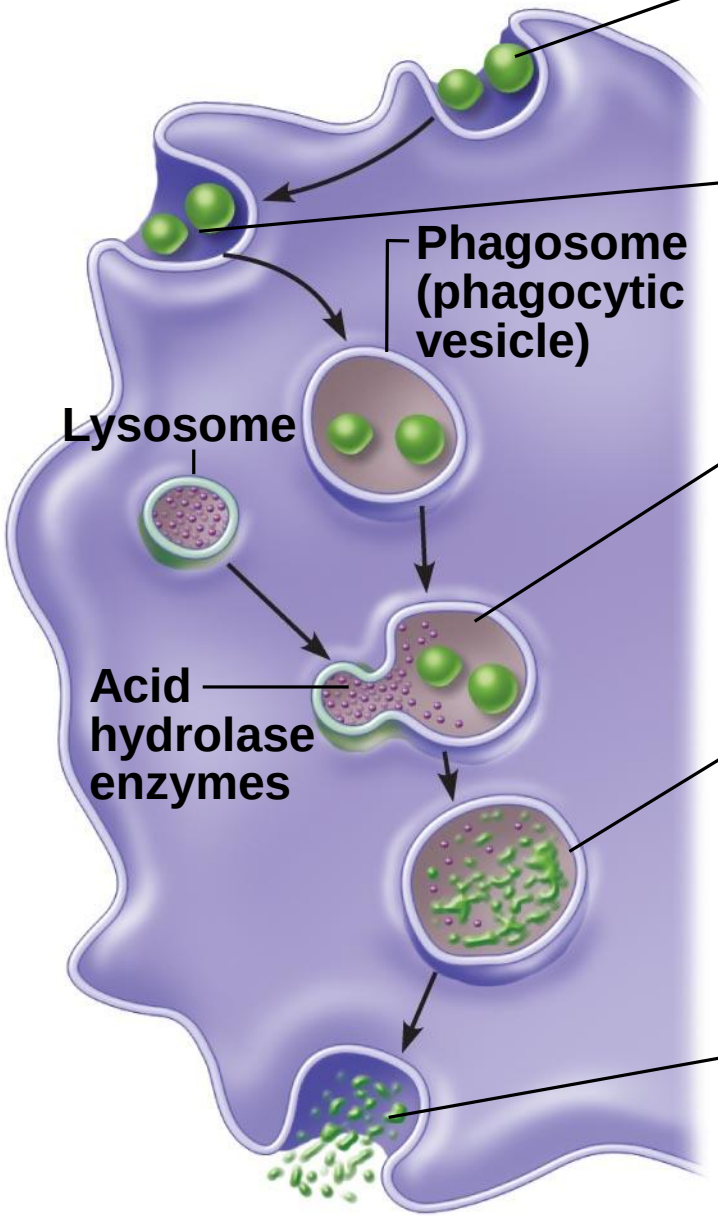
- Phagocytes
  - Cells such as neutrophils and macrophages
  - Engulf foreign material into a vacuole
  - Enzymes from lysosomes digest the material

Innate (Nonspecific) Defense System Cells and Chemicals: Second Line of Defense

- Phagocytosis
  - Neutrophils move by diapedesis to clean up damaged tissue and/or pathogens
  - Monocytes become macrophages and complete disposal of cell debris

(a) A macrophage (purple) uses its cytoplasmic extensions to pull spherical bacteria (green) toward it. Scanning electron micrograph (2550×).

Figure 12.9a



(b) Events of phagocytosis

1 Phagocyte adheres to pathogens.

2 Phagocyte engulfs the particles, forming a phagosome.

3 Lysosome fuses with the phagocytic vesicle, forming a phagolysosome.

4 Lysosomal enzymes digest the pathogens or debris, leaving a residual body.

5 Exocytosis of the vesicle removes indigestible and residual material.

Figure 12.9b

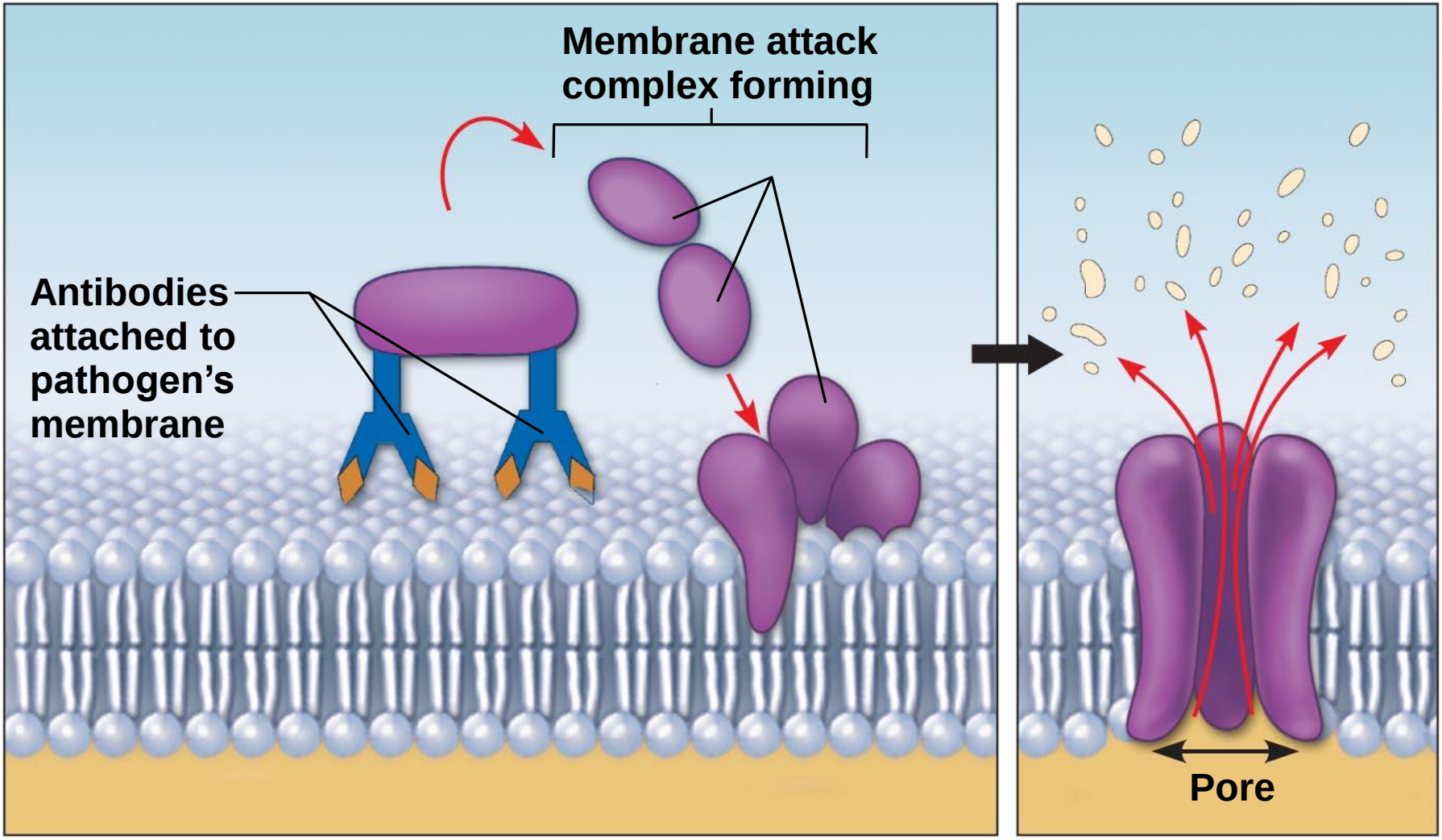
Cells and Chemicals: Second Line of Defense

- Antimicrobial proteins
  - Attack microorganisms
  - Hinder reproduction of microorganisms

- Most important
  - Complement proteins
  - Interferon

Cells and Chemicals: Second Line of Defense

- Complement proteins
  - A group of at least 20 plasma proteins
  - Activated when they encounter and attach to cells (complement fixation)
  - Damage foreign cell surfaces
  - Release vasodilators and chemotaxis chemicals, cause **opsonization**



Activated complement proteins attach to pathogen's membrane in step-by-step sequence, forming a membrane attack complex (a MAC attack).

MAC pores in the membrane lead to fluid flows that cause cell lysis.

Figure 12.10

Cells and Chemicals: Second Line of Defense

- Interferon
  - Proteins secreted by virus-infected cells
  - Bind to healthy cell surfaces to interfere with the ability of viruses to multiply

Cells and Chemicals: Second Line of Defense

- Fever
  - Abnormally high body temperature
  - Hypothalamus heat regulation can be reset by **pyrogens** (secreted by white blood cells)
  - High temperatures inhibit the release of iron and zinc from the liver and spleen needed by bacteria
  - Fever also increases the speed of tissue repair

Adaptive Defense System: Third Line of Defense

- Immune response is the immune system's response to a threat
- **Immunology** is the study of immunity
- **Antibodies** are proteins that protect from pathogens

Adaptive Defense System: Third Line of Defense

- Three aspects of adaptive defense
  - **Antigen specific** —recognizes and acts against particular foreign substances
  - **Systemic** —not restricted to the initial infection site
  - **Memory** —recognizes and mounts a stronger attack on previously encountered pathogens

Adaptive Defense System: Third Line of Defense

- Types of Immunity
  - **Humoral immunity** = antibody-mediated immunity
    - Provided by antibodies present in body fluids
  - **Cellular immunity** = cell-mediated immunity
    - Targets virus-infected cells, cancer cells, and cells of foreign grafts

Adaptive Defense System: Third Line of Defense

- **Antigens** (nonself)
  - Any substance capable of exciting the immune system and provoking an immune response
  - Examples of common antigens
    - Foreign proteins (strongest)
    - Nucleic acids
    - Large carbohydrates
    - Some lipids
    - Pollen grains
    - Microorganisms

Adaptive Defense System: Third Line of Defense

- **Self-antigens**
  - Human cells have many surface proteins
  - Our immune cells do not attack our own proteins
  - Our cells in another person's body can trigger an immune response because they are foreign
    - Restricts donors for transplants

Adaptive Defense System: Third Line of Defense

- Allergies
  - Many small molecules (called **haptens** or incomplete antigens) are not antigenic, but link up with our own proteins
  - The immune system may recognize and respond to a protein-hapten combination
  - The immune response is harmful rather than protective because it attacks our own cells

Adaptive Defense System: Third Line of Defense

- Cells of the adaptive defense system
  - Lymphocytes respond to specific antigens
    - B lymphocytes (B cells)
    - T lymphocytes (T cells)
  - Macrophages help lymphocytes

Adaptive Defense System: Third Line of Defense

- **Immunocompetent** —cell becomes capable of responding to a specific antigen by binding to it

- Cells of the adaptive defense system
  - **Lymphocytes**
    - Originate from **hemocytoblasts** in the red bone marrow
    - **B lymphocytes become immunocompetent in the bone marrow (remember B for Bone marrow)**
    - **T lymphocytes become immunocompetent in the thymus (remember T for Thymus)**

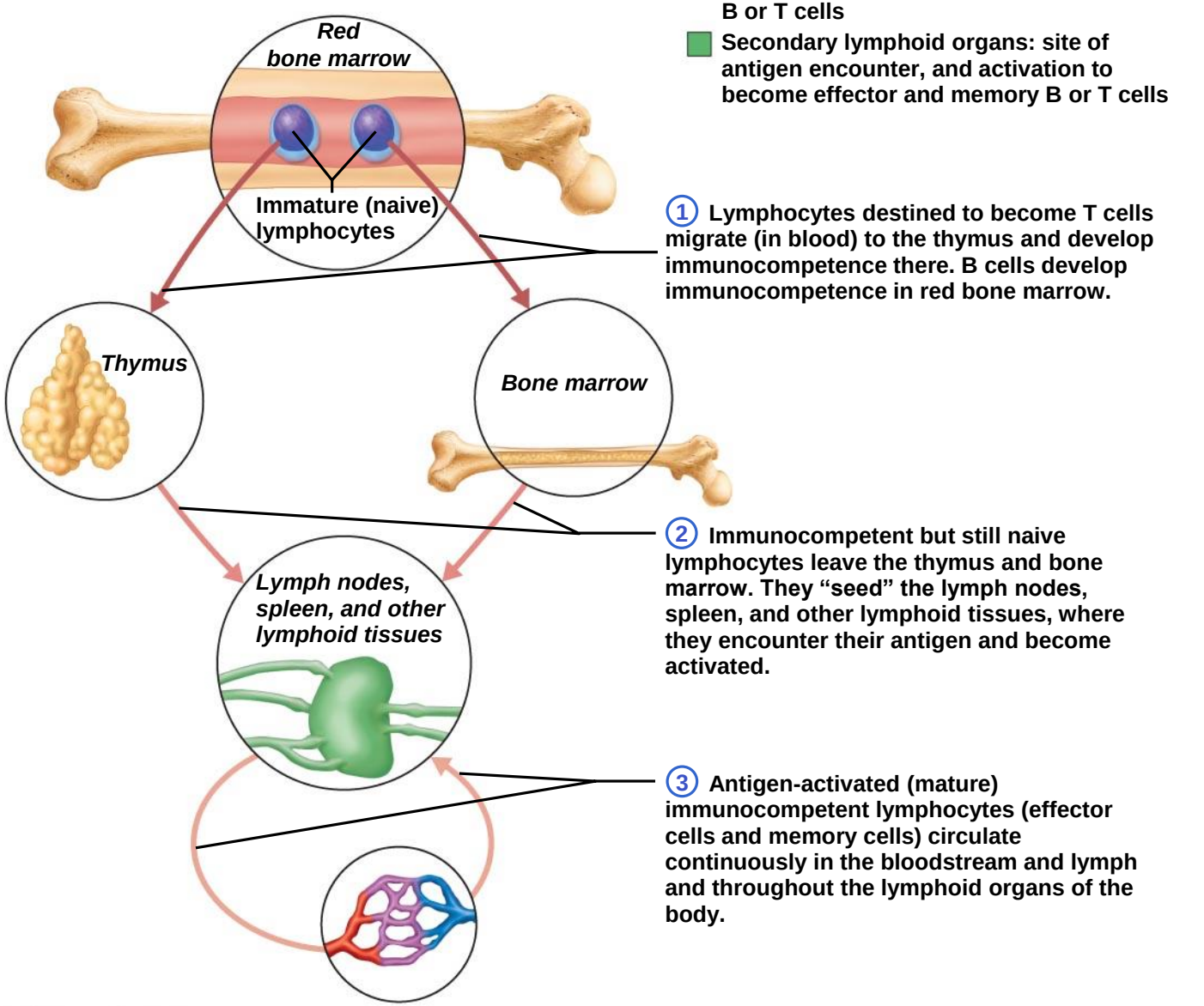


Figure 12.11

Adaptive Defense System: Third Line of Defense

- Cells of the adaptive defense system (continued)
  - **Macrophages**
    - Arise from **monocytes**
    - Become widely distributed in lymphoid organs
    - Secrete **cytokines** (proteins important in the immune response)
    - Tend to remain fixed in the lymphoid organs

Humoral (Antibody-Mediated) Immune Response

- B lymphocytes with specific receptors bind to a specific antigen
- The binding event activates the lymphocyte to undergo **clonal selection**
- A large number of clones are produced (primary humoral response)

Humoral Immune Response

- Most B cells become **plasma cells**
  - Produce antibodies to destroy antigens
  - Activity lasts for 4 or 5 days
- Some B cells become long-lived **memory cells** (secondary humoral response)

Humoral Immune Response

- Secondary humoral responses
  - Memory cells are long-lived
  - A second exposure causes a rapid response
  - The secondary response is stronger and longer lasting

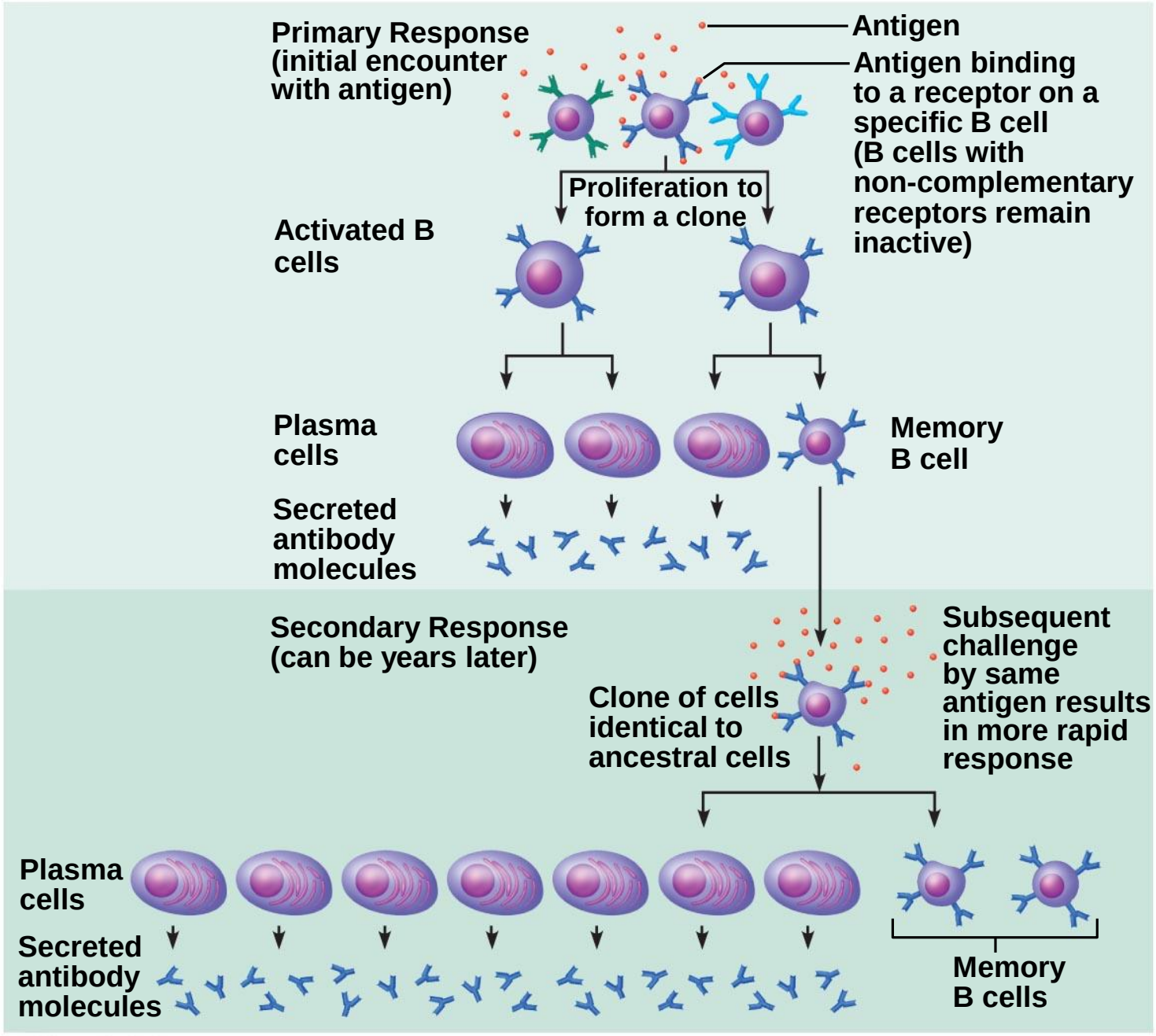


Figure 12.12

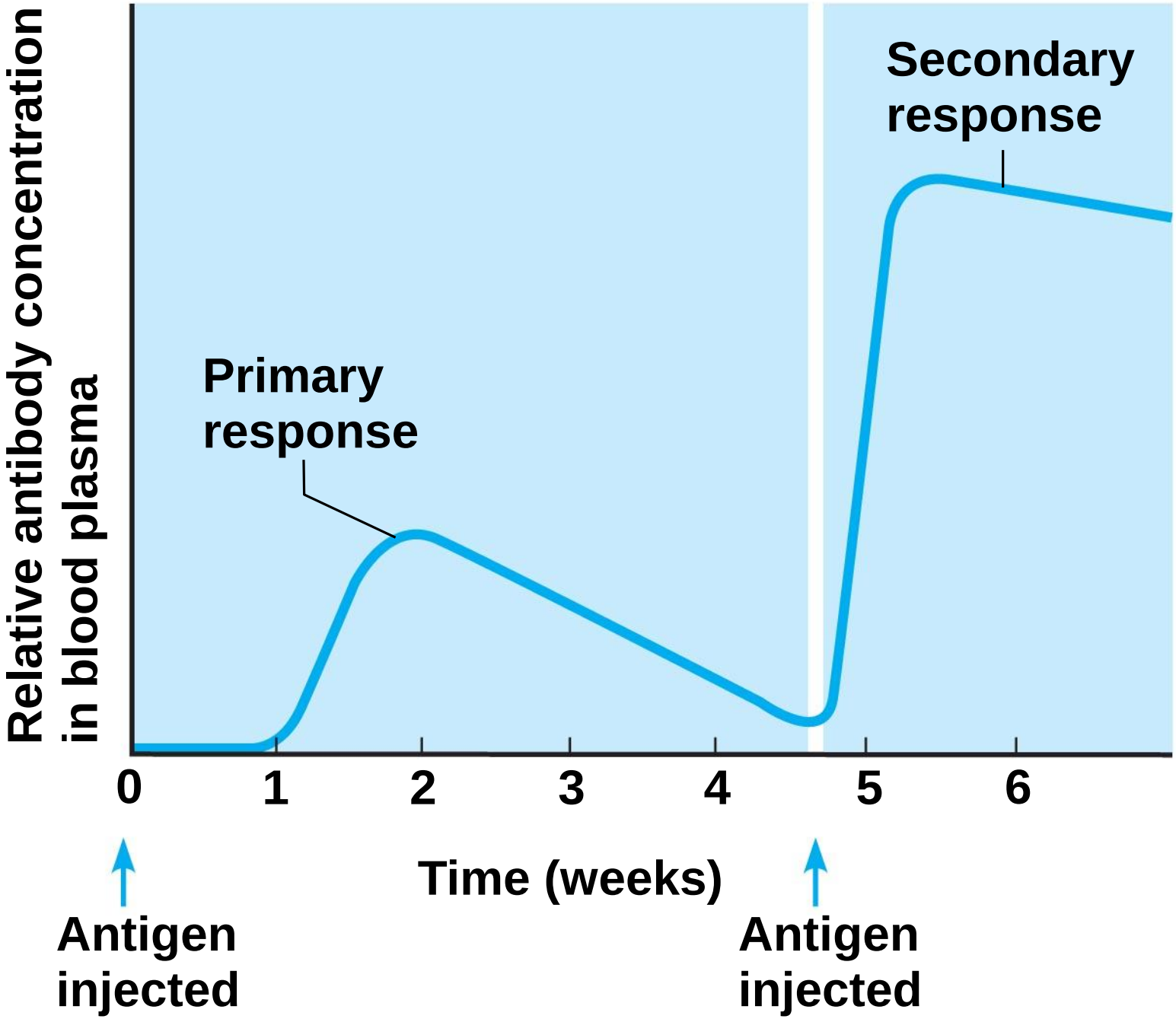


Figure 12.13

Active Immunity

- Occurs when B cells encounter antigens and produce antibodies

- Active immunity can be

  - **Naturally acquired** during bacterial and viral infections

  - **Artificially acquired** from vaccines

Passive Immunity

- Occurs when antibodies are obtained from someone else
  - Conferred naturally from a mother to her fetus (naturally acquired)
  - Conferred artificially from immune serum or gamma globulin (artificially acquired)
- Immunological memory does not occur
- Protection provided by “borrowed antibodies”

Passive Immunity

- Monoclonal antibodies
  - Antibodies prepared for clinical testing or diagnostic services
  - Produced from descendents of a single cell line
  - Examples of uses for monoclonal antibodies
    - Diagnosis of pregnancy
    - Treatment after exposure to hepatitis and rabies

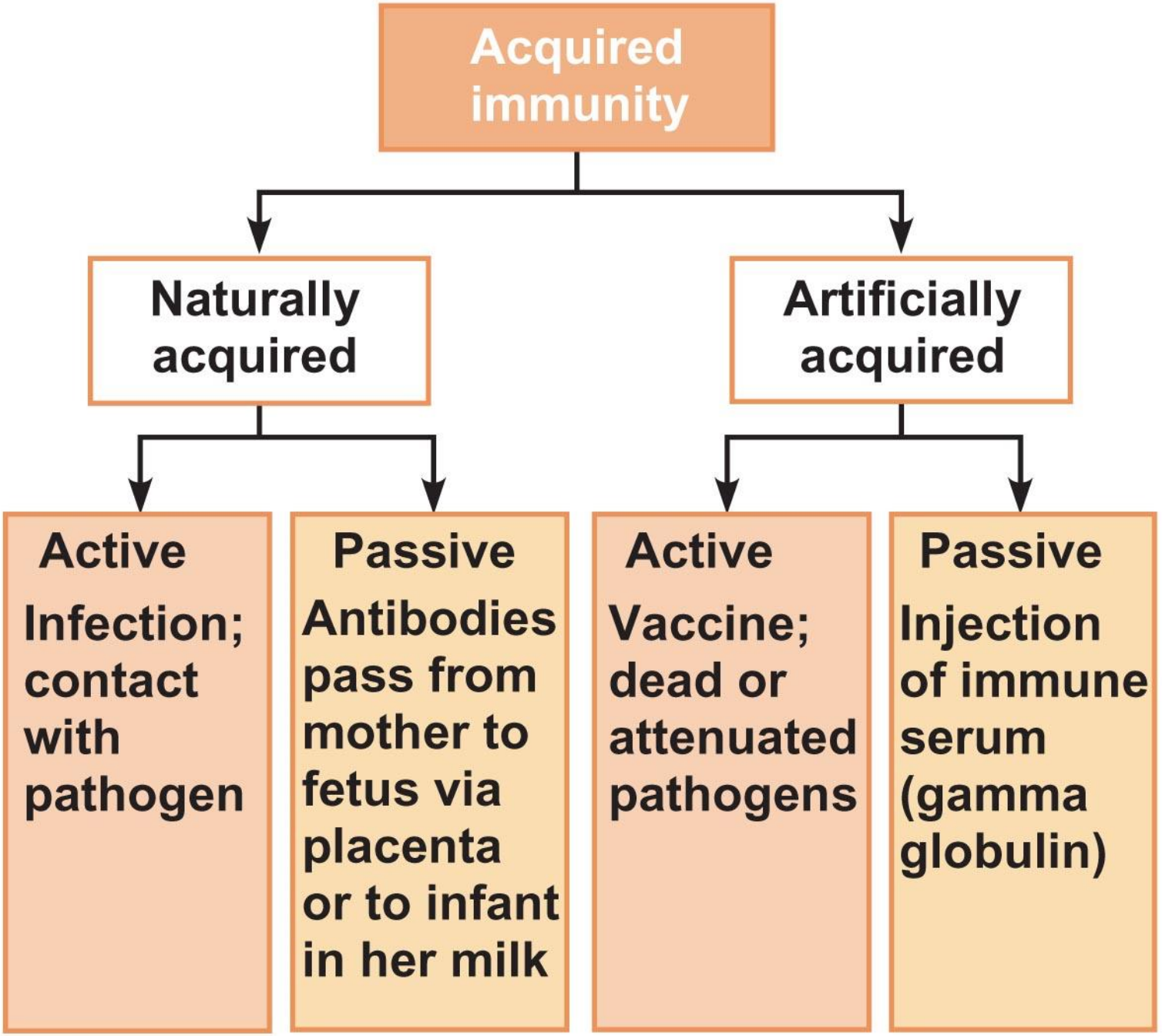
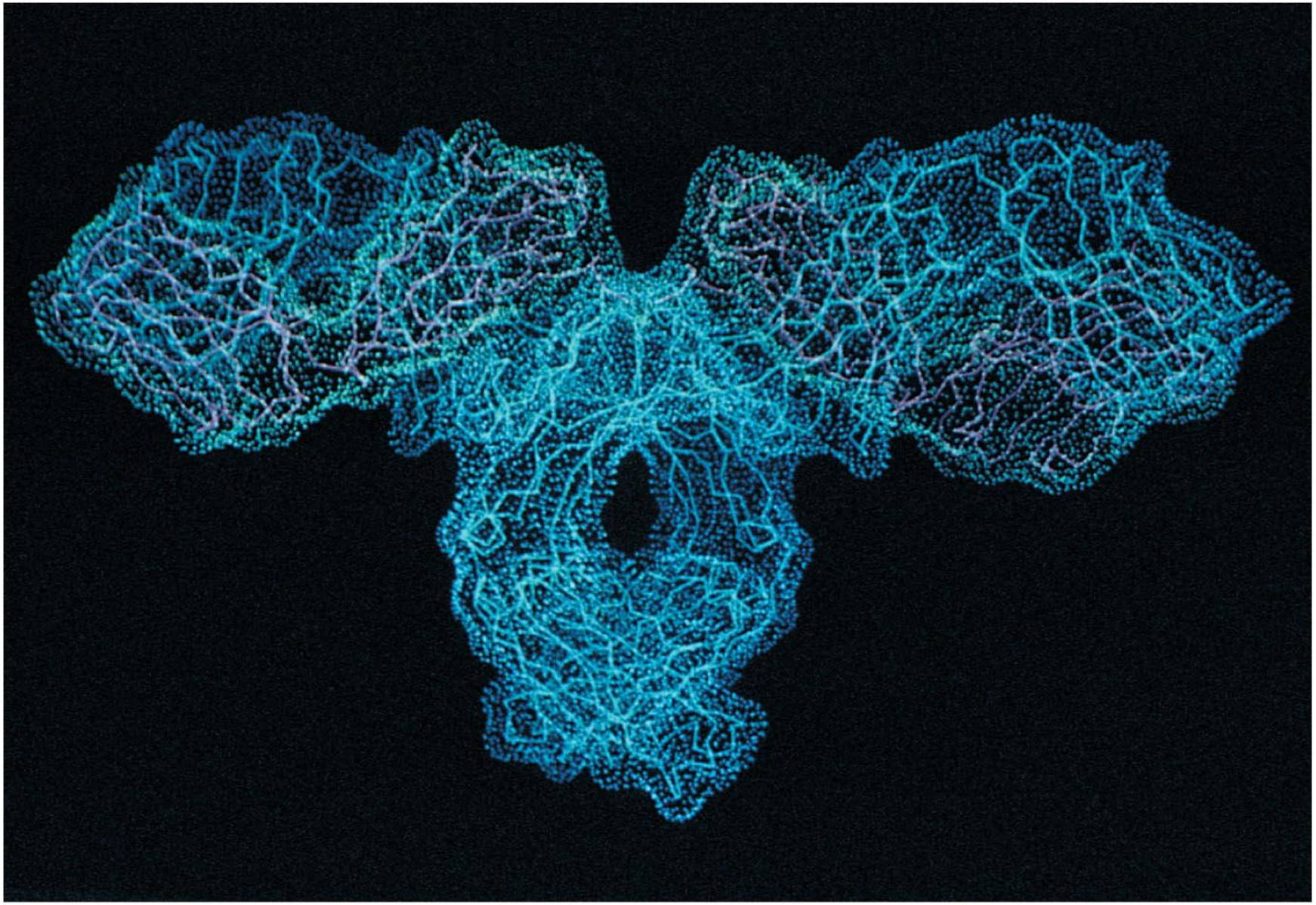


Figure 12.14

Antibodies (Immunoglobulins or Igs)

- Soluble proteins secreted by B cells (plasma cells)
- Carried in blood plasma
- Capable of binding specifically to an antigen

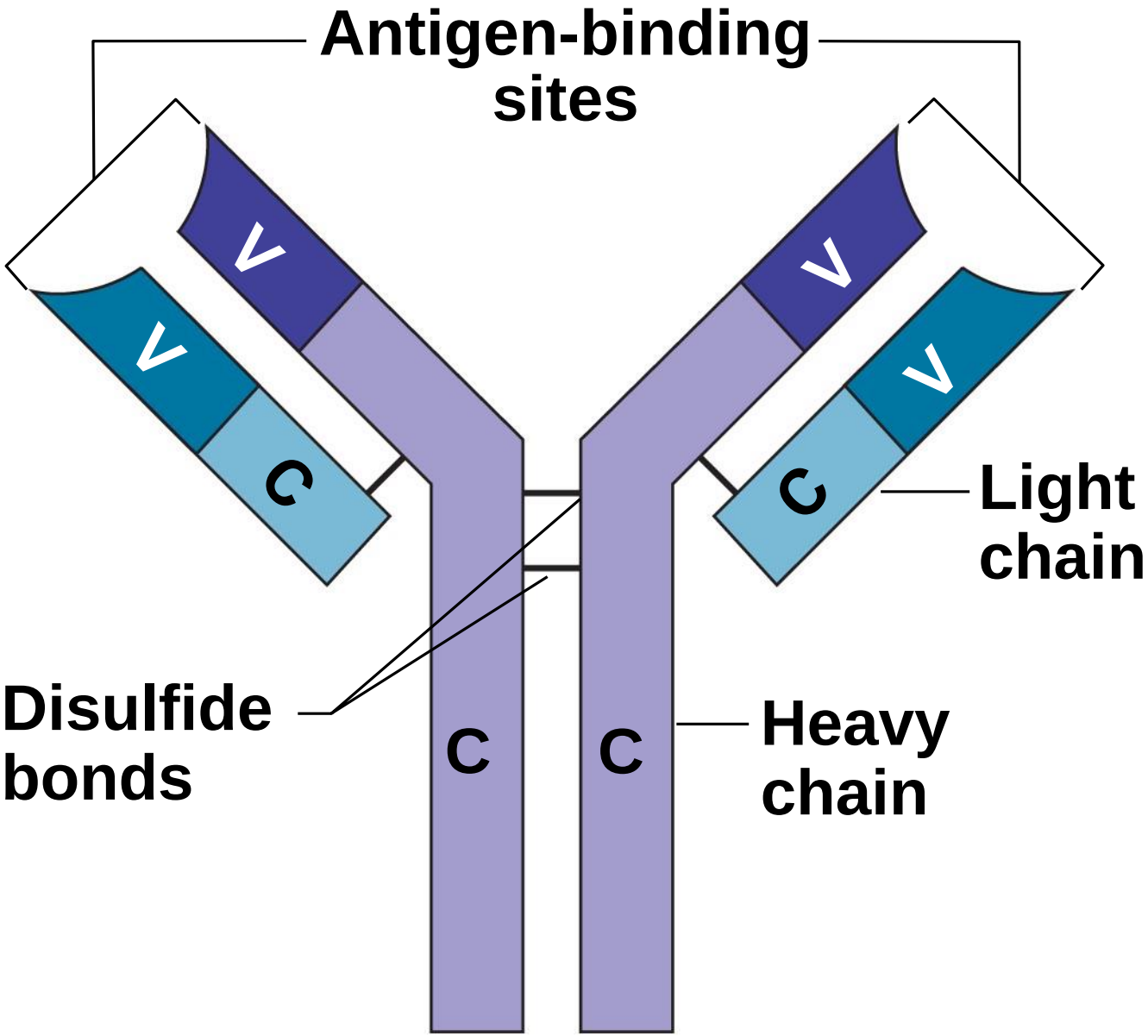


(a)

Figure 12.15a

Antibodies

- Antibody structure
  - Four amino acid chains linked by disulfide bonds
  - Two identical amino acid chains are linked to form a heavy chain
  - The other two identical chains are light chains
  - Specific antigen-binding sites are present



(b)

Figure 12.15b

Antibodies

- Antibody classes
  - Antibodies of each class have slightly different roles
  - Five major immunoglobulin classes (MADGE)
    - **IgM** —can fix complement
    - **IgA** —found mainly in mucus
    - **IgD** —important in activation of B cell
    - **IgG** —can cross the placental barrier and fix complement
    - **IgE** —involved in allergies

Antibodies

- Antibody function
  - Antibodies inactivate antigens in a number of ways
    - Complement fixation
    - Neutralization
    - Agglutination
    - Precipitation

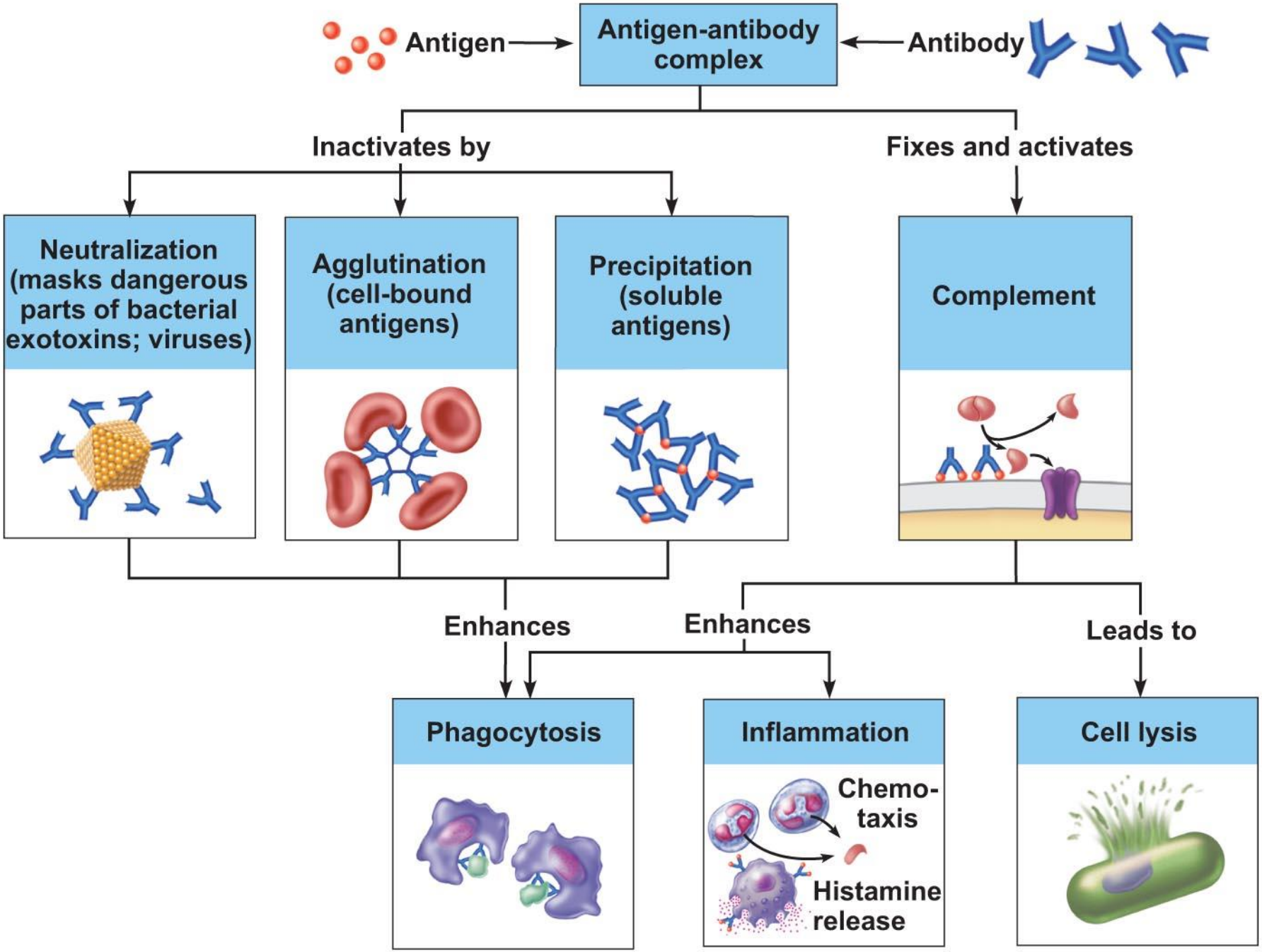


Figure 12.16

Cellular (Cell-Mediated) Immune Response

- Antigens must be presented by macrophages to an immunocompetent T cell (antigen presentation)
- T cells must recognize nonself and self (double recognition)
- After antigen binding, clones form as with B cells, but different classes of cells are produced

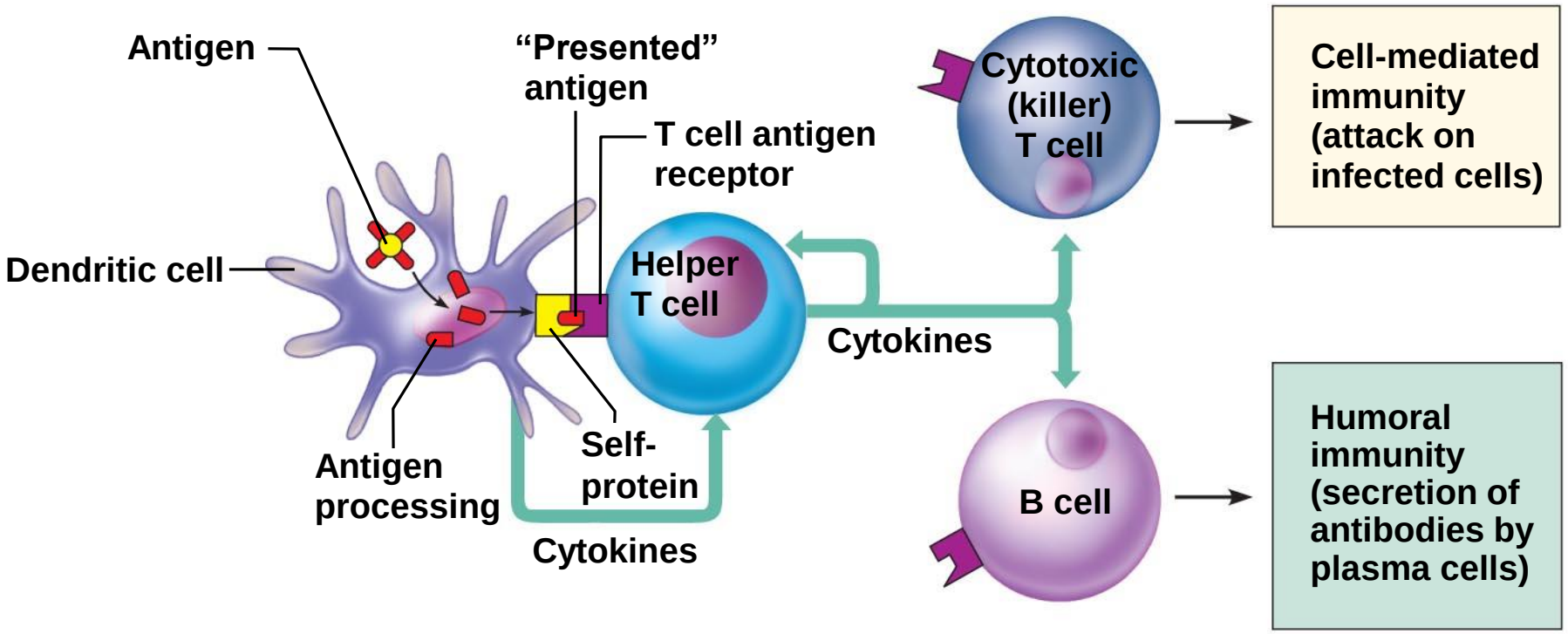


Figure 12.17

Cellular (Cell-Mediated) Immune Response

- T cell clones
  - Cytotoxic (killer) T cells
    - Specialize in killing infected cells
    - Insert a toxic chemical (perforin)
  - Helper T cells
    - Recruit other cells to fight the invaders
    - Interact directly with B cells

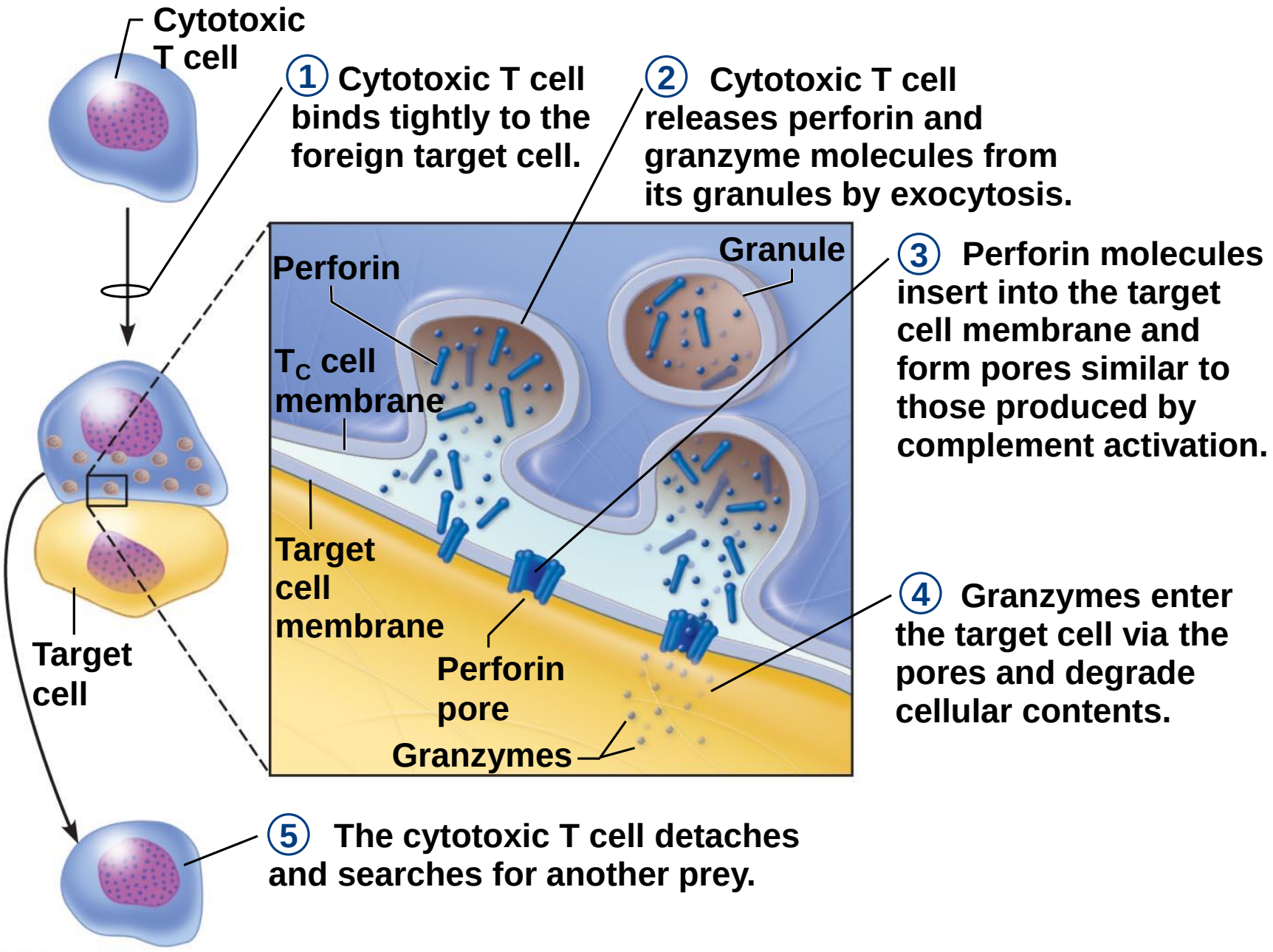


Figure 12.18

Cellular (Cell-Mediated) Immune Response

- T cell clones (continued)
  - Regulatory T cells
    - Release chemicals to suppress the activity of T and B cells
    - Stop the immune response to prevent uncontrolled activity
  - A few members of each clone are memory cells

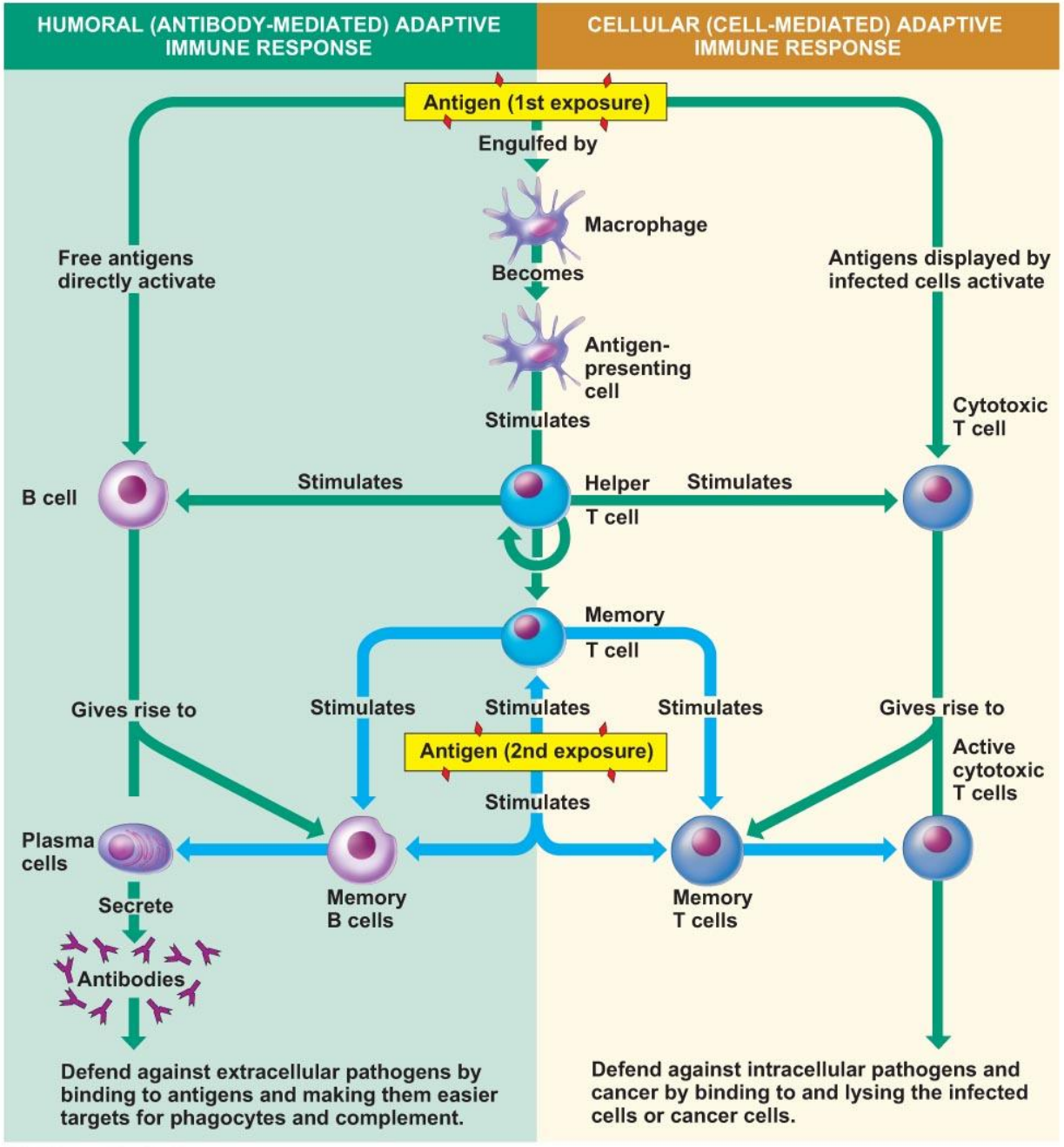


Figure 12.19

Organ Transplants and Rejection

- Major types of grafts
  - **Autografts** —tissue transplanted from one site to another on the same person
  - **Isografts** —tissue grafts from an identical person (identical twin)
  - **Allografts** —tissue taken from an unrelated person
  - **Xenografts** —tissue taken from a different animal species

Disorders of Immunity: Allergies (Hypersensitivity)

- Abnormal, vigorous immune responses

- Types of allergies
  - **Immediate hypersensitivity**
    - Triggered by release of histamine from IgE binding to mast cells
    - Reactions begin within seconds of contact with allergen
    - **Anaphylactic shock** —dangerous, systemic response

Disorders of Immunity: Allergies (Hypersensitivity)

- Types of allergies (continued)
  - **Delayed hypersensitivity**
    - Triggered by the release of **lymphokines** from activated **helper T cells**
    - Symptoms usually appear 1–3 days after contact with antigen

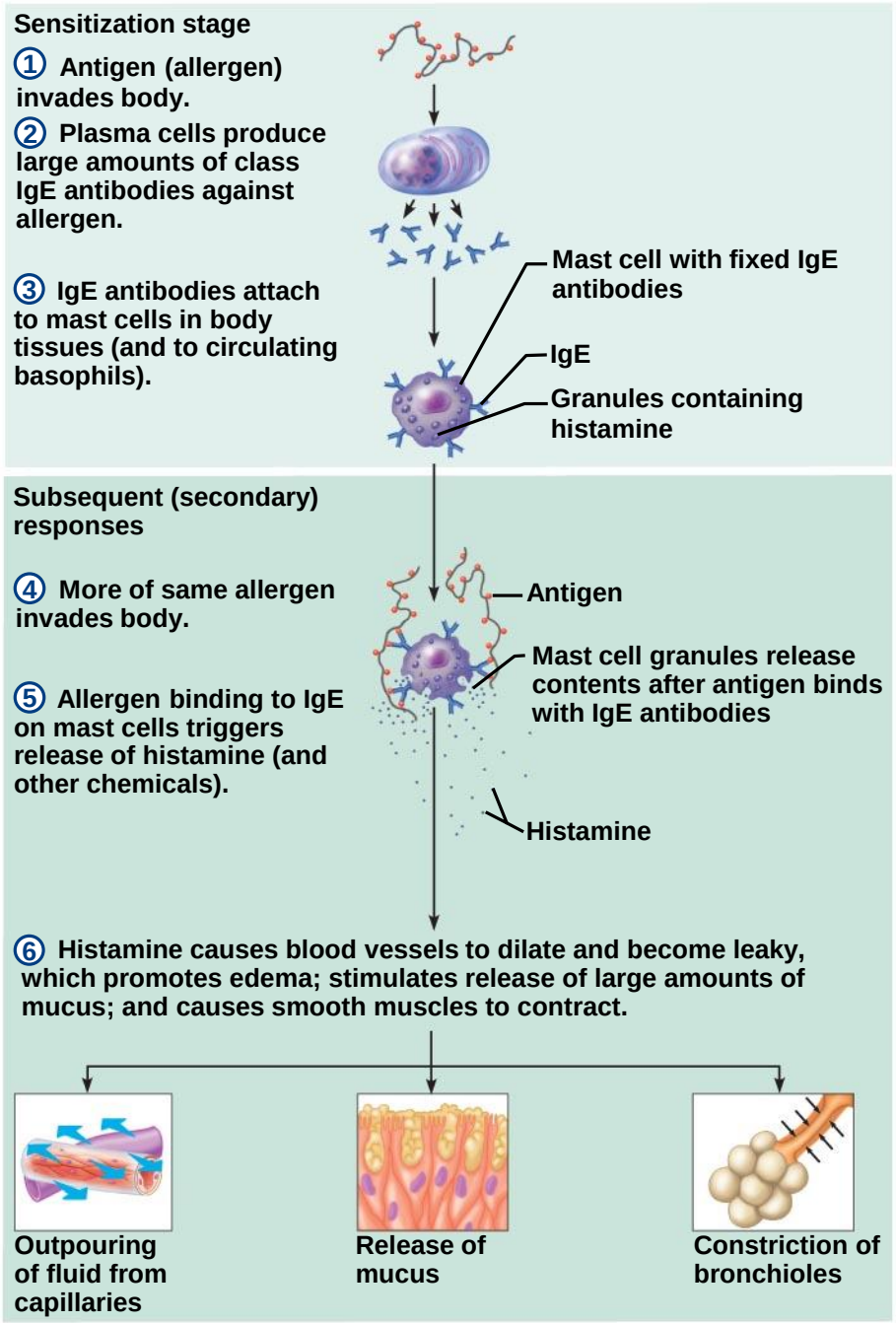


Figure 12.20

Disorders of Immunity: Immunodeficiencies

- Production or function of immune cells or complement is abnormal
- May be congenital or acquired
- Includes AIDS (Acquired Immune Deficiency Syndrome)

Disorders of Immunity: Autoimmune Diseases

- **Multiple sclerosis** —white matter of brain and spinal cord are destroyed
- **Myasthenia gravis** —impairs communication between nerves and skeletal muscles
- **Type I diabetes mellitus** —destroys pancreatic beta cells that produce insulin

Disorders of Immunity: Autoimmune Diseases

- **Rheumatoid arthritis** —destroys joints
- **Systemic lupus erythematosus (SLE)**
  - Affects kidney, heart, lung, and skin
- **Glomerulonephritis** —impairment of renal function

Self Tolerance Breakdown

- Cross-reaction of antibodies produced against foreign antigens with self-antigens
  - Rheumatic fever

Developmental Aspects of the Lymphatic System and Body Defenses

- Except for thymus and spleen, the lymphoid organs are poorly developed before birth
- A newborn has no functioning lymphocytes at birth, only passive immunity from the mother
- If lymphatics are removed or lost, severe edema results, but vessels grow back in time