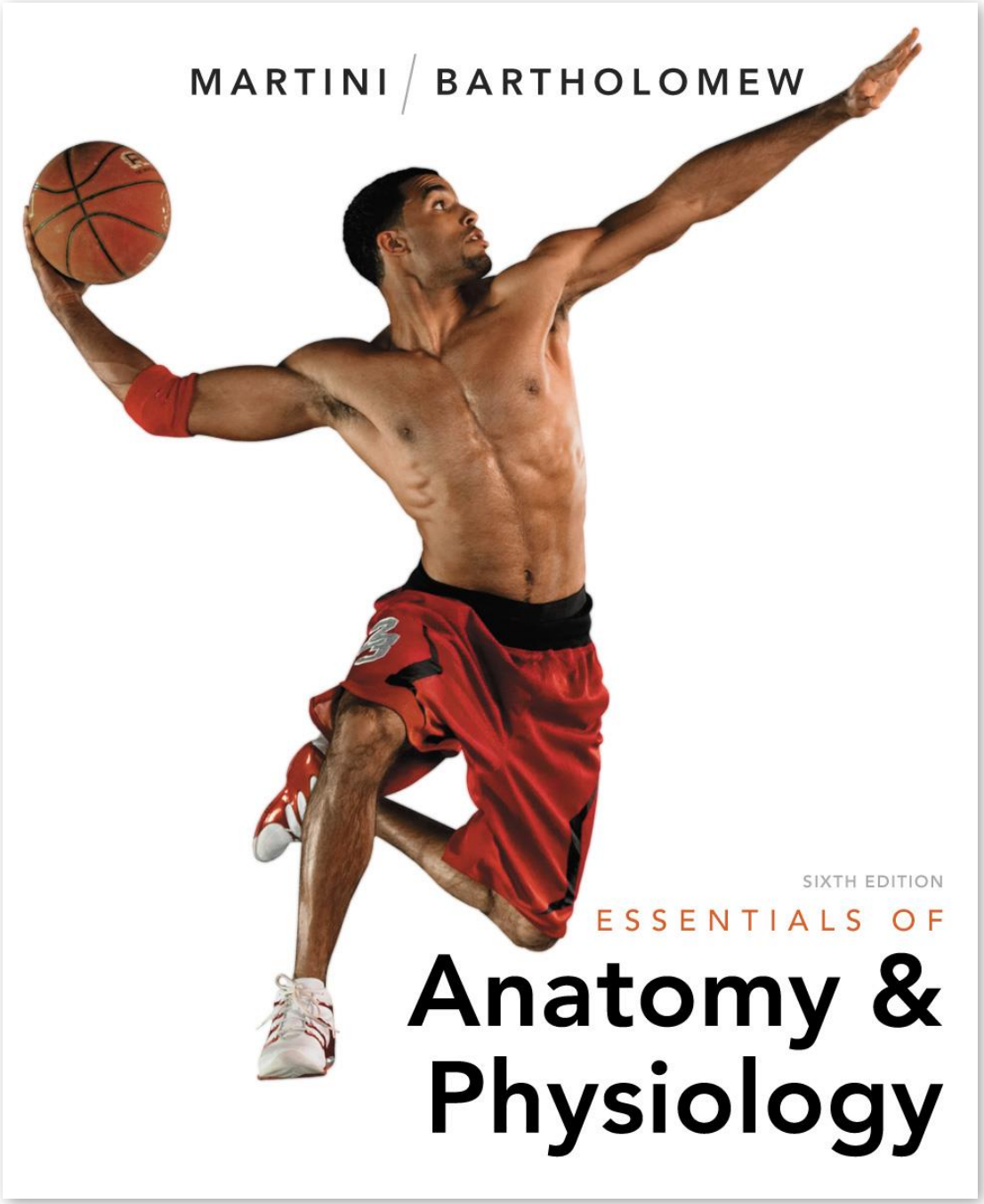

PowerPoint® Lecture Slides
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CHAPTER 14

The Lymphatic System and Immunity

Chapter 14 Learning Outcomes

- 14-1
  - Distinguish between innate (nonspecific) and adaptive (specific) defenses.
- 14-2
  - Identify the major components of the lymphatic system, and explain the functions of each.
- 14-3
  - List the body's innate (nonspecific) defenses and explain how each functions.
- 14-4
  - Define adaptive (specific) defenses, identify the forms and properties of immunity, and distinguish between cell-mediated immunity and antibody-mediated (humoral) immunity.

Chapter 14 Learning Outcomes

- 14-5
  - Discuss the different types of T cells and their roles in the immune response.
- 14-6
  - Discuss B cell sensitization, activation, and differentiation, describe the structure and function of antibodies, and explain the primary and secondary immune responses to antigen exposure.
- 14-7
  - List and explain examples of immune disorders and allergies, and discuss the effects of stress on immune function.
- 14-8
  - Describe the effects of aging on the lymphatic system and the immune response.

Chapter 14 Learning Outcomes

- 14-9
  - Give examples of interactions between the lymphatic system and other body systems.

Basics of Immunity (14-1)

- **Pathogens** are disease-causing organisms
  - Include viruses, bacteria, fungi, and parasites
- **Lymphatic system**
  - Includes cells, tissues, and organs that defend against pathogens
  - Lymphocytes are primary cells

Immunity (14-1)

- The ability to resist infection and disease
- *Innate* or *nonspecific immunity*
  - Anatomical barriers and defense mechanisms
  - Do not distinguish between pathogens
- *Adaptive* or *specific immunity*
  - Lymphocytes respond to specific pathogen
  - Called the **immune response**

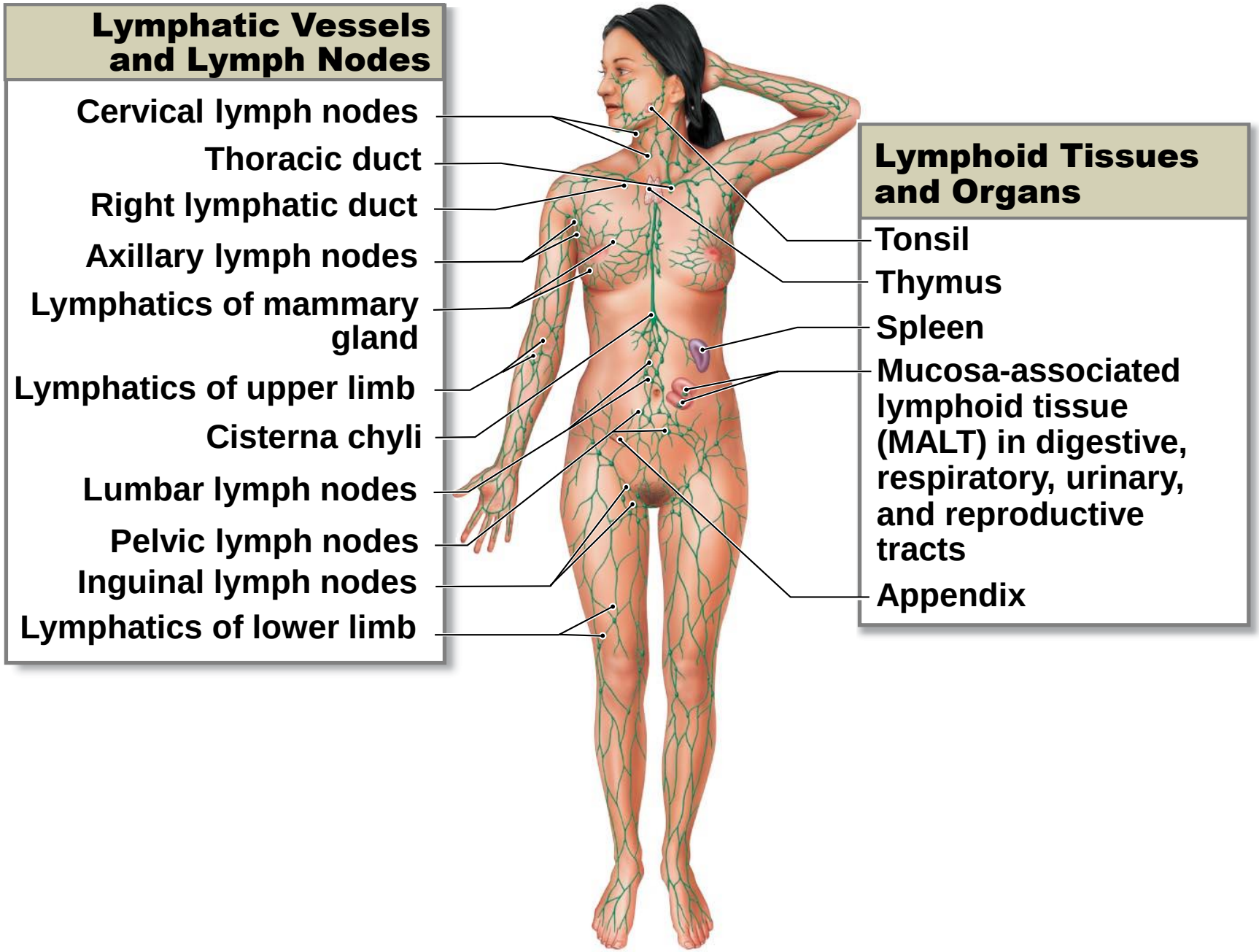
Checkpoint (14-1)

1. Define pathogen.
2. Explain the difference between nonspecific defense and specific defense.

Four Components of the Lymphatic System (14-2)

1. **Lymphatic vessels** or **lymphatics**
   - From peripheral tissue to veins
2. **Lymph fluid**
   - Found in vessels, similar to plasma, lower in proteins
3. **Lymphocytes**
   - Specialized white blood cells
4. **Lymphoid tissues** and **lymphoid organs**

Figure 14-1 The Components of the Lymphatic System.



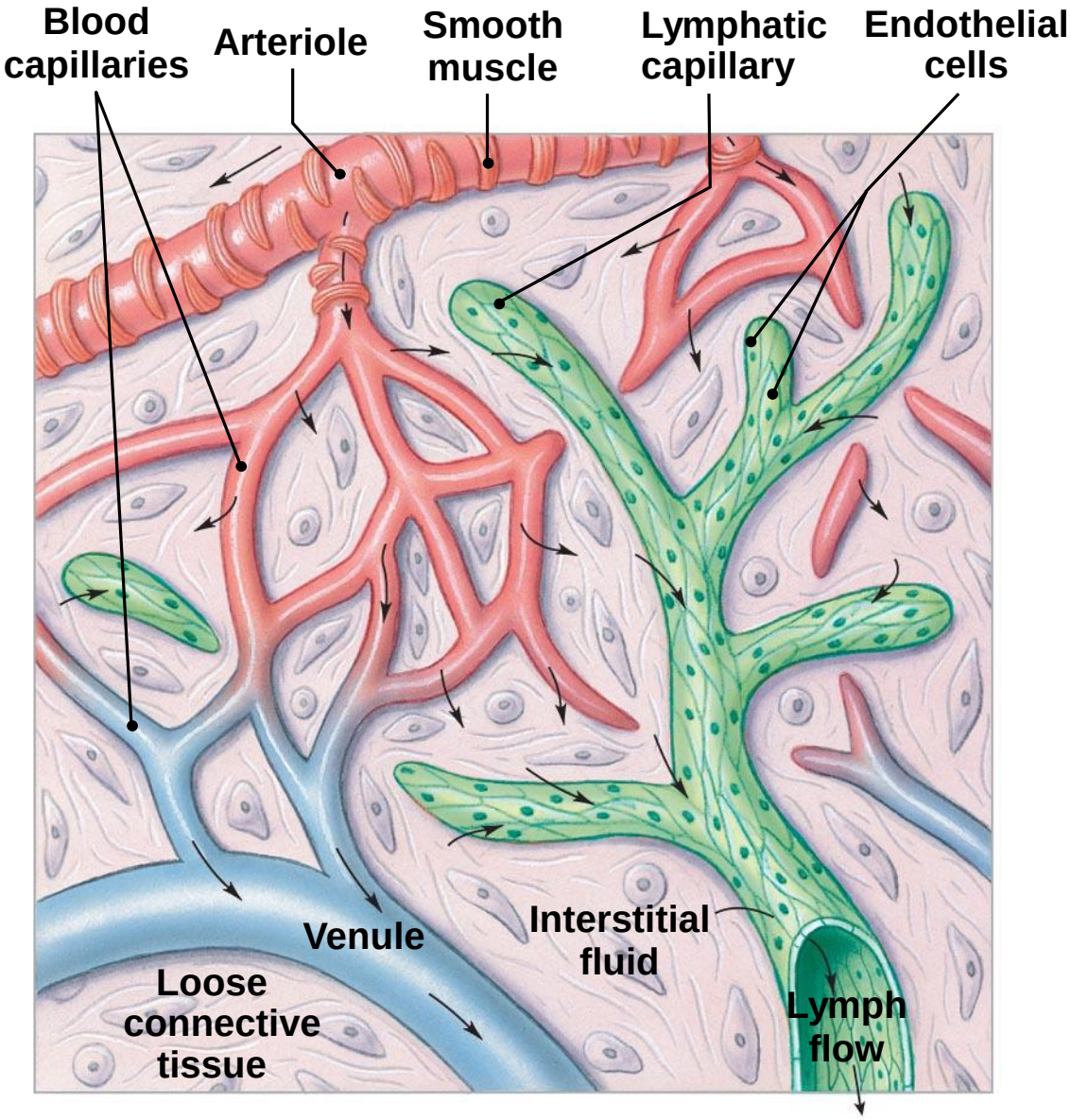
Functions of the Lymphatic System (14-2)

1. Production, maintenance, and distribution of lymphocytes
2. Returns fluid and solutes from peripheral tissues to bloodstream
3. Distributes hormones, nutrients, and waste products into general circulation

Lymphatic Capillaries (14-2)

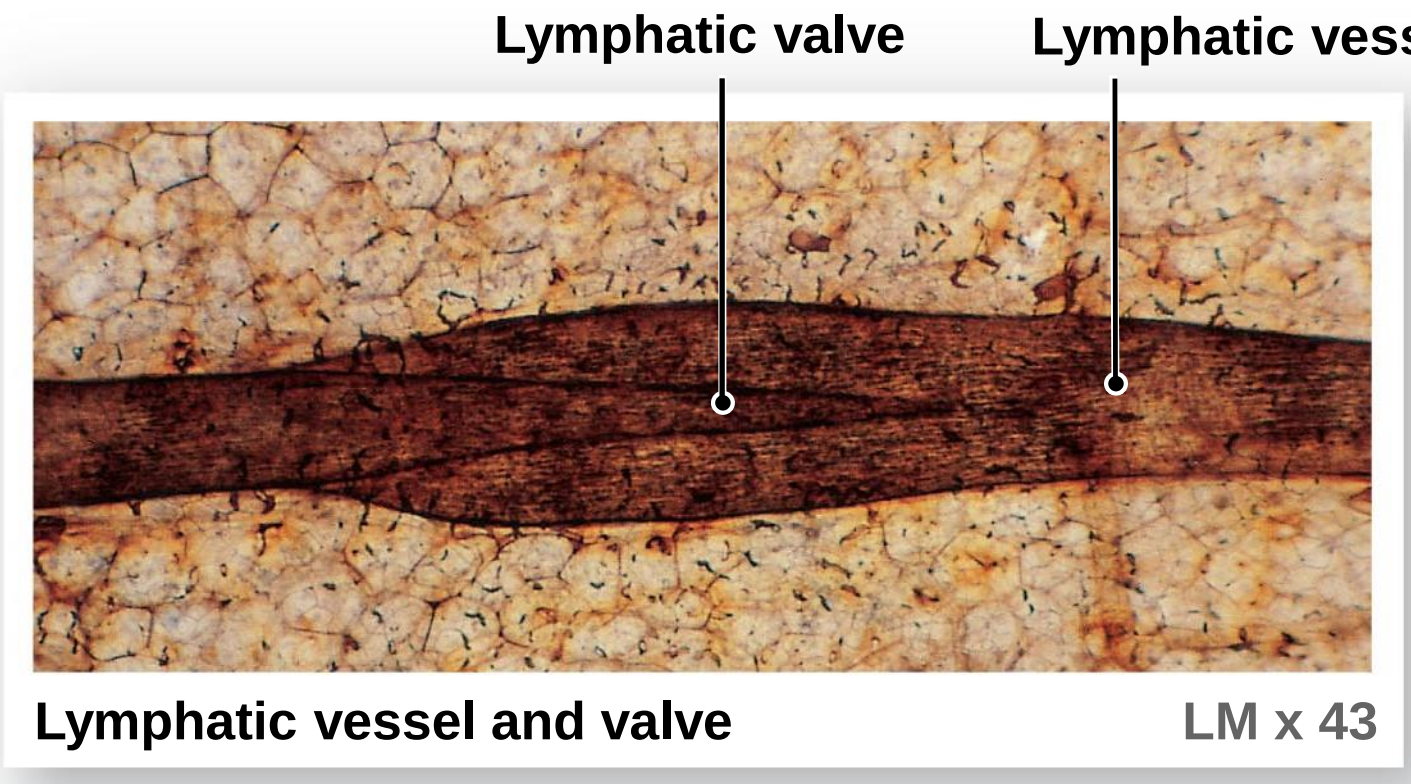
- Blind-end pockets in tissues
- Overlapping endothelial cells
  - Allows fluid and solutes to enter
  - Prevents solutes from returning to interstitial fluid
- One-way flow into larger vessels
- Eventually empty into the lymphatic ducts

Figure 14-2a Lymphatic Capillaries.



a The interwoven network formed by blood capillaries and lymphatic capillaries. Arrows indicate the movement of fluid out of blood capillaries and the net flow of interstitial fluid and lymph.

Figure 14-2b Lymphatic Capillaries.

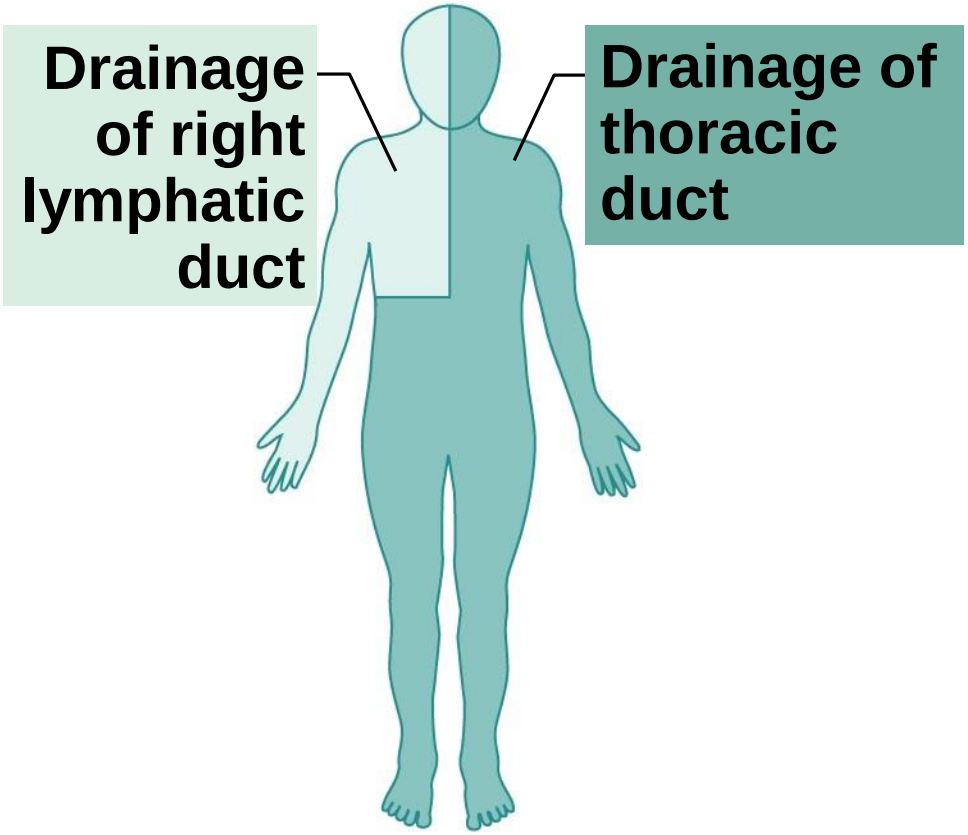


b **Like valves in veins, each lymphatic valve permits movement of fluid in only one direction.**

Lymphatic Ducts (14-2)

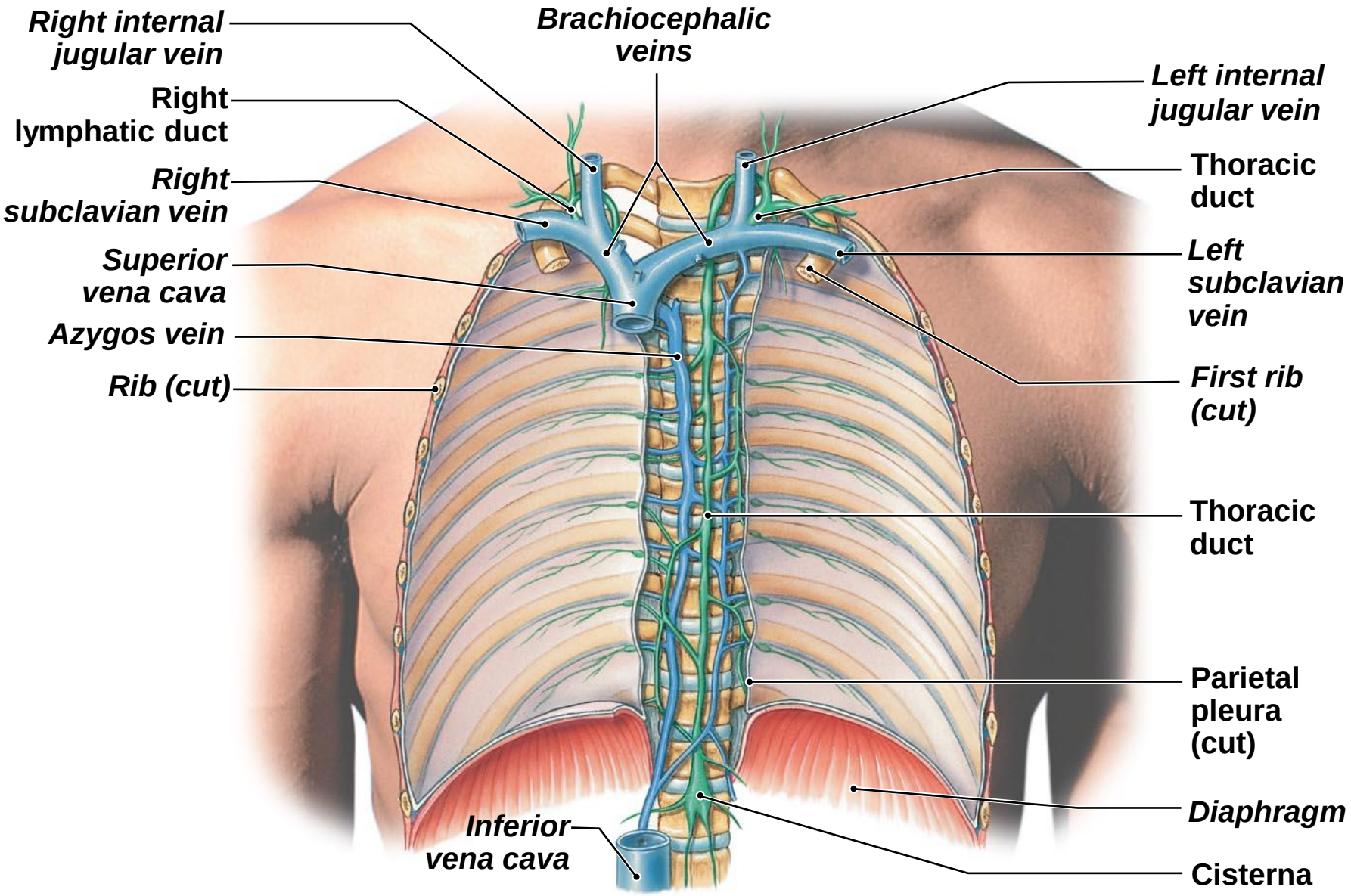
- **Thoracic duct**
  - Drains lymph from lower body and upper left side
  - Base is enlarged **cisterna chyli**
  - Drains into left subclavian vein
- **Right lymphatic duct**
  - Drains upper right side of body into right subclavian
- Blockage of vessels causes **lymphedema**

Figure 14-3a The Lymphatic Ducts and the Venous System.



a **The thoracic duct carries lymph originating in tissues inferior to the diaphragm and from the left side of the upper body. The right lymphatic duct drains the right half of the body superior to the diaphragm.**

Figure 14-3b The Lymphatic Ducts and the Venous System.



b The thoracic duct empties into the left subclavian vein. The right lymphatic duct drains into the right subclavian vein.

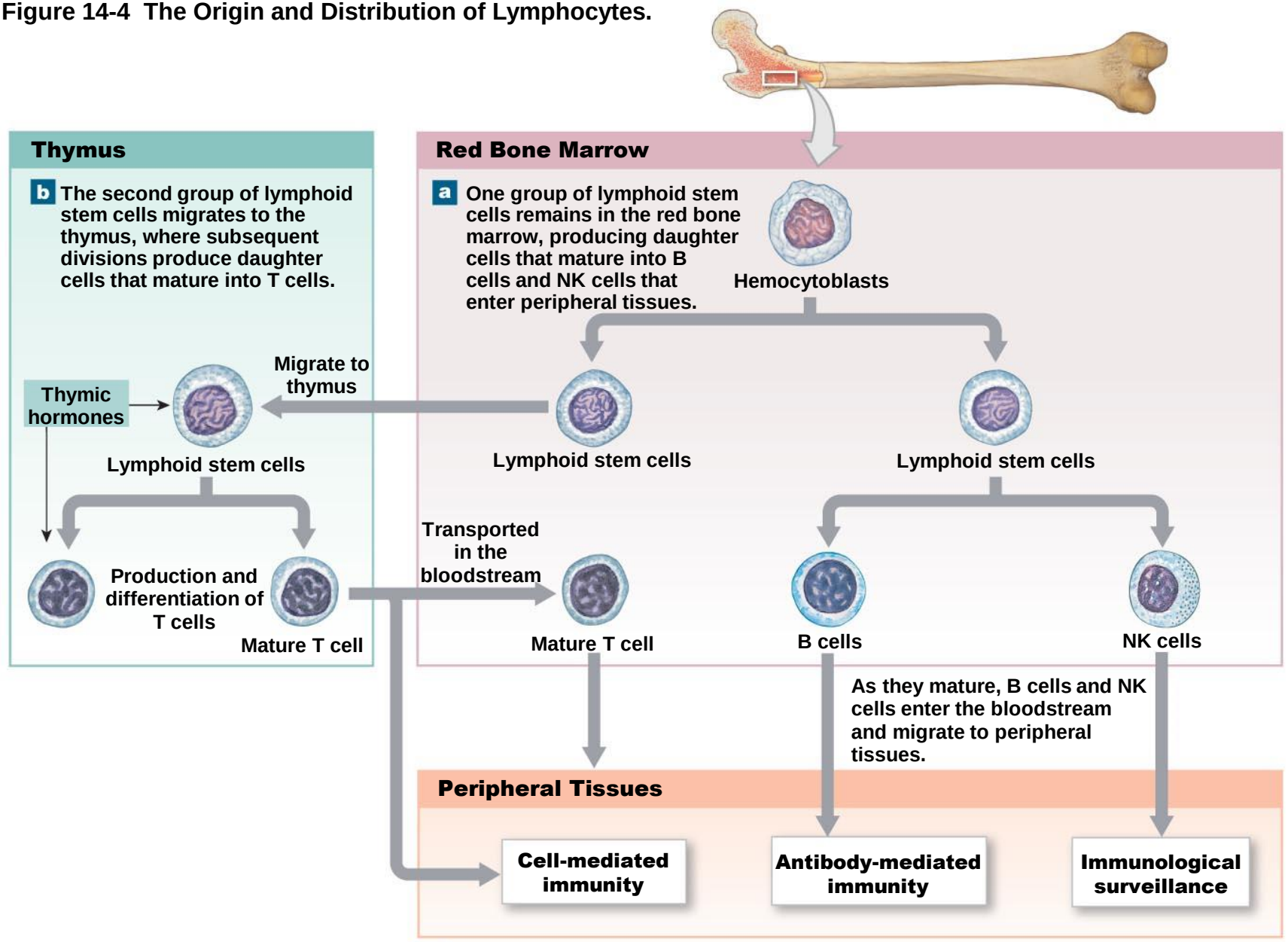
Lymphocytes (14-2)

- Most of 1 trillion lymphocytes within lymph organs
- **T cells** make up 80 percent
  - Cytotoxic, helper, suppressor, and regulatory T cells
- **B cells** make up 10–15 percent
  - **Plasma cells** secrete **antibodies** or **immunoglobulins**
- **NK cells** make up 5–10 percent
  - Natural killer cells

Lymphopoiesis (14-2)

- Lymphocytes derived from *hemocytoblasts* in red bone marrow
- Some lymphoid stem cells differentiate into B and NK cells
- Remainder migrate to thymus
  - *Thymosins* trigger differentiation into T cells

Figure 14-4 The Origin and Distribution of Lymphocytes.



c Mature T cells leave the circulation to take temporary residence in peripheral tissues. All three types of lymphocytes circulate throughout the body in the bloodstream.

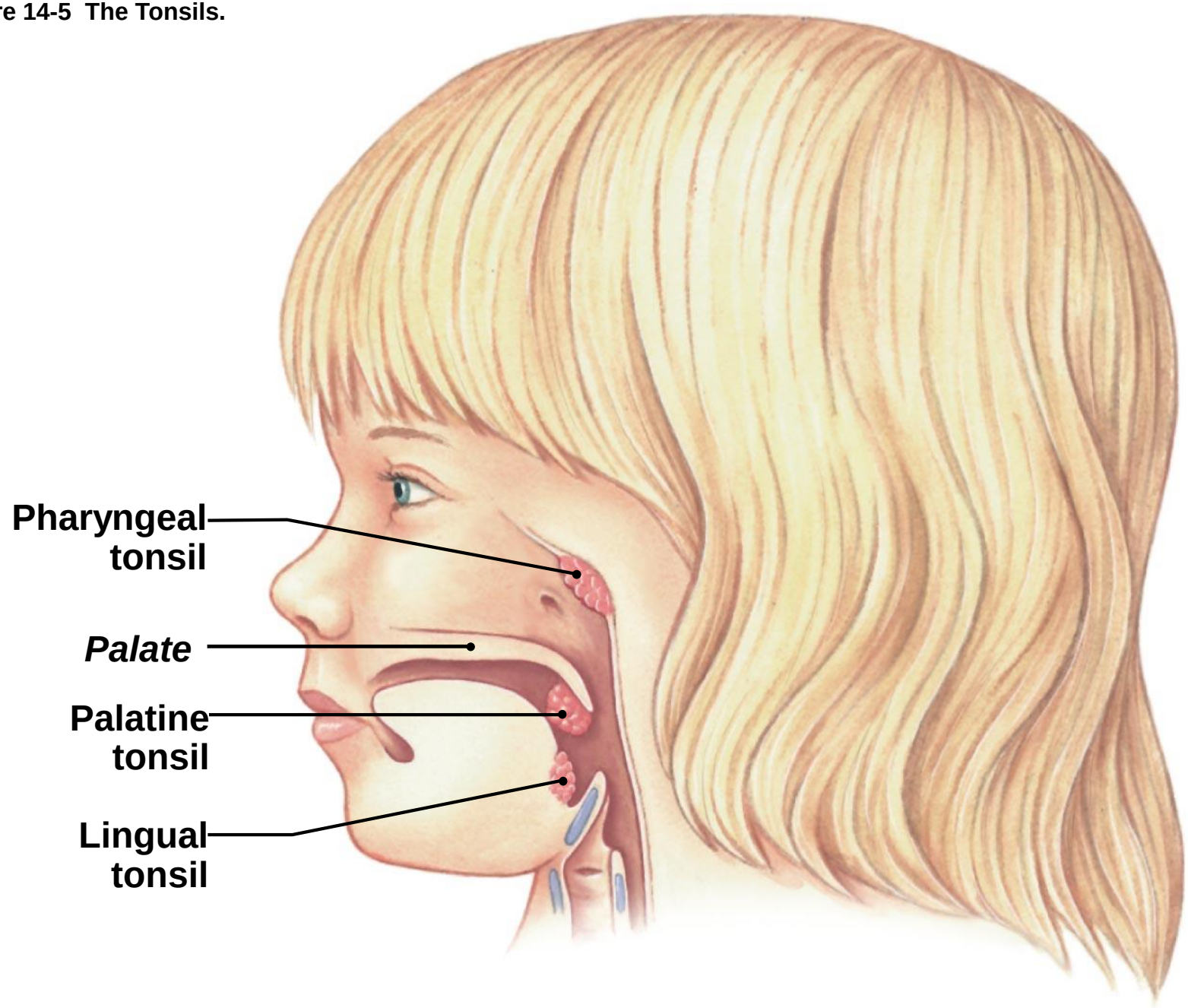
Lymphoid Nodules (14-2)

- Small, non-encapsulated masses of lymphoid tissue
- Germinal center where lymphocyte division occurs
- Protect epithelia in body systems open to the external environment
- Collections referred to as mucosa-associated lymphoid tissues (MALT)
  - Tonsils, Peyer patches, vermiform appendix

MALT (14-2)

- **Tonsils** in pharynx
  - *Pharyngeal/adenoid*
  - *Palatine*
  - *Lingual*
- **Peyer patches** in lining of intestines
- **Vermiform appendix** near junction of small and large intestines

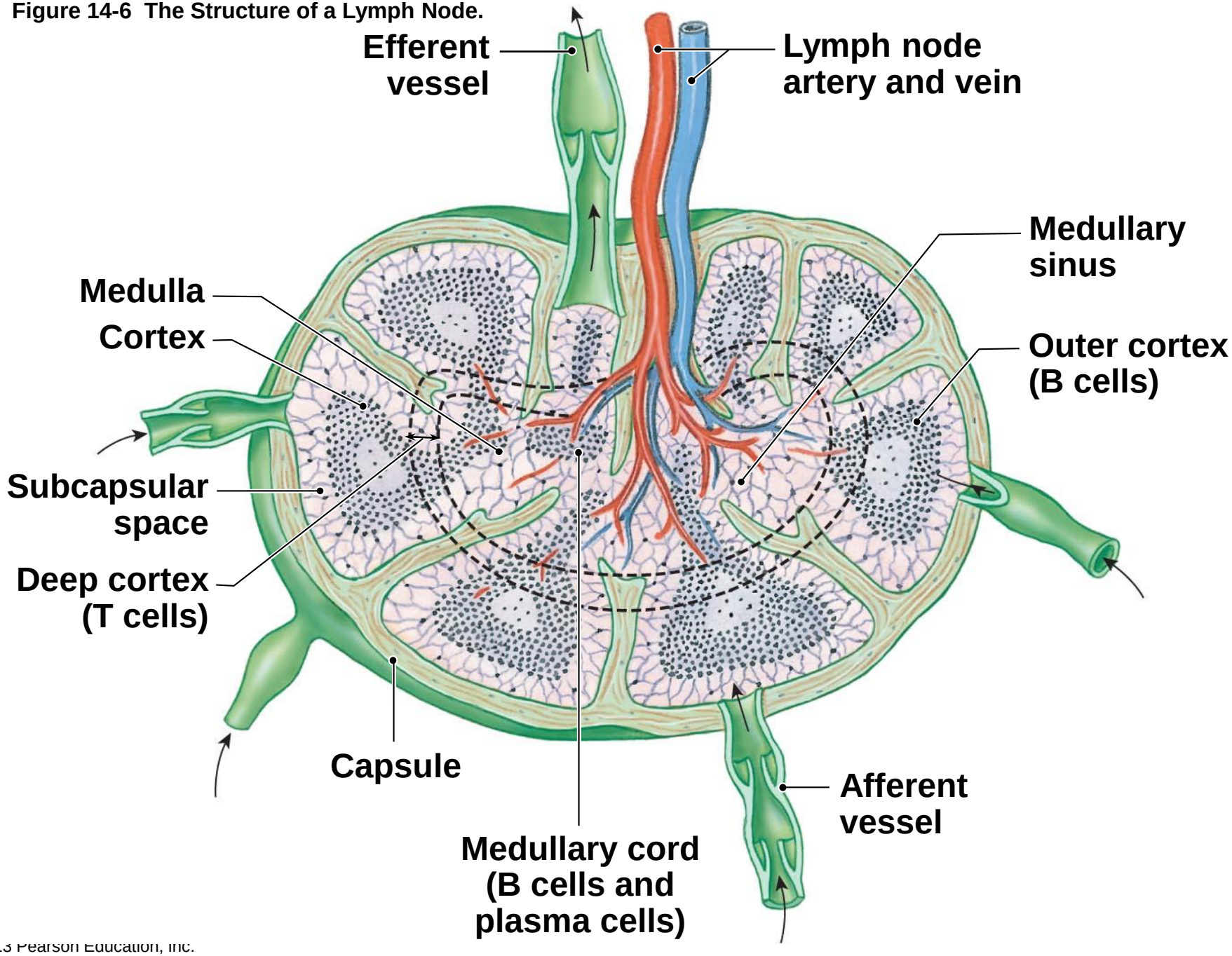
Figure 14-5 The Tonsils.



Lymph Nodes (14-2)

- Encapsulated lymphoid tissue
- Concentrated in neck, armpits, and groin
- Afferent lymphatics bring lymph to node
- Pathogens are filtered from lymph
  - Macrophages and dendritic cells destroy pathogens
  - T and B cells are activated
- Efferent lymphatic drains node

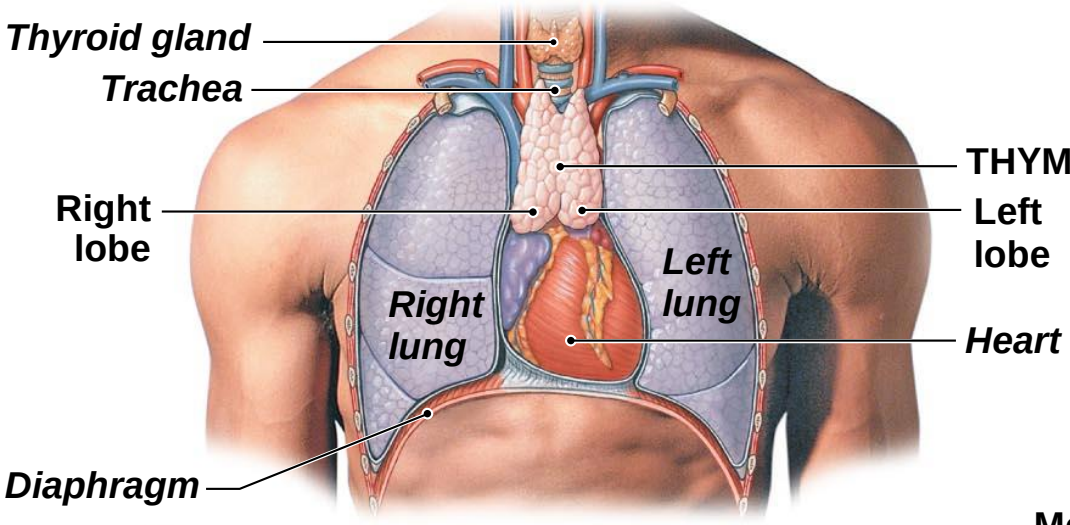
Figure 14-6 The Structure of a Lymph Node.



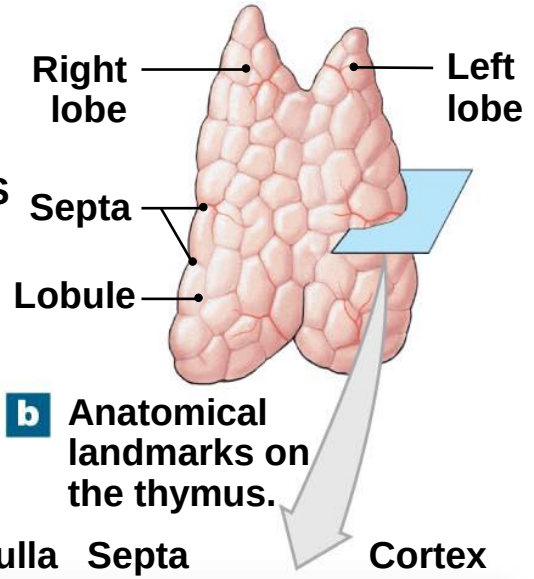
The Thymus (14-2)

- Located in mediastinum, posterior to sternum
- Site of T cell production and maturation
- Develops to maximum size during puberty
- Gradually atrophies after that
- Has two lobes made of lobules
  - Cortex contains T cells and thymosins
  - Medulla has capillaries where T cells enter circulation

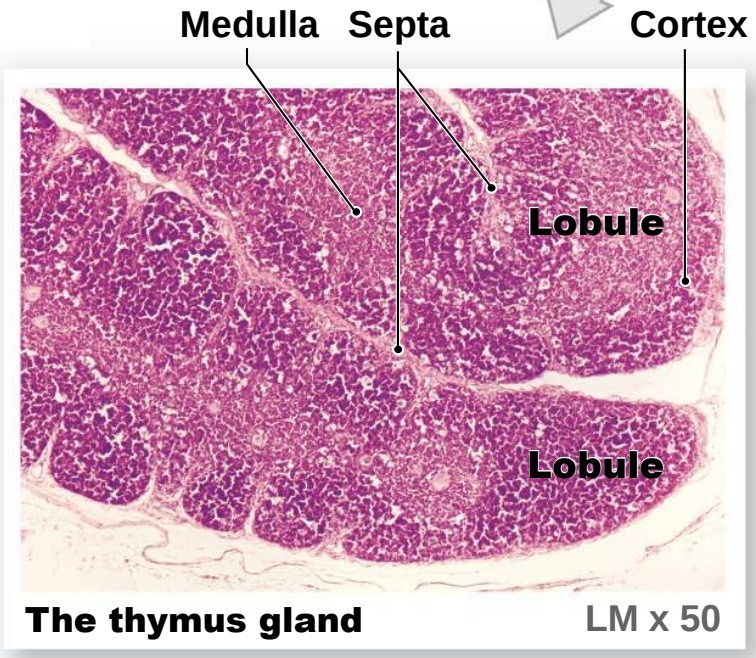
Figure 14-7 The Thymus.



a The appearance and position of the thymus in relation to other organs in the chest.



b Anatomical landmarks on the thymus.

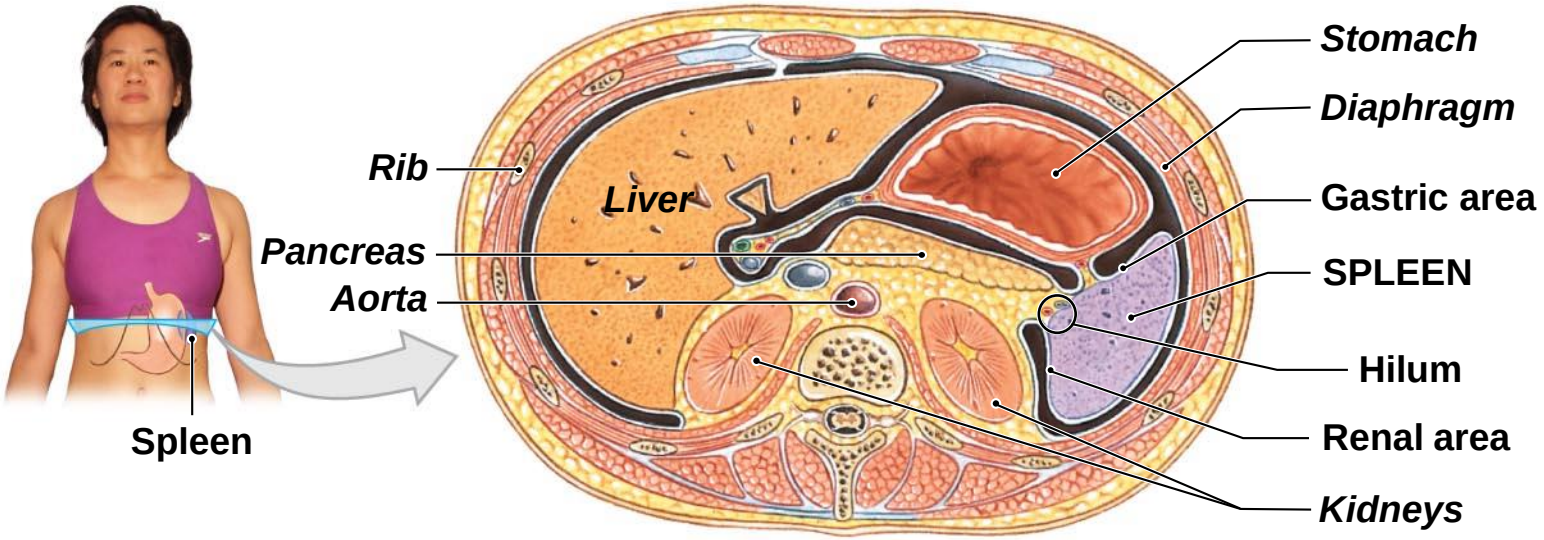


c Fibrous septa divide the tissue of the thymus into lobules resembling interconnected lymphoid nodules.

The Spleen (14-2)

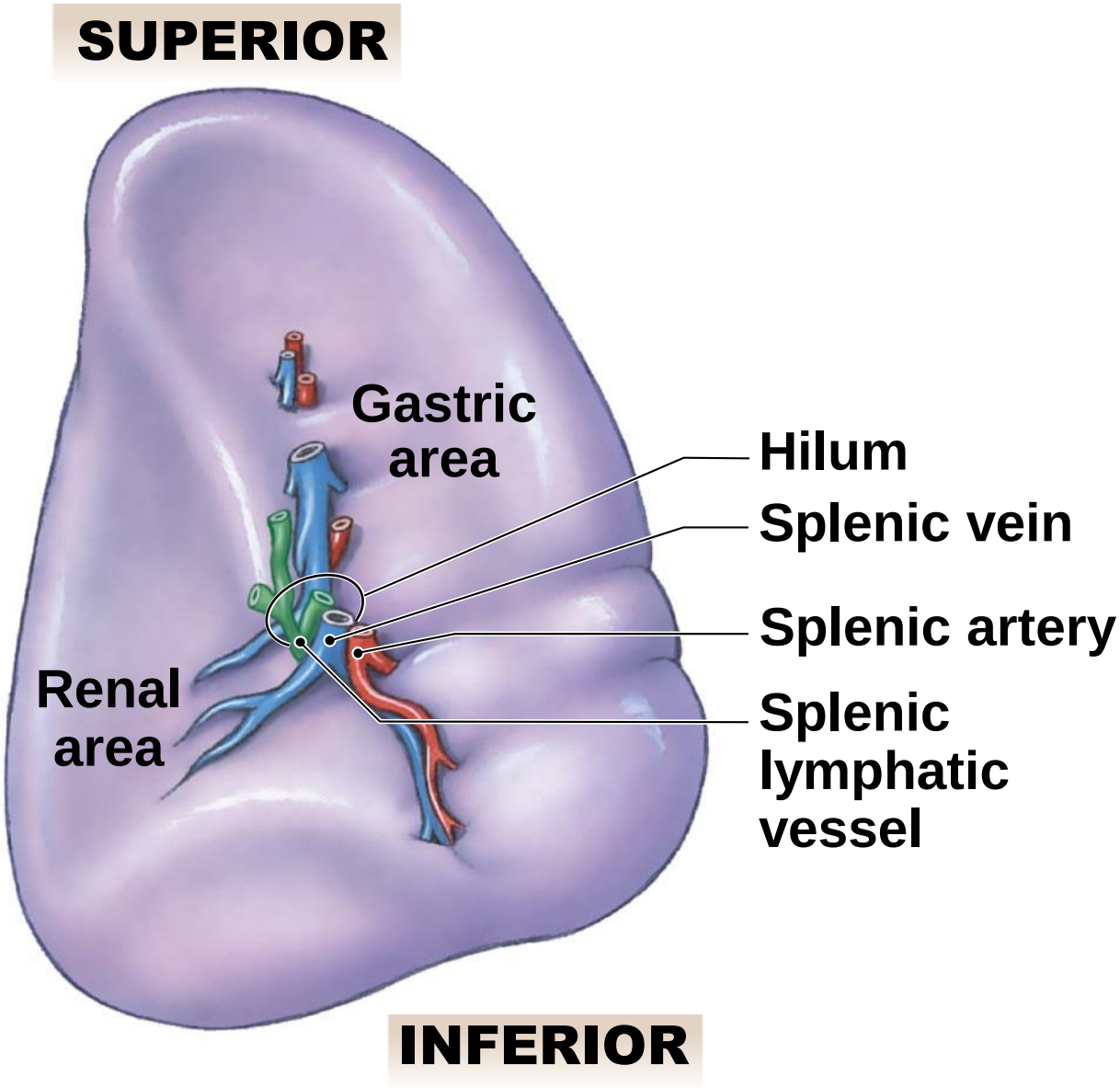
- Largest collection of lymphoid tissue
  - Red pulp contains a lot of RBCs
  - White pulp resembles lymphoid nodules
- Located between stomach, left kidney, and diaphragm
- Functions similar to lymph nodes

Figure 14-8a The Spleen.



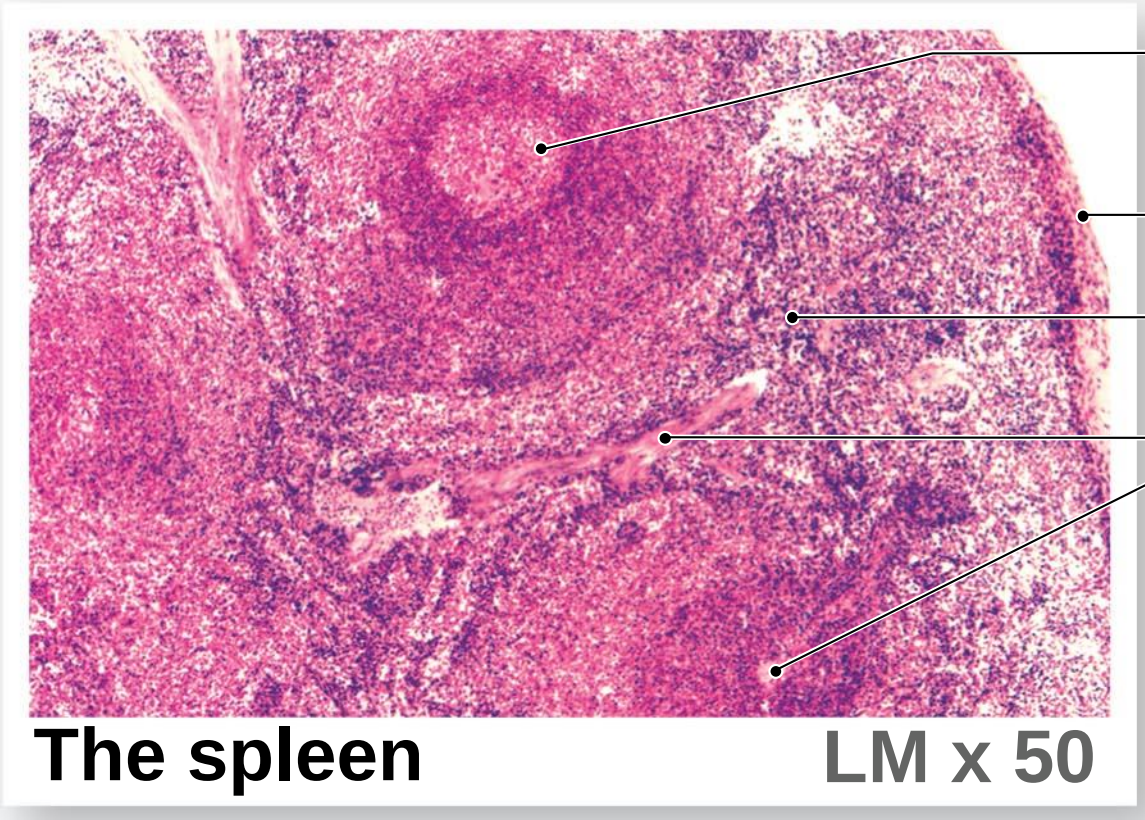
a A transverse section through the trunk, showing the typical position of the spleen projecting into the abdominopelvic cavity. The shape of the spleen roughly conforms to the shapes of adjacent organs.

Figure 14-8b The Spleen.



b A posterior view of the surface of an intact spleen, showing major anatomical landmarks.

Figure 14-8c The Spleen.



C The histological appearance of the spleen. White pulp is dominated by lymphocytes; it appears purple because the nuclei of lymphocytes stain very darkly. Red pulp contains a large number of red blood cells.

Checkpoint (14-2)

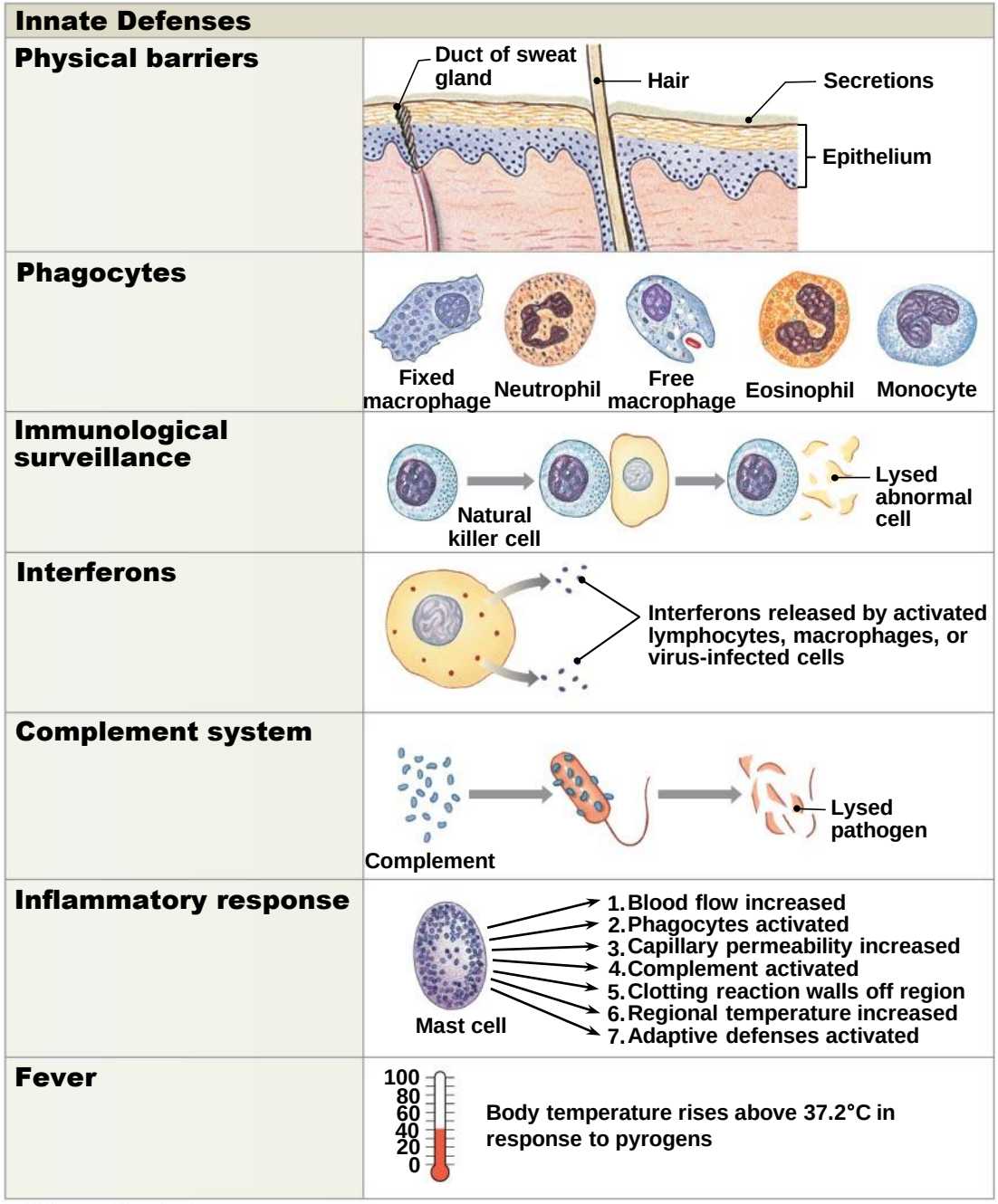
3. List the components of the lymphatic system.
4. How would blockage of the thoracic duct affect the circulation of lymph?
5. If the thymus gland failed to produce thymic hormones, which population of lymphocytes would be affected in what way?
6. Why do lymph nodes enlarge during some infections?

Innate (Nonspecific) Defenses (14-3)

- Present at birth
- Do not distinguish between threats
- Include physical barriers, phagocytic cells, immunological surveillance, interferons, complement, inflammation, and fever
- Provide body with **nonspecific resistance**

PLAY ***ANIMATION*** **Immunity: Non-specific Defenses**

Figure 14-9 The Body's Innate Defenses.



Physical Barriers (14-3)

- Provide blocking from invasive pathogens
- Include skin
  - Keratin coating and tight desmosome junctions
  - Hair acts as barrier to hazardous material and insects
  - Secretions from glands flush surface and have lysozymes
- Mucous membranes
  - Special enzymes, antibodies, and low pH

Phagocytes (14-3)

- "First line of cellular defense" by removing cellular debris
  - Move into tissues through diapedesis
  - Respond to surrounding chemicals through **chemotaxis**
- **Microphages**
  - Neutrophils and eosinophils
    - Leave bloodstream, enter infected tissue to phagocytize

Phagocytes (14-3)

- **Macrophages**
  - Derived from monocytes
  - Some fixed, some free
  - Make up the **monocyte–macrophage system**
- Specialized fixed macrophages
  - Microglial cells in CNS
  - Kupffer cells in liver

Immunological Surveillance (14-3)

- Normal cells contain proteins that identify cells as "self" called antigens
- Abnormal cells have "non-self" or foreign antigens
- NK cells recognize foreign antigens
  - Secrete perforins, killing the cells
  - Rapid response

Interferons (14-3)

- A **cytokine** released by activated lymphocytes, macrophages, and infected tissue cells
- Normal cell response to interferons
  - Produce antiviral proteins
  - Slow spread of viral infections
  - Stimulate macrophages and NK cells

The Complement System (14-3)

- Involves 11 plasma complement proteins
- Support action of antibodies
- Functions in cascade-event mechanism to:
  - Attract phagocytes
  - Stimulate phagocytosis
  - Destroy plasma membranes
  - Promote inflammation

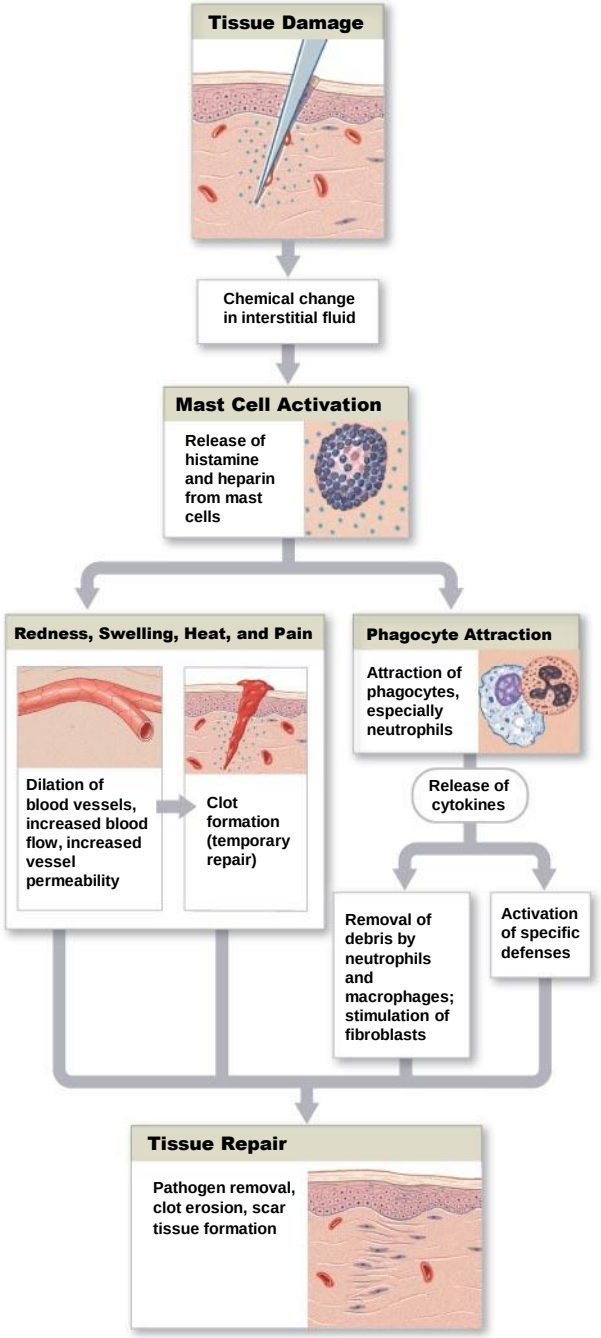
Inflammation (14-3)

- Localized response to injury
- Produces swelling, redness, heat, and pain
  - Due to release of histamines and heparin
- Effects include:
  - Temporary repair of damaged tissue
  - Slowing the spread of pathogens away from injury
  - Mobilizing defenses to promote *regeneration*

Inflammation (14-3)

- Tissue destruction occurs before repair
  - Called **necrosis**
  - Caused by lysosomal enzymes
  - **Pus** is dead and dying cells accumulating at injury site
  - **Abscess** is pus enclosed in a tissue space

Figure 14-10 Events in Inflammation.



Fever (14-3)

- Defined as body temperature >37.2°C (99°F)
- **Pyrogens**
  - Proteins that reset temperature center in hypothalamus
  - Elevate body temperature
- Mild fever is beneficial, increasing metabolism
- High fever, >40°C (104°F), can cause CNS problems

Checkpoint (14-3)

7. List the body's nonspecific defenses.

8. What types of cells would be affected by a decrease in the number of monocyte-forming cells in red bone marrow?

9. A rise in the level of interferon in the body indicates what kind of infection?

10. What effects do pyrogens have in the body?

Adaptive (Specific) Defenses (14-4)

- Provided by coordinated activities of T and B cells
- **Cell-mediated immunity**
  - Result of T cell defense specifically against pathogens inside living cells
- **Antibody-mediated immunity**
  - Result of B cell defense specifically against pathogens in body fluids

Two Types of Immunity (14-4)

1. **Innate** or **nonspecific immunity**
   - Present at birth
   - Includes nonspecific defenses
2. **Adaptive** or **specific immunity**
   - Not present at birth
   - Acquired either actively or passively
   - Acquired either naturally or artificially

Active Immunity (14-4)

- Individual is exposed to an antigen
- Immune response occurs
- Naturally acquired active immunity
  - Due to exposure to pathogens in environment
- Artificially acquired active immunity
  - Antibody production stimulated through **vaccines**

Passive Immunity (14-4)

- Due to transfer of antibodies from other source
- Naturally acquired passive immunity
  - Antibodies provided to baby through placental transfer or, after birth, through breast milk
- Artificially acquired passive immunity
  - Antibodies are injected to fight infection or disease

Four Properties of Adaptive Immunity (14-4)

1. **Specificity**
   - **Antigen recognition** is a specific response to specific antigen
2. **Versatility**
   - Immune system produces millions of different lymphocyte populations, each for a specific antigen

Four Properties of Adaptive Immunity (14-4)

3. Memory

- First exposure triggers development of **memory cells**
- Second exposure to an antigen triggers stronger, longer immune response

4. Tolerance

- Exists when immune system does not respond to "self" antigens
- Any T or B cells that attack "self" are destroyed

Figure 14-11 Types of Immunity.

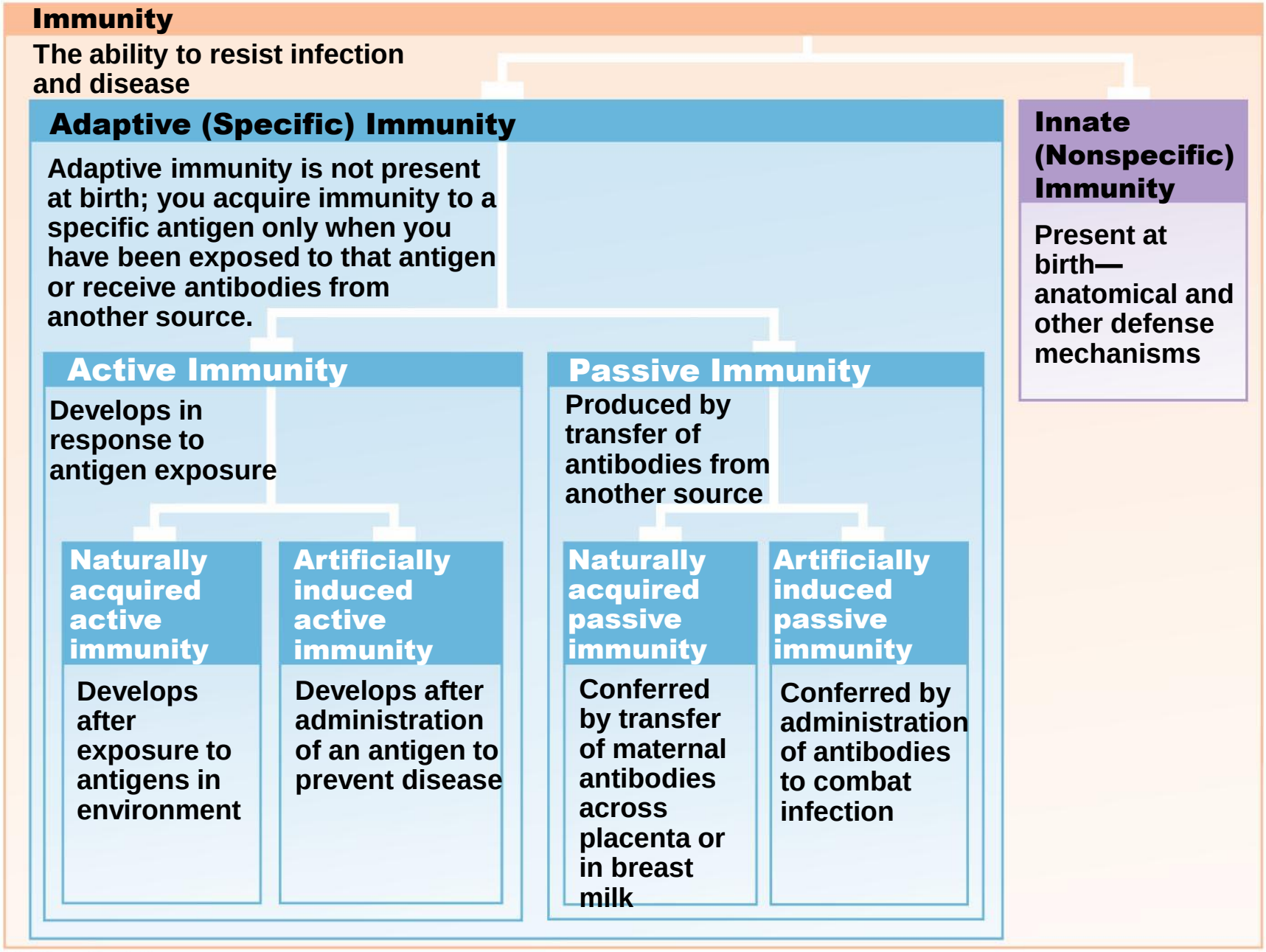
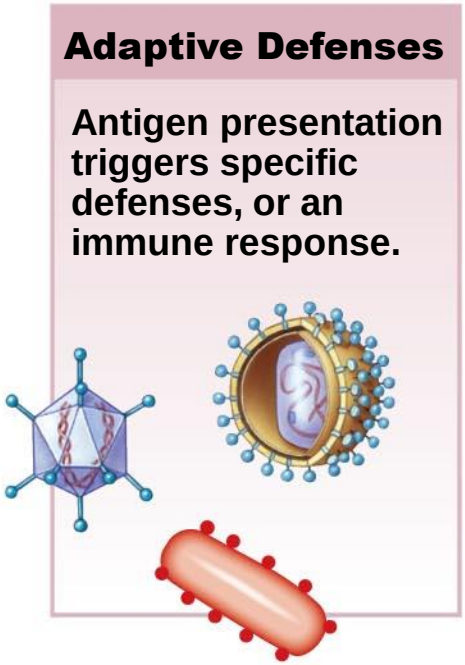


Figure 14-12 An Overview of the Immune Response.



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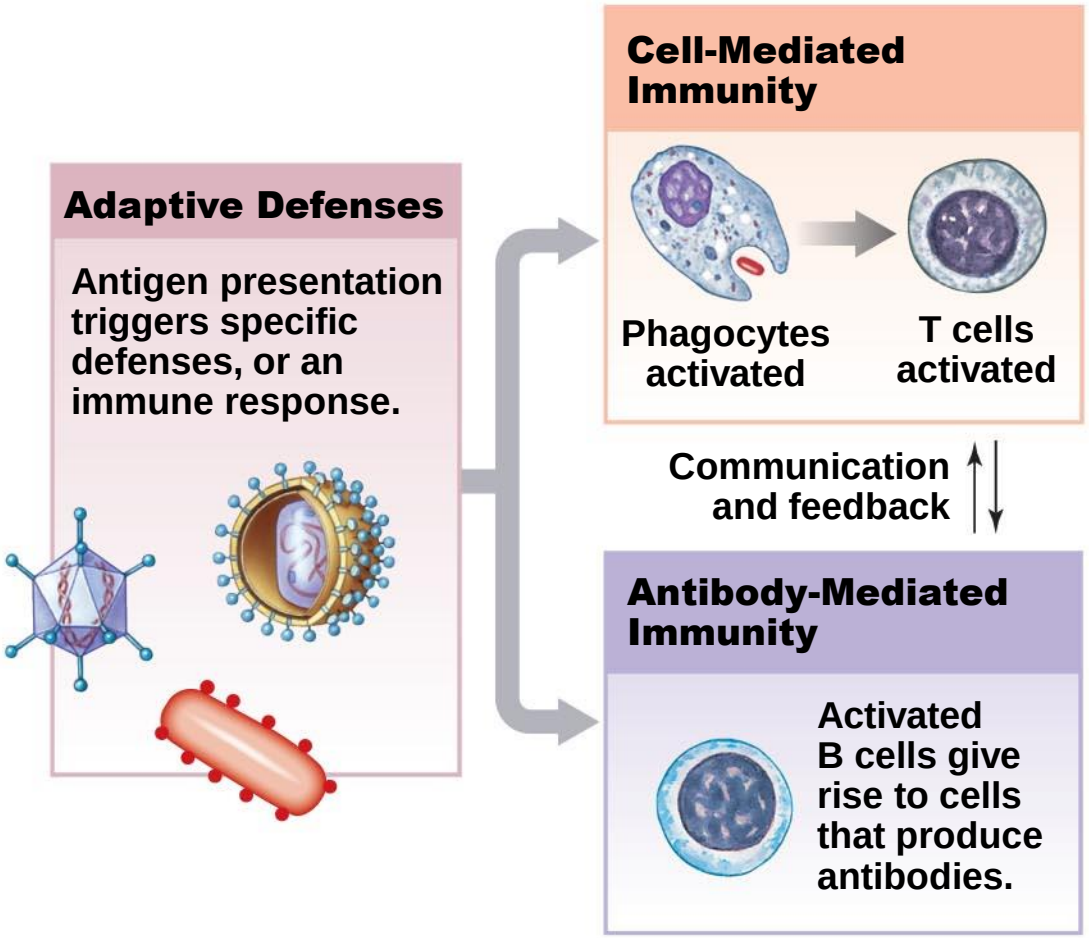

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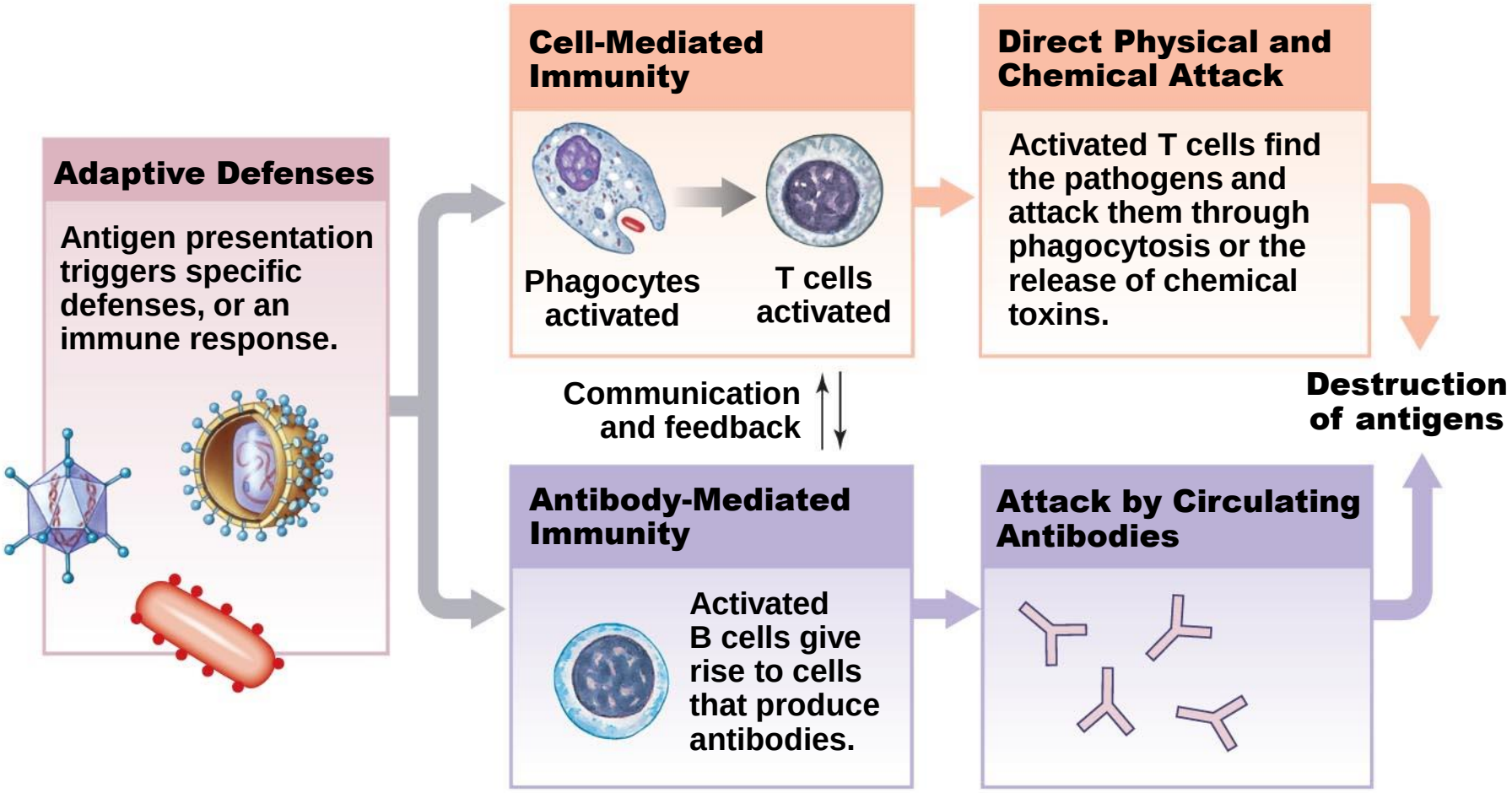


Checkpoint (14-4)

11. Distinguish between cell-mediated (cellular) immunity and antibody-mediated (humoral) immunity.

12. Identify the two forms of active immunity and the two types of passive immunity.

13. List the four general properties of adaptive immunity.

Antigen Presentation (14-5)

- *Major histocompatibility complex (MHC) proteins*
  - Antigen-binding receptors are genetically determined
- Class I MHC protein
  - In plasma membrane of all nucleated cells
  - Identifies the cell as foreign
  - Activates a T cell attack on that cell when an antigen binds to it

Class II MHC Proteins (14-5)

- Found in membranes of lymphocytes and *antigen-presenting cells (APCs)*
  - All phagocytes and **dendritic cells**
- APCs phagocytize pathogens and foreign antigens
- Fragments are then displayed by binding to MHC
- T cells that engage with these APCs respond with immune response

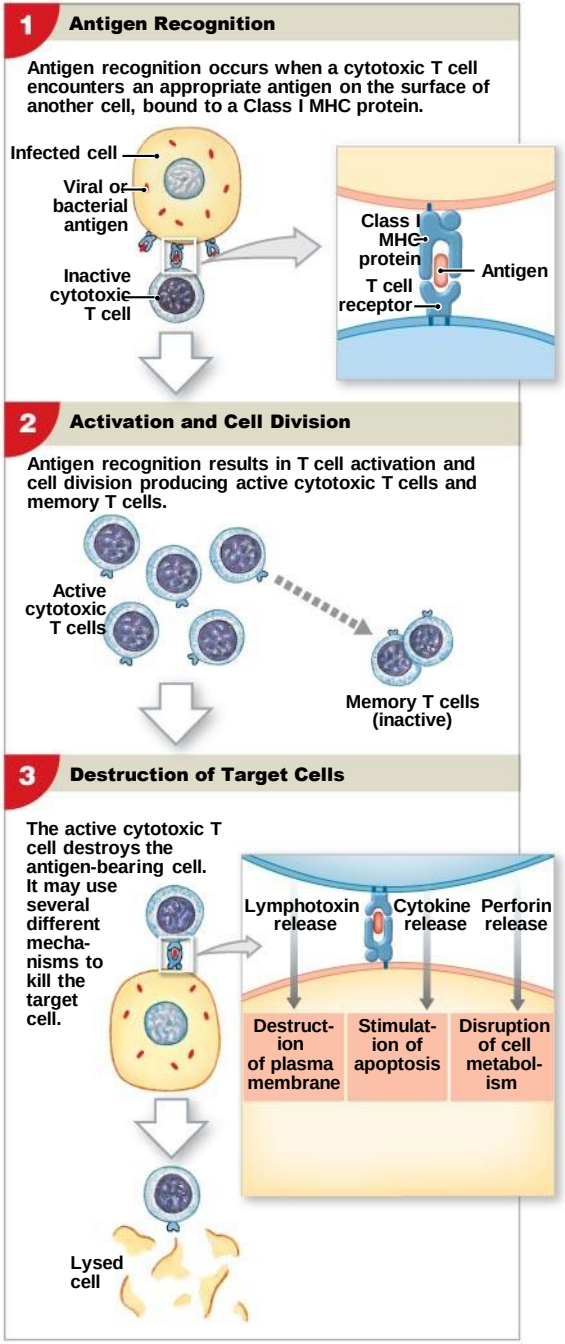
T Cell Activation (14-5)

- T cells have membrane proteins, **CD markers**
- Type of CD marker determines response to MHCs
- Two key CD markers
  1. CD8 T cells respond to Class I MHC proteins
  2. CD4 T cells respond to Class II MHC proteins
- When activated, T cells differentiate into *cytotoxic, helper, memory, and suppressor T cells*

Cytotoxic T Cells (14-5)

- CD8 cells responsible for cell-mediated immunity
- Activated cells divide into cytotoxic and memory cells
- Destroy bacteria, fungi, transplanted tissue by:
  - Secreting lymphotoxins, disrupting target metabolism
  - Secreting cytokines that activate apoptosis, genetically programmed cell death
  - Secreting perforins that rupture plasma membrane

Figure 14-13 Antigen Recognition and Activation of Cytotoxic T Cells



Helper T Cells (14-5)

- CD4 T cells
  - Secrete various cytokines
  - Stimulate both cell-mediated and antibody-mediated immunity
- Divide into memory and active helper T cells

Memory T Cells (14-5)

- Both cytotoxic and helper T cells can divide into memory cells
- Are in reserve to mount a rapid attack if the same antigen appears again
- Will rapidly differentiate into cytotoxic and helper T cells

Suppressor T Cells (14-5)

- Are CD8 cells that develop slowly
- Dampen response of other T cells and B cells
- Secrete cytokines called *suppression factors*
- Limit degree of immune response

Checkpoint (14-5)

14. Identify the four types of T cells.

15. How can the presence of an abnormal peptide within a cell start an immune response?

16. A decrease in the number of cytotoxic T cells would affect what type of immunity?

17. How would a lack of helper T cells affect the antibody-mediated immune response?

B Cell Activation and Sensitization (14-6)

- Each B cell has specific antibody molecule
- When matching antigen appears:
  - Antibodies will bind to and engulf them
  - Antigens bind to Class II MHC causing *sensitization*
- Active B cells divide into:
  - Plasma cells that secrete large amounts of antibodies
  - **Memory B cells** in reserve for second response

Figure 14-14 The B Cell Response to Antigen Exposure.

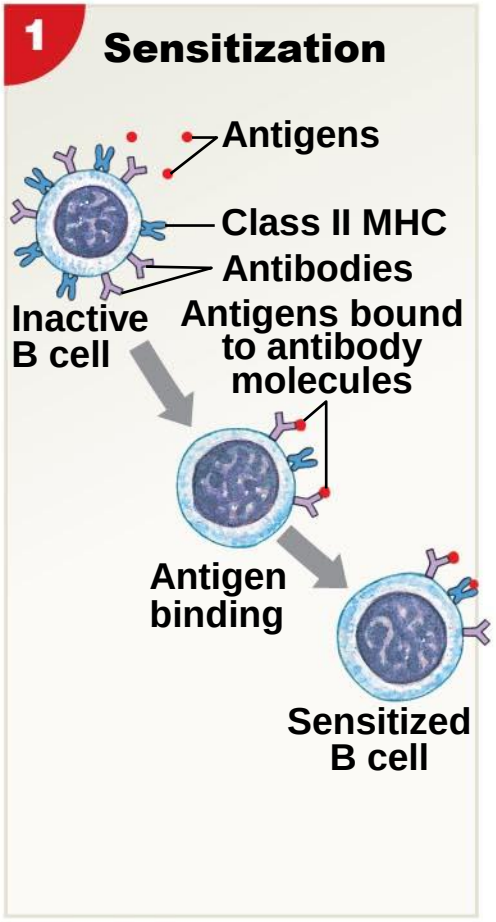


Figure 14-14 The B Cell Response to Antigen Exposure.

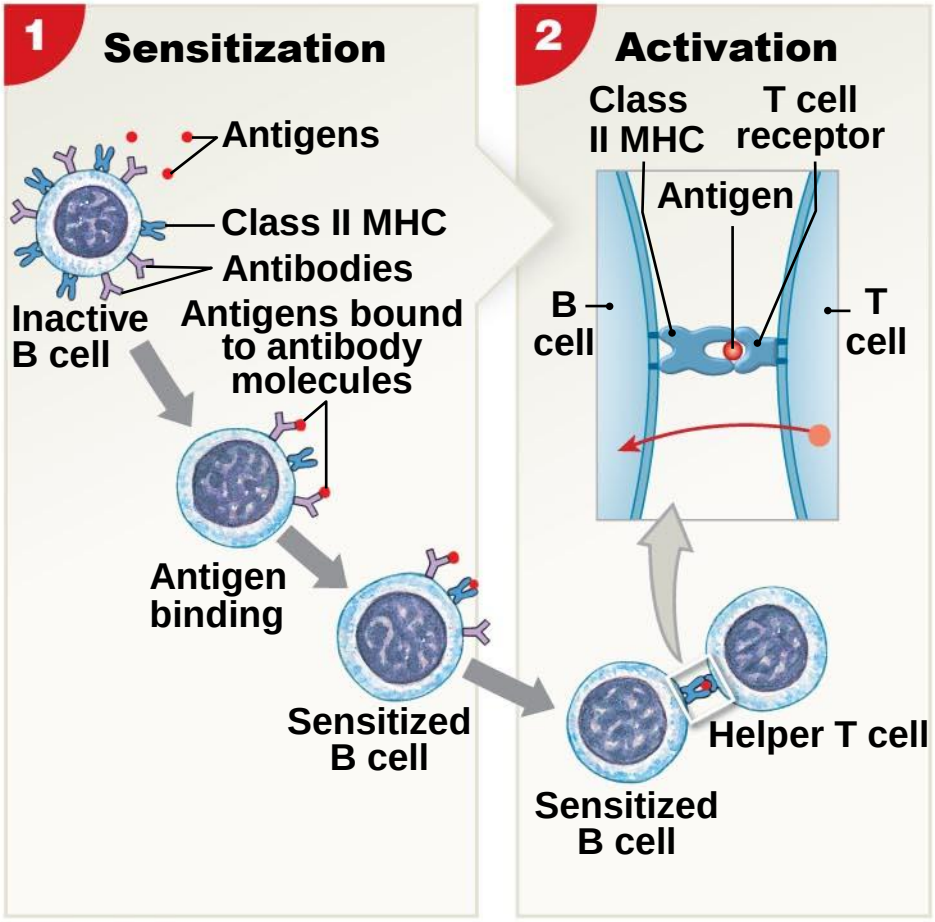
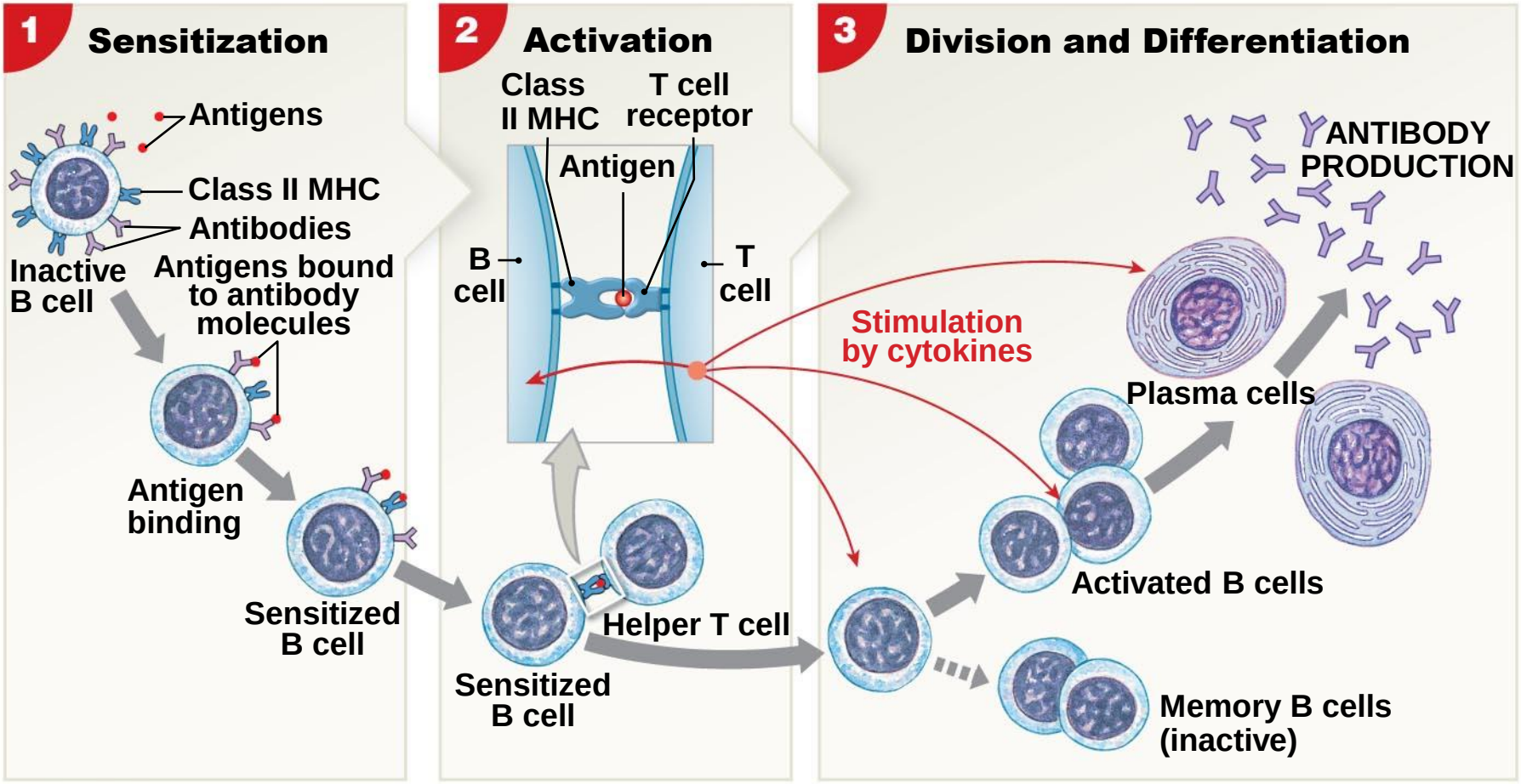


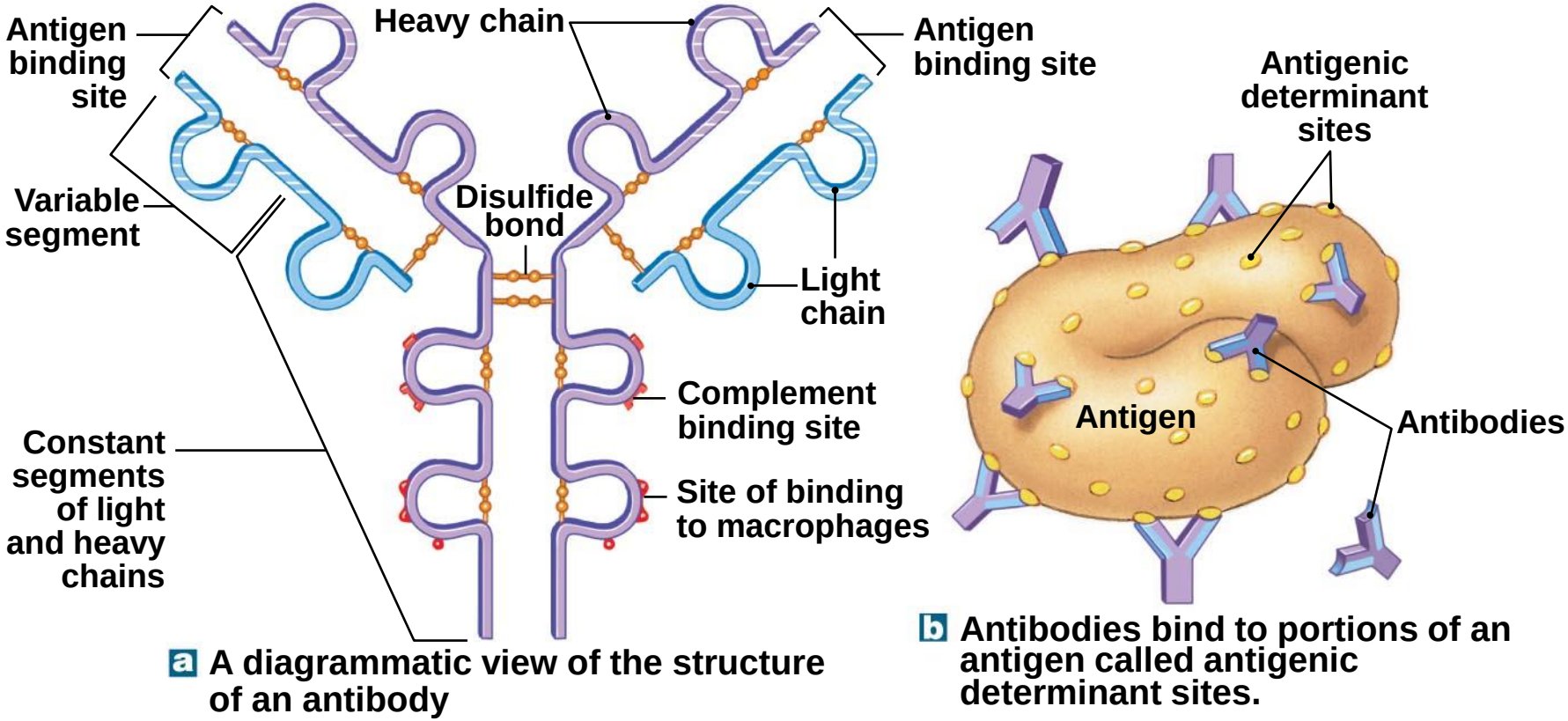
Figure 14-14 The B Cell Response to Antigen Exposure.



Antibody Structure (14-6)

- A Y-shaped protein with two parallel pairs of chains
  - One pair of long *heavy chains*
    - Constant segment provides base for antibody
  - One pair of *light* chains
- **Antigen binding sites**
  - The free tips of variable segments
  - Determine the specificity of antibody

Figure 14-15 Antibody Structure.



Antigen–Antibody Complex (14-6)

- Antibodies bind to portions of antigen called *antigenic determinant sites*
- Depends on three-dimensional fit between variable segments and the antigen
- A *complete antigen* has at least two antigenic determinant sites

Five Classes of Antibodies (14-6)

- Antibodies also called **immunoglobulins** (**Igs**)
  1. IgG
     - Largest and most diverse class
     - Responsible for resistance against viruses, bacteria
     - Can cross the placenta for passive immunity for fetus
  2. IgM
     - Attack bacteria
     - Responsible for cross-reactions of blood types

Five Classes of Antibodies (14-6)

3. IgA
   - Found in exocrine secretions like tears, saliva
   - Attack antigens before they enter the body
4. IgE
   - Stimulates basophils and inflammatory response
5. IgD
   - Attached to B cells, aid in sensitization

Table 14-1 Classes of Antibodies

Table 14-1 Classes of Antibodies		
Class	**Function**	**Remarks**
IgG	Responsible for defense against many viruses, bacteria, and bacterial toxins	Largest class (80%) of antibodies, with several subtypes; also cross the placenta and provide passive immunity to fetus; anti-Rh antibodies produced by Rh-negative mothers are IgG antibodies that can cross the placenta and attack fetal Rh-positive red blood cells, producing *hemolytic disease of the newborn.* p. 391
IgM	Anti-A and anti-B forms responsible for cross-reactions between incompatible blood types; other forms attack bacteria insensitive to IgG	First antibody type secreted following initial exposure to antigen; levels decline as IgG production accelerates
IgA	Attacks pathogens before they enter the body tissues	Found in glandular secretions (tears, mucus, and saliva)
IgE	Accelerates inflammation on exposure to antigen	Bound to surfaces of mast cells and basophils and stimulates release of histamine and other inflammatory chemicals; also important in allergic response
IgD	Binds antigens in the extracellular fluid to B cells	Binding can play a role in sensitization of B cells

Six Functions of Antibodies (14-6)

1. **Neutralization**
   - Antigen–antibody complex prevents antigen from attaching to a cell
2. Agglutination and precipitation
   - Antibodies bind to several antigens forming large complexes, process called **agglutination**
   - **Precipitation** occurs when large complexes settle out of solution

Six Functions of Antibodies (14-6)

3. Activation of complement
    - When antibody binds to antigen, it changes shape allowing it to bind with complement proteins
4. Attraction of phagocytes
    - Antigen–antibody complex attracts eosinophils, neutrophils, and macrophages

Six Functions of Antibodies (14-6)

5. Enhancement of phagocytosis
   - Coating of antibodies and complement makes pathogens easier to phagocytize
   - Referred to as opsonins, causing opsonization
6. Stimulation of inflammation
   - Antibodies stimulate basophils and mast cells, mobilizing nonspecific defenses

Primary and Secondary Responses (14-6)

- **Primary response** takes time to develop
  - Antigen must activate B cells, which then differentiate
  - Plasma cell antibody secretion takes 1–2 weeks to develop
- **Secondary response**
  - Memory B cells differentiate into plasma cells when exposed the second time
  - Increase in IgG is immediate and higher than first response

Figure 14-16 The Primary and Secondary Immune Responses.

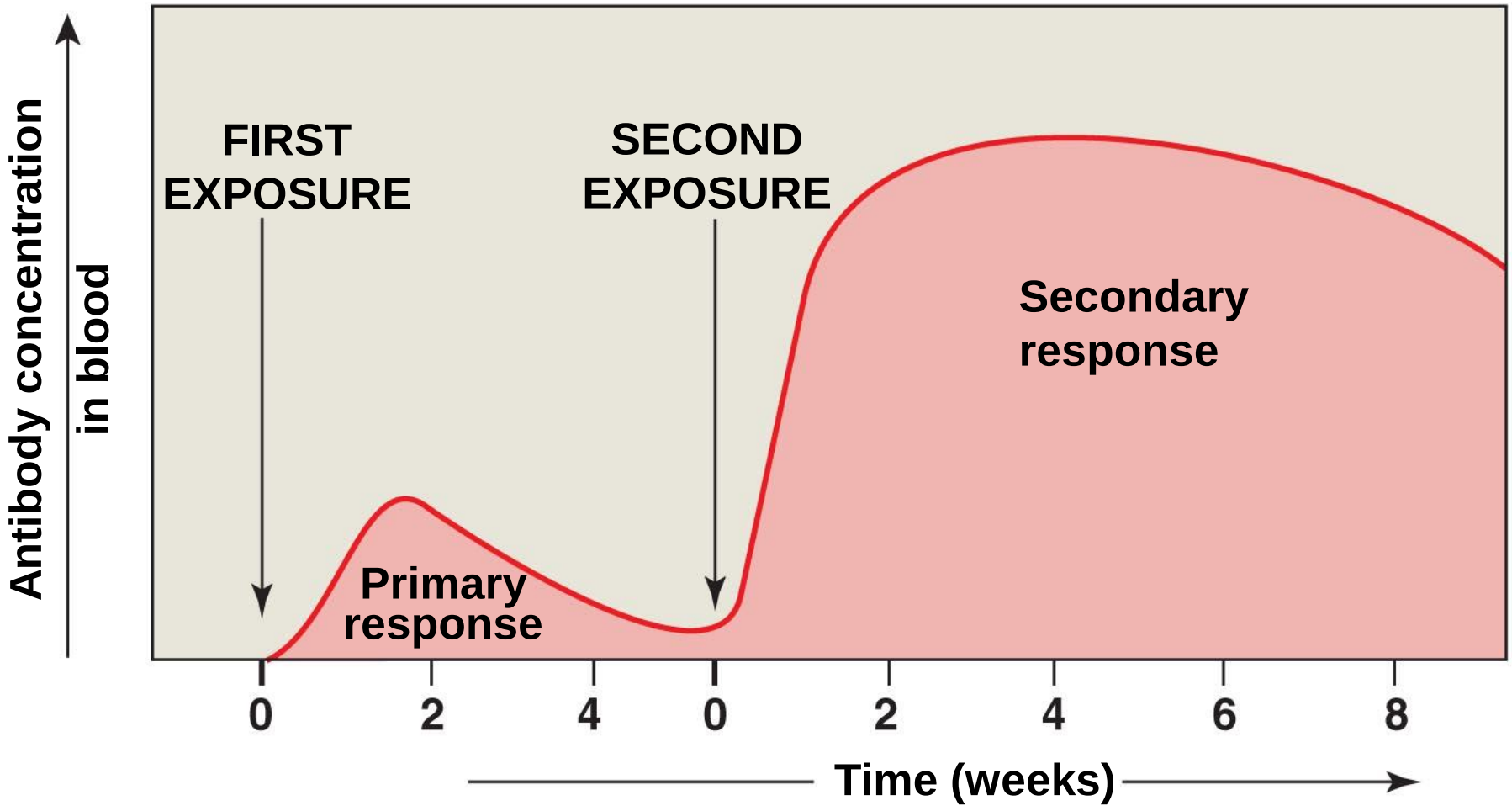
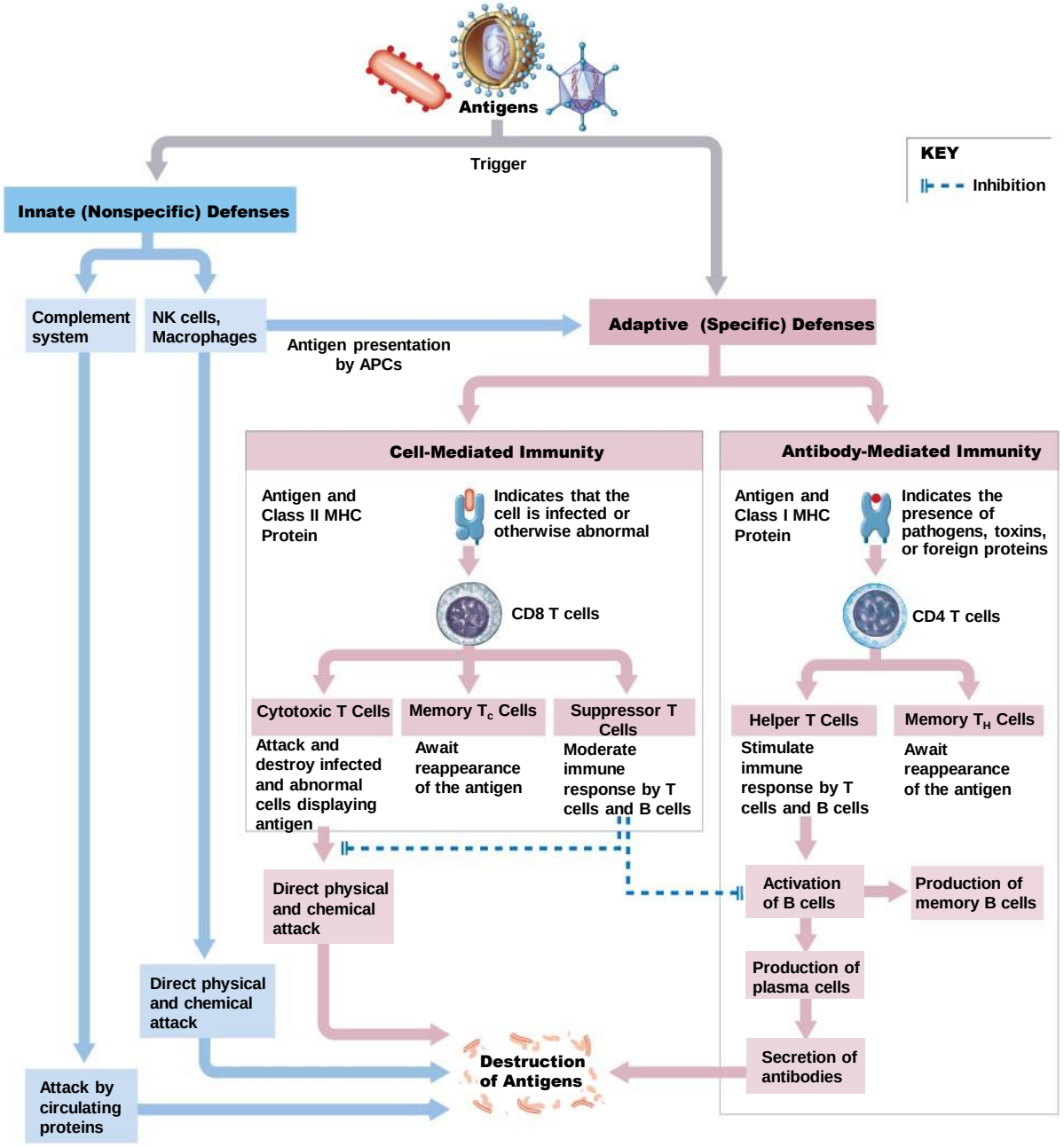


Table 14-2 Cells That Participate in Tissue Defenses

Table 14-2 Cells That Participate in Tissue Defenses	
Cell	**Functions**
Neutrophils	Phagocytosis; stimulation of infl ammation
Eosinophils	Phagocytosis of antigen–antibody complexes; suppression of infl ammation; participation in allergic response
Mast cells and basophils	Stimulation and coordination of infl ammation by release of histamine, heparin, prostaglandins
ANTIGEN-PRESENTING CELLS	
Macrophages (free and fi xed macrophages, Kupffer cells, microglia, etc.)	Phagocytosis; antigen processing; antigen presentation with Class II MHC proteins; secretion of cytokines, especially interleukins and interferons
Dendritic Cells	Pinocytosis; antigen processing; antigen presentation with Class II MHC proteins
LYMPHOCYTES	
NK cells	Destruction of plasma membranes containing abnormal antigens
Cytotoxic T cells (T_C)	Lysis of plasma membranes containing antigens bound to Class I MHC proteins; secretion of perforin, lymphotoxin, and other cytokines
Helper T cells (T_H)	Secretion of cytokines that stimulate cell-mediated and antibody-mediated immunity; activation of sensitized B cells; enhance nonspecifi c defenses by attracting macrophages to affected areas
B cells	Differentiation into plasma cells, which secrete antibodies and provide antibody-mediated immunity
Suppressor T cells (T_S)	Secretion of suppression factors that inhibit the immune response
Memory cells (T_C, T_H, B)	Produced during the activation of T cells and B cells; remain in tissues awaiting reappearance of antigens

Figure 14 -17 A Summary of the Immune Response and Its Relationship to Innate (Nonspecific) Defenses.



Hormones of the Immune System (14-6)

- Cytokines are chemical coordinators of defenses
  - **Interleukins** (**IL**) are most diverse
    - Increase T cell sensitivity to antigens
    - Stimulate B cell activity and antibody production
    - Enhance nonspecific defenses
    - Some suppress immune function
  - **Interferons** make cells resistant to viral infection
    - Attract and stimulate NK cells

Hormones of the Immune System (14-6)

- **Tumor necrosis factors** (**TNFs**)
  - Slow tumor growth and kill tumor cells
  - Stimulate neutrophils, eosinophils, and basophils
- **Phagocytic regulators**
  - Coordinate specific and nonspecific defenses by adjusting phagocyte activity

Hormones of the Immune System (14-6)

- **Colony-stimulating factors** (**CSFs**)
  - Stimulate production of blood cells in bone marrow and of lymphocytes in lymphoid tissues

Checkpoint (14-6)

18. Define sensitization.

19. Describe the structure of an antibody.

20. A sample of lymph contains an elevated number of plasma cells. Would you expect the number of antibodies in the blood to be increasing or decreasing? Why?

21. Would the primary response or the secondary response be more affected by a lack of memory B cells for a particular antigen?

Autoimmune Disorders (14-7)

- Activated B cells begin to develop **autoantibodies**
- Autoantibodies attack normal cells and tissues
  - *Rheumatoid arthritis*
  - *Insulin-dependent diabetes mellitus*
- Some virus-related proteins resemble normal tissue proteins
  - Explains neurological damage after vaccine or virus

Immunodeficiency Diseases (14-7)

- Immune system fails to develop normally or:
- Immune response is blocked somehow
- **AIDS** is result of viral destruction of T cells
- **Severe combined immunodeficiency disease (SCID)**
  - Infants fail to develop cell- or antibody-mediated immunity

Allergies (14-7)

- Inappropriate or excessive immune responses
- Four types of allergies
  1. **Immediate hypersensitivity**, hay fever
  2. Cytotoxic reactions, cross-reactions in transfusions
  3. Immune complex disorders, slow phagocyte activity
  4. Delayed hypersensitivity, poison ivy

Anaphylaxis (14-7)

- A type I, immediate hypersensitivity
- Rapid changes in capillary permeability causing swelling
- Raised welts or hives
- Smooth muscles in airways contract
- Can lead to circulatory failure, **anaphylactic shock**

Checkpoint (14-7)

22. Under what circumstances is an autoimmune disorder produced?

23. How does increased stress reduce the effectiveness of the immune response?

Immunity and Aging (14-8)

- T cells become less responsive
  - Fewer cytotoxic T cells to respond to infection
- B cells become less responsive
  - Slower production of antibodies
- Increase in susceptibility to viral and bacterial infections
- Increase in incidence of cancer due to less effective tumor cell destruction

Checkpoint (14-8)

24. Why are the elderly more susceptible to viral and bacterial infections?

25. What may account for the increased incidence of cancer among the elderly?

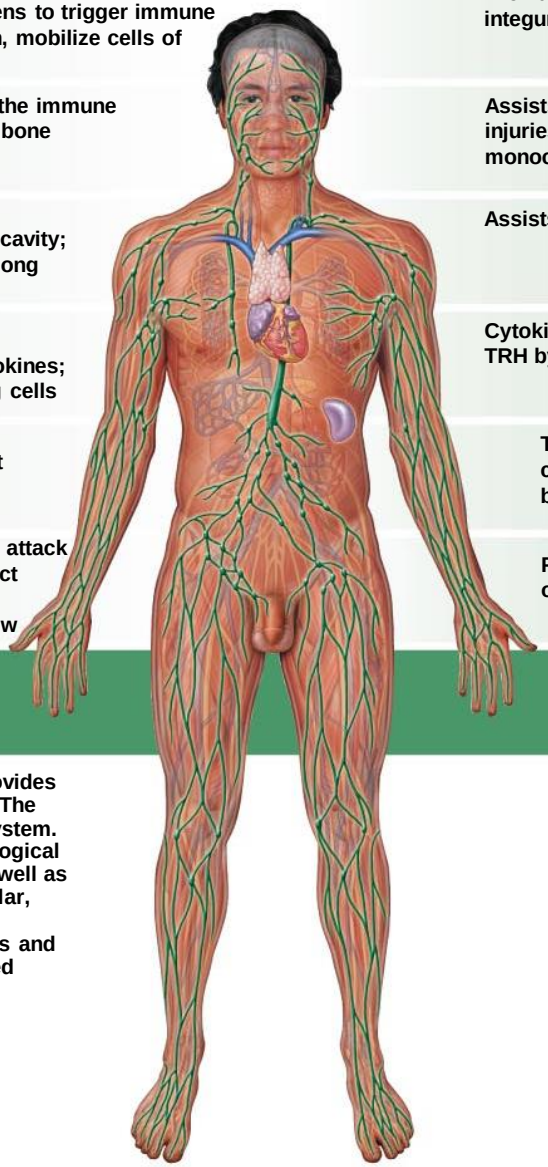
Lymphatics Essential for All Systems (14-9)

- Endocrine responses to infection triggers increases in metabolic activity
- Some dendritic cells are innervated
  - Neurotransmitter release increases local immune response
  - Emotional stress can decrease immune response

Figure 14 -18

SYSTEM INTEGRATOR

Body System → Lymphatic System	Lymphatic System → Body System
Integumentary: Provides physical barriers to pathogen entry; macrophages in dermis resist infection and present antigens to trigger immune response; mast cells trigger inflammation, mobilize cells of lymphatic system	Provides IgA antibodies for secretion onto integumentary surfaces → **Integumentary** (Page 138)
Skeletal: Lymphocytes and other cells involved in the immune response are produced and stored in red bone marrow	Assists in repair of bone after injuries; osteoclasts differentiate from monocyte–macrophage cell line → **Skeletal** (Page 188)
Muscular: Protects superficial lymph nodes and the lymphatic vessels in the abdominopelvic cavity; muscle contractions help propel lymph along lymphatic vessels	Assists in repair after injuries → **Muscular** (Page 241)
Nervous: Microglia present antigens that stimulate adaptive defenses; glial cells secrete cytokines; innervation stimulates antigen-presenting cells	Cytokines affect production of CRH and TRH by hypothalamus → **Nervous** (Page 302)
Endocrining: Glucocorticoids have anti-inflammatory effects; thymosins stimulate development and maturation of lymphocytes; many hormones affect immune function	Thymus secretes thymosins; cytokines affect cells throughout the body → **Endocrine** (Page 376)
Cardiovascular: Distributes WBCs; carries antibodies that attack pathogens; clotting response helps restrict spread of pathogens; granulocytes and lymphocytes produced in red bone marrow	Fights infections of cardio- vascular organs; returns tissue fluid to circulation → **Cardiovascular** (Page 467)



For all body systems, the lymphatic system provides adaptive (specific) defenses against infection. The lymphatic system is an anatomically distinct system. In comparison, the immune system is a physiological system that includes the lymphatic system, as well as components of the integumentary, cardiovascular, respiratory, digestive, and other body systems. Through immunological surveillance, pathogens and abnormal body cells are continuously eliminated throughout the body.

Respiratory (Page 532)
Digestive (Page 572)
Urinary (Page 637)
Reproductive (Page 671)

Checkpoint (14-9)

26. Identify the role of the lymphatic system for all body systems.

27. How does the cardiovascular system aid the body's defense mechanisms?