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MICROBIOLOGY

WITH DISEASES BY TAXONOMY, THIRD EDITION

Chapter 15 Innate Immunity

先天性免疫

學習目標

- Understand the nature of innate immunity.
- Understand the characteristics of crucial lines of defense of human body.

An Overview of the Body's Defenses

- Resistance to most plant and animal pathogens
- Species resistance 種系抵抗力
  - Due to physiological processes of humans that are incompatible with those of the pathogen
    - Correct chemical receptors not present on human cells
    - Conditions may be incompatible with those needed for pathogen's survival
- Number of pathogens for which humans don't have innate resistance

The Body's First Line of Defense

- Structures, chemicals, and processes that work to prevent pathogens entering the body
- Skin and mucous membranes of the respiratory, digestive, urinary, and reproductive systems

The Body's First Line of Defense

- The Role of Skin in Innate Immunity
  - Skin composed of two major layers
    - Epidermis
      - Multiple layers of tightly packed cells
        - Few pathogens can penetrate these layers
        - Shedding of dead skin cells removes microorganisms
      - Epidermal dendritic cells phagocytize pathogens
    - Dermis
      - Collagen fibers help skin resist abrasions that could introduce microorganisms

A scanning electron micrograph of a section of skin

Figure 15.1

The Body's First Line of Defense

- The Role of Skin in Innate Immunity
  - Skin has chemicals that defend against pathogens
    - Perspiration secreted by *sweat glands*
      - Salt inhibits growth of pathogens
      - Antimicrobial peptides act against microorganisms
      - Lysozyme destroys cell wall of bacteria
    - Sebum secreted by *sebaceous (oil) glands*
      - Helps keep skin pliable and less likely to break or tear
      - Lowers skin pH to a level inhibitory to many bacteria

The Body's First Line of Defense

- The Role of Mucous Membranes and the Lacrimal Apparatus in Innate Immunity
  - Mucous membranes line all body cavities open to environment
  - Two distinct layers
    - Epithelium
      - Thin, outer covering of the mucous membranes
      - Epithelial cells are living
      - Tightly packed to prevent entry of pathogens
      - Continual shedding of cells carries away microorganisms
    - Deeper connective layer that supports the epithelium

The structure of the respiratory system

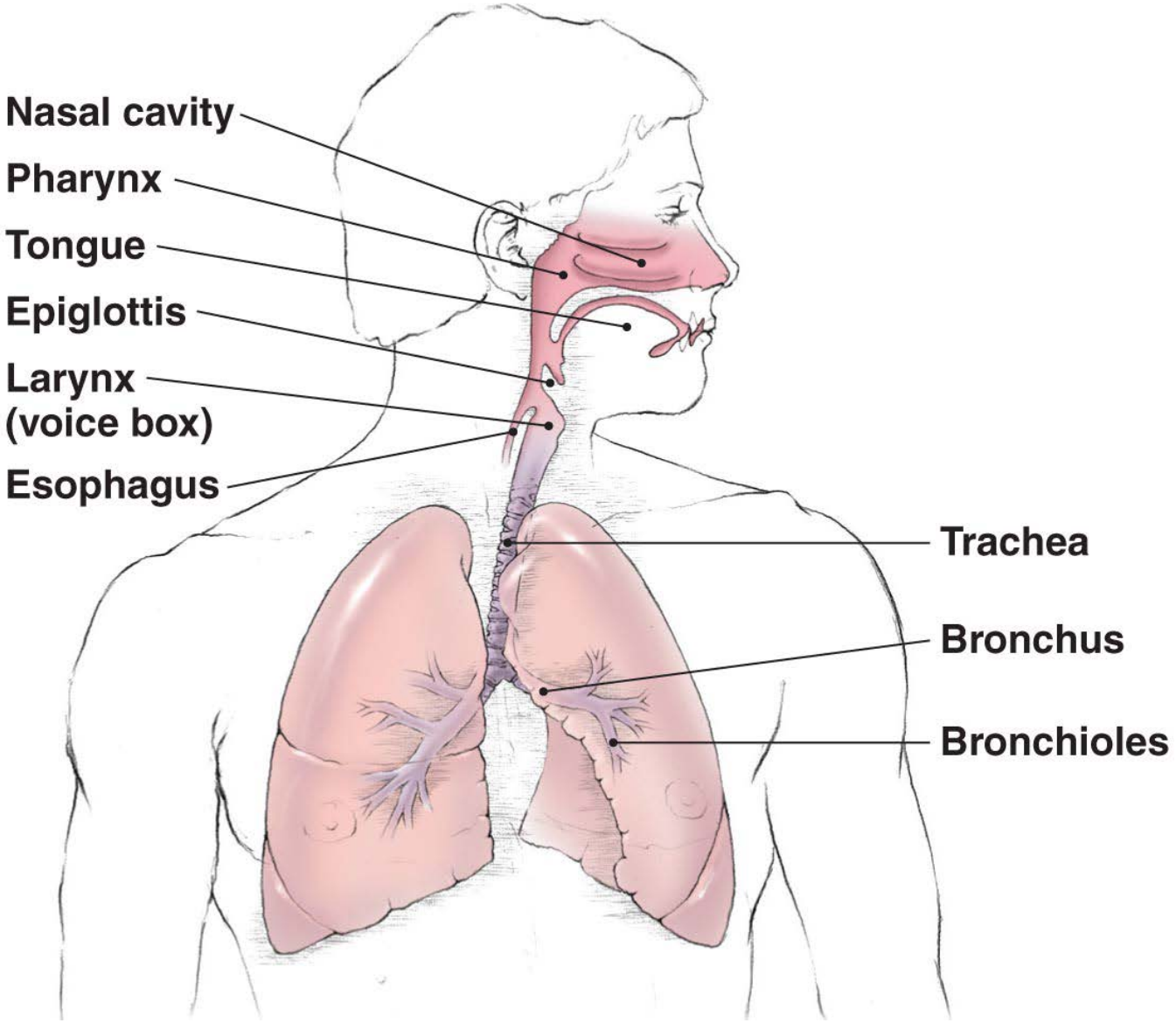


Figure 15.2

The Body's First Line of Defense

- The Role of Mucous Membranes and the Lacrimal Apparatus in Innate Immunity
  - Lacrimal apparatus 淚器
    - Produces and drains tears
    - Blinking spreads tears and washes surface of the eye
    - Lysozyme in tears destroys bacteria

The lacrimal apparatus

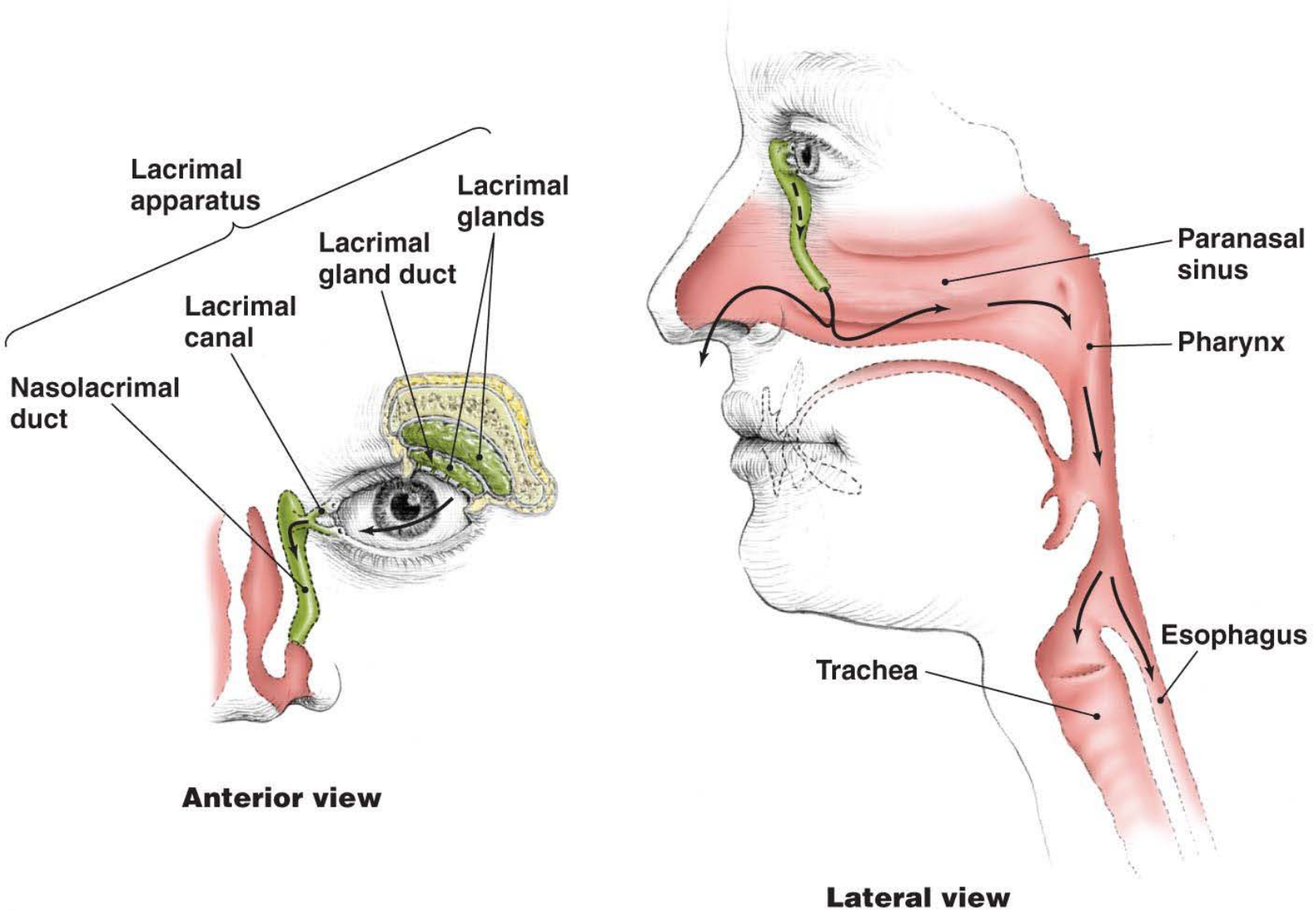


Figure 15.3

The Body's First Line of Defense

- The Role of Normal Microbiota in Innate Immunity
  - Microbial antagonism 微生物拮抗作用
    - Normal microbiota compete with potential pathogens
  - Activities of normal microbiota make it hard for pathogens to compete
    - Consumption of nutrients
    - Create an environment unfavorable to other microorganisms
    - Help stimulate the body's second line of defense
    - Promote overall health by providing vitamins to host

The Body's First Line of Defense

- Other First-Line Defenses
  - Antimicrobial peptides
    - Present in skin, mucous membranes, neutrophils
    - Act against a variety of microbes
    - Work in several ways
  - Other processes and chemicals
    - Many organs secrete chemicals with antimicrobial properties

The Body's Second Line of Defense

- Operates when pathogens penetrate the skin or mucous membranes
- Composed of cells, antimicrobial chemicals
  - Many of these components are contained or originate in the blood

The Body's Second Line of Defense

- Defense Components of Blood
  - Plasma 血漿
    - Mostly water containing electrolytes, dissolved gases, nutrients, and proteins
      - Serum is the fluid remaining when clotting factors are removed
      - Includes iron-binding compounds, complement proteins and antibodies

Serum = Plasma – Clotting factors

The Body's Second Line of Defense

- Defense Components of Blood
  - Cells and cell fragments in plasma are called *formed elements*
  - Three types of formed elements
    - Erythrocytes
      - Carry oxygen and carbon dioxide in the blood
    - Platelets
      - Involved in blood clotting
    - Leukocytes
      - Involved in defending the body against invaders
      - Divided into granulocytes and agranulocytes

Schematic representation of hematopoiesis

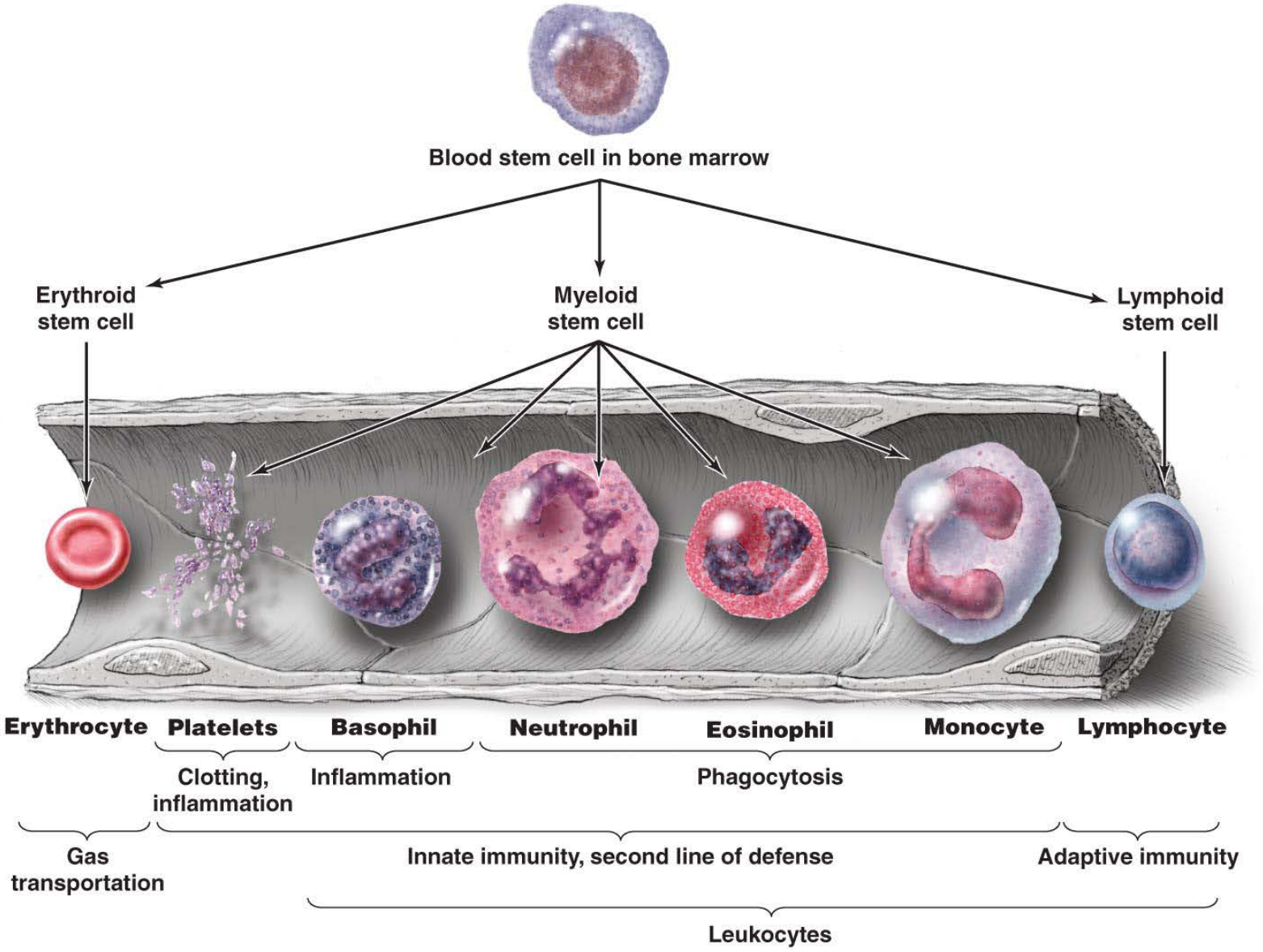


Figure 15.4

The Body's Second Line of Defense

- Defense Components of Blood
  - Granulocytes
    - Contain large granules that stain different colors
    - Three types
      - Basophils – stain blue with basic dye methylene blue
      - Eosinophils – stain red/orange with acidic dye eosin
      - Neutrophils – stain lilac (light purple) with mix of acidic and basic dyes
    - Neutrophils and eosinophils
      - Phagocytize pathogens
      - Capable of diapedesis 血球滲出

The Body's Second Line of Defense

- Defense Components of Blood
  - Agranulocytes
    - Cytoplasm appears uniform under a light microscope
    - Two types
      - Lymphocytes
        - Most involved in adaptive immunity
      - Monocytes
        - Leave the blood and mature into macrophages

Leukocytes as seen in stained blood smears

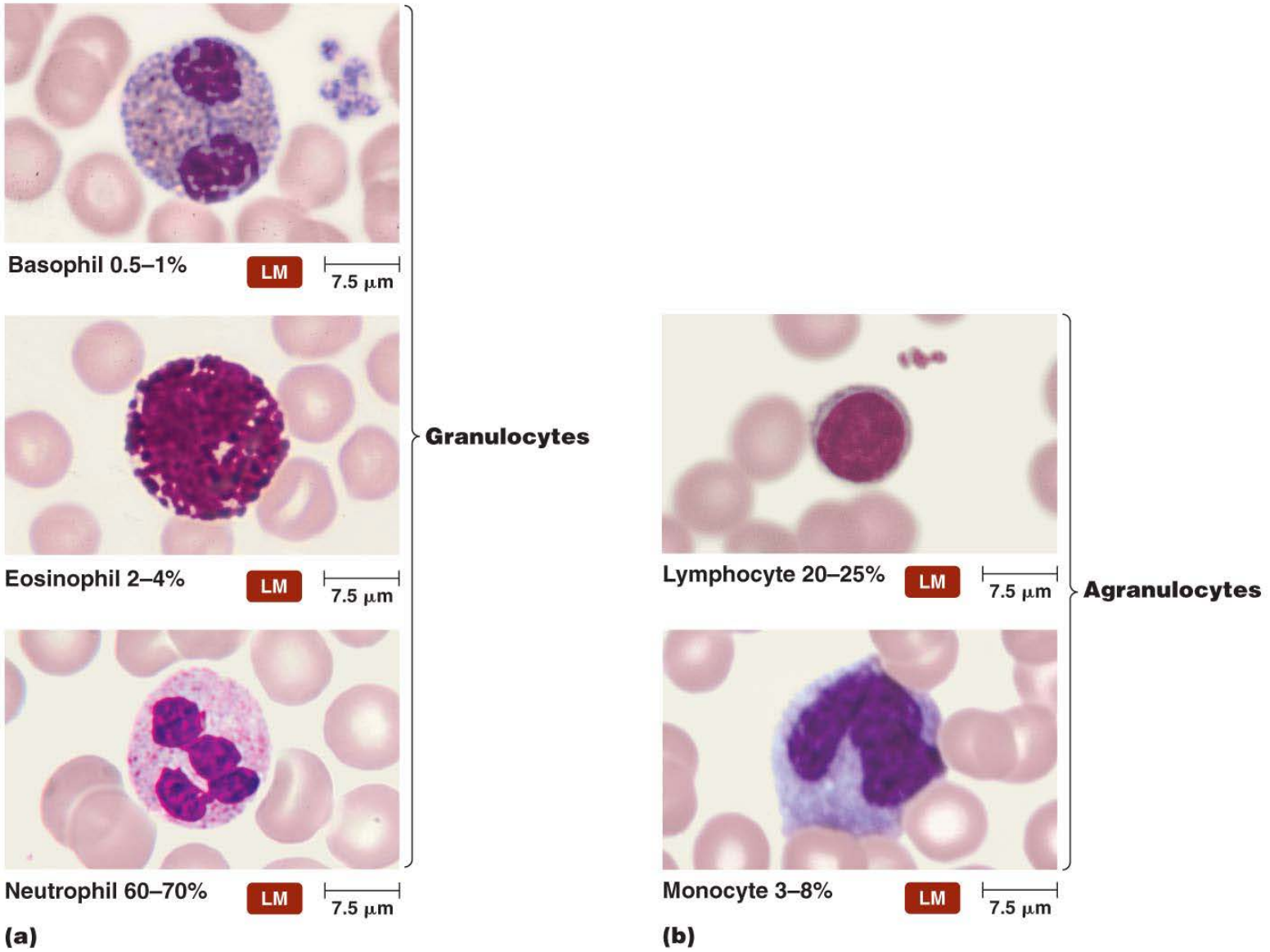


Figure 15.5

The Body's Second Line of Defense

- Defense Components of Blood
  - Lab analysis of leukocytes
    - Differential white blood cell count (DBC) can signal signs of disease
      - Increased eosinophils (eosinophilia) indicate allergies or parasitic worm infection
      - Bacterial diseases often show increase in leukocytes and neutrophils
      - Viral infections show increase in lymphocytes

The Body's Second Line of Defense

- Phagocytosis
  - Cells capable of phagocytosis are called phagocytes
  - Phagocytosis is not completely understood
  - Can be divided into six stages
    - Chemotaxis
    - Adherence
    - Ingestion
    - Maturation
    - Killing
    - Elimination

The events of phagocytosis

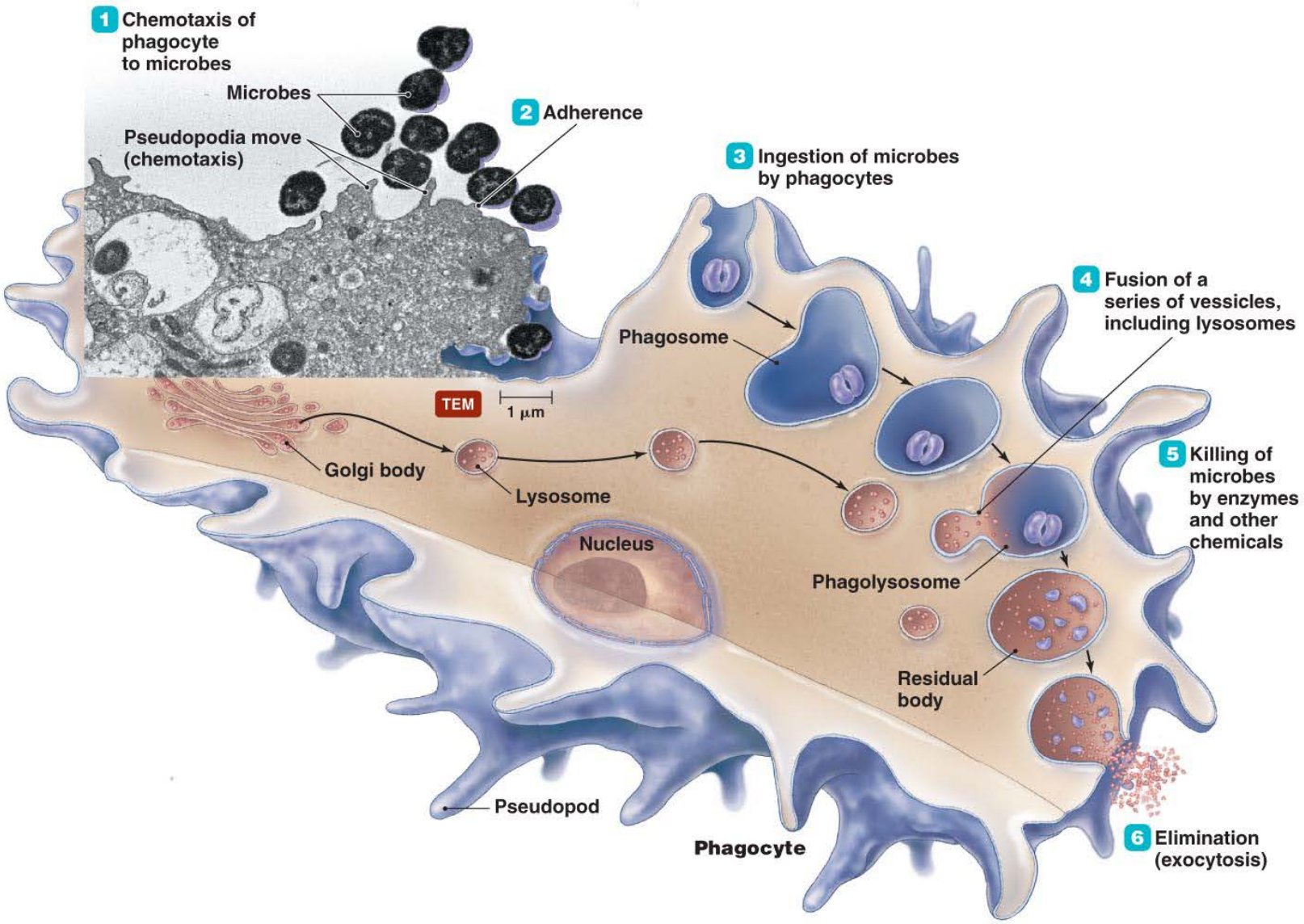


Figure 15.6

The Body's Second Line of Defense

- Nonphagocytic Killing
  1. Killing by eosinophils
     - Attack parasitic helminths by attaching to their surface
       - Secrete toxins that weaken or kill the helminth
       - Eosinophilia (elevated eosinophils) is often indicative of a helminth infestation
     - Eosinophil mitochondrial DNA and proteins form structure that kills some bacteria

The Body's Second Line of Defense

- Nonphagocytic Killing
  2. Killing by natural killer lymphocytes
     - Secrete toxins onto surface of virally infected cells and tumors
     - Differentiate normal body cells because they have membrane proteins similar to the NK cells

The Body's Second Line of Defense

- Nonphagocytic Killing
  3. Killing by neutrophils
     - Produce chemicals that kill nearby invaders
     - Generate extracellular fibers called neutrophil extracellular traps (NETs) that bind to and kill bacteria

The Body's Second Line of Defense

- Nonspecific Chemical Defenses Against Pathogens
  - Toll-like receptors (TLRs)
    - Integral membrane proteins produced by phagocytic cells
    - Bind pathogen-associated molecular patterns (PAMPs)
    - Initiate defensive responses
      - Apoptosis
      - Secretion of inflammatory mediators
      - Production of stimulants of adaptive immune response
  - NOD proteins
    - Cytosolic proteins that bind PAMPs

The Body's Second Line of Defense

- Nonspecific Chemical Defenses Against Pathogens
  - Interferons 干擾素
    - Protein molecules released by host cells to nonspecifically inhibit the spread of viral infections
    - Cause many symptoms associated with viral infections
    - Two types
      - Types I (alpha and beta)
      - Type II (gamma)

The actions of alpha and beta interferons

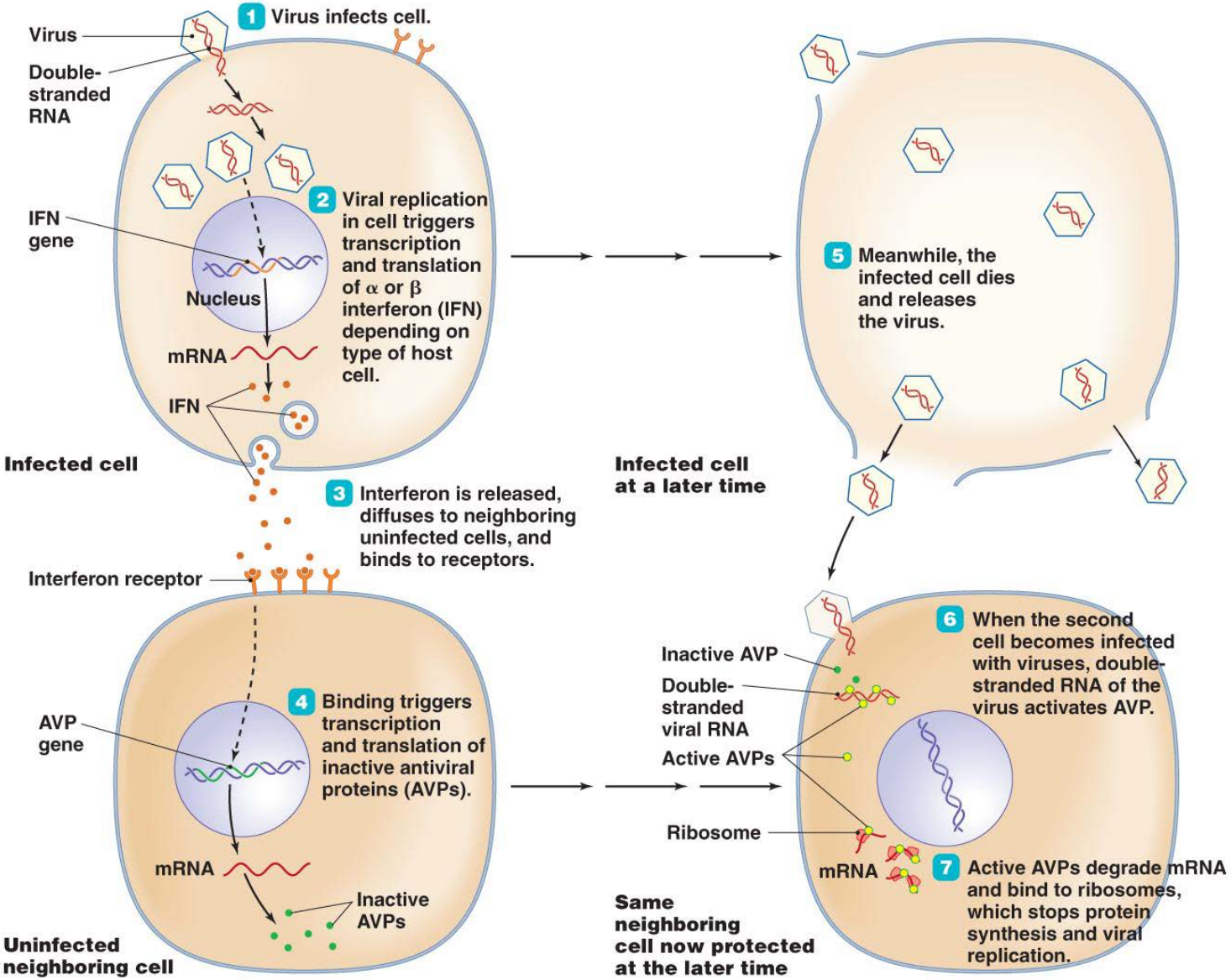


Figure 15.7

The Body's Second Line of Defense

- Nonspecific Chemical Defenses Against Pathogens
  - Complement 補體
    - Set of serum proteins designated numerically according to their order of discovery
    - Complement activation results in lysis of the foreign cell
    - Complement can be activated in three ways
      - Classical pathway
      - Alternate pathway
      - Lectin pathway

Pathways by which complement is activated

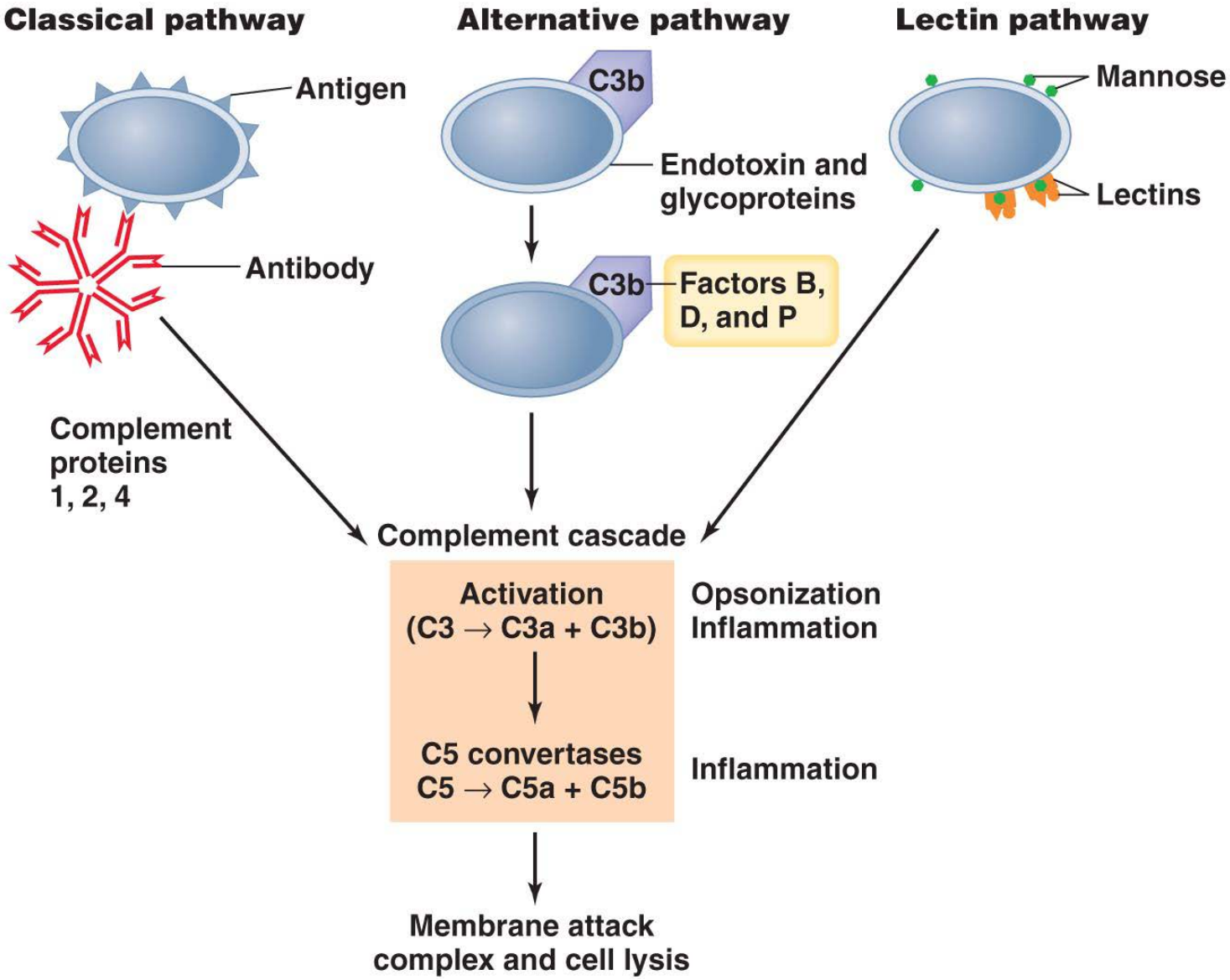


Figure 15.8

The complement cascade

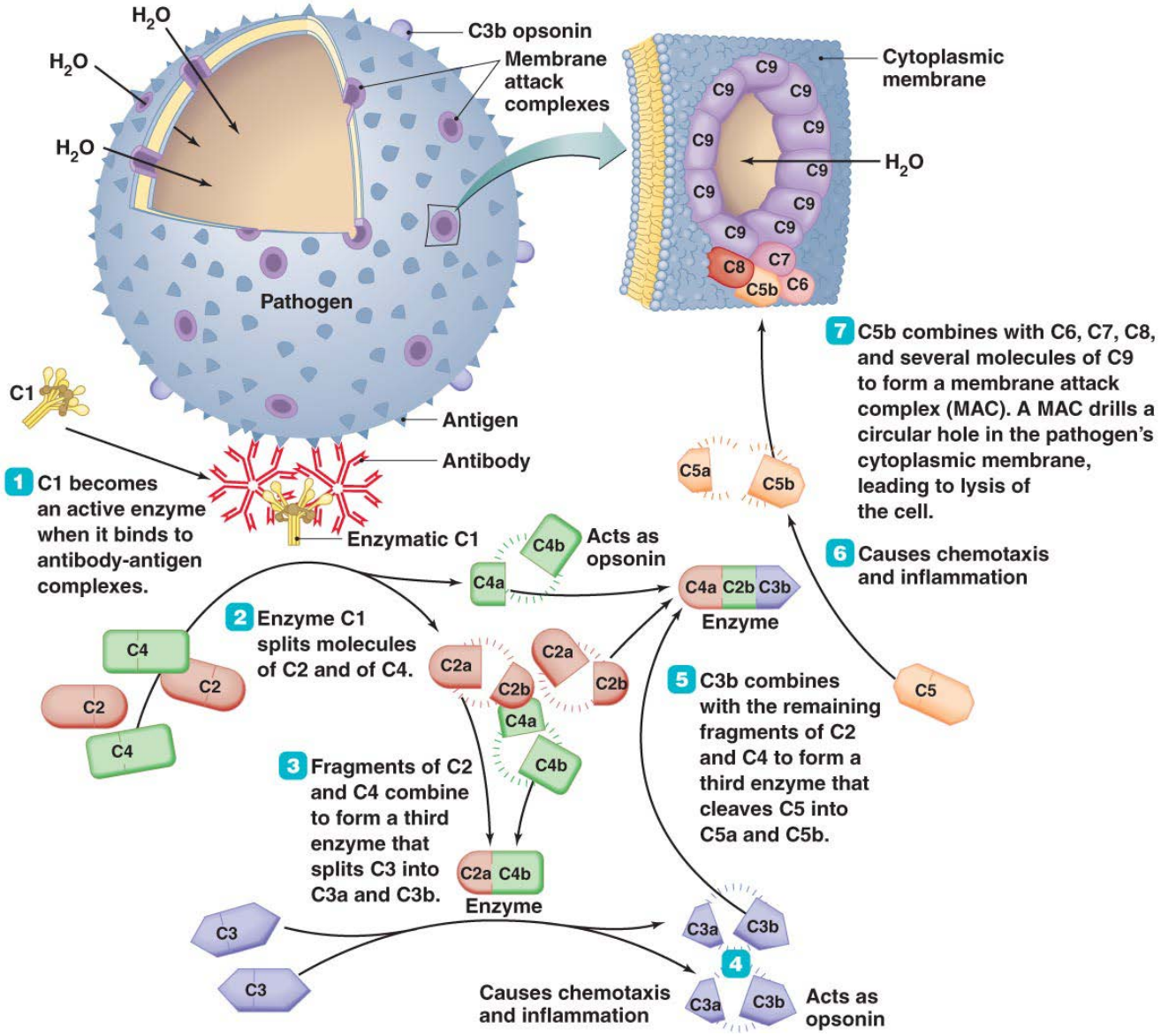


Figure 15.9

Membrane attack complexes

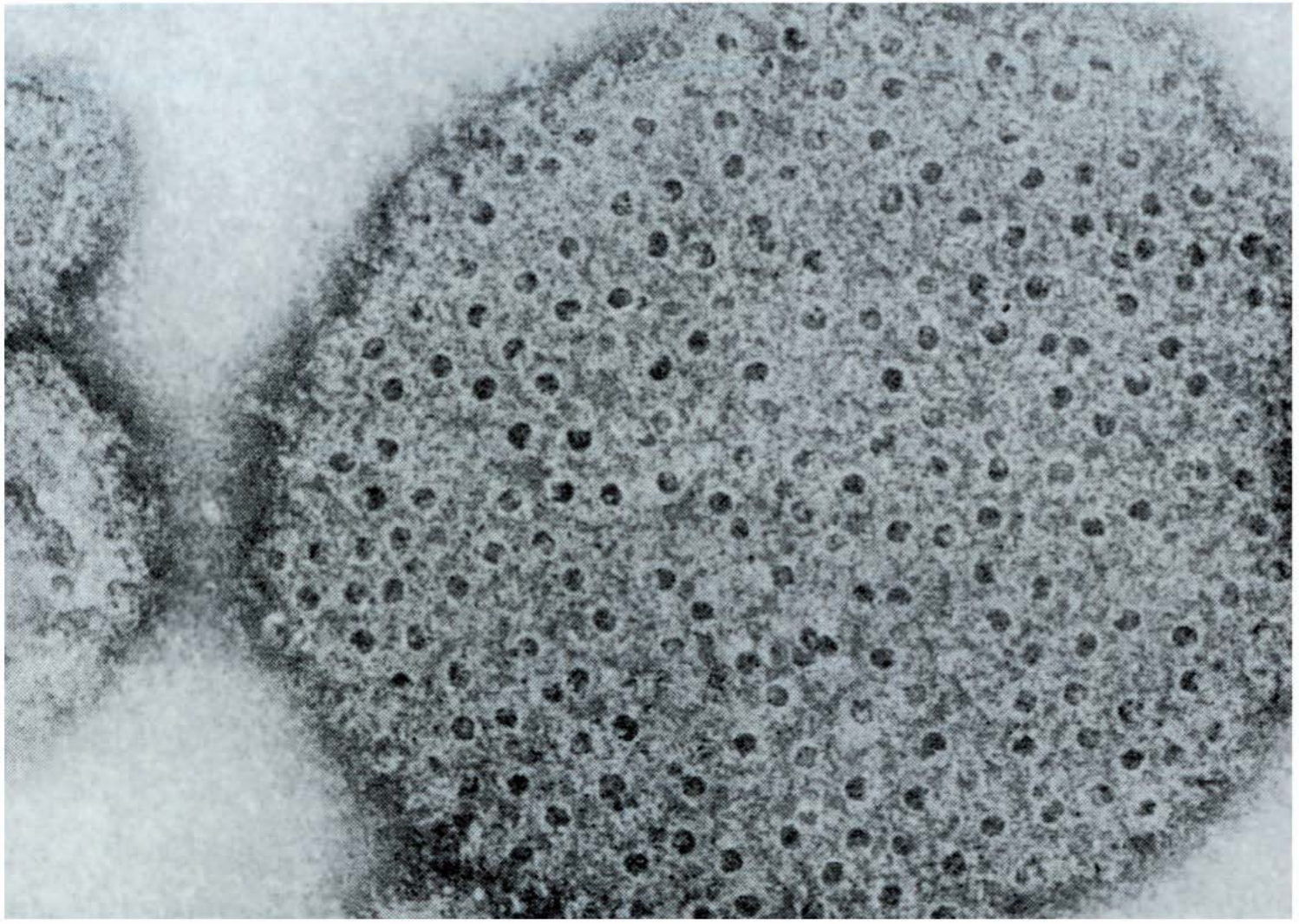


Figure 15.10

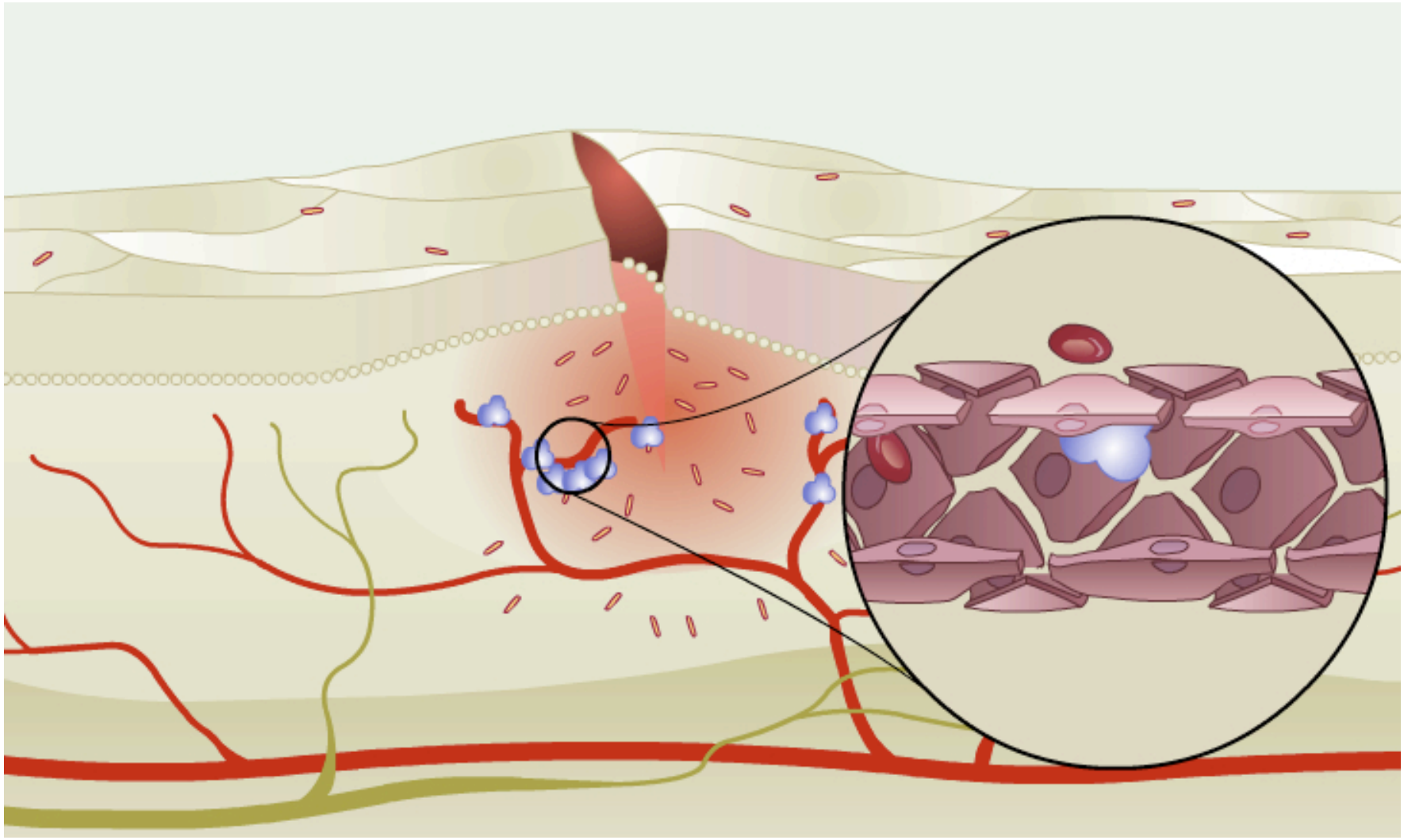
The Body's Second Line of Defense

- Nonspecific Chemical Defenses Against Pathogens
  - Complement
    - Inactivation of complement
      - Body's own cells withstand complement cascade
        - Proteins on many cells bind and break down activated complement proteins

The Body's Second Line of Defense

- Inflammation
  - Nonspecific response to tissue damage from various causes
  - Characterized by redness, heat, swelling, and pain
  - Two types
    - Acute
    - Long-lasting (chronic)

The Body's Second Line of Defense



PLAY Animation: Inflammation: Overview

The Body's Second Line of Defense

- Inflammation
  - Acute inflammation
    - Develops quickly and is short lived
    - Is typically beneficial
    - Is important in the second line of defense
      - Dilation and increased permeability of the blood vessels
      - Migration of phagocytes (diapedesis)
      - Tissue repair

The stimulation of inflammation by complement

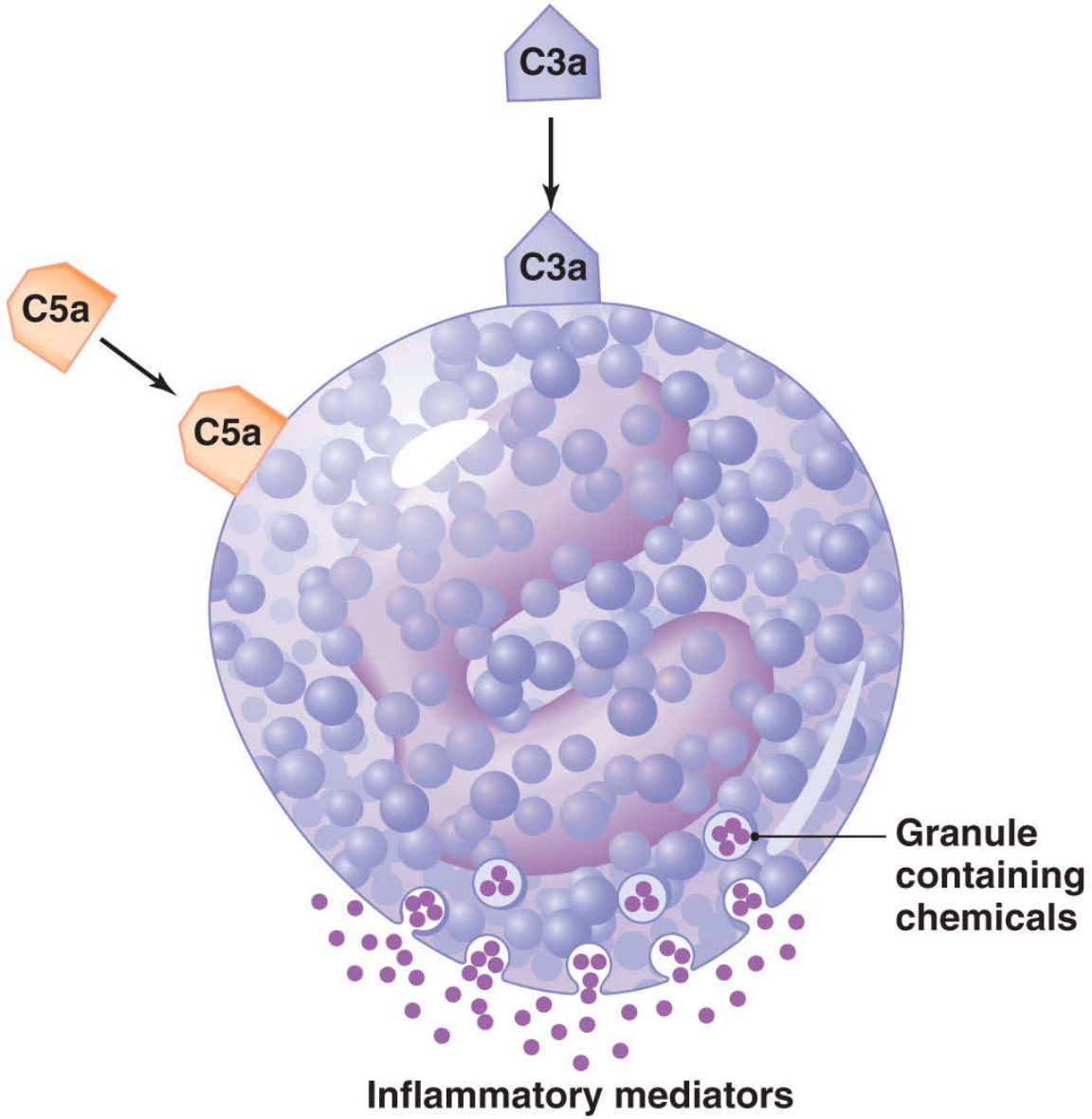


Figure 15.11

The dilating effect of inflammatory mediators

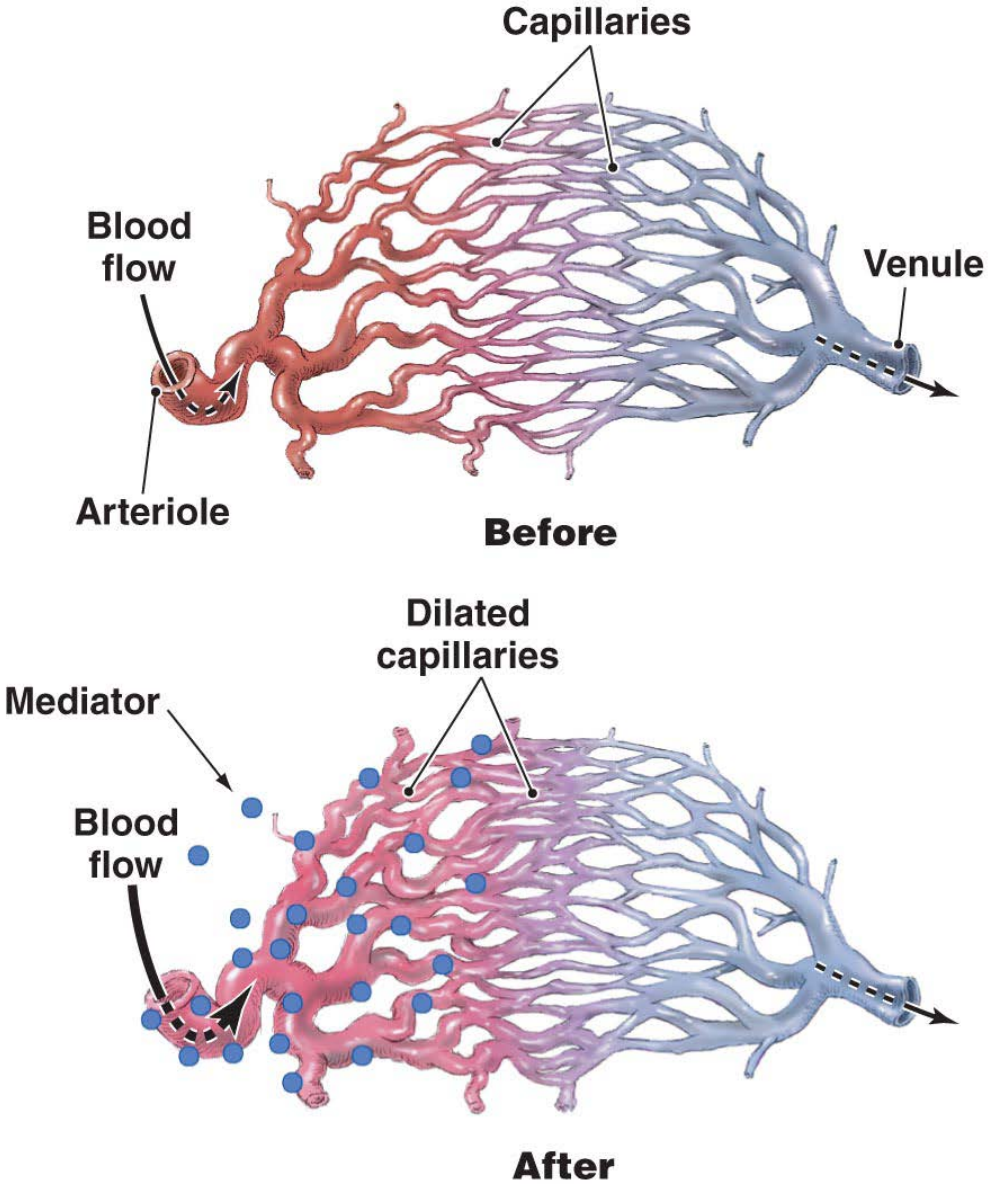


Figure 15.12

Increased vascular permeability during inflammation

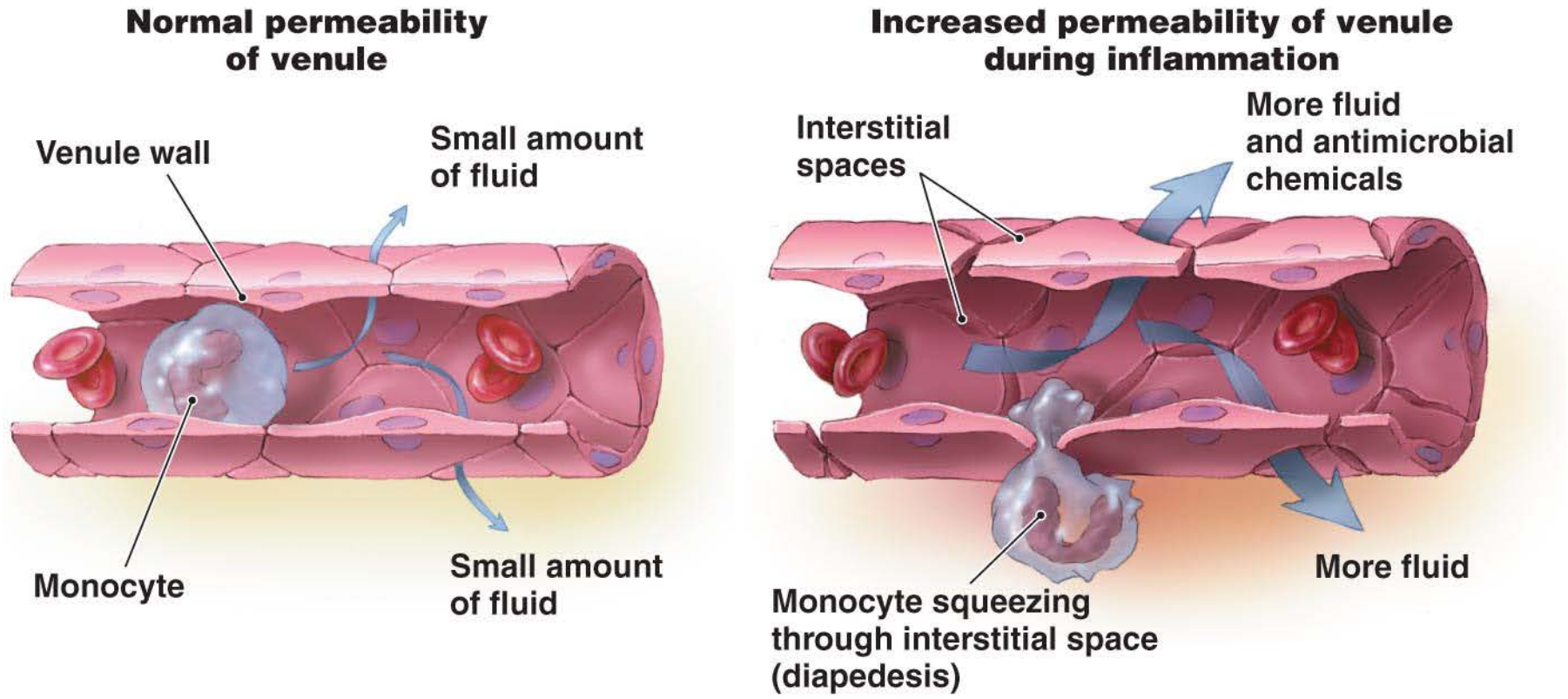
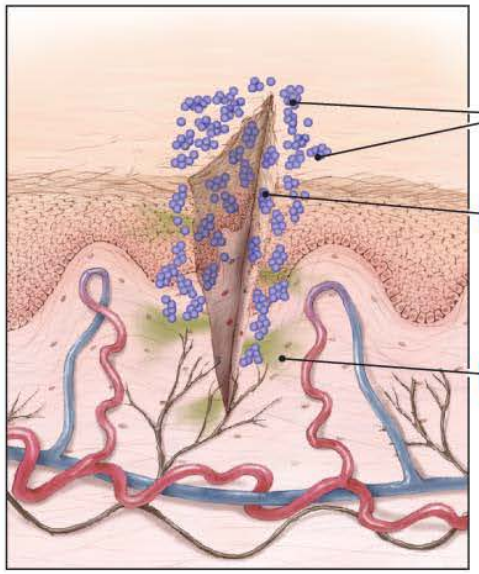


Figure 15.13

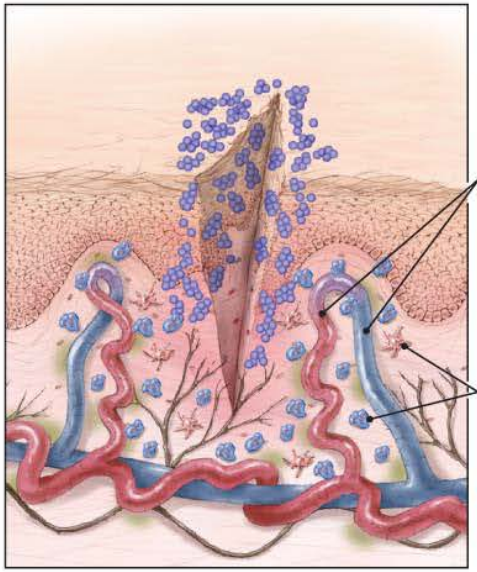
An overview of the events of inflammation



Bacteria

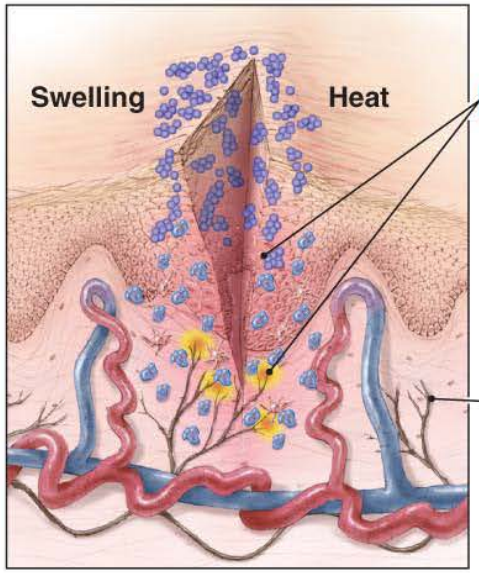
1 A cut penetrates the epidermis barrier, and bacteria invade.

2 Damaged cells release prostaglandins, leukotrienes, and histamine (shown in green here).



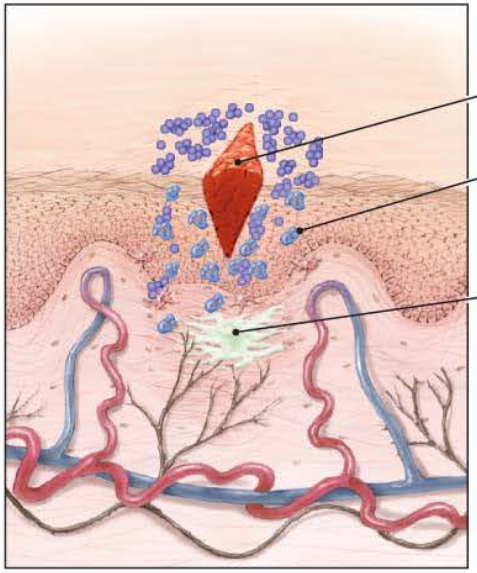
3 Prostaglandins and leukotrienes make vessels more permeable. Histamine causes vasodilation, increasing blood flow to the site.

4 Macrophages and neutrophils squeeze through walls of blood vessels (diapedesis).



5 Increased permeability allows antimicrobial chemicals and clotting proteins to seep into damaged tissue but also results in swelling, pressure on nerve endings, and pain.

Nerve ending



6 Blood clot forms.

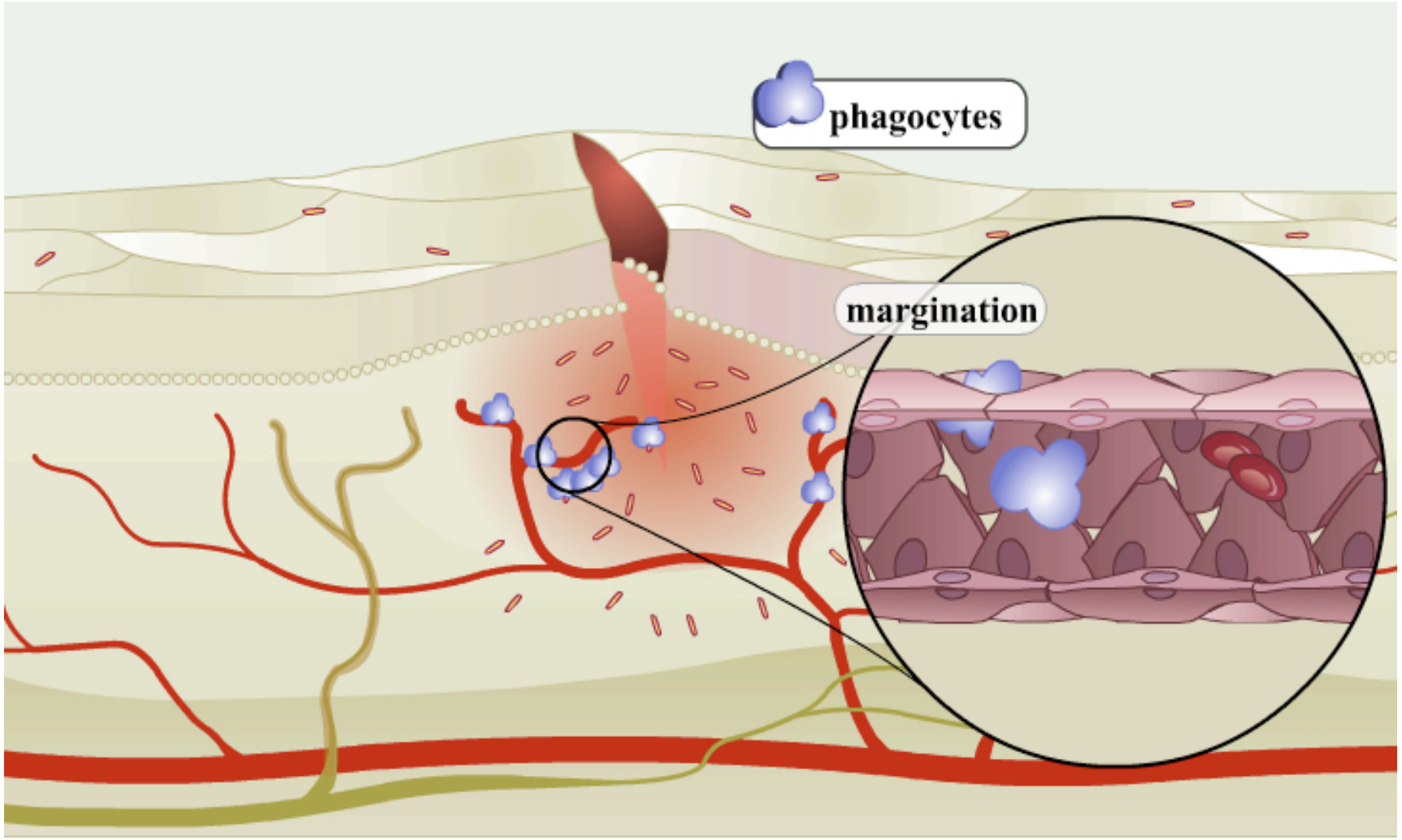
7 More phagocytes migrate to the site and devour bacteria.

8 Accumulation of damaged tissue and leukocytes forms pus.

9 Undifferentiated stem cells repair the damaged tissue. Blood clot is absorbed or falls off as a scab.

Figure 15.14

The Body's Second Line of Defense



PLAY Animation: Inflammation: Steps

The Body's Second Line of Defense

- Fever
  - A body temperature over 37°C
  - Results when pyrogens 致熱原 trigger the hypothalamus to increase the body's core temperature
  - Various types of pyrogens
    - Bacterial toxins
    - Cytoplasmic contents of bacteria released by lysis
    - Antibody-antigen complexes
  - These signal for the production of interleukin-I (IL-1)

One explanation for fever in response to infection

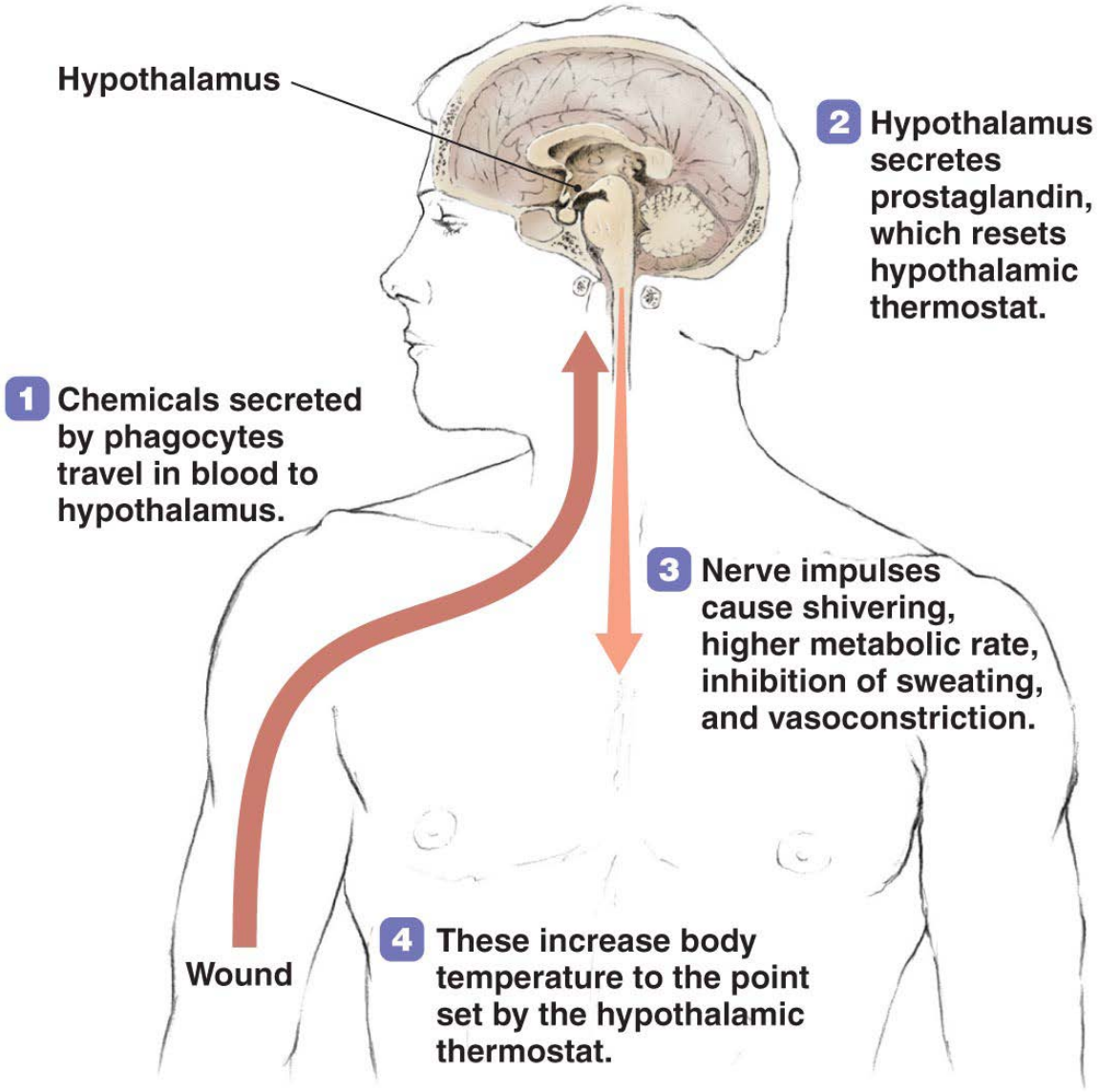


Figure 15.15

End of Chapter