Chapter 43

The Immune System

PowerPoint Lectures for
Biology, Seventh Edition
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- Overview: Reconnaissance, Recognition, and Response
- An animal must defend itself
  - From the many dangerous pathogens it may encounter in the environment
- Two major kinds of defense have evolved that counter these threats
  - Innate immunity and acquired immunity

- Innate immunity
  - Is present before any exposure to pathogens and is effective from the time of birth
  - Involves nonspecific responses to pathogens

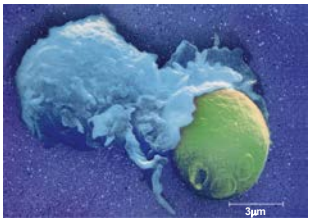

Figure 43.1

- Acquired immunity, also called adaptive immunity
  - Develops only after exposure to inducing agents such as microbes, toxins, or other foreign substances
  - Involves a very specific response to pathogens

- A summary of innate and acquired immunity

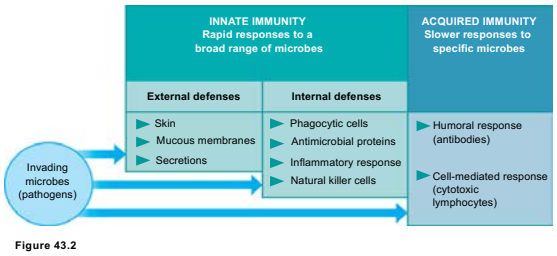

Figure 43.2

- Concept 43.1: Innate immunity provides broad defenses against infection
- A pathogen that successfully breaks through an animal's external defenses
  - Soon encounters several innate cellular and chemical mechanisms that impede its attack on the body

External Defenses

- Intact skin and mucous membranes
  - Form physical barriers that bar the entry of microorganisms and viruses
- Certain cells of the mucous membranes produce mucus
  - A viscous fluid that traps microbes and other particles

- In the trachea, ciliated epithelial cells
  - Sweep mucus and any entrapped microbes upward, preventing the microbes from entering the lungs

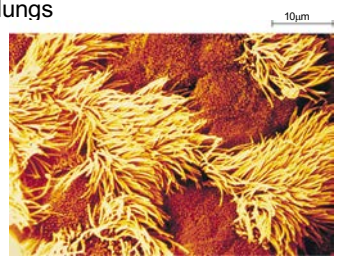

Figure 43.3

- Secretions of the skin and mucous membranes
  - Provide an environment that is often hostile to microbes
- Secretions from the skin
  - Give the skin a pH between 3 and 5, which is acidic enough to prevent colonization of many microbes
  - Also include proteins such as lysozyme, an enzyme that digests the cell walls of many bacteria

Internal Cellular and Chemical Defenses

- Internal cellular defenses
  - Depend mainly on phagocytosis
- Phagocytes, types of white blood cells
  - Ingest invading microorganisms
  - Initiate the inflammatory response

Phagocytic Cells

- Phagocytes attach to their prey via surface receptors
  - And engulf them, forming a vacuole that fuses with a lysosome

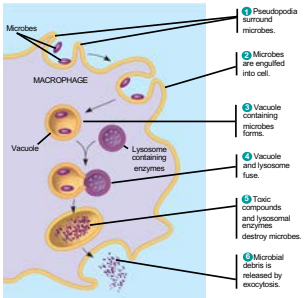

Figure 43.4

- Macrophages, a specific type of phagocyte
  - Can be found migrating through the body
  - Can be found in various organs of the lymphatic system

- The lymphatic system
  - Plays an active role in defending the body from pathogens

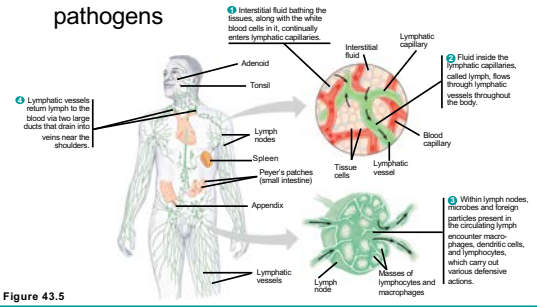

Figure 43.5

Antimicrobial Proteins

- Numerous proteins function in innate defense
  - By attacking microbes directly of by impeding their reproduction

- About 30 proteins make up the complement system
  - Which can cause lysis of invading cells and help trigger inflammation
- Interferons
  - Provide innate defense against viruses and help activate macrophages

Inflammatory Response

- In local inflammation, histamine and other chemicals released from injured cells
  - Promote changes in blood vessels that allow more fluid, more phagocytes, and antimicrobial proteins to enter the tissues

- Major events in the local inflammatory response

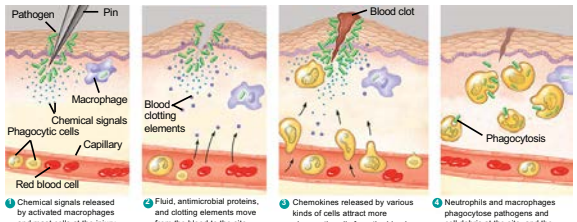

Figure 43.6

Natural Killer Cells

- Natural killer (NK) cells
  - Patrol the body and attack virus-infected body cells and cancer cells
  - Trigger apoptosis in the cells they attack

Invertebrate Immune Mechanisms

- Many invertebrates defend themselves from infection
  - By many of the same mechanisms in the vertebrate innate response

- Concept 43.2: In acquired immunity, lymphocytes provide specific defenses against infection
- Acquired immunity
  - Is the body's second major kind of defense
  - Involves the activity of lymphocytes

- An antigen is any foreign molecule
  - That is specifically recognized by lymphocytes and elicits a response from them
- A lymphocyte actually recognizes and binds
  - To just a small, accessible portion of the antigen called an epitope

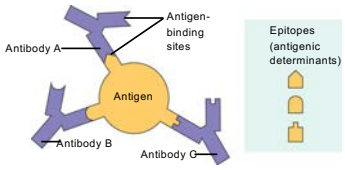

Figure 43.7

Antigen Recognition by Lymphocytes

- The vertebrate body is populated by two main types of lymphocytes
  - B lymphocytes (B cells) and T lymphocytes (T cells)
  - Which circulate through the blood
- The plasma membranes of both B cells and T cells
  - Have about 100,000 antigen receptor that all recognize the same epitope

B Cell Receptors for Antigens

- B cell receptors
  - Bind to specific, intact antigens
  - Are often called membrane antibodies or membrane immunoglobulins

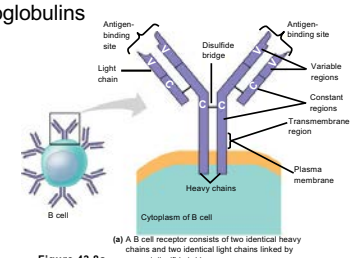

Figure 43.8a (a) A B cell receptor consists of two identical heavy chains and two identical light chains linked by several disulfide bridges.

T Cell Receptors for Antigens and the Role of the MHC

- Each T cell receptor
  - Consists of two different polypeptide chains

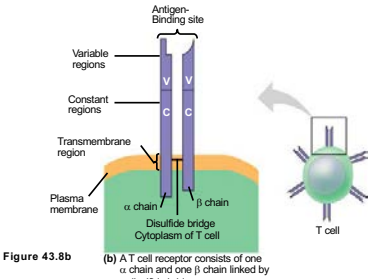

Figure 43.8b (b) A T cell receptor consists of one α chain and one β chain linked by a disulfide bridge.

- T cells bind to small fragments of antigens
  - That are bound to normal cell-surface proteins called MHC molecules
- MHC molecules
  - Are encoded by a family of genes called the major histocompatibility complex

- Infected cells produce MHC molecules
  - Which bind to antigen fragments and then are transported to the cell surface in a process called antigen presentation
- A nearby T cell
  - Can then detect the antigen fragment displayed on the cell's surface

- Depending on their source
  - Peptide antigens are handled by different classes of MHC molecules

- Class I MHC molecules, found on almost all nucleated cells of the body
  - Display peptide antigens to cytotoxic T cells

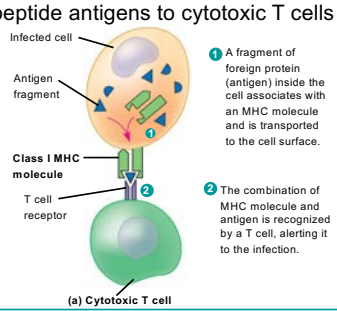

Figure 43.9a

- Class II MHC molecules, located mainly on dendritic cells, macrophages, and B cells
  - Display antigens to helper T cells

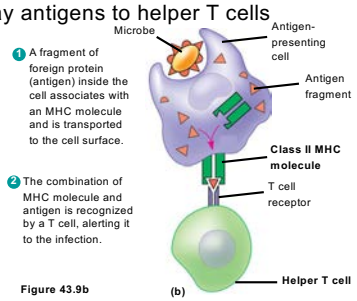

Figure 43.9b

Lymphocyte Development

- Lymphocytes
  - Arise from stem cells in the bone marrow

- Newly formed lymphocytes are all alike
  - But they later develop into B cells or T cells, depending on where they continue their maturation

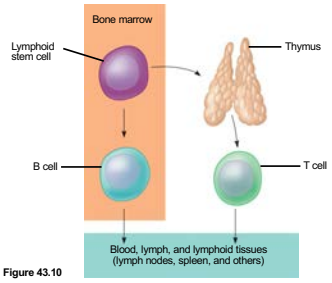

Figure 43.10

Generation of Lymphocyte Diversity by Gene Rearrangement

- Early in development, random, permanent gene rearrangement
  - Forms functional genes encoding the B or T cell antigen receptor chains

- Immunoglobulin gene rearrangement

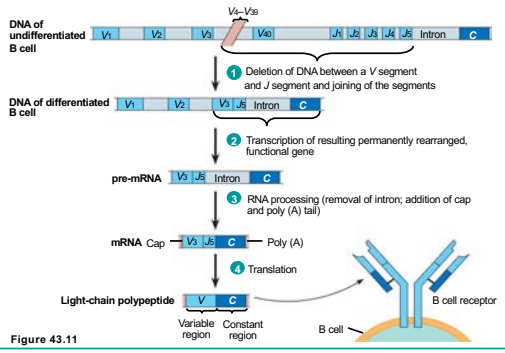

Figure 43.11

Testing and Removal of Self-Reactive Lymphocytes

- As B and T cells are maturing in the bone and thymus
  - Their antigen receptors are tested for possible self-reactivity
- Lymphocytes bearing receptors for antigens already present in the body
  - Are destroyed by apoptosis or rendered nonfunctional

Clonal Selection of Lymphocytes

- In a primary immune response
  - Binding of antigen to a mature lymphocyte induces the lymphocyte's proliferation and differentiation, a process called clonal selection

- Clonal selection of B cells
  - Generates a clone of short-lived activated effector cells and a clone of long-lived memory cells

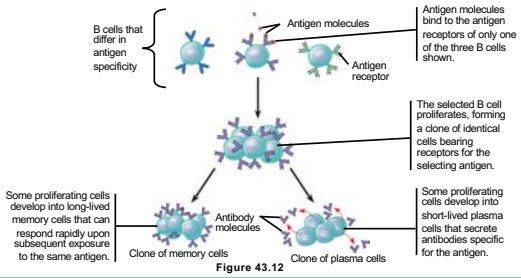

Figure 43.12

- In the secondary immune response
  - Memory cells facilitate a faster, more efficient response

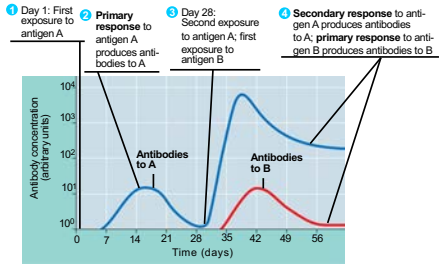

Figure 43.13

- Concept 43.3: Humoral and cell-mediated immunity defend against different types of threats
- Acquired immunity includes two branches
  - The humoral immune response involves the activation and clonal selection of B cells, resulting in the production of secreted antibodies
  - The cell-mediated immune response involves the activation and clonal selection of cytotoxic T cells

- The roles of the major participants in the acquired immune response

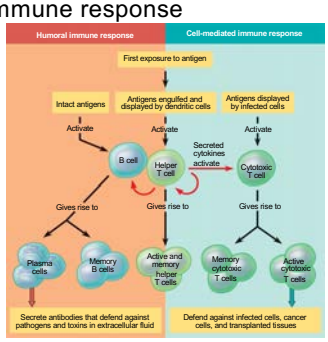

Figure 43.14

Helper T Cells: A Response to Nearly All Antigens

- Helper T cells produce CD4, a surface protein
  - That enhances their binding to class II MHC molecule–antigen complexes on antigen-presenting cells
- Activation of the helper T cell then occurs

- Activated helper T cells
  - Secrete several different cytokines that stimulate other lymphocytes

- The role of helper T cells in acquired immunity

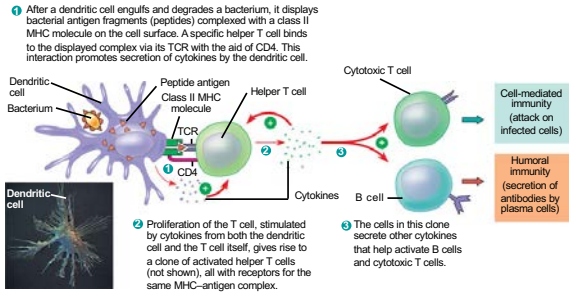

Figure 43.15

Cytotoxic T Cells: A Response to Infected Cells and Cancer Cells

- Cytotoxic T cells make CD8
  - A surface protein that greatly enhances the interaction between a target cell and a cytotoxic T cell

- Cytotoxic T cells
  - Bind to infected cells, cancer cells, and transplanted tissues
- Binding to a class I MHC complex on an infected body cell
  - Activates a cytotoxic T cell and differentiates it into an active killer

- The activated cytotoxic T cell
  - Secretes proteins that destroy the infected target cell

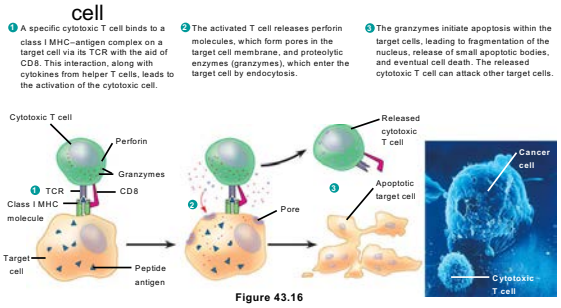

Figure 43.16

B Cells: A Response to Extracellular Pathogens

- Activation of B cells
  - Is aided by cytokines and antigen binding to helper T cells

- The clonal selection of B cells
  - Generates antibody-secreting plasma cells, the effector cells of humoral immunity

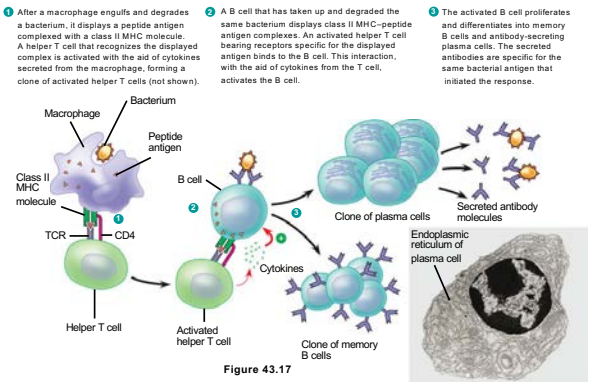

Figure 43.17

Antibody Classes

- The five major classes of antibodies, or immunoglobulins
  - Differ in their distributions and functions within the body

- The five classes of immunoglobulins

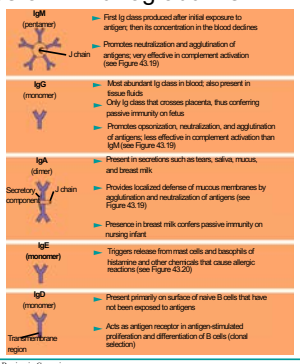

Figure 43.18

Antibody-Mediated Disposal of Antigens

- The binding of antibodies to antigens
  - Is also the basis of several antigen disposal mechanisms
  - Leads to elimination of microbes by phagocytosis and complement-mediated lysis

- Antibody-mediated mechanisms of antigen disposal

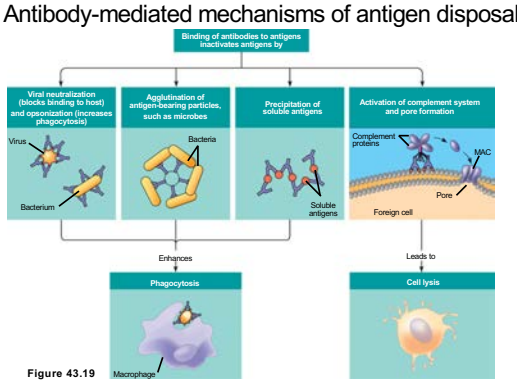

Figure 43.19

Active and Passive Immunization

- Active immunity
  - Develops naturally in response to an infection
  - Can also develop following immunization, also called vaccination

- In immunization
  - A nonpathogenic form of a microbe or part of a microbe elicits an immune response to an immunological memory for that microbe

- Passive immunity, which provides immediate, short-term protection
  - Is conferred naturally when IgG crosses the placenta from mother to fetus or when IgA passes from mother to infant in breast milk
  - Can be conferred artificially by injecting antibodies into a nonimmune person

- Concept 43.4: The immune system's ability to distinguish self from nonself limits tissue transplantation
- The immune system
  - Can wage war against cells from other individuals
- Transplanted tissues
  - Are usually destroyed by the recipient's immune system

Blood Groups and Transfusions

- Certain antigens on red blood cells
  - Determine whether a person has type A, B, AB, or O blood

- Antibodies to nonself blood types
  - Already exist in the body
- Transfusion with incompatible blood
  - Leads to destruction of the transfused cells

- Recipient-donor combinations
  - Can be fatal or safe

Table 43.1 Blood Groups That Can and Cannot Be Safely Combined in Transfusion*

Recipient's Blood Group	Antibodies in Recipient's Blood	Presence (+) or Absence (–) of Tranfusion Reaction: Donated Blood Group (Packed Cells)			
		A	B	AB	O
A	Anti-B	–	+	+	–
B	Anti-A	+	–	+	–
AB	No anti-A or anti-B	–	–	–	–
O	Anti-A and anti-B	+	+	+	–

*Individuals with type AB blood are universal recipients (blue row); those with type O blood are universal donors (green column).

Table 43.1

- Another red blood cell antigen, the Rh factor
  - Creates difficulties when an Rh-negative mother carries successive Rh-positive fetuses

Tissue and Organ Transplants

- MHC molecules
  - Are responsible for stimulating the rejection of tissue grafts and organ transplants

- The chances of successful transplantation are increased
  - If the donor and recipient MHC tissue types are well matched
  - If the recipient is given immunosuppressive drugs

- Lymphocytes in bone marrow transplants
  - May cause a graft versus host reaction in recipients

- Concept 43.5: Exaggerated, self-directed, or diminished immune responses can cause disease
- If the delicate balance of the immune system is disrupted
  - The effects on the individual can range from minor to often fatal consequences

Allergies

- Allergies are exaggerated (hypersensitive) responses
  - To certain antigens called allergens

- In localized allergies such as hay fever
  - IgE antibodies produced after first exposure to an allergen attach to receptors on mast cells

- The next time the allergen enters the body
  - It binds to mast cell–associated IgE molecules
- The mast cells then release histamine and other mediators
  - That cause vascular changes and typical symptoms

- The allergic response

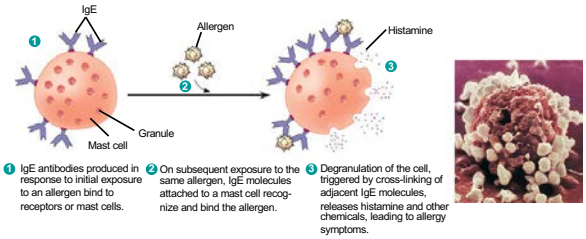

Figure 43.20

- An acute allergic response sometimes leads to anaphylactic shock
  - A whole-body, life-threatening reaction that can occur within seconds of exposure to an allergen

Autoimmune Diseases

- In individuals with autoimmune diseases
  - The immune system loses tolerance for self and turns against certain molecules of the body

- Rheumatoid arthritis
  - Is an autoimmune disease that leads to damage and painful inflammation of the cartilage and bone of joints

Figure 43.21

- Other examples of autoimmune diseases include
  - Systemic lupus erythematosus
  - Multiple sclerosis
  - Insulin-dependent diabetes

Immunodeficiency Diseases

- An inborn or primary immunodeficiency
  - Results from hereditary or congenital defects that prevent proper functioning of innate, humoral, and/or cell-mediated defenses

- An acquired or secondary immunodeficiency
  - Results from exposure to various chemical and biological agents

Inborn (Primary) Immunodeficiencies

- In severe combined immunodeficiency (SCID)
  - Both the humoral and cell-mediated branches of acquired immunity fail to function

Acquired (Secondary) Immunodeficiencies

- Acquired immunodeficiencies
  - Range from temporary states to chronic diseases

Stress and the Immune System

- Growing evidence shows
  - That physical and emotional stress can harm immunity

- Acquired Immunodeficiency Syndrome (AIDS)
- People with AIDS
  - Are highly susceptible to opportunistic infections and cancers that take advantage of an immune system in collapse

- Because AIDS arises from the loss of helper T cells
  - Both humoral and cell-mediated immune responses are impaired

- The loss of helper T cells
  - Results from infection by the human immunodeficiency virus (HIV)

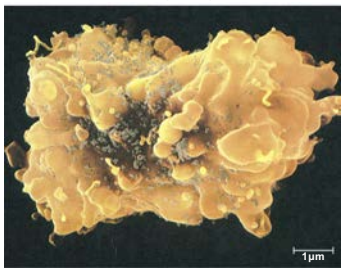

Figure 43.22

- The spread of HIV
  - Has become a worldwide problem
- The best approach for slowing the spread of HIV
  - Is educating people about the practices that transmit the virus