Chapter 43
The Immune System
Overview: Recognition and Response

• **Pathogens**, agents that cause disease, infect a wide range of animals, including humans
• The **immune system** recognizes foreign bodies and responds with the production of immune cells and proteins
• All animals have **innate immunity**, a defense active immediately upon infection
• Vertebrates also have **adaptive immunity**
• Innate immunity is present before any exposure to pathogens and is effective from the time of birth
• It involves nonspecific responses to pathogens
• Innate immunity consists of external barriers plus internal cellular and chemical defenses
Adaptive immunity, or acquired immunity, develops after exposure to agents such as microbes, toxins, or other foreign substances. It involves a very specific response to pathogens.
<table>
<thead>
<tr>
<th>INNATE IMMUNITY (all animals)</th>
<th>Barrier defenses:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Recognition of traits shared by broad ranges of pathogens, using a small set of receptors</td>
<td>Skin</td>
</tr>
<tr>
<td>• Rapid response</td>
<td>Mucous membranes</td>
</tr>
<tr>
<td></td>
<td>Secretions</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Internal defenses:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phagocytic cells</td>
</tr>
<tr>
<td>Natural killer cells</td>
</tr>
<tr>
<td>Antimicrobial proteins</td>
</tr>
<tr>
<td>Inflammatory response</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ADAPTIVE IMMUNITY (vertebrates only)</th>
<th>Humoral response:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Recognition of traits specific to particular pathogens, using a vast array of receptors</td>
<td>Antibodies defend against infection in body fluids.</td>
</tr>
</tbody>
</table>

| | Cell-mediated response: |
| | Cytotoxic cells defend against infection in body cells. |

Figure 43.2

Pathogens (such as bacteria, fungi, and viruses)
Concept 43.1: In innate immunity, recognition and response rely on traits common to groups of pathogens

- Innate immunity is found in all animals and plants
- In vertebrates, innate immunity is a first response to infections and also serves as the foundation of adaptive immunity
Innate Immunity of Invertebrates

- In insects, an exoskeleton made of chitin forms the first barrier to pathogens.
- The digestive system is protected by a chitin-based barrier and lysozyme, an enzyme that breaks down bacterial cell walls.
- Hemocytes circulate within hemolymph and carry out phagocytosis, the ingestion and digestion of foreign substances including bacteria.
Figure 43.3

Pathogen

PHAGOCYTIC CELL

Vacuole

Lysosome containing enzymes

© 2011 Pearson Education, Inc.
Hemocytes also secrete antimicrobial peptides that disrupt the plasma membranes of fungi and bacteria.
• The immune system recognizes bacteria and fungi by structures on their cell walls
• An immune response varies with the class of pathogen encountered
Can a single antimicrobial peptide protect fruit flies against infection?
RESULTS (part 1)

Fruit fly survival after infection by *N. crassa* fungi

- **Wild type**
- **Mutant**
- **Mutant + drosomycin**
- **Mutant + defensin**

<table>
<thead>
<tr>
<th>Hours post-infection</th>
<th>% survival</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>75</td>
</tr>
<tr>
<td></td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>0</td>
</tr>
</tbody>
</table>

© 2011 Pearson Education, Inc.
RESULTS (part 2)

Fruit fly survival after infection by *M. luteus* bacteria

<table>
<thead>
<tr>
<th>Hours post-infection</th>
<th>Wild type</th>
<th>Mutant + defensin</th>
<th>Mutant + drosomycin</th>
<th>Mutant</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>24</td>
<td>75</td>
<td>75</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td>48</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>72</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>96</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>120</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Innate Immunity of Vertebrates

• The immune system of mammals is the best understood of the vertebrates
• Innate defenses include barrier defenses, phagocytosis, antimicrobial peptides
• Additional defenses are unique to vertebrates: natural killer cells, interferons, and the inflammatory response
Barrier Defenses

• Barrier defenses include the skin and mucous membranes of the respiratory, urinary, and reproductive tracts
• Mucus traps and allows for the removal of microbes
• Many body fluids including saliva, mucus, and tears are hostile to many microbes
• The low pH of skin and the digestive system prevents growth of many bacteria
Cellular Innate Defenses

- Pathogens entering the mammalian body are subject to phagocytosis.
- Phagocytic cells recognize groups of pathogens by *TLRs, Toll-like receptors*.
Figure 43.6

EXTRACELLULAR FLUID

Lipopolysaccharide

Helper protein

Flagellin

PHAGOCYTIC CELL

VESICLE

CpG DNA

TLR9

ds RNA

TLR3

Innate immune responses

TLR4

TLR5

Helper protein

Innate immune responses
• A white blood cell engulfs a microbe, then fuses with a lysosome to destroy the microbe

• There are different types of **phagocytic** cells
  – **Neutrophils** engulf and destroy pathogens
  – **Macrophages** “large eaters” are found throughout the body
  – **Dendritic cells** stimulate development of adaptive immunity
  – **Eosinophils** discharge destructive enzymes

© 2011 Pearson Education, Inc.
Cellular innate defenses in vertebrates also involve **natural killer cells**

- These circulate through the body and detect abnormal cells
- They release chemicals leading to cell death, inhibiting the spread of virally infected or cancerous cells
- Many cellular innate defenses involve the lymphatic system
Thymus
Peyer’s patches (small intestine)
Appendix (cecum)
Adenoid Tonsils
Lymphatic vessels
Spleen
Lymph nodes
Blood capillary
Interstitial fluid
Tissue cells
Lymphatic vessel
Lymphatic vessel
Masses of defensive cells

Figure 43.7
Antimicrobial Peptides and Proteins

- Peptides and proteins function in innate defense by attacking pathogens or impeding their reproduction.
- **Interferon** proteins provide innate defense, interfering with viruses and helping activate macrophages.
- About 30 proteins make up the **complement system**, which causes lysis of invading cells and helps trigger inflammation.
Inflammatory Responses

- The inflammatory response, such as pain and swelling, is brought about by molecules released upon injury of infection
- Mast cells, a type of connective tissue, release histamine, which triggers blood vessels to dilate and become more permeable
- Activated macrophages and neutrophils release cytokines, signaling molecules that enhance the immune response
• *Pus*, a fluid rich in white blood cells, dead pathogens, and cell debris from damaged tissues
Figure 43.8-3

Pathogen

Splinter

Mast cell

Signaling molecules

Macrophage

Capillary

Red blood cells

Neutrophil

Movement of fluid

Phagocytosis

© 2011 Pearson Education, Inc.
• Inflammation can be either local or systemic (throughout the body)
• Fever is a systemic inflammatory response triggered by pyrogens released by macrophages and by toxins from pathogens
• *Septic shock* is a life-threatening condition caused by an overwhelming inflammatory response
Evasion of Innate Immunity by Pathogens

• Some pathogens avoid destruction by modifying their surface to prevent recognition or by resisting breakdown following phagocytosis
• Tuberculosis (TB) is one such disease and kills more than a million people a year
Concept 43.2: In adaptive immunity, receptors provide pathogen-specific recognition

• The adaptive response relies on two types of lymphocytes, or white blood cells
• Lymphocytes that mature in the thymus above the heart are called T cells, and those that mature in bone marrow are called B cells
• **Antigens** are substances that can elicit a response from a B or T cell

• Exposure to the pathogen activates B and T cells with **antigen receptors** specific for parts of that pathogen

• The small accessible part of an antigen that binds to an antigen receptor is called an **epitope**
Figure 43.UN01

Antigen receptors

Mature B cell

Mature T cell

© 2011 Pearson Education, Inc.
• B cells and T cells have receptor proteins that can bind to foreign molecules
• Each individual lymphocyte is specialized to recognize a specific type of molecule
Antigen Recognition by B Cells and Antibodies

- Each B cell antigen receptor is a Y-shaped molecule with two identical heavy chains and two identical light chains
- The constant regions of the chains vary little among B cells, whereas the variable regions differ greatly
- The variable regions provide antigen specificity
• Binding of a B cell antigen receptor to an antigen is an early step in B cell activation
• This gives rise to cells that secrete a soluble form of the protein called an antibody or immunoglobulin (Ig)
• Secreted antibodies are similar to B cell receptors but lack transmembrane regions that anchor receptors in the plasma membrane
Figure 43.10

(a) B cell antigen receptors and antibodies

(b) Antigen receptor specificity
Figure 43.10a

(a) B cell antigen receptors and antibodies
(b) Antigen receptor specificity
Each T cell receptor consists of two different polypeptide chains (called $\alpha$ and $\beta$).
The tips of the chain form a variable (V) region; the rest is a constant (C) region.
T cell and B cell antigen receptors are functionally different.
Figure 43.11

The diagram illustrates the structure of the T cell antigen receptor. The receptor consists of two chains: the \( \alpha \) chain and the \( \beta \) chain. The variable regions are located on the V side, while the constant regions are on the C side. A disulfide bridge connects these regions, and the transmembrane region spans the plasma membrane.

Key Components:
- **Antigen-binding site**
- **Variable regions**
- **Constant regions**
- **Disulfide bridge**
- **Transmembrane region**
- **\( \alpha \) chain**
- **\( \beta \) chain**
- **Plasma membrane**
- **Cytoplasm of T cell**

The T cell antigen receptor is depicted as a component of the T cell, with the binding site facing the cytoplasm of the T cell.
• T cells bind to antigen fragments displayed or presented on a host cell
• These antigen fragments are bound to cell-surface proteins called MHC molecules
• MHC (major histocompatibility complex) molecules are host proteins that display the antigen fragments on the cell surface
In infected cells, MHC molecules bind and transport antigen fragments to the cell surface, a process called **antigen presentation**.

A T cell can then bind both the antigen fragment and the MHC molecule.

This interaction is necessary for the T cell to participate in the adaptive immune response.
Figure 43.12

(a) Antigen recognition by a T cell

(b) A closer look at antigen presentation
Displayed antigen fragment
MHC molecule
Antigen fragment
Pathogen
Host cell

(a) Antigen recognition by a T cell
(b) A closer look at antigen presentation
B Cell and T Cell Development

• The adaptive immune system has four major characteristics
  – Diversity of lymphocytes and receptors
  – Self-tolerance; lack of reactivity against an animal’s own molecules
  – B and T cells proliferate after activation
  – Immunological memory
Generation of B and T Cell Diversity

• By combining variable elements, the immune system assembles a diverse variety of antigen receptors
• The immunoglobulin (Ig) gene encodes one chain of the B cell receptor
• Many different chains can be produced from the same gene by rearrangement of the DNA
• Rearranged DNA is transcribed and translated and the antigen receptor formed
DNA of undifferentiated B cell

1. Recombination deletes DNA between randomly selected V segment and J segment

DNA of differentiated B cell

2. Transcription

pre-mRNA

3. RNA processing

mRNA

4. Translation

Light-chain polypeptide

Variable region

Constant region

Antigen receptor

B cell

Figure 43.13
Origin of Self-Tolerance

- Antigen receptors are generated by random rearrangement of DNA.
- As lymphocytes mature in bone marrow or the thymus, they are tested for self-reactivity.
- Some B and T cells with receptors specific for the body’s own molecules are destroyed by apoptosis, or programmed cell death.
- The remainder are rendered nonfunctional.
Proliferation of B Cells and T Cells

- In the body there are few lymphocytes with antigen receptors for any particular epitope.
- In the lymph nodes, an antigen is exposed to a steady stream of lymphocytes until a match is made.
- This binding of a mature lymphocyte to an antigen initiates events that activate the lymphocyte.
Once activated, a B or T cell undergoes multiple cell divisions.

This proliferation of lymphocytes is called clonal selection.

Two types of clones are produced: short-lived activated effector cells that act immediately against the antigen and long-lived memory cells that can give rise to effector cells if the same antigen is encountered again.
B cells that differ in antigen specificity

Figure 43.14
Immunological Memory

- Immunological memory is responsible for long-term protections against diseases, due to either a prior infection or vaccination.
- The first exposure to a specific antigen represents the primary immune response.
- During this time, selected B and T cells give rise to their effector forms.
- In the secondary immune response, memory cells facilitate a faster, more efficient response.
Humoral Immunity

Antigens from pathogens

B cells

Copyright © 2006 Pearson Education, Inc., publishing as Benjamin Cummings
Primary immune response to antigen A produces antibodies to A.

Secondary immune response to antigen A produces antibodies to A; primary immune response to antigen B produces antibodies to B.

**Figure 43.15**

<table>
<thead>
<tr>
<th>Time (days)</th>
<th>Antibody concentration (arbitrary units)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>10^0</td>
</tr>
<tr>
<td>7</td>
<td>10^0</td>
</tr>
<tr>
<td>14</td>
<td>10^1</td>
</tr>
<tr>
<td>21</td>
<td>10^2</td>
</tr>
<tr>
<td>28</td>
<td>10^3</td>
</tr>
<tr>
<td>35</td>
<td>10^4</td>
</tr>
<tr>
<td>42</td>
<td>10^0</td>
</tr>
<tr>
<td>49</td>
<td>10^0</td>
</tr>
<tr>
<td>56</td>
<td>10^0</td>
</tr>
</tbody>
</table>
Concept 43.3: Adaptive immunity defends against infection of body fluids and body cells

- Acquired immunity has two branches: the humoral immune response and the cell-mediated immune response
- In the **humoral immune response** antibodies help neutralize or eliminate toxins and pathogens in the blood and lymph
- In the **cell-mediated immune response** specialized T cells destroy affected host cells
Helper T Cells: A Response to Nearly All Antigens

• A type of T cell called a helper T cell triggers both the humoral and cell-mediated immune responses
• Signals from helper T cells initiate production of antibodies that neutralize pathogens and activate T cells that kill infected cells
• Antigen-presenting cells have class I and class II MHC molecules on their surfaces
• Class II MHC molecules are the basis upon which antigen-presenting cells are recognized
• Antigen receptors on the surface of helper T cells bind to the antigen and the class II MHC molecule; then signals are exchanged between the two cells
• The helper T cell is activated, proliferates, and forms a clone of helper T cells, which then activate the appropriate B cells
Figure 43.16

Antigen-presenting cell

Pathogen

Antigen fragment

Class II MHC molecule

Accessory protein

Antigen receptor

Helper T cell

Cytokines

Humoral immunity

B cell

Cytotoxic T cell

Cell-mediated immunity
Cytotoxic T Cells: A Response to Infected Cells

- **Cytotoxic T cells** are the effector cells in the cell-mediated immune response.
- Cytotoxic T cells recognize fragments of foreign proteins produced by infected cells and possess accessory protein that binds to class I MHC molecules.
- The activated cytotoxic T cell secretes proteins that disrupt the membranes of target cells and trigger apoptosis.
Figure 43.17-3

1. Cytotoxic T cell
   - Accessory protein
   - Class I MHC molecule
   - Infected cell
   - Antigen receptor
   - Antigen fragment

2. Released cytotoxic T cell
   - Perforin
   - Pore
   - Granzymes
   - Dying infected cell

3. Released cytotoxic T cell
   - Dying infected cell
B Cells and Antibodies: A Response to Extracellular Pathogens

• The humoral response is characterized by secretion of antibodies by B cells
Activation of B Cells

- Activation of the humoral immune response involves B cells and helper T cells as well as proteins on the surface of pathogens.
- In response to cytokines from helper T cells and an antigen, a B cell proliferates and differentiates into memory B cells and antibody-secreting effector cells called plasma cells.
Figure 43.18-3

1. Antigen-presenting cell
   - Pathogen
   - Antigen fragment
   - Class II MHC molecule
   - Accessory protein
   - Antigen receptor
   - Helper T cell

2. B cell
   - Activated helper T cell
   - Cytokines
   - Memory B cells

3. Plasma cells
   - Secreted antibodies

© 2011 Pearson Education, Inc.
Antibody Function

- Antibodies do not kill pathogens; instead they mark pathogens for destruction
- In neutralization, antibodies bind to viral surface proteins preventing infection of a host cell
- Antibodies may also bind to toxins in body fluids and prevent them from entering body cells
• In opsonization, antibodies bind to antigens on bacteria creating a target for macrophages or neutrophils, triggering phagocytosis
• Antigen-antibody complexes may bind to a complement protein—which triggers a cascade of complement protein activation
• Ultimately a membrane attack complex forms a pore in the membrane of the foreign cell, leading to its lysis
Figure 43.19

Neutralization

Opsonization

Activation of complement system and pore formation

- Antibody
- Virus
- Bacterium
- Macrophage
- Complement proteins
- Formation of membrane attack complex
- Flow of water and ions
- Pore
- Antigen
- Foreign cell
Neutralization

Antibody

Virus
Opsonization

Bacterium

Macrophage
Activation of complement system and pore formation

Complement proteins

Formation of membrane attack complex

Flow of water and ions

Pore

Foreign cell

Antigen

© 2011 Pearson Education, Inc.
B cells can express five different forms (or classes) of immunoglobulin (Ig) with similar antigen-binding specificity but different heavy chain C regions

- IgD: Membrane bound
- IgM: First soluble class produced
- IgG: Second soluble class; most abundant
- IgA and IgE: Remaining soluble classes
Summary of the Humoral and Cell-Mediated Immune Responses

- Both the humoral and cell-mediated responses can include primary and secondary immune response
- Memory cells enable the secondary response
Active and Passive Immunization

- **Active immunity** develops naturally when memory cells form clones in response to an infection.
- It 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.
• **Passive immunity** provides immediate, short-term protection
• It is conferred naturally when IgG crosses the placenta from mother to fetus or when IgA passes from mother to infant in breast milk
• It can be conferred artificially by injecting antibodies into a nonimmune person
Humoral (antibody-mediated) immune response

- Antigen (1st exposure)
  - Engulfed by
  - Antigen-presenting cell
  - Stimulates
    - B cell
    - Helper T cell

  - Helper T cell
    - Stimulates
      - Memory helper T cells
      - Memory B cells
      - Memory cytotoxic T cells

  - Memory B cells
    - Secreted antibodies
      - Defend against extracellular pathogens

  - Memory cytotoxic T cells
    - Active cytotoxic T cells
    - Defend against intracellular pathogens and cancer

Cell-mediated immune response

- Antigen (1st exposure)
  - Engulfed by
  - Antigen-presenting cell
  - Stimulates
    - Cytotoxic T cell

- Cytotoxic T cell
  - Stimulates
    - Memory cytotoxic T cells
Figure 43.20a

Humoral (antibody-mediated) immune response

1. Antigen (1st exposure) is engulfed by an antigen-presenting cell.
2. Antigen-presenting cell stimulates B cells to produce antibodies.
3. B cells give rise to helper T cells.

Cell-mediated immune response

1. Antigen-presenting cell stimulates helper T cells.
2. Helper T cells stimulate cytotoxic T cells.
3. Cytotoxic T cells give rise to more cytotoxic T cells.

Key:
- Green arrows: Stimulates
- Brown arrows: Gives rise to

© 2011 Pearson Education, Inc.
Figure 43.20b

- Helper T cell
- Memory T cells
- Antigen (2nd exposure)
- B cell
- Memory B cells
- Plasma cells
- Cytotoxic T cell
- Memory cytotoxic T cells
- Active cytotoxic T cells

Helper T cells activate B cells to differentiate into plasma cells that produce secreted antibodies, which defend against extracellular pathogens. Memory T cells are generated after initial exposure to antigen and are activated upon re-exposure, allowing rapid response to the same antigen. Cytotoxic T cells defend against intracellular pathogens and cancer.
Antibodies as Tools

- Antibody specificity and antigen-antibody binding have been harnessed in research, diagnosis, and therapy.
- Polyclonal antibodies, produced following exposure to a microbial antigen, are products of many different clones of plasma cells, each specific for a different epitope.
- **Monoclonal antibodies** are prepared from a single clone of B cells grown in culture.
Figure 43.21

Endoplasmic reticulum of plasma cell

2 µm

© 2011 Pearson Education, Inc.
Immune Rejection

• Cells transferred from one person to another can be attacked by immune defenses
• This complicates blood transfusions or the transplant of tissues or organs
Blood Groups

- Antigens on red blood cells determine whether a person has blood type A (A antigen), B (B antigen), AB (both A and B antigens), or O (neither antigen)
- Antibodies to nonself blood types exist in the body
- Transfusion with incompatible blood leads to destruction of the transfused cells
- Recipient-donor combinations can be fatal or safe
Tissue and Organ Transplants

• MHC molecules are different among genetically nonidentical individuals
• Differences in MHC molecules stimulate rejection of tissue grafts and organ transplants
• Chances of successful transplantation increase if donor and recipient MHC tissue types are well matched
• Immunosuppressive drugs facilitate transplantation
• Lymphocytes in bone marrow transplants may cause the donor tissue to reject the recipient
Concept 43.4: Disruptions in immune system function can elicit or exacerbate disease

- Some pathogens have evolved to diminish the effectiveness of host immune responses
Exaggerated, Self-Directed, and Diminished Immune Responses

- If the delicate balance of the immune system is disrupted, effects range from minor to sometimes fatal
Allergies

• Allergies are exaggerated (hypersensitive) responses to 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
Figure 43.22

IgE

Allergen

Histamine

Granule

Mast cell
• The next time the allergen enters the body, it binds to mast cell–associated IgE molecules.

• Mast cells release histamine and other mediators that cause vascular changes leading to typical allergy symptoms.

• An acute allergic response can lead to anaphylactic shock, a life-threatening reaction, within seconds of allergen exposure.
Autoimmune Diseases

• In individuals with **autoimmune diseases**, the immune system loses tolerance for self and turns against certain molecules of the body

• Autoimmune diseases include systemic lupus erythematosus, rheumatoid arthritis, insulin-dependent diabetes mellitus, and multiple sclerosis
Exertion, Stress, and the Immune System

• Moderate exercise improves immune system function
• Psychological stress has been shown to disrupt immune system regulation by altering the interactions of the hormonal, nervous, and immune systems
• Sufficient rest is also important for immunity
**Immunodeficiency Diseases**

- Inborn **immunodeficiency** results from hereditary or developmental defects that prevent proper functioning of innate, humoral, and/or cell-mediated defenses.
- Acquired immunodeficiency develops later in life and results from exposure to chemical and biological agents.
- **Acquired immunodeficiency syndrome (AIDS)** is caused by a virus.
Evolutionary Adaptations of Pathogens That Underlie Immune System Avoidance

- Pathogens have evolved mechanisms to thwart immune responses
Antigenic Variation

- Through antigenic variation, some pathogens are able to change epitope expression and prevent recognition.
- The human influenza virus mutates rapidly, and new flu vaccines must be made each year.
- Human viruses occasionally exchange genes with the viruses of domesticated animals.
- This poses a danger as human immune systems are unable to recognize the new viral strain.
Figure 43.24

Antibodies to variant 1 appear
Antibodies to variant 2 appear
Antibodies to variant 3 appear

Weeks after infection

Variant 1
Variant 2
Variant 3

Millions of parasites per mL of blood

0 0.5 1.0 1.5

25 26 27 28

© 2011 Pearson Education, Inc.
Latency

- Some viruses may remain in a host in an inactive state called latency
- Herpes simplex viruses can be present in a human host without causing symptoms
Attack on the Immune System: HIV

- Human immunodeficiency virus (HIV) infects helper T cells
- The loss of helper T cells impairs both the humoral and cell-mediated immune responses and leads to AIDS
- HIV eludes the immune system because of antigenic variation and an ability to remain latent while integrated into host DNA
Figure 43.25

Latency

AIDS

Relative anti-HIV antibody concentration

Relative HIV concentration

Helper T cell concentration

Years after untreated infection

Helper T cell concentration (in blood (cells/mm$^3$))

0 1 2 3 4 5 6 7 8 9 10

© 2011 Pearson Education, Inc.
• People with AIDS are highly susceptible to opportunistic infections and cancers that take advantage of an immune system in collapse
• The spread of HIV is a worldwide problem
• The best approach for slowing this spread is education about practices that transmit the virus
Cancer and Immunity

- The frequency of certain cancers increases when adaptive immunity is impaired
- 20% of all human cancers involve viruses
- The immune system can act as a defense against viruses that cause cancer and cancer cells that harbor viruses
- In 2006, a vaccine was released that acts against human papillomavirus (HPV), a virus associated with cervical cancer
Stem cell

Cell division and gene rearrangement

Elimination of self-reactive B cells

Clonal selection

Formation of activated cell populations

Memory B cells

Plasma cells

Antigen

Antibody

Pathogen

Receptors bind to antigens