Introduction: *The Kissing Disease?!?*

- **Mononucleosis (mono)**
  - Caused by Epstein-Barr virus (EBV)
  - 95% of humans infected by adulthood
  - Infected children show few symptoms
  - Half of infected adolescents/young adults get mono
  - Symptoms include
    - Fever
    - Sore throat
    - Swollen lymph glands
Introduction: *The Kissing Disease?!?*

- There is no vaccine for mono
- There is no effective treatment for mono
- Rest, fluids, and pain relievers assist recovery
- Mono is almost never fatal
Introduction: *The Kissing Disease*?!?

- Mono is spread by saliva
  - Kissing
  - Shared dishes or utensils
- EBV infects B cells, weakening the immune system
- Infections are life-long but rarely cause symptoms again
  - An infected person acquires long-lasting immunity against EBV
  - An infected person can spread the disease
INNATE DEFENSES AGAINST INFECTION
Both invertebrates and vertebrates have innate defenses against infection

- Innate defenses—first line of defense
  - Found in all animals
  - Includes
    - Skin
    - Mucous membranes
    - Phagocytic cells
    - Antimicrobial proteins
  - Same response to invaders each time
24.1 Both invertebrates and vertebrates have innate defenses against infection

- Invertebrates have only innate immunity
- Vertebrates have innate and acquired immunity
<table>
<thead>
<tr>
<th>Innate immunity (24.1-3)</th>
<th>Acquired immunity (24.4-15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Response is the same whether or not pathogen has been previously encountered</td>
<td>Found only in vertebrates; previous exposure to pathogen enhances immune response</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>External barriers</th>
<th>Internal defenses</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Skin/exoskeleton</td>
<td>Phagocytic cells</td>
<td>Antibodies (24.8-10)</td>
</tr>
<tr>
<td>Secretions</td>
<td>NK cells</td>
<td>Lymphocytes (24.11-14)</td>
</tr>
<tr>
<td>Mucous membranes</td>
<td>Defensive proteins</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Inflammatory response (24.2)</td>
<td></td>
</tr>
</tbody>
</table>

The lymphatic system (24.3)
24.1 Both invertebrates and vertebrates have innate defenses against infection

- **Interferons** are proteins produced by virus-infected cells
  - Interferons help other cells resist viruses
  - Found only in vertebrates
Virus

Viral nucleic acid

1

2 Interferon genes turned on

3 DNA

mRNA

4 Interferon molecules

Host cell 1
Makes interferon; is killed by virus

Antiviral proteins block viral reproduction

New viruses

3 Interferon molecules

5 Interferon stimulates cell to turn on genes for antiviral proteins

Host cell 2
Protected against virus by interferon from cell 1

Copyright © 2009 Pearson Education, Inc.
24.2 The inflammatory response mobilizes innate defenses

- Tissue damage triggers the **inflammatory response**
- The inflammatory response can
  - Disinfect tissues
  - Limit further infection
1. Tissue injury; release of chemical signals such as histamine

2. Dilation and increased leakiness of local blood vessels; migration of phagocytes to the area

3. Phagocytes (macrophages and neutrophils) consume bacteria and cell debris; tissue heals
Tissue injury; release of chemical signals such as histamine
2. Dilation and increased leakiness of local blood vessels; migration of phagocytes to the area
3 Phagocytes (macrophages and neutrophils) consume bacteria and cell debris; tissue heals
24.3 The lymphatic system becomes a crucial battleground during infection

- The **lymphatic system** is a network of
  - Lymphatic vessels
  - Organs

- Lymphatic vessels
  - Collect fluid from body tissues
  - Return it as **lymph** to the blood

- Lymph organs
  - Such as the spleen and lymph nodes
  - Are packed with white blood cells that fight infections
24.3 The lymphatic system becomes a crucial battleground during infection

- As lymph circulates through lymphatic organs it
  - Collects
    - Microbes
    - Parts of microbes
    - Microbe toxins
  - Transports them to lymphatic organs
    - Macrophages in lymphatic organs engulf the invaders
    - Lymphocytes may mount an acquired immune response
Lymphatic capillary
Interstitial fluid
Blood capillary
Tissue cells
Interstitial fluid

Lymph node
Masses of lymphocytes and macrophages
Valve
Lymphatic vessel

Lymphatic capillary
ACQUIRED IMMUNITY
24.4 The acquired immune response counters specific invaders

- Our immune system
  - Responds to foreign molecules called antigens

- The acquired immune system
  - Reacts to antigens
  - And “remembers” an invader
Infection or vaccination triggers **active immunity**.

We can temporarily acquire **passive immunity** by receiving premade antibodies.
Two kinds of lymphocytes carry out the immune response

- **B cells**
  - Secrete antibodies
  - Mount the humoral immune response

- **T cells**
  - Attack cells infected with bacteria or viruses
  - Cell-mediated immune response
Humoral immune response

- Bone marrow
  - Stem cell
    - Immature lymphocytes
      - Antigen receptor
        - B cell
          - Via blood
        - Via blood
          - Lymph nodes, spleen, and other lymphatic organs
            - Final maturation of B and T cells in lymphatic organ

Cell-mediated immune response

- Thymus
  - Antigen receptor
    - T cell
      - Via blood

- Immature lymphocytes
  - Via blood
  - Thymus

24.5 Lymphocytes mount a dual defense

- Millions of kinds of B cells and T cells
  - Each with different membrane receptors
  - Wait in the lymphatic system
  - Where they may respond to invaders
24.6 Antigens have specific regions where antibodies bind to them

- **Antigens**
  - Not usually part of the host
  - Most are proteins or large polysaccharides on the surfaces of
    - Viruses
    - Foreign cells

- **Antigenic determinants**
  - Specific regions on an antigen
  - To which antibodies bind
Antigen molecule

Antigen-binding sites

Antibody A molecule

Antibody B molecule

Antigenic determinants
24.7 Clonal selection musters defensive forces against specific antigens

- When an antigen enters the body
  - It activates only a small subset of lymphocytes
  - Those with complementary receptors

- The selected lymphocyte cells multiply into clones of short-lived effector cells
  - Specialized for defending against the antigen that triggered the response
  - And into memory cells that confer long-term immunity
24.7 Clonal selection musters defensive forces against specific antigens

- The steps of **clonal selection**
  - Primary immune response, clonal selection
    - Produces **effector cells**
    - **Memory cells** that may confer lifelong immunity
  - Secondary immune response
    - Memory cells are activated by a second exposure to the same antigen
    - This initiates a faster and stronger response

Animation: Role of B Cells
Primary immune response
B cells with different antigen receptors

Cell activation: growth, division, and differentiation

First clone

First exposure to antigen

Endoplasmic reticulum

Plasma (effector) cells secreting antibodies

Memory cells

Second exposure to same antigen

Antigen molecules

Antigen receptor (antibody on cell surface)

Second clone

Secondary immune response (May occur long after primary immune response.)

Copyright © 2009 Pearson Education, Inc.
Primary immune response
B cells with different antigen receptors

Antigen receptor (antibody on cell surface)
Primary immune response

B cells with different antigen receptors

1. Antigen receptor (antibody on cell surface)

2. Antigen molecules
Primary immune response

B cells with different antigen receptors

Cell activation: growth, division, and differentiation

1. Antigen receptor (antibody on cell surface)
2. Antigen molecules
3. First exposure to antigen
Primary immune response

B cells with different antigen receptors

Cell activation: growth, division, and differentiation

First clone

Plasma (effector) cells secreting antibodies
Primary immune response

B cells with different antigen receptors

Cell activation: growth, division, and differentiation

First clone

Antigen receptor (antibody on cell surface)

First exposure to antigen

Antibody molecules

Endoplasmic reticulum

Plasma (effector) cells secreting antibodies

Memory cells
Secondary immune response (May occur long after primary immune response.)

Second clone

Antigen molecules

6 Second exposure to same antigen

Secondary immune response (May occur long after primary immune response.)

Antibody molecules

Endoplasmic reticulum

Plasma (effector) cells secreting antibodies

Memory cells
24.7 Clonal selection musters defensive forces against specific antigens

- Primary vs. secondary immune response
  - The primary immune response
    - Occurs upon first exposure to an antigen
    - Is slower than the secondary immune response
  - The secondary immune response
    - Occurs upon second exposure to an antigen
    - Is faster and stronger than the primary immune response
Time (days)

- First exposure to antigen X
- Secondary exposure to antigen X
- First exposure to antigen Y
- Secondary immune response to antigen X
- Primary immune response to antigen X
- Primary immune response to antigen Y

Antibodies to X

Antibodies to Y

Antibody concentration

0 7 14 21 28 35 42 49 56

Copyright © 2009 Pearson Education, Inc.
24.8 Antibodies are the weapons of the humoral immune response

- Antibodies
  - Are secreted by plasma (effector) B cells
  - Into the blood and lymph
24.8 Antibodies are the weapons of the humoral immune response

- An antibody molecule
  - Is Y-shaped
  - With two antigen-binding sites
  - Specific to the antigenic determinants
  - That elicited its secretion
Antigen

Antigen-binding sites

Light chain

Heavy chain
24.9 Antibodies mark antigens for elimination

- Antibodies promote antigen elimination through several mechanisms
  - Mark invaders
  - Which triggers mechanisms to neutralize or destroy invaders
Binding of antibodies to antigens inactivates antigens by

- Neutralization
- Agglutination of microbes
- Precipitation of dissolved antigens
- Activation of complement system

Enhances

- Phagocytosis
- Cell lysis

leads to

Copyright © 2009 Pearson Education, Inc.
24.10 CONNECTION: Monoclonal antibodies are powerful tools in the lab and clinic

- **Monoclonal antibodies (mAb)**
  - Name means all antibody-producing cells come from one cell
  - Produced by fusing
    - B cells specific for a single antigenic determinant with
    - Easy to grow tumor cells
Early pregnancy (HCG in blood and urine)

Urine applied to strip

HCG

1\textsuperscript{st} band

HCG/mAb complex

Control mAb

2\textsuperscript{nd} band

3\textsuperscript{rd} band

Copyright © 2009 Pearson Education, Inc.
24.10 CONNECTION: Monoclonal antibodies are powerful tools in the lab and clinic

- Monoclonal antibodies are useful in
  - Research
  - Diagnosis
  - Treatment of certain cancers
24.11 Helper T cells stimulate the humoral and cell-mediated immune responses

- **Helper T cells** and **cytotoxic T cells**
  - Are primarily responsible for the cell-mediated immune response
  - Helper T cells also stimulate the humoral response
24.11 Helper T cells stimulate the humoral and cell-mediated immune responses

- In the cell-mediated immune response, an antigen-presenting cell displays
  - A foreign antigen (a nonself molecule) and
  - One of the body’s own self proteins
  - To a helper T cell
24.11 Helper T cells stimulate the humoral and cell-mediated immune responses

- The helper T cell’s receptors
  - Recognize the self–nonself complexes
  - The interaction activates the helper T cells

- The helper T cell can then activate
  - Cytotoxic T cells and
  - B cells

Animation: Helper T Cell
Video: T Cell Receptors
Microbe

Macrophage

Self protein

Self-nonself complex

T cell receptor

Interleukin-2 stimulates cell division

Helper T cell

Antigen-presenting cell

Interleukin-1刺激s helper T cell

Binding site for antigen

Binding site for self protein

Cytotoxic T cell

Cell-mediated immune response (attack on infected cells)

Interleukin-2 activates B cells and other T cells

Humoral immune response (secretion of antibodies by plasma cells)

B cell

1. Antigen from microbe (nonself molecule)
2. Antigen-presenting cell
3. Interleukin-1 stimulates helper T cell
4. Binding site for antigen
5. Interleukin-2 stimulates cell division
6. Interleukin-2 activates B cells and other T cells
7. Cell-mediated immune response (attack on infected cells)
Microbe

Macrophage

Self protein

Antigen from microbe (nonself molecule)
Self vs. non-self complex

T cell receptor

Interleukin-2 stimulates cell division

Interleukin-1 stimulates helper T cell

Binding site for antigen

Binding site for self protein

Helper T cell

Cytotoxic T cell

Interleukin-2 activates B cells and other T cells

Humoral immune response (secretion of antibodies by plasma cells)

Cell-mediated immune response (attack on infected cells)

Antigen-presenting cell

Copyright © 2009 Pearson Education, Inc.
24.12 Cytotoxic T cells destroy infected body cells

- Cytotoxic T cells
  - Are the only T cells that kill infected cells

- Cytotoxic T cells
  - Bind to infected body cells
  - Destroy them
1 Cytotoxic T cell binds to infected cell

Self-nonself complex

Infected cell

Foreign antigen

Perforin molecule

Cytotoxic T cell
1. Cytotoxic T cell binds to infected cell

Self-nonself complex

Infected cell

Foreign antigen

Perforin molecule

Cytotoxic T cell

2. Perforin makes holes in infected cell’s membrane and enzyme enters

Enzyme that can promote apoptosis

Hole forming
1. Cytotoxic T cell binds to infected cell

- Infected cell
- Self-nonself complex
- Foreign antigen
- Perforin molecule
- Cytotoxic T cell

2. Perforin makes holes in infected cell’s membrane and enzyme enters

- Enzyme that can promote apoptosis

3. Infected cell is destroyed
24.13 CONNECTION: HIV destroys helper T cells, compromising the body’s defenses

- **AIDS (acquired immunodeficiency syndrome)**
  - Results from infection by HIV (human immunodeficiency virus)
  - Between 1981 and 2007 AIDS killed more than 27 million people
  - In 2006, 4.3 million people were newly infected with HIV, including 400,000 children under age 15
  - Most AIDS deaths occur in nonindustrialized nations
  - In some African nations, about 40% of adults are HIV positive
The AIDS virus usually attacks helper T cells impairing the

- Cell-mediated immune response and
- Humoral immune response
- Opening the way for **opportunistic infection**
24.13 CONNECTION: HIV destroys helper T cells, compromising the body’s defenses

- AIDS patients typically die from
  - Opportunistic infections and
  - Cancers
  - That would normally be resisted by a person with a healthy immune system
24.14 EVOLUTION CONNECTION: The rapid evolution of HIV complicates AIDS treatment

- HIV mutates faster than any pathogen ever studied
- New strains may be resistant to AIDS drugs
- Drug-resistant strains now infect new patients
24.14 EVOLUTION CONNECTION: The rapid evolution of HIV complicates AIDS treatment

- The evolution of the AIDS virus is the number one obstacle to eradicating AIDS

- Current drugs are unable to
  - Eliminate HIV from a patient
  - Cure AIDS
24.15 The immune system depends on our molecular fingerprints

- The immune system normally reacts
  - Only against nonself substances
  - Not against self
24.15 The immune system depends on our molecular fingerprints

- Transplanted organs
  - May be rejected
  - Because the transplanted cells lack the unique “fingerprint” of the patient’s self proteins

- Donors are used that most closely match the patients tissues

- Transplants between identical twins do not typically have this problem
DISORDERS
OF THE IMMUNE SYSTEM
24.16 CONNECTION: Malfunction or failure of the immune system causes disease

- **In autoimmune diseases**
  - The immune system turns against the body’s own molecules
  - Examples include
    - Lupus
    - Rheumatoid arthritis
    - Insulin-dependent diabetes mellitus
    - Multiple sclerosis
24.16 CONNECTION: Malfunction or failure of the immune system causes disease

- In **immunodeficiency diseases**
  - Immune components are lacking
  - Recurrent infections are frequent

- The immune system may be weakened by
  - Physical stress
  - Emotional stress
  - Students are more likely to be sick during a week of exams
24.17 CONNECTION: Allergies are overreactions to certain environmental antigens

- **Allergies**
  - Are hypersensitive (exaggerated) responses
  - To antigens *(allergens)* in our environment
24.17 CONNECTION: Allergies are overreactions to certain environmental antigens

- Allergic reactions typically occur
  - Very rapidly in response to
  - Tiny amounts of an allergen

- Allergic reactions can occur in many parts of the body
  - Nasal passages
  - Bronchi
  - Skin
**Sensitization: Initial exposure to allergen**

1. Allergen (pollen grain) enters bloodstream
2. B cells make antibodies
3. Antibodies attach to mast cell

**Later exposure to same allergen**

4. Allergen binds to antibodies on mast cell
5. Histamine is released, causing allergy symptoms
B cell (plasma cell)

Mast cell

Histamine

Antibodies attach to mast cell

Antigenic determinant

1. Allergen (pollen grain) enters bloodstream
2. B cells make antibodies
3. Antibodies attach to mast cell

Sensitization: Initial exposure to allergen
Allergen binds to antibodies on mast cell

Later exposure to same allergen

 Histamine is released, causing allergy symptoms
24.17 CONNECTION: Allergies are overreactions to certain environmental antigens

- **Antihistamines**
  - Interfere with histamine’s action
  - Provide temporary relief
  - Often make people drowsy

- **Anaphylactic shock**
  - Extreme life-threatening allergic reaction
  - Can be treated with injections of epinephrine
The cell-mediated immune response

The humoral immune response

B cell

makes

Antibodies

which bind to

Antigens in body fluid

T cell

Infected body cell

Self-nonself complex
Body's defenses include:

- **(a)** Present at birth in vertebrates and invertebrates.
- **(b)** Present only after exposure in vertebrates, produced by cells called Lymphocytes.

Lymphocytes include:

- **(c)** Lymphocytes secrete and are responsible for the humoral immune response.
- **(d)** Lymphocytes stimulate cytotoxic T cells and are responsible for the cell-mediated immune response.
- **(e)** Humoral immune response
- **(f)** Cytotoxic T cells
Body's defenses include:

(a) is present found in at birth vertebrates and invertebrates

(b) is present found in only after exposure vertebrates

produced by cells called Lymphocytes
Lymphocytes

(c) include responsible for cell-mediated immune response

(d) include responsible for humoral immune response

(e) secrete

(f) stimulate cytotoxic T cells

stimulate
You should now be able to

1. Describe the causes, symptoms, and treatments for mononucleosis
2. Describe the structure and functions of the lymphatic system
3. Describe the specific nature of an immune system response
4. Define antigen, antibody, passive immunity, and active immunity
You should now be able to

5. Distinguish between the humoral immune response and the cell-mediated immune response

6. Explain how an antigen and antibody interact

7. Compare a primary immune response to a secondary immune response

8. Relate the structure of an antibody to its functions

9. Describe the production of and uses for monoclonal antibodies
You should now be able to

10. Describe the specific functions of helper T cells and cytotoxic T cells

11. Explain how HIV infects cells, multiplies, and causes disease

12. Explain the causes of immunodeficiency diseases and allergies