Chapter 43
The Immune System
What do you know about the immune system?
What you need to know:

• Elements of an innate immune response
• The differences between B & T cells relative to their activation and actions.
• How antigens are recognized by immune system cells
• The difference in humoral and cell-mediated immunity
• Why Helper T cells are central to immune responses
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
Overview: Recognition and Response

- 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
  
  - nonspecific responses to pathogens
    • external barriers
    • 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.
### INNATE IMMUNITY
*all animals*
- Recognition of traits shared by broad ranges of pathogens, using a small set of receptors
- Rapid response

### Barrier defenses:
- Skin
- Mucous membranes
- Secretions

### Internal defenses:
- Phagocytic cells
- Natural killer cells
- Antimicrobial proteins
- Inflammatory response

### ADAPTIVE IMMUNITY
*vertebrates only*
- Recognition of traits specific to particular pathogens, using a vast array of receptors
- Slower response

### Humoral response:
Antibodies defend against infection in body fluids.

### Cell-mediated response:
Cytotoxic cells defend against infection in body cells.
Concept 43.1: Innate immunity

- Innate immunity is found in all animals and plants
  - Innate immune responses include barrier defenses as well as defenses to combat pathogens that enter the body.
- In vertebrates, innate immunity is a first response to infections and also serves as the foundation of adaptive immunity.
1st line of Defense:

DO NOW:

• Take out a sheet of paper and, on the left side of it make a list of all the parts of the human body that are open to the environment. Next to each exposed body part, write the ways that your body defends that part against pathogens.
Skin – very dry; pH 3-5; glands secrete salty sweat and anti-microbial proteins
Mouth (and esophagus) – continual flow to stomach (pH 2); coughing; mucus, saliva and other anti-microbial proteins
Eyes – hairs; continual outward flow of tears containing salt and antimicrobial proteins
Ears – hairs; wax; low pH
Nose (and trachea) – hairs; cilia; mucus, salt and anti-microbial proteins; sneezing; inhabited by “good” bacteria
Urethra – periodic, high-speed outward flow to rinse tube; low pH (urine)
Vagina – continuous outward flow of fluid; low pH; inhabited by “good” bacteria
Anus – periodic outward flow; inhabited by “good” bacteria
Barrier defenses include:

- Skin
- Mucous membranes covering the surface and lining the openings of the animals body.
- Provide physical barriers and also produces:
  - Secretions that result in a skin pH from 3→5
  - Antimicrobial enzyme called lysozyme, an enzyme that breaks down bacterial cell walls, found in saliva, mucus secretions, and tears
First Lines of Defence

- saliva
  - antibacterial enzymes
- tears
  - antibacterial enzymes
- skin
  - prevents entry
- mucus linings
  - traps dirt and microbes
- stomach acid
  - low pH kills harmful microbes
- “good” gut bacteria
  - out compete bad microbes
Cellular innate defenses:

- Combat pathogens that get through the skin-like in a cut
  - Include **phagocytic white blood cells** and antimicrobial proteins

What is phagocytosis? What happens?

![Diagram of phagocytosis process](image)
Figure 43.3

Pathogen

PHAGOCYTIC CELL

Vacuole

Lysosome containing enzymes

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• The immune system recognizes bacteria and fungi by structures on their cell walls

• An immune response varies with the class of pathogen encountered
Innate Immunity of Vertebrates

• **What are types of common innate immune defenses?**

• 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.
Lipopolysaccharides, flagellin, CpG (unmethylated CG DNA sequences), and dsRNA (double-stranded RNA) are all found in fungi, bacteria, or viruses, but not animal cells.

Why do you think TLR proteins are inside and outside the cell.
• A white blood cell (leukocyte) 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 capacity WBCs. Found throughout the body
  - Dendritic cells stimulate development of adaptive immunity
  - Eosinophils Defend against parasitic invaders such as worms by discharge destructive enzymes
• Neutrophils
   White blood cells that circulate the blood, are attracted by signals from infected tissues, and will ingest and destroy microbes using phagocytosis.

• Macrophages
   GIANT phagocytic cells formed from another type of phagocytic leukocyte (monocytes). May circulate though blood or settle into areas likely to encounter pathogens.

• Dendritic cells
   Mainly found in tissues such as skin, that contact the environment. They stimulate adaptive immunity against pathogens they encounter and engulf.

• Eosinophils
   Leukocytes that defend against parasitic invaders such as worms by positioning themselves near the parasite’s wall and discharging hydrolytic enzymes.
• **Cellular innate defenses** in vertebrates also involve **natural killer cells**
  - These circulate through the body and **recognize and remove** abnormal or diseased 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**
Figure 43.7

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

Tissue cells
Innate Cellular Defense: Antimicrobial Peptides and Proteins

- **Interferon** proteins provide innate defense against viral infection.
  - They cause cells adjacent to infected cells to produce substances to **inhibit viral replication**.
  - Also help 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.
- **Basophils & Mast cells**, (2 types of leukocytes) release **histamine**, which triggers blood vessels to dilate and become more permeable. This aids in delivering clotting agents and phagocytic cells in the injured area.
- **Activated macrophages and neutrophils** release **cytokines**, signaling molecules that enhance the immune response.
• Inflammation results in the formation of *Pus*, a fluid rich in white blood cells, dead pathogens, and cell debris from damaged tissues.
Inflammation can be either local or systemic (throughout the body)

- **Fever** is a systemic inflammatory response triggered by substances released by macrophages in response to certain pathogens

- **Septic shock** is a life-threatening condition caused by an overwhelming inflammatory response
  - High fever
  - Low BP
  - Poor blood flow
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

• What structure surrounds many bacteria that may interfere with recognition or prevent breakdown?
Reading Quiz

1. Types of immune response that are not influenced by prior experiences are called ______ immune responses.

2. Name two barrier defenses that contain the anti-microbial lysozyme.

3. Large phagocytic leukocytes that develop from monocytes.

4. What is another term for Immunoglobulin?

5. T lymphocytes are named for where they maturate. This structure is known as the ___________.
Review:

- Type of immunity that includes skin and phagocytic cells (your born with it).
  - **Innate**
- What is histamine released by and what does it do?
  - **Released by basophils & Mast cells, (2 types of leukocytes)**
  - Triggers blood vessels to dilate and become more permeable
- These help to recognize and remove diseased or damaged cells.
  - **Natural killer cells**
- Enzyme released that helps to break down bacterial cell walls.
  - **Lysozyme**
- What is a fever?
  - **A systemic inflammatory response** triggered by substances released by macrophages in response to certain pathogens
- One of the Barrier defenses is a lowered pH of the skin and digestive system. Why?
  - Decreases reproduction of bacterial cells
- Explain TLRs
  - Toll Like Receptors are found in phagocytic cells and help recognize pathogens by identifying foreign molecules
**Neutrophils**

White blood cells that circulate the blood, are attracted by signals from infected tissues, and will ingest and destroy microbes using phagocytosis.

**Macrophages**

GIANT phagocytic cells formed from another type of phagocytic leukocyte (monocytes). May circulate though blood or settle into areas likely to encounter pathogens.

**Dendritic cells**

Mainly found in tissues such as skin, that contact the environment. They stimulate adaptive immunity against pathogens they encounter and engulf.

**Eosinophils**

Leukocytes that defend against parasitic invaders such as worms by positioning themselves near the parasite’s wall and discharging hydrolytic enzymes.
B-cell vs. T-cell

- **B lymphocytes** (B-Cells) from bone marrow
- Responsible for **Humoral** (in the fluid) **response**
- Make **Antibodies** (soluble proteins secreted by B-cells)
  - Receptors bind intact **antigens** (Finds them in ECF)
    - **Antigens** are foreign molecules that elicit a response from lymphocytes. (B & T cells recognize them by specific receptors)
  - **Cytokinins** (made by helper T cells) enhance B-cell activation
  - **Clonal selection** results in 1000's of cells specific to an antigen
    - **Effector cells** combat the antigen
    - **Memory cells** are long-lived, bear receptors for the same antigen, allowing them to act quickly the next time.
B-cell vs. T-cell

- **T lymphocytes (T-Cells) Cells from thymus**

- **2 types:**
  - **Helper T cells** *(Binds Class 2 MHCs on antigen-presenting cells (APCs) Activates B cells and Cytotoxic T cells)*
  - **Cytotoxic T cells** *(Cell Mediated Response (kills infected cells))*
    - Receptors for both bind **antigens** that are displayed by cells on their MHCs.
      - **Major histocompatibility complex (MHC) molecules** are proteins that are the product of a group of genes. (Individuals differ in their MHCs. This is a major component of “self.”)
  - **2 Types of MHCs**
    - **Class 1 MHCs** are found in almost all cells of the body, except RBCs (antigen fragments are targets of cytotoxic T cells)
    - **Class 2 MHCs** are made by some cells of the immune system, including dendritic cells, macrophages, and B cells. (antigen fragments are targets of Helper T cells)
In a nutshell

• B cells make antibodies, which provide humoral immunity. This helps fight pathogens that are circulating in body fluids.

• Cytotoxic T cells destroy body cells that are infected by a pathogen or cancer cell

• Helper T cells activate both B & T cells
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
  - Worth noting: all blood cells proliferate from stem cells in the bone marrow
Where do B & T cells get their names?

- B cells are made in the bone marrow
- T cells mature in the thymus
• **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**
Where would the epitope be located?

The epitope will be located on the pathogen's antigen, where it will bind to the B or T cell's receptor.
• 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
  - There are constant regions
  - Variable regions differ greatly
    • The variable regions provide antigen specificity
Figure 43.9

B cell antigen receptor

Antigen-binding site

Disulfide bridge

Variable regions

Constant regions

Transmembrane region

Heavy chains

Plasma membrane

Cytoplasm of B cell
• 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

Antigen receptor

Antigen

Epitope

Pathogen

Antibody

clonal selection
Figure 43.10b

(b) Antigen receptor specificity

Antibody A

Antibody B

Antibody C

Antigen
Antigen Recognition by T Cells

- 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
- **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

![Diagram of immune system components]
In infected cells, MHC molecules bind and transport antigen fragments to the cell surface, a process called **antigen presentation**.
After antigen presentation

- A T cell can bind both the antigen fragment and the MHC molecule
  - (individuals differ in their MHCs. This is a major component of “self”)

(a) Antigen recognition by a T cell
(b) A closer look at antigen presentation
After antigen presentation

- **2 Types of MHCs**
  - **Class I MHCs**: found on almost all body cells except the RBCs.
  - **Class II MHCs**: Made by dendritic cells, macrophages, and B cells
(a) Antigen recognition by a T cell
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

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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
  - 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.

Animation: Role of B Cells
Humoral Immunity

Antigens from pathogens

B cells

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Animation: Role of B Cells
Right-click slide / select “Play”
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.

Exposure to antigen A

Exposure to antigens A and B

Time (days)

Antibody concentration (arbitrary units)

Antibodies to A

Antibodies to B

Figure 43.15
Review

- B vs. T cell origin, receptors & function
- B or T cell Activation
- Antigens
- Immunoglobulin/Antibodies
- Class 1 & 2 MHCs
- Clonal Selection
- Effector vs. Memory cells
- Primary vs. secondary immune response
Concept 43.3: Adaptive immunity defends against infection of body fluids and body cells

- Acquired immunity has two branches:
  - **humoral immune response**
  - **cell-mediated immune response**
- In the **humoral immune response** antibodies help neutralize or eliminate toxins and pathogens in the blood and lymph (mostly B cells)
- 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 (made by B cells) 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.
Animation: Helper T Cells
Right-click slide / select “Play”
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

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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 an 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

Animation: Cytotoxic T Cells
Cell-mediated Immunity

Infected cell

Cytotoxic T cell

Animation: Cytotoxic T Cells
Right-click slide / select “Play”
Cytotoxic T cell

Accessory protein

Class I MHC molecule

Infected cell

Antigen fragment

Antigen receptor
Figure 43.17-2

Cytotoxic T cell

Accessory protein

Class I MHC molecule

Infected cell

Antigen fragment

1

Antigen receptor

Perforin

Pore

2

Gran-zymes

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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**.

![Diagram](image-url)
Figure 43.18-1

Antigen-presenting cell

Pathogen Antigen fragment

Class II MHC molecule

Accessory protein

Antigen receptor

Helper T cell
Figure 43.18-2

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

2. B cell
   - Activated helper T cell
   - Cytokines

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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

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Antibody Function: What do they do?

- **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.
Antibody Function: What do they do?

- 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**.
Activation of complement system and pore formation

- Complement proteins
- Formation of membrane attack complex
- Flow of water and ions
- Pore

Foreign cell
Antigen
Use the illustrations below to explain the humoral immune response. Be sure to explain the difference between **Opsonization** and **Activation of the Complement System**.
Both the humoral and cell-mediated responses can include primary and secondary immune response

- Memory cells enable the secondary response
Keeping stuff Straight

• B cells:
  Make antibodies, which provide **humoral** immunity. This helps fight circulating pathogens—*in the blood*
  Neutralize then—*Opsinization or Compliment Protein Activation*

• **Cytotoxic T Cells:**
  **Cell Mediated Immunity**—Destroys body cells that are infected or cancerous cells

• **Helper T Cells:**
  Activates both B & T cells
Humoral (antibody-mediated) immune response

- Antigen (1st exposure)
  - Engulfed by Antigen-presenting cell
  - Helper T cell
  - Memory helper T cells
  - Antigen (2nd exposure)
  - Plasma cells
    - Secreted antibodies
      - Defend against extracellular pathogens
  - Memory B cells
  - 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
  - Helper T cell
  - Cytotoxic T cell
    - Memory cytotoxic T cells
      - Active cytotoxic T cells

Key:
- Stimulates
- Gives rise to

Figure 43.20

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Figure 43.20a

Humoral (antibody-mediated) immune response

- Antigen (1st exposure)
  - Engulfed by Antigen-presenting cell
    - Stimulates
    - Gives rise to B cell
      - +
    - +
  - Helper T cell
    - +
  - Cytotoxic T cell
    - +

Cell-mediated immune response

- Antigen-presenting cell
  - +
  - Helper T cell
    - +
  - Cytotoxic T cell
    - +

Key:
- Stimulates
- Gives rise to
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

Many pediatric physicians recommend holding off on antibiotics for infants under 1 year old. Why might this be true? Are there any potential problems for treating a bacterial induced fever with antibiotics? Why or why not?
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 nonsel 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

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## The ABO Blood System

<table>
<thead>
<tr>
<th>Blood Type (genotype)</th>
<th>Type A (AA, AO)</th>
<th>Type B (BB, BO)</th>
<th>Type AB (AB)</th>
<th>Type O (OO)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Red Blood Cell Surface Proteins (phenotype)</strong></td>
<td>A agglutinogens only</td>
<td>B agglutinogens only</td>
<td>A and B agglutinogens</td>
<td>No agglutinogens</td>
</tr>
<tr>
<td><strong>Plasma Antibodies (phenotype)</strong></td>
<td>b agglutinin only</td>
<td>a agglutinin only</td>
<td>No agglutinin</td>
<td>a and b agglutinin</td>
</tr>
</tbody>
</table>
Tissue and Organ Transplants

- Differences in MHC molecules stimulate rejection of tissue grafts and organ transplants
  - MHC (Major Histocompatibility Complex) molecules are different among genetically nonidentical individuals
Chances of successful transplantation increase if donor and recipient MHC tissue types are well matched
  - The recipient also must take Immunosuppressive drugs
Review

1. Cells that make antibodies?
   - B Lymphocytes

2. Process in which the binding of antibodies to a pathogen’s surface proteins prevents the pathogen from entering or infecting cells?
   - neutralization

3. Process in which the binding of antibodies leads to the increased phagocytosis of pathogens.
   - opsonization

4. Process in which the binding of antibodies leads to the activation of the compliment system... these proteins destroy the pathogen.
   - lysis

5. Differences between active and passive immunity?
   - **Active immunity** develops naturally (or artificially in regards to vaccines) in response to an infection.
   - **Passive immunity** occurs when an individual receives antibodies, such as those passed to the fetus across the placenta, or to infants in breast milk.
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
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.

![Mast cell diagram](image)
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.
Figure 43.22

IgE

Granule
Mast cell

Allergen

Histamine
The first time an allergy prone person runs across an allergen such as ragweed he or she makes large amounts of ragweed IgE antibody. These IgE molecules attach themselves to mast cells.

The second time that person has a brush with ragweed, the IgE primed mast cells release granules and powerful chemical mediators, such as histamine and cytokines, into the environment. These chemical mediators cause the characteristic symptoms of allergy.
Anaphylactic Shock

- Acute, whole-body, life-threatening reaction within seconds of exposure to an allergen.
  - Widespread release of mast cell contents
    - Dialololation leads to drop in BP
    - Constriction of the bronchioles (passageways by which the air passes through the nose or mouth to the air sacs of the lungs)
      - Death may result from lack of blood flow and inability to breath.
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
IT'S NOT LUPUS
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 - HIV
  - HIV infects Helper T Cells.
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

Millions of parasites per mL of blood

Variant 1
Variant 2
Variant 3

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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
Animation: HIV Reproductive Cycle
Right-click slide / select “Play”
Figure 43.25

Latency

AIDS

Relative anti-HIV antibody concentration

Relative HIV concentration

Helper T cell concentration (in blood (cells/mm³))

Years after untreated infection

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• 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