The Immune System 24

If it were not for your immune system, you would have died long ago from measles, chicken pox, pneumonia, influenza, or any of hundreds of other diseases. Many times during your life, dangerous bacteria or viruses broke through the skin or other nonspecific defenses. Each time, your immune system protected you, and each time it was 100% successful. Microorganisms can overwhelm the body so quickly that 99% effectiveness won't do. The cells and antibodies of the immune system must specifically identify and destroy every invader and at the same time spare the body's own cells. Your immune system's remarkable ability to recognize and protect your "self" from "nonself" is the topic of this chapter.

Organizing Your Knowledge

Exercise 1 (Modules 24.1 - 24.3)

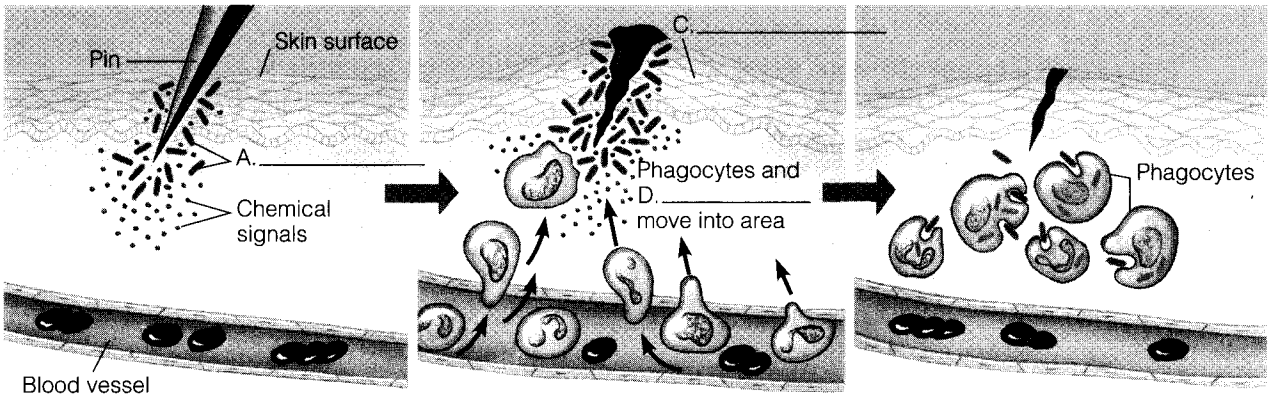
Nonspecific obstacles are the body's first line of defense. Match each of the following nonspecific defenses with a phrase from the left.

A. Protein that cuts holes in bacteria
B. Seals off infected region
C. Protective enzyme in sweat and tears
D. Barrier that is first line of defense
E. Large phagocytic cell of interstitial fluid
F. Digests most microorganisms in food
G. White blood cell that engulfs bacteria
H. Attacks cancer cells and cells infected by viruses
I. Helps cells resist viruses
J. Triggered by histamine, it disinfects and cleans injured tissues
K. Filters inhaled air
H. May become swollen due to infection-fighting activity

_____ 1. Natural killer cell
_____ 2. Lymph node
_____ 3. Macrophage
_____ 4. Interferon
_____ 5. Stomach acid
_____ 6. Complement
_____ 7. Lysozyme
_____ 8. Hair
_____ 9. Neutrophil
_____ 10. Clotting protein
_____ 11. Inflammatory response
_____ 12. Skin

Exercise 2 (Module 24.2)

Study this module on the inflammatory response. Then, from memory, fill in the missing words in this diagram.



(1) Tissue injury; release of chemical signals such as B. _____

(2) Dilation and increased E. _____ of local blood vessels; migration of phagocytes to the area

(3) Phagocytes (macrophages and neutrophils) consume F. _____ and G. _____; tissue heals

Exercise 3 (Modules 24.3 - 24.5)

These modules introduce some basic concepts and terminology related to the immune and lymphatic systems. To test your knowledge of this material, state the difference between the terms in each of the following pairs.

1. antigen—antibody

2. T cell—B cell

3. cell-mediated immunity—humoral immunity

4. lymphatic system—circulatory system

5. passive immunity—active immunity

6. blood capillary—lymphatic capillary

7. specific defenses—nonspecific defenses

Exercise 4 (Modules 24.4 – 24.8)

What is immunity? Why do you sometimes have to get sick to become immune to a disease? To answer these questions, fill in the blanks in the following story, using words and phrases from Modules 24.4 – 24.8.

Brian stopped by one afternoon to visit his friends Tom and Alicia and their 2-year-old daughter Samantha. Little did any of them suspect that Samantha was coming down with the measles. She had not yet been immunized, and she had caught the virus from a little boy in her day-care group.

Brian had never had the measles either. Once he had been exposed, and his [1]_____ defenses had been breached, it was too late to do anything. It was up to the specific defenses of the [2]_____ system to fight the invading viruses.

Both B and T lymphocytes were involved in the battle, but we will concentrate on the B cells. The viruses' protein coats contained protein molecules foreign to Brian's body; these [3]_____ are what triggered his immune response. Throughout his body were many different types of B lymphocytes, each capable of responding to a different antigen. On each of these B cells were [4]_____ that acted as receptors for various potential foreign antigens. Only a specific B-cell type possessed antibodies whose [5]_____ were complementary to the shape of the measles virus antigens. Eventually the measles viruses encountered some of these B cells in a [6]_____ node. Only these cells were "chosen" to be activated to fight the invading viruses. This process is called clonal [7]_____.

The stimulated B cells began to multiply, forming a [8]_____, a population of genetically identical [9]_____ cells. These cells secreted [10]_____ capable of locking on to the viral antigens and inactivating the measles viruses.

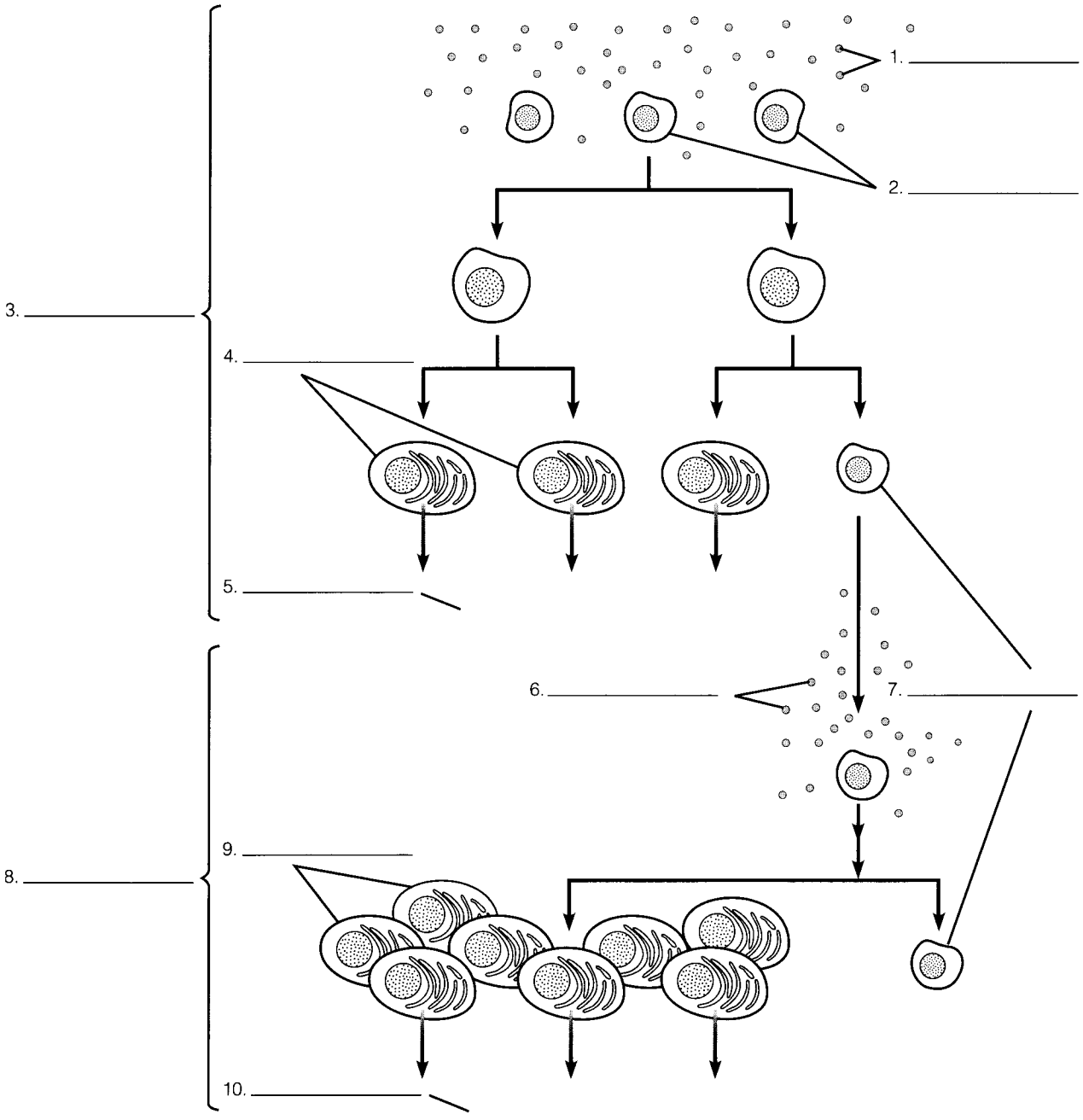
The initial phase of immunity described so far is called the [11]_____ immune response. Unfortunately, Brian had to suffer through the measles, because this response is too slow to wipe out the invaders before they cause harm. It usually takes several [12]_____ for lymphocytes to become activated and form effector cell clones, and by that time Brian was already sick.

After he recovered, however, Brian was [13]_____ to measles. When his college roommate came down with measles just before final exams, Brian was safe. A second exposure to the same antigen triggers the [14]_____ immune response, which is much quicker and stronger than the primary response and also lasts longer. The explanation for this is that the first exposure actually triggers the formation of two cell clones, the effector cells that fought the original infection and also a clone of [15]_____ cells, which are held in reserve. Whereas effector cells may live only a few days, these other cells may last for [16]_____. They are capable of mounting a quick and powerful secondary response.

Although Brian was protected from the measles, he still caught a cold the day before his math exam. But that is another story entirely.

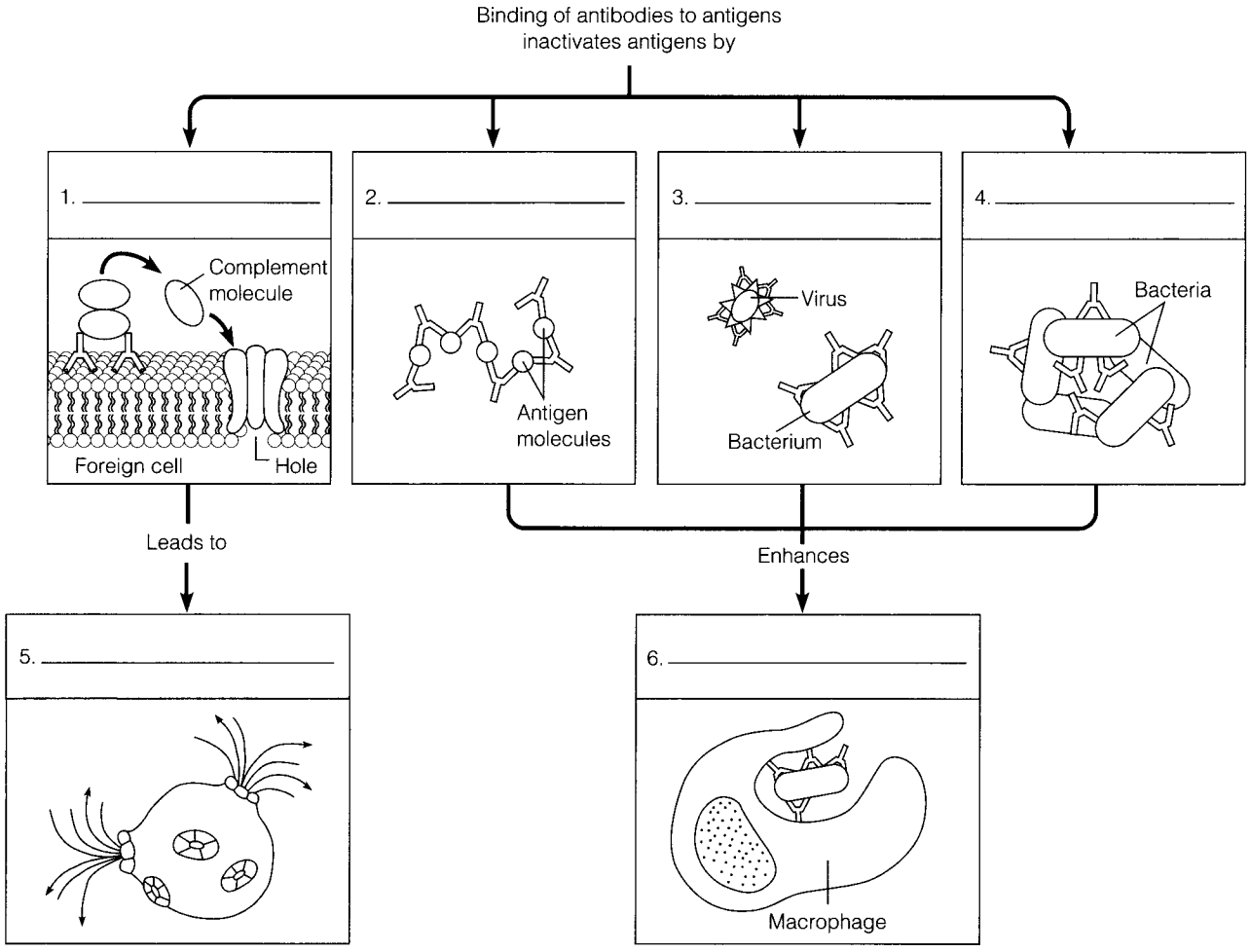
Exercise 5 (Module 24.9)

This module details the role of B cells in immunity. Review the action of B cells by labeling and coloring the following diagram. First identify and label the **primary immune response** and the **secondary immune response.** Label **antigens,** and color them red. Label **B cells,** and color them light blue. Draw green antigen receptors on the B-cell types, and also draw green **antibodies** produced by plasma cells. Be sure to make antibodies "fit" antigens. Label **plasma cells,** and color them dark blue. Label **memory B cells,** and color them purple. When you are done, explain the diagram.



Exercise 6 (Modules 24.10 - 24.11)

The variable regions at the tips of an antibody's "arms" recognize antigens, and the constant region in the base of the Y helps destroy and eliminate antigens. As shown in Figure 24.11 in the text, there are a number of ways in which antibodies assist in destruction of antigens. These processes have been scrambled in the diagrams below. Identify each process, and label the diagrams accordingly. Choose from **phagocytosis, precipitation of dissolved antigens, neutralization, cell lysis, activation of complement,** and **agglutination of cells.**



Exercise 7 (Module 24.12)

The usefulness of monoclonal antibodies stems from their ability to recognize and attach to specific molecules, which otherwise might be difficult to single out. See if you can think of several areas not mentioned in the text where this ability might be useful, and write your ideas on a separate piece of paper. Try not to limit your speculations to medicine. For example, how might monoclonal antibodies be useful in criminology, wildlife management, or archaeology?

Exercise 8 (Module 24.13)

Web/CD Activity 24A *Immune Responses*

T cells are responsible for cell-mediated immunity. Contrast this arm of the immune system with humoral immunity, described in Module 24.9. Then match each of the following components with its role in cell-mediated immunity.

A. Protein that recognizes antigens
B. Chemical that attacks infected cell
C. Chemical signal that activates T and B cells
D. Macrophage that displays antigen
E. Identity marker on body cells
F. Cell that helps activate T and B cells
G. Cell that attacks infected cells
H. Chemical signal from APC to T cell

_____ 1. Interleukin-1
_____ 2. Antigen-presenting cell
_____ 3. Helper T cell
_____ 4. T-cell receptor
_____ 5. Self protein
_____ 6. Perforin
_____ 7. Interleukin-2
_____ 8. Cytotoxic T cell

Exercise 9 (Modules 24.14 – 24.19)

Web/CD Activity 24B *HIV Reproductive Cycle*

Sometimes the immune system fails to respond to invaders. Sometimes it goes overboard, responding to harmless substances in the environment, or even attacking the body's own tissues. Briefly describe how the normal function of the immune system goes awry in each of the following situations.

1. An immunodeficiency disease, like severe combined immunodeficiency

2. An allergy to cat hair

3. A cancerous brain tumor

4. Rejection of a heart transplant

5. Rheumatoid arthritis, an autoimmune disease

6. AIDS

7. Catching a cold after a stressful period, like final exams

Exercise 10 (Module 24.18 and Introduction)

Web/CD Activity 24B *HIV Reproductive Cycle*

Understanding the immune system is important and useful. Understanding AIDS could save your life. Choose the correct italicized words or phrases to complete this story.

Lauren was worried and anxious because last week, her friend Robert told her that he had tested positive to antibodies against (1) *HIV, SCID,* the virus that causes AIDS. Now Lauren was waiting for the results of a blood test to determine whether she had been infected by Robert.

Lauren and Robert had had a sexual relationship that had ended about 6 months before. Because she was using birth control pills, they had never used (2) *an IUD, condoms, withdrawal,* which might have given them some protection. When he called, Robert told her that he was very sorry; he had no idea that he was HIV-positive. He said that he had probably been infected by a woman with whom he had had an earlier relationship. She had in fact experimented with drugs and had probably been infected by blood on a needle shared with a person infected with HIV. Robert was probably infected via contact with the woman's (3) *blood, skin, saliva* during intercourse. Lauren may have contracted HIV from Robert's blood or semen.

As Robert and Lauren now knew, the rate of HIV infection is increasing among the heterosexual, non-drug-using population, including college students. In the United States about (4) *a million, a hundred thousand* people are living with HIV; in 2001 alone, over (5) *10,000, 40,000* were newly infected with the virus.

Lauren had learned about HIV and AIDS in her biology class. The virus attacks the body's immune system, specifically (6) *B lymphocytes, helper T cells, cytotoxic T cells.* The virus contains *RNA.* When it enters a cell, this molecule directs the synthesis of *DNA* that becomes part of the cell's chromosomes. The viral instructions may remain dormant for as long as (7) *six months, ten years,* but eventually direct the cell to make more viruses. The viruses then destroy the host cell and leave to infect other cells. Because HIV attacks cells of the immune system, the body of the AIDS patient can be wracked by infection. Death may result from disease or (8) *autoimmunity, cancer, allergies.* New combinations of drugs offer healthier, longer lives to individuals who are infected with HIV, but the drugs are expensive. It may take years to develop (9) *antibiotics, a vaccine* that could prevent the disease. At present, (10) *drugs, education* is/are the best weapon against AIDS.

Lauren had had a bad cold for the previous 2 weeks. At first she had thought nothing of it, but now she wondered if her immune system was beginning to falter. The telephone rang. She took a deep breath, sat down at the desk, and picked up the phone. The voice at the other end was professional. All Lauren could get out was, "Negative? The test was negative?"

She had never been so scared—or felt so relieved.

Testing Your Knowledge

Multiple Choice

1. An antigen is
   a. a protein molecule that helps defend the body against disease.
   b. a type of white blood cell.
   c. an invading virus or bacterium.
   d. a foreign molecule that evokes an immune response.
   e. a body cell attacked by an invading microorganism.
2. Your lymphatic system fights infection and
   a. delivers food and water to tissues.
   b. carries glandular secretions.
   c. maintains high blood pressure.
   d. allows red blood cells to approach cells more closely.
   e. drains fluid from tissues.
3. How do memory cells differ from effector cells?
   a. Memory cells are more numerous.
   b. Memory cells are responsible for the primary immune response.
   c. Memory cells attack invaders, and effector cells do not.
   d. Memory cells live longer.
   e. Memory cells are capable of producing antibodies.
4. Which of the following triggers tissue inflammation?
   a. accumulation of phagocytes in an injured area
   b. release of interferon by infected cells
   c. increased blood flow in an infected or injured area
   d. fever
   e. release of chemicals such as histamine by damaged cells
5. A cell capable of producing monoclonal antibodies is produced by fusing a lymphocyte with a
   a. tumor cell.
   b. red blood cell.
   c. bone marrow cell.
   d. T cell.
   e. macrophage.
6. A clone of lymphocytes
   a. produces different antibodies.
   b. lives in the same area of the body.
   c. consists of immature cells, incapable of carrying out an immune response.
   d. makes antibodies against the same antigens.
   e. consists of both B cells and T cells.
7. Individuals infected with HIV
   a. can live for 15 to 20 years without symptoms.
   b. have little chance of developing AIDS.
   c. often die from autoimmune reactions.
   d. suffer from increased sensitivity to foreign antigens.
   e. can die from other infections or cancer.
8. Tissues are "typed" before an organ transplant to make sure that the _____ of donor and recipient match as closely as possible.
   a. T cells
   b. antibodies
   c. "self" proteins
   d. histamines
   e. B cells
9. A vaccine contains
   a. white blood cells that fight infection.
   b. antibodies that recognize invading microbes.
   c. inactivated disease-causing microbes.
   d. a hormone that boosts immunity.
   e. lymphocyte antigens.
10. When you are immune to a disease
    a. antibodies against the disease are constantly circulating in your blood.
    b. certain lymphocytes are able to make the proper antibodies quickly.
    c. your nonspecific defenses are strengthened.
    d. B cells are stimulated to quickly engulf invaders.
    e. antigens are altered so invaders can no longer attack your tissues.
11. An antibody is a
    a. protein that attaches to an antigen.
    b. foreign substance or organism.
    c. white blood cell that attacks invading bacteria or viruses.
    d. molecule on a body cell that identifies the cell as "self."
    e. large carbohydrate molecule that helps defend the body.

12. B lymphocytes
    a. attack cells that have been infected by viruses.
    b. engulf and destroy bacteria and viruses.
    c. multiply and make antibodies that circulate in blood and lymph.
    d. are responsible for cell-mediated immunity.
    e. do all of the above.
13. HIV infects mostly
    a. cells of the nervous system.
    b. B lymphocytes.
    c. cytotoxic T cells.
    d. macrophages.
    e. helper T cells.
14. The biggest difference between cell-mediated immunity and humoral immunity is
    a. how long their protection lasts.
    b. whether a subsequent secondary immune response can occur.
    c. whether clonal selection occurs.
    d. how they respond to and dispose of invaders.
    e. how fast they can respond to an invader.
15. Viruses and bacteria in body fluids are attacked by
    a. antibodies from B cells.
    b. cytotoxic T cells.
    c. complement proteins.
    d. helper T cells.
    e. antigens.
16. What do the antibodies secreted by plasma cells (the effector cells of humoral immunity) do to attack their targets?
    a. activate complement to punch holes in them
    b. clump cells together so that phagocytes can ingest them
    c. cause antigen molecules to settle out of solution
    d. attach to antigens and detoxify them
    e. all of the above

Essay

1. Explain how vaccination allows you to develop immunity to a disease without becoming ill. Include in your explanation the primary and secondary immune responses.
2. Compare humoral and cell-mediated immunity. In your comparison, discuss types of lymphocytes involved, roles of antibodies in the immune response, where invaders are attacked, and methods used to destroy invaders.
3. When biologists first started to work out the mechanisms of immunity, they found that the body produced antibodies that matched the shape of invading antigens. The researchers suspected that they would find that the immune system somehow analyzed the antigens and custom-built antibodies to fit. Did they find this to be the case? Explain.
4. Joan was telling her friend Jim why she had not been able to make it to biology class for several days: "My throat has been so sore I could hardly swallow," she croaked. "And the glands in my neck are really sore and swollen." Jim said, "We have been talking about this in class. They are not really 'glands,' you know, and the reason they are sore is . . ." Complete Jim's explanation.
5. Describe the inflammatory response and how it helps the body deal with injury or infection.

Applying Your Knowledge

Multiple Choice

1. Which of the following is not present until after the primary immune response occurs?
    a. memory cells
    b. macrophages
    c. helper T cells
    d. complement proteins
    e. antigens
2. The relationship between an antigen and an antibody is most like
    a. a battery and a flashlight.
    b. a hand and a glove.
    c. a hammer and a nail.
    d. a left foot and a right foot.
    e. a recipe and a cake.
3. A group of researchers have tested many chemicals and found several that have potential for use in treating malfunctions of the immune system. Which of the following would seem to have the most promise as a drug for inhibiting autoimmune diseases?
    a. Compound A13: acts like histamine
    b. Compound Q6: stimulates cytotoxic T cells
    c. Compound N98: a potent allergen
    d. Compound B55: suppresses specific cytotoxic T cells
    e. Compound M31: stimulates helper T cells

4. The body produces antibodies complementary to foreign antigens. The process by which the body comes up with the correct antibodies to a given disease is most like
   a. going to a tailor and having a suit made to fit you.
   b. ordering the lunch special at a restaurant without looking at the menu.
   c. going to a shoe store and trying on shoes until you find a pair that fits.
   d. picking out a video that you haven't seen yet.
   e. selecting a lottery prize winner by means of a random drawing.

5. Rhonda has been diagnosed as suffering from an immunodeficiency disease. Her doctor suspected Rhonda might have an immunodeficiency because
   a. Rhonda strongly rejected an organ transplant.
   b. Rhonda suffered from numerous allergies.
   c. Rhonda's blood showed high levels of numerous antibodies.
   d. Rhonda seemed to be immune to her own "self" molecules.
   e. Rhonda suffered from repeated, prolonged infections.

6. The idea behind vaccination is to induce _____ without the vaccinated individual having to get sick.
   a. passive immunity
   b. the primary immune response
   c. anaphylactic shock
   d. nonspecific defenses
   e. inflammation

7. Researchers found that when laboratory rats were already infected with a virus, they were better able to resist infection by a second completely different virus. The first infection apparently caused _____, which protected the rats from the second infection.
   a. increased stress
   b. secretion of interferons
   c. production of antibodies
   d. passive immunity
   e. cell agglutination

8. Which of the following would be effective in eliminating bacteria but ineffective against viruses? (Hint: Viruses are not cells.)
   a. activation of complement proteins
   b. secretion of interferon by infected cells
   c. neutralization by antibodies
   d. agglutination by antibodies
   e. perforin secretion by cytotoxic T cell

9. An allergen acts like
   a. an antigen.
   b. histamine.
   c. interferon.
   d. an antibody.
   e. complement.

10. In a series of immune system experiments, the thymus glands were removed from baby mice. Which of the following would you predict as a likely result?
    a. The mice suffered from numerous allergies.
    b. The mice never developed cancerous tumors.
    c. The mice suffered from autoimmune diseases.
    d. The mice readily accepted tissue transplants.
    e. The mice were unable to produce an inflammatory response.

Essay

1. More people die each year from bee stings than from rattlesnake bites. The individual who is stung dies of anaphylactic shock, a massive, life-threatening allergic response. Anaphylactic shock usually occurs the second time an individual is stung by a bee. Why does this occur the second time and not the first time?

2. Researchers have not yet come up with a cure for the common cold, but they have made some interesting observations, among them: (1) There are more than 50 different known kinds of rhinoviruses, the viruses that cause colds; and (2) an average 2-year-old might catch three or four colds per year, but an 80-year-old catches a cold only once every 3 or 4 years. How do these findings relate to each other and the function of the immune system?

3. Before traveling to Africa, John got a "gamma-globulin" injection containing antibodies against hepatitis. Two years later, John planned another trip to Africa. His doctor recommended another gamma-globulin injection because John was no longer immune to hepatitis. What kind of immunity did John acquire from the first injection? Why didn't the immunity last?
4. After the flu season, blood samples were obtained from flu patients, and antibodies in the blood were analyzed. Researchers found that the antibodies produced by different patients in response to the same virus were often quite different. In some cases, the antigen-binding sites of the antibodies were completely different shapes. Explain how this could occur.
5. Antibodies are Y-shaped, with antigen-binding sites at the tip of each "arm" of the Y. How does the fact that an antibody has two antigen-binding sites help the antibody inactivate invaders? (Think what would happen if they had only one antigen-binding site.)
6. Organ transplant recipients must be very careful to avoid infections, especially viral infections. Explain why.

Extending Your Knowledge

1. Do you know anyone who has AIDS or is HIV-positive? Did you know anyone who died of AIDS? Is there anything you can do to help confront the AIDS crisis?
2. Recently, several college campuses were disrupted by major measles epidemics. Are you immune to measles? Have you been immunized, or did you have measles when you were younger? How about other diseases? Do you know where to look or whom to ask to find out whether you are immune to specific diseases?