Chapter 24

Immune System and Disease

24.1 Lesson 24.1: Nonspecific Defenses

Lesson Objectives

- Describe mechanical, chemical, and biological barriers that keep most pathogens out of the human body.
- Explain how the inflammatory response and white blood cells help fight pathogens that enter the body.

Introduction

The immune system protects the body from ”germs” and other harmful substances. The immune system is like a medieval castle. The outside of a medieval castle was protected by a moat and high stone walls. Inside the castle, soldiers were ready to defend the castle against any invaders that got through the outer defenses. Like a medieval castle, the immune system has a series of defenses. Only pathogens that are able to get through all the defenses can cause harm to the body.

First Line of Defense

The immune system has three lines of defense. The first line of defense includes a variety of barriers against pathogens that keep most pathogens out of the body. Pathogens are disease-causing agents, such as bacteria and viruses. Defenses in the first line are the same regardless of the type of pathogen. This is why they are called nonspecific defenses. Several types of pathogens that are common causes of human disease can be seen in the **Figure** 24.1.

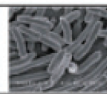
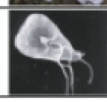
Type of pathogen		Description	Human Disease caused by pathogens of that type
Bacteria Escherichia coli		Single - celled organisms without a nucleus	Strep throat,staph infections, tuberculosis,food poisoning, tetanus,pneumona,syphilis
Viruses Herpes simplex		Non living particles that reproduce by taking over living cells	Common cold,flu,genital herpes, cold sores,measle,AIDS,genital warts,chicken pox,small pox
Fungi Death Cap mushroom		Simple organisms,including mushrooms and yeasts,that grow as single cells or thread like filaments	Ringworm,athlete's foot,tineas, candidiasis,histoplasmosis, mushroom poisoning
Giardia Lamblia		Single celled organism with a nucleus	Malaria,"traveller's diarrhea" giardiasis,typano somiasis ("sleeping sickness")

Figure 24.1: Common Human Pathogens (1)

Mechanical Barriers

Mechanical barriers physically block pathogens from entering the body. The skin is the most important mechanical barrier. In fact, it is the single most important defense of the body against pathogens. It forms a physical barrier between the body and the outside world. The outer layer of the skin is a tough, nearly water-proof coating that is very difficult for pathogens to penetrate.

At body openings, such as the mouth and nose, the body has a different mechanical barrier. Instead of skin, mucous membranes line these and other organs that are exposed to the outside environment. They include the organs of the respiratory, gastrointestinal, and urinary tracts. Mucous membranes secrete mucus, a slimy substance that coats the membranes and traps pathogens. Mucous membranes also have cilia, which are tiny projections that have wavelike motions. The movements of cilia sweep mucus and trapped pathogens toward body openings to be removed from the body.

Pathogens are removed from the respiratory tract when you sneeze or cough. In addition, tears wash pathogens from the eyes, and urine flushes pathogens out of the urinary tract.

Chemical Barriers

Chemical barriers are proteins that destroy pathogens at the body's surface. The skin and mucous membranes secrete proteins that kill many of the pathogens with which they come into contact. For example, enzymes called lysozymes—which are found in sweat, mucus, tears, and saliva—kill pathogens by breaking open their cell walls. Urine and vaginal secretions are too acidic for many pathogens, and semen contains zinc, which most pathogens cannot tolerate. Hydrochloric acid secreted by mucous membranes lining the stomach kills pathogens that enter the stomach in food or water.

Biological Barriers

Biological barriers involve living organisms that compete with pathogens. Human skin is covered by millions of bacteria. Millions more colonize the gastrointestinal, urinary, and genital tracts. Most of these bacteria are helpful or at least not harmful. They are important in defense because they help prevent harmful bacteria from becoming established in or on the body. They do this by competing with harmful bacterial for food and space. Helpful bacteria may also change pH or other factors and make conditions less suitable for harmful bacteria.

Second Line of Defense

If you have a cut on your hand, the break in the skin provides a way for pathogens to enter your body. Assume bacteria enter through the cut and infect the wound. These bacteria would then encounter the second line of defense.

Inflammatory Response

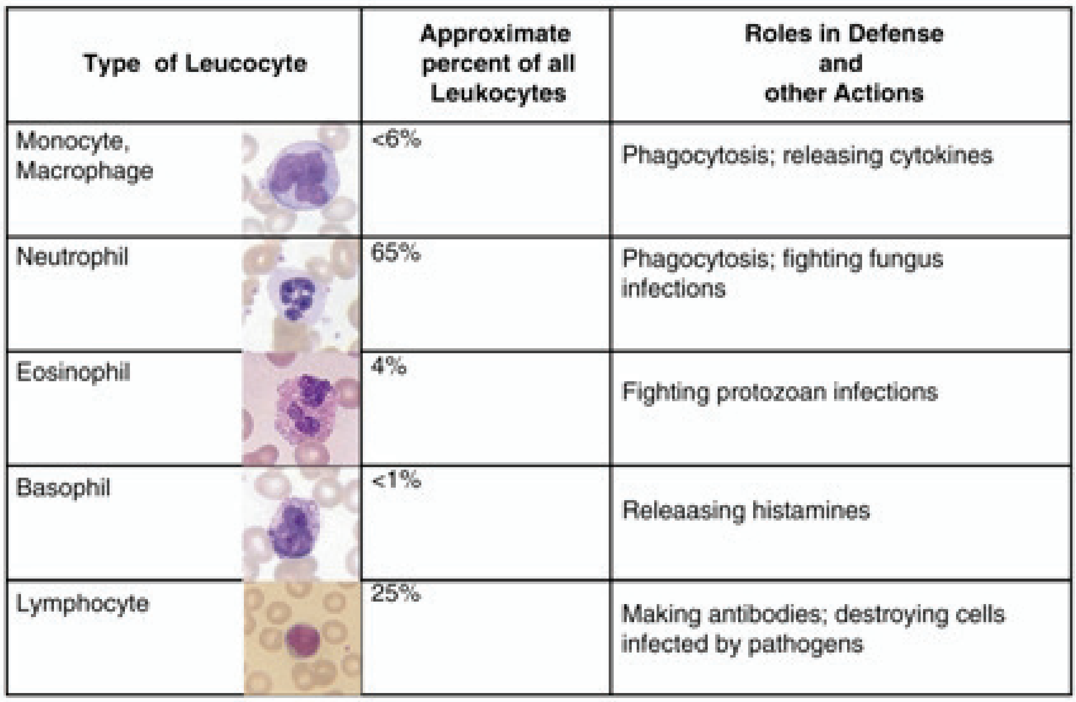
The cut on your hand is likely to become red, warm, swollen, and painful. These are all signs that an inflammatory response has occurred. An inflammatory response is a complex biological reaction to tissue damage. It is one of the first responses of the immune system to infection or injury. Inflammation is triggered by chemicals called cytokines and histamines, which are released when tissues are damaged.

- Cytokines are chemical signals used to communicate between cells.
- Histamines are chemicals that cause inflammation and allergies.

The cytokines and histamines released when tissue is damaged cause many changes in the damaged tissue. The changes help remove the cause of the damage and start the healing process. For example, the chemicals cause local blood vessels to dilate, which increases blood flow to the area. They also cause other changes in blood vessels that allow blood components to leak into the damaged tissue.

White Blood Cells

Another role of cytokines is to attract white blood cells, or leukocytes, to the site of inflammation. Leukocytes are immune system cells that are specialized to fight infections. They are the primary cells of the immune system and found throughout the body. The general function of leukocytes is to identify and eliminate pathogens, debris, and abnormal body cells. **Figure** 24.2 shows several different types of leukocytes. Each type plays a different role in the removal of pathogens and other unwanted substances from the body.



Type of Leucocyte	Approximate percent of all Leukocytes	Roles in Defense and other Actions
Monocyte, Macrophage	<6%	Phagocytosis; releasing cytokines
Neutrophil	65%	Phagocytosis; fighting fungus infections
Eosinophil	4%	Fighting protozoan infections
Basophil	<1%	Releaasing histamines
Lymphocyte	25%	Making antibodies; destroying cells infected by pathogens

Figure 24.2: Types of Leukocytes (3)

Some leukocytes are nonspecific and respond in the same way to most pathogens. Nonspecific leukocytes include monocytes, macrophages, neutrophils, eosinophils, and basophils. These leukocytes are part of the second line of defense. A magnified image of an actual macrophage is shown in **Figure** 24.3.

Figure 24.3: Magnified image of a macrophage. (12)

Monocytes, macrophages, and neutrophils destroy pathogens in the blood and tissues by phagocytosis. Phagocytosis is the process of engulfing and breaking down pathogens and other unwanted substances. Phagocytosis of a pathogen by a macrophage is illustrated in **Figure** 24.4. Once a pathogen has been engulfed, it is broken down within the macrophage. Macrophages are found in tissues, and monocytes and neutrophils are found in the blood.

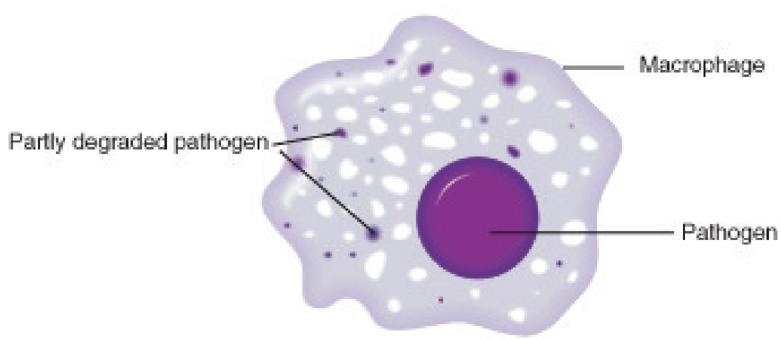


Figure 24.4: Phagocytosis by a macrophage. (2)

Both monocytes and neutrophils migrate through the bloodstream to sites of inflammation.

Neutrophils are the most common leukocytes and usually the first leukocytes to arrive at the scene of infection. Neutrophils and dead pathogens are the main components of pus.

In addition to phagocytosis, both monocytes and phagocytes produce chemicals such as cytokines that cause inflammation and fever. A fever is a higher-than-normal body temperature that may help fight infection. Monocytes or macrophages may also trigger the third line of defense, which you will read about in Lesson 24.2: Immune Response.

Eosinophils and basophils are responsible for allergies, which are discussed in Lesson 24.3: Immune System Diseases. Eosinophils also help fight infections by combating parasites such as protozoa. Basophils release cytokines, histamines, and other chemicals that contribute to inflammation as well as allergies.

Lymphocytes are different from these nonspecific leukocytes. Lymphocytes launch an attack that is tailored to a particular pathogen. For example, some lymphocytes attack only herpes viruses, others only flu viruses. This is called a specific defense. This type of defense is the topic of the next lesson.

Lesson Summary

- Mechanical, chemical, and biological barriers are the body's first line of defense against pathogens.
- The inflammatory response and phagocytosis by white blood cells are major components of the body's second line of defense.

Review Questions

1. Identify two defenses in the body's first line of defense.
2. Describe the process of phagocytosis.
3. How does the inflammatory response help fight infections?
4. Describe the roles of leukocytes in the body's second line of defense.

Further Reading / Supplemental Links

- Farrell, Jeanette, Invisible Enemies: Stories of Infectious Disease. Farrar, Straus and Giroux, 2005.
- http://en.wikibooks.org/wiki/Human_Physiology/The_Immune_System
- http://www.clevelandclinic.org/health/health-info/docs/0200/0217.asp?index=4857
- http://library.thinkquest.org/C0115080/?c=wbc
- http://www.sciencedaily.com/releases/2007/07/070711135623.htm
- http://en.wikipedia.org

Vocabulary

biological barriers Living organisms that compete with pathogens; help prevent harmful bacteria from becoming established in or on the body.

chemical barriers Proteins that destroy pathogens at the body's surface.

cytokines Chemical signals used to communicate between cells.

fever A higher-than-normal body temperature that may help fight infection.

histamines Chemicals that cause inflammation and allergies.

inflammatory response A complex biological reaction to tissue damage; one of the first responses of the immune system to infection or injury; triggered by chemicals called cytokines and histamines.

lysozymes Enzymes that kill pathogens by breaking open their cell walls; found in sweat, mucus, tears, and saliva.

mechanical barriers Physically blocks pathogens from entering the body; the skin is the most important mechanical barrier.

mucus A slimy substance secreted by mucus membranes; coats the membranes and traps pathogens.

nonspecific defenses Defenses that are the same regardless of the type of pathogen; found in the first and second line of defense.

pathogens Disease-causing agents, such as bacteria and viruses.

phagocytosis The process of engulfing and breaking down pathogens and other unwanted substances.

white blood cells Leukocytes; immune system cells that are specialized to fight infections; they identify and eliminate pathogens, debris, and abnormal body cells; leukocytes includes monocytes, macrophages, neutrophils, eosinophils, and basophils.

Points to Consider

The body's first and second lines of defense are the same regardless of the particular pathogen involved. The body's third line of defense is different. It defends the body against specific pathogens.

- Think about how the immune system could identify a particular pathogen.
- Can you develop possible mechanisms for how these pathogens could be destroyed?
- What roles do you think various cell types (such as lymphocytes) play in the specific defenses of the immune system?

24.2 Lesson 24.2: Immune Response

Lesson Objectives

- Describe the lymphatic system and state its general functions in the immune response.
- Explain the role of antigens in the immune response.
- List the steps that occur in a humoral immune response.
- Identify roles of different types of T cells in a cell-mediated immune response.
- Define immunity and distinguish between active and passive immunity.

Introduction

If pathogens manage to get through the body's first two lines of defense, a third line of defense takes over. This third line of defense is often referred to as the immune response. This defense is specific to a particular pathogen, and it allows the immune system to "remember" the pathogen after the infection is over. If the pathogen tries to invade the body again, the immune system can launch a much faster, stronger attack. This lets the immune system destroy the pathogen before it can cause harm. The immune response mainly involves the lymphatic system.

Lymphatic System

The lymphatic system is a major component of the immune system. Because of its important role in the immune system, the terms "immune system" and "lymphatic system" are sometimes used interchangeably. However, as you read in Lesson 24.1, nonspecific defenses of the body include organs such as the skin, which is not part of the lymphatic system. In addition, the lymphatic system has another function not directly related to defense.

Functions of the Lymphatic System

The lymphatic system has three basic functions. The first function is related to digestion. The other functions are involved in the immune response.

1. The lymphatic system absorbs fatty acids after the digestion of lipids in the small intestine. It then transports the fatty acids to the bloodstream, where they circulate throughout the body.
2. The lymphatic system removes excess fluid from body tissues and returns the fluid to the blood. The fluid is filtered as it passes through the lymphatic system, and any pathogens it contains are destroyed before the fluid enters the bloodstream.
3. The lymphatic system produces lymphocytes. Lymphocytes are the type of white blood cells, or leukocytes, primarily involved in the immune response. They recognize and help destroy specific foreign invaders in body fluids and cells.

Parts of the Lymphatic System

The lymphatic system, which is shown in **Figure** 24.5, consists of lymphatic organs, lymphatic vessels, lymph, and lymph nodes. Organs of the lymphatic system include the red bone marrow, thymus, spleen, and tonsils.

- Red bone marrow is found inside many bones, including the hip, breast, and skull bones. It produces leukocytes.
- The thymus is a gland located in the upper chest behind the breast bone. It stores and matures lymphocytes.
- The spleen is a gland in the upper abdomen. It filters blood and destroys worn-out red blood cells. Lymphocytes in the spleen destroy any pathogens filtered out of the blood.
- Tonsils are glands on either side of the pharynx in the throat. They trap pathogens, which are then destroyed by lymphocytes in the tonsils.

Lymphatic vessels make up a body-wide circulatory system, similar to the arteries and veins of the cardiovascular system. However, lymphatic vessels circulate lymph instead of blood. Lymph is fluid that leaks out of tiny blood vessels, called capillaries, into spaces between cells in tissues. At sites of inflammation, there is usually more lymph around cells, and it is likely to contain many pathogens.

Unlike the cardiovascular system, the lymphatic system does not have a pump to force lymph through its vessels. Lymph circulates due to peristalsis of lymphatic vessels and rhythmic contractions of the skeletal muscles that surround the vessels. Valves in the lymphatic vessels prevent lymph from flowing backwards through the system.

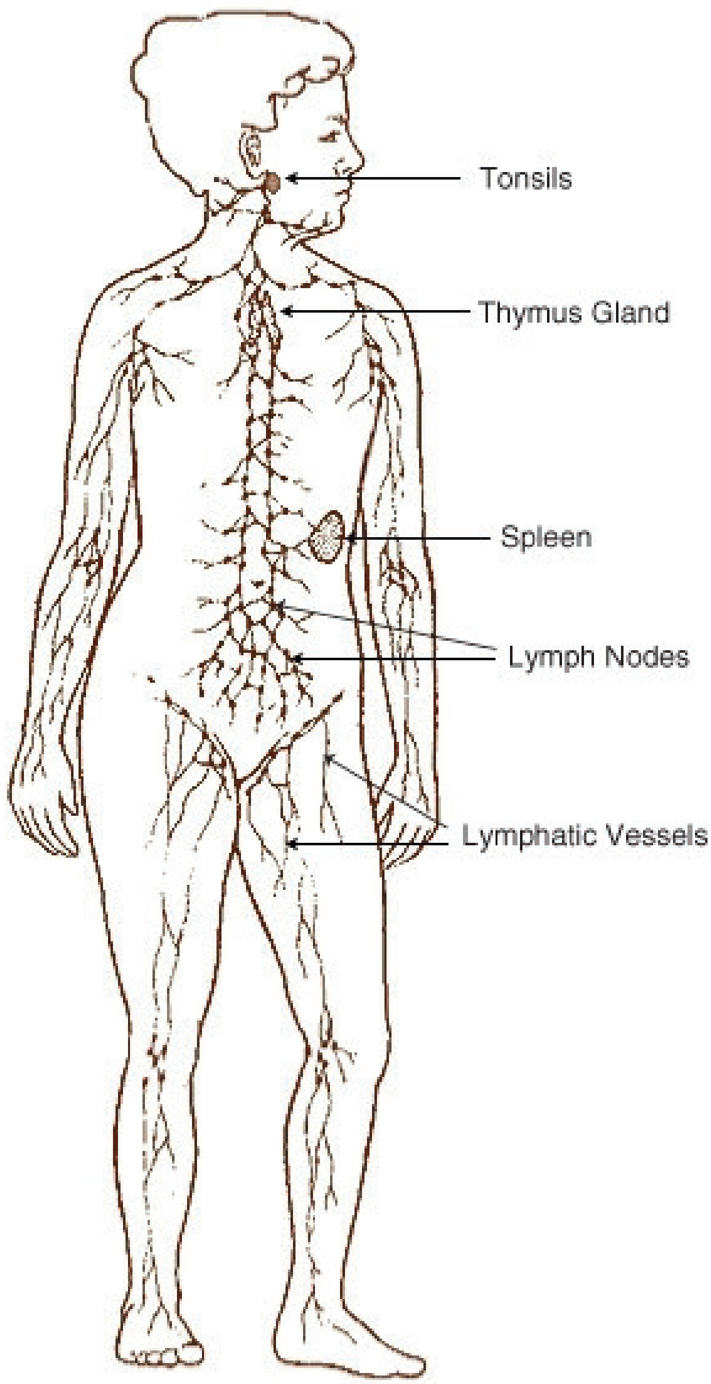


Figure 24.5: Human lymphatic system. (7)

As lymph accumulates between cells, it diffuses into tiny lymphatic vessels. The lymph then moves through the lymphatic system, from smaller to larger vessels, until it reaches the main lymphatic ducts in the chest. Here, the lymph drains into the bloodstream.

Before lymph reaches the bloodstream, pathogens are filtered out of it at lymph nodes. Lymph nodes are small, oval structures located along the lymphatic vessels that act like filters. Any pathogens filtered out of the lymph at lymph nodes are destroyed by lymphocytes in the nodes.

Lymphocytes

Lymphocytes are the key cells involved in the immune response. There are an estimated two trillion lymphocytes in the human body, and they make up about 25 percent of all leukocytes. Usually, fewer than half the body's lymphocytes are found in the blood. The rest are found in the lymphatic system, where they are most likely to encounter pathogens.

The immune response depends on two types of lymphocytes: B lymphocytes, or B cells, and T lymphocytes, or T cells. Both types of lymphocytes are produced in the red bone marrow. The two types are named for the sites where they mature. B cells mature in the red bone marrow, and T cells mature in the thymus. Both B and T cells can recognize and respond to specific pathogens. B or T cells that respond to the body's own molecules as though they were foreign, or "nonself," receive a signal that causes them to die. Only those B and T cells that have shown they are unlikely to react to "self" molecules are released into the circulation.

Antigen Recognition

B and T cells do not actually recognize and respond to pathogens but to the antigens they carry. Antigens are protein molecules that the immune system recognizes as nonself. Any protein that can trigger an immune response because it is foreign to the body is called an antigen. Antigens include proteins on pathogens, cancer cells, and the cells of transplanted organs.

Antigen Receptors

Both B and T cells can "recognize" specific antigens because they have receptor molecules on their surface that bind to particular antigen molecules or pieces of antigen molecules. As shown in **Figure** 24.6, the fit between a receptor molecule and a specific antigen is like a lock and key. Receptors on each B or T cell recognize and bind to just one type of antigen. The human body makes lymphocytes with receptor sites for a huge number of possible antigens that may be encountered throughout a person's life.

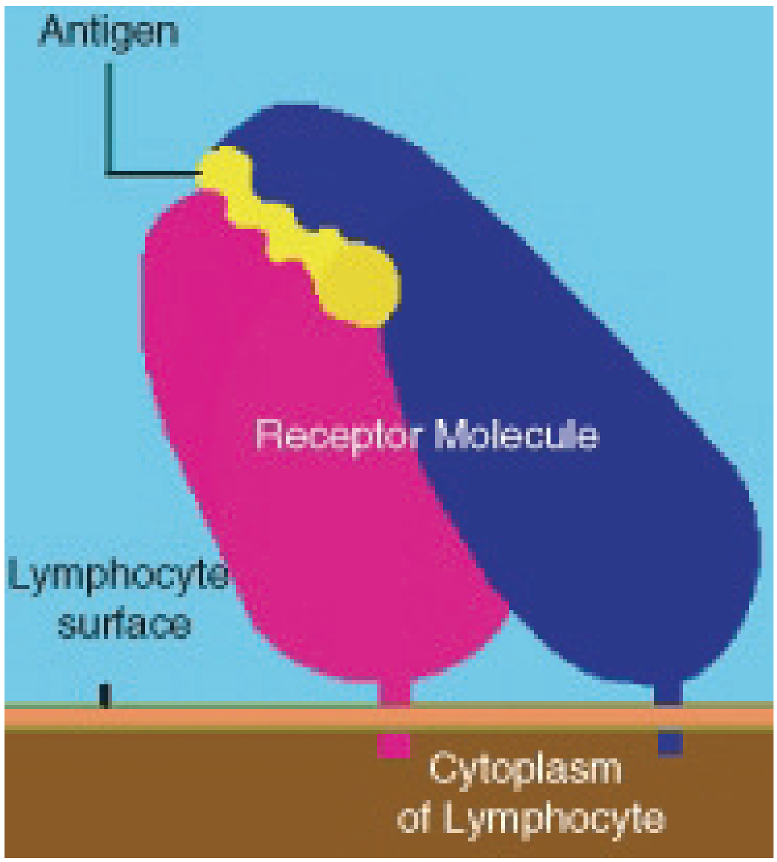


Figure 24.6: A receptor molecule on the surface of a lymphocyte binds to a particular antigen like a lock and key. (15)

Activation of Lymphocytes

Before lymphocytes can function, they must be activated. Activation occurs the first time the cells encounter their specific antigens after leaving the red bone marrow or thymus. Until these circulating B and T cells have been activated, they are called "naïve" cells.

Humoral Immune Response

B cells are responsible for the humoral immune response. The humoral immune response takes place in blood and lymph and involves the production of antibodies. Antibodies are large, Y-shaped proteins called immunoglobulins (Ig) that recognize and bind to antigens. In humans (and other mammals) there are five types of immunoglobulins: IgA, IgD, IgE, IgG, and IgM. Antibodies are produced by activated B cells.

B Cell Activation

Naïve B cells are activated by an antigen in the sequence of events shown in **Figure** 24.7. A B cell encounters its matching antigen and engulfs it. The B cell then displays fragments of the antigen on its surface. This attracts a helper T cell (which you will read about below). The helper T cell binds to the B cell at the antigen site and releases cytokines. As you read in Lesson 24.1, cytokines are chemical signals used to communicate between cells. Cytokines from the helper T cell stimulate the B cell to develop into plasma cells or memory cells.

Plasma Cells and Antibody Production

Plasma cells are activated B cells that secrete antibodies. They are specialized to act like antibody factories. Antibodies produced by plasma cells circulate in the blood and lymph. Each antibody recognizes and binds to a specific antigen, depending on the plasma cell that produced it and other factors. The binding of an antibody to its matching antigen forms an antigen-antibody complex, as shown in **Figure** 24.8. An antigen-antibody complex flags a pathogen or foreign cell for destruction by phagocytosis. The liver removes antigen-antibody complexes from the blood and the spleen removes them from the lymph.

Memory Cells

Whereas most plasma cells live just a few days, memory cells live much longer. They may even survive for the lifetime of the individual. Memory cells are activated B (or T) cells that retain a "memory" of a specific pathogen long after an infection is over. They help launch a rapid response against the pathogen if it invades the body in the future. Memory B cells

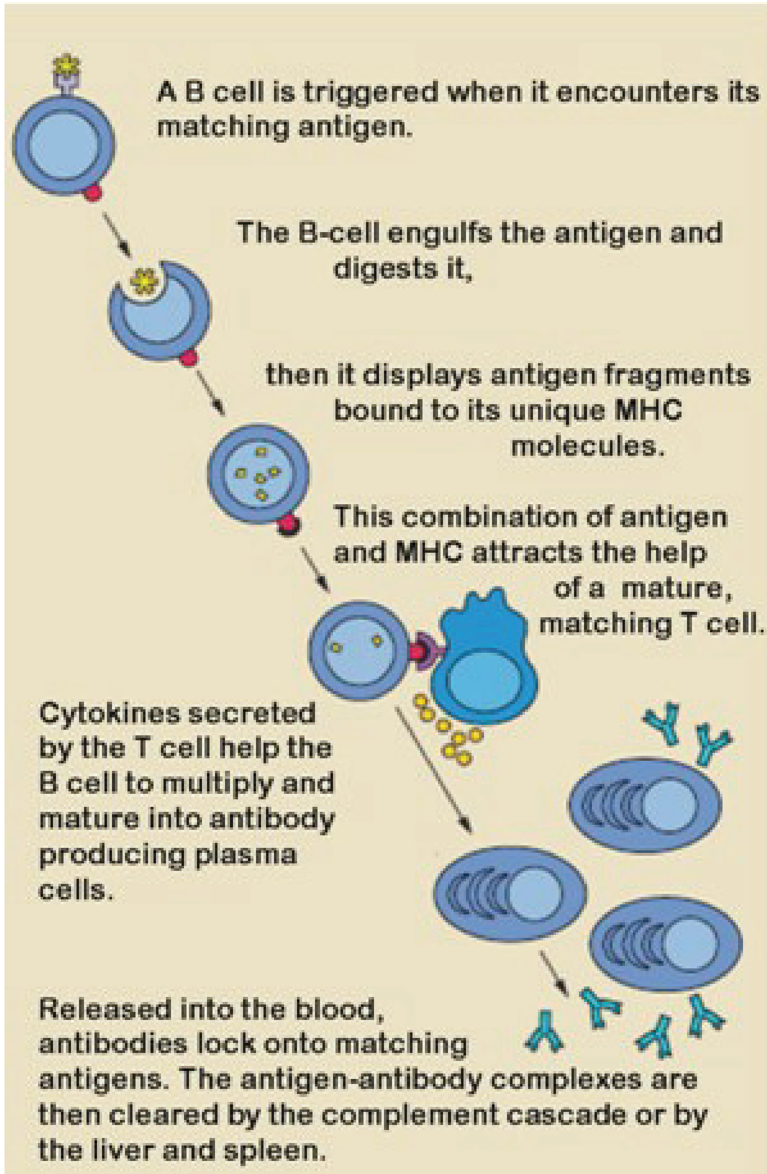


Figure 24.7: After engulfing an antigen, a naïve B cell presents the antigen to a mature T cell. The T cell, in turn, releases cytokines that activate the B cell. Once activated, the B cell can produce antibodies to that particular pathogen. (8)

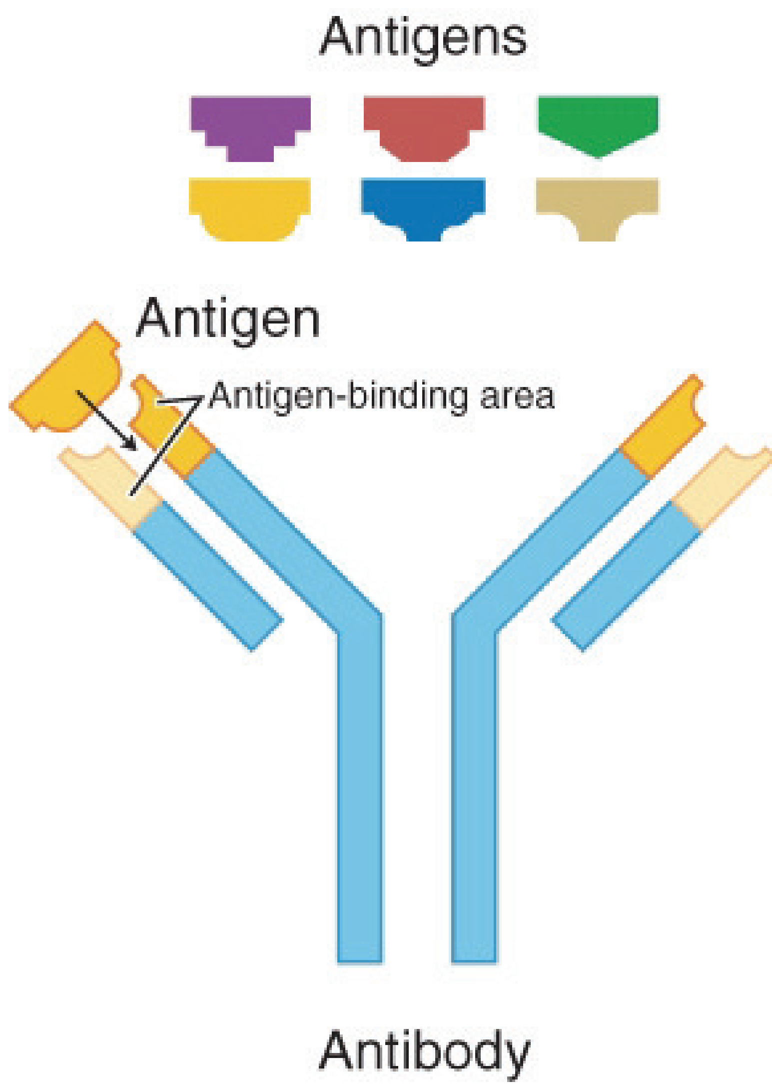


Figure 24.8: An antibody molecule has an area that "fits" one particular antigen. This area is where the antigen binds to the antibody, creating an antigen-antibody complex. (9)

remain in the lymph, ready to produce specific antibodies against the same pathogen if it shows up in body fluids again.

Cell-Mediated Immune Response

There are several different types of T cells, including helper, cytotoxic, memory, and regulatory T cells. T cells are responsible for cell-mediated immunity. Cell-mediated immunity involves the destruction of body cells that are infected with pathogens or have become damaged or cancerous.

T Cell Activation

The different types of naïve T cells are activated in the same general way. The mechanism is shown in **Figure** 24.9. It involves B cells or leukocytes such as macrophages. These other cells engulf pathogens in phagocytosis and display parts of the pathogens' antigens on their surface. The cells are then called antigen-presenting cells. When a naïve T cell encounters one of these cells with an antigen matching its own, it begins the activation process. After T cells are activated, the various types of T cells play different roles in the immune response.

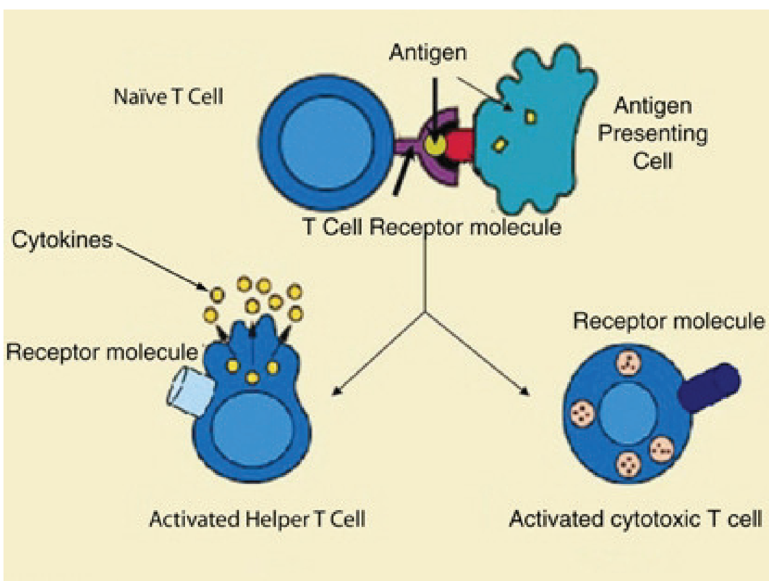


Figure 24.9: A naïve T cell is activated when it encounters a B cell or macrophage that has engulfed a pathogen and presents the pathogen's antigen on its surface. (6)

Helper T Cells

Activated helper T cells do not kill pathogens or destroy infected cells, but they are still necessary for the immune response. In fact, they are considered to be the "managers" of the immune response. After activation, helper T cells divide rapidly and secrete cytokines. These chemical signals control the activity of other lymphocytes. As mentioned above, cytokines from helper T cells activate B cells. They also activate other T cells.

Most activated helper T cells die out once a pathogen has been cleared from the body. However, some helper T cells remain in the lymph as memory cells. These memory cells are ready to produce large numbers of antigen-specific helper T cells if they are exposed to the same antigen again in the future.

Cytotoxic T Cells

Helper cells are needed to activate cytotoxic T cells. Activated cytotoxic T cells destroy tumor cells, damaged cells, and cells infected with viruses. They are also involved in the rejection of transplanted organs. Once activated, a cytotoxic T cell divides rapidly and produces an "army" of cells identical to itself. These cells travel throughout the body "searching" for more cells carrying their specific antigen. Whenever they encounter the cells, they destroy them. Illustrated in **Figure** 24.10 is how a cytotoxic T cell destroys a body cell infected with viruses. The cytotoxic T cell releases toxins that form pores, or holes, in the infected cell's membrane. This causes the cell to burst, destroying both the cell and the viruses inside it.

After cytotoxic T cells bring a viral infection under control, most of the cytotoxic T cells die off. However, some of them remain as memory cells. If the same pathogen tries to infect the body again, the memory cells mount an effective immune response by producing a new army of antigen-specific cytotoxic T cells.

Regulatory T Cells

Regulatory T cells shut down cell-mediated immunity toward the end of an immune response. They also try to suppress any T cells that react against self antigens as though they were foreign. This occurs in automimmune diseases, which you will read about in Lesson 24.3.

Immunity

Memory B and T cells help protect you from re-infection by pathogens that have infected you in the past. Being able to resist a pathogen in this way is called immunity. Immunity can be active or passive.

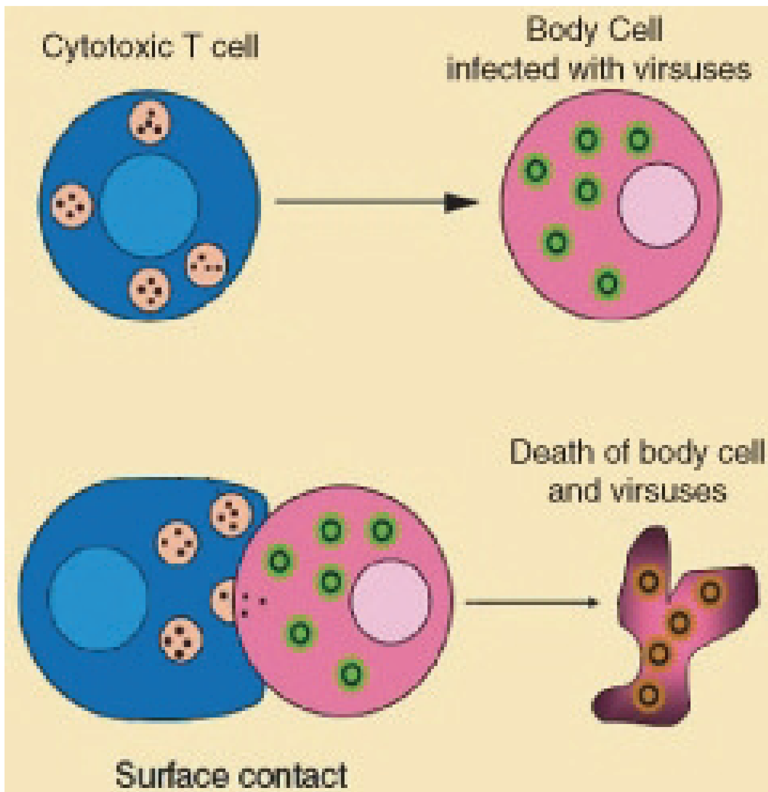


Figure 24.10: A cytotoxic T cell releases toxins that destroy an infected body cell and the viruses it contains. (5)

Active Immunity

Active immunity is immunity that results from a pathogen stimulating an immune response and leaving you with memory cells for the specific pathogen. This happens when a pathogen infects your body and makes you sick. As long as the memory cells survive, the pathogen will be unlikely to re-infect you and make you sick again. In the case of some pathogens, memory cells and active immunity last for the life of the individual.

Active immunity can also occur through immunization. Immunization is deliberate exposure of a person to a pathogen in order to provoke an immune response. The purpose of immunization is to prevent actual infections by the pathogen. The pathogen is typically injected. However, only part of a pathogen, a weakened form of the pathogen, or a dead pathogen is used. This provokes an immune response without making you sick. Diseases you have likely been immunized against include measles, mumps, rubella, whooping cough, and chicken pox.

Passive Immunity

Passive immunity is humoral immunity that results when antibodies to a specific pathogen are transferred to an individual who has never been exposed to the pathogen before. Passive immunity lasts only as long as the antibodies survive in body fluids, generally between a few days and several months.

Passive immunity is acquired by a fetus when it receives antibodies from the mother's blood. It is acquired by an infant when it receives antibodies from the mother's milk. Older children and adults can acquire passive immunity through injection of antibodies into the blood. Injection of antibodies is sometimes used as treatment for a disease, such as measles, when people have not been immunized against the disease.

Lesson Summary

- The lymphatic system is a major component of the immune system. It filters pathogens from lymph and produces lymphocytes, which are the key cells in an immune response.
- Antigens are proteins that the immune system recognizes as foreign to the body. They trigger the activation of lymphocytes.
- Activated B cells produce antibodies against a pathogen's antigens. Long-lasting memory B cells remain in the body to provide immunity to the specific pathogen.
- Activated T cells destroy tumor cells and cells infected with viruses. Memory T cells remain after an infection to provide antigen-specific immunity.
- Immunity is the ability to resist infection by a pathogen. It can occur by having an immune response to a pathogen or receiving antibodies to a pathogen.

Review Questions

1. List three parts of the lymphatic system and their functions.
2. What are antigens and how do lymphocytes "recognize" them?
3. How do plasma cells form and help fight pathogens?
4. Describe how cytotoxic T cells destroy cells infected with viruses.
5. What type of immune response would occur if bacteria invaded your lymph? Explain your answer.
6. Explain how immunization prevents a disease such as measles.
7. If a disease destroyed a person's helper T cells, how might this affect the immune response?
8. Compare and contrast humoral and cell-mediated immune responses.

Further Reading / Supplemental Links

- Panno, Joseph, Ph.D., Immune System. Facts on File, 2008.
- http://en.wikibooks.org/wiki/Human_Physiology/The_Immune_System
- http://www.acm.uiuc.edu/sigbio/project/lymphatic/index.html
- http://www.cancer.gov/cancertopics/understandingcancer/immunesystem
- http://www.howstuffworks.com/immune-system.htm
- http://www.kidshealth.org/parent/general/body_basics/immune.html
- http://www.kidshealth.org/parent/general/body_basics/spleen_lymphatic.html
- http://www.lymphomation.org/lymphatic.htm
- http://www.niaid.nih.gov/final/immun/immun.htm
- http://www.niaid.nih.gov/publications/immune/the_immune_system.pdf
- http://www.sciencedaily.com/releases/2007/08/070802181939.htm
- http://www.thebody.com/content/art1788.html
- http://en.wikipedia.org

Vocabulary

active immunity Immunity that results from a pathogen stimulating an immune response and leaving you with memory cells for the specific pathogen.

antibody Large, Y-shaped proteins called immunoglobulins (Ig) that recognize and bind to antigens; produced by activated B cells. In humans (and other mammals) there are five types of immunoglobulins: IgA, IgD, IgE, IgG, and IgM.

antigen Any protein that can trigger an immune response because it is foreign to the body; includes proteins on pathogens, cancer cells, and the cells of transplanted organs.

antigen receptor A receptor molecule on the surface of a lymphocyte that binds to a particular antigen like a lock and key.

B lymphocytes (B cells) Lymphocytes that are produced in the red bone marrow and mature in the red bone marrow; can recognize and respond to specific pathogens.

cell-mediated immunity Involves the destruction of body cells that are infected with pathogens or have become damaged or cancerous.

cytotoxic T cells Cells that destroy tumor cells, damaged cells, and cells infected with viruses.

helper T cells Considered to be the "managers" of the immune response. After activation, helper T cells divide rapidly and secrete cytokines. These chemical signals control the activity of other lymphocytes.

immunity Protection from re-infection by pathogens that have infected you in the past.

immune response The third line of defense; specific to a particular pathogen.

immunization The deliberate exposure of a person to a pathogen in order to provoke an immune response.

lymph Fluid that leaks out of tiny blood vessels, called capillaries, into spaces between cells in tissues.

lymph nodes Small, oval structures located along the lymphatic vessels that act like filters; pathogens filtered out of the lymph at lymph nodes are destroyed by lymphocytes in the nodes.

lymphatic system System that makes lymphocytes; consists of lymphatic organs, lymphatic vessels, lymph, and lymph nodes. Organs of the lymphatic system include the red bone marrow, thymus, spleen, and tonsils.

lymphatic vessels Form a body-wide circulatory system, similar to the arteries and veins of the cardiovascular system; circulate lymph instead of blood.

lymphocytes Type of white blood cells, or leukocytes, primarily involved in the immune response; recognize and help destroy specific foreign invaders in body fluids and cells.

memory cells Memory cells are activated B (or T) cells that retain a "memory" of a specific pathogen long after an infection is over; help launch a rapid response against the pathogen if it invades the body in the future.

passive immunity A humoral immunity that results when antibodies to a specific pathogen are transferred to an individual who has never been exposed to the pathogen before.

phagocytosis The process of engulfing and breaking down pathogens and other unwanted substances.

plasma cells Activated B cells that secrete antibodies.

red bone marrow Found inside many bones, including the hip, breast, and skull bones; produces leukocytes.

regulatory T cells T cells that shut down cell-mediated immunity toward the end of an immune response; also try to suppress any T cells that react against self antigens as though they were foreign.

spleen A gland in the upper abdomen; filters blood and destroys worn-out red blood cells. Lymphocytes in the spleen destroy any pathogens filtered out of the blood.

T lymphocytes (T cells) Lymphocytes that are produced in the red bone marrow and mature in the thymus; can recognize and respond to specific pathogens; includes helper, cytotoxic, memory, and regulatory T cells.

thymus A gland located in the upper chest behind the breast bone; stores and matures lymphocytes.

tonsils Glands on either side of the pharynx in the throat; traps pathogens, which are then destroyed by lymphocytes in the tonsils.

Points to Consider

- Sometimes the immune system makes mistakes and things go wrong. What if the immune system responded to a harmless allergen as though it were a deadly pathogen?
- What if the immune system responded to normal body cells as though they were foreign invaders?
- What if pathogens attacked and destroyed cells of the immune system itself? Would it still be able to function?

24.3 Lesson 24.3: Immune System Diseases

Lesson Objectives

- Explain how allergies occur and list common allergens.
- Describe how autoimmune diseases affect the body.
- Define immunodeficiency and identify ways it can be acquired.
- Explain how HIV is transmitted and how it causes AIDS.

Introduction

The immune system usually protects you from pathogens and keeps you well. However, like any other body system, the immune system can malfunction or become diseased. Sometimes the immune system responds to harmless foreign substances as though they were pathogens. Sometimes it mistakes self for nonself and launches an attack against the body's own cells. Certain diseases can also attack and damage the immune system so it loses the ability to defend the body.

Allergies

An allergy is a disease in which the immune system makes an inflammatory response to a harmless antigen. Any antigen that causes an allergic reaction is called an allergen. You can be exposed to allergens by inhaling or ingesting them or by having direct skin contact with them.

Allergies can vary greatly from person to person. Some people are allergic to many allergens, others to few or none. A tendency to develop allergies can be inherited, so if your mom or dad has allergies, you are more likely to have them as well. Allergy symptoms may be mild or severe. They may develop immediately after exposure to an allergen or not until several days after exposure.

Severity of Allergies

Allergy symptoms are caused by the release of histamines, the chemicals that also stimulate inflammation. The symptoms range from scarcely noticeable to potentially fatal. Typical symptoms of mild allergies include itchy eyes, sneezing, and skin rashes. These symptoms may be uncomfortable, but they are not life threatening. Mild allergy symptoms are often treated with antihistamines. Antihistamines are drugs that reduce or eliminate the effects of histamines.

Immunotherapy, commonly called "allergy shots," is sometimes recommended for more severe allergies. A person with an allergy is injected with larger and larger amounts of the offending allergen over a period of months or years. This gradually desensitizes the person's immune system to the allergen. Rather than just treating the symptoms of the allergy, immunotherapy reduces the severity of the allergy or eliminates the allergy altogether.

The most severe allergic reaction is anaphylaxis. Anaphylaxis is an allergic response in which there is a sudden, massive release of histamines throughout the body. This causes collapse of the circulatory system and severe constriction of the breathing passages. Without emergency treatment, anaphylaxis is likely to be fatal. Treatment is usually injection of epinephrine. Epinephrine is the "fight-or-flight" hormone that your adrenal glands normally produce when you are in danger. The hormone suppresses non-emergency body processes, including the immune response.

Immediate Hypersensitivity Reaction

When exposure to an antigen causes immediate allergy symptoms, the response is called an immediate hypersensitivity reaction. This is a humoral immune response. Examples of allergens that cause this type of reaction include pollens, bee stings, and peanuts. Anaphylaxis may occur if the allergy is severe.

Allergic rhinitis is a common immediate hypersensitivity reaction. It affects mainly mucous membranes lining the nose. Typical symptoms include runny nose and nasal congestion. Pollens are the most common cause of allergic rhinitis. Tiny pollens of wind-pollinated plants like ragweed (**Figure** 24.11) are the usual culprits. Other causes of allergic rhinitis include mold, animal dander, and dust. Allergic rhinitis may occur seasonally or year-round, depending on its cause.

Allergic rhinitis is often called hay fever, although pollen—not hay—is the most likely cause. It is called hay fever because it is most common during the time of year when hay is cut. This is also the time of year when plant pollens are most concentrated in outdoor air.

Delayed Hypersensitivity Reaction

When an antigen causes allergy symptoms hours or days after exposure, the response is called a delayed hypersensitivity reaction. This is a cell-mediated immune response. Examples of allergens that cause delayed hypersensitivity reactions include poison ivy, poison oak, and poison sumac. If you have skin contact with these plants and are allergic to them, a rash, like the one in **Figure** 24.12, may develop.

Figure 24.11: Ragweed, a common cause of allergic rhinitis. (11)

Figure 24.12: Allergic rash caused by contact with poison ivy. (4)

Autoimmune Diseases

Autoimmune diseases occur when the immune system fails to recognize the body's own molecules as self and attacks the body's cells as though they were foreign invaders. Relatively common autoimmune diseases include rheumatoid arthritis, type 1 diabetes mellitus, multiple sclerosis, and systemic lupus erythematosus (**Table** 24.1). These four diseases are described in the table below. They are currently incurable, but treatment can help relieve the symptoms and prevent some of the long-term damage.

Table 24.1: **Common Autoimmune Diseases**

Autoimmune Disease	Object of Immune Attack	Results of Immune Attack	Treatment(s)
Rheumatoid arthritis	Tissues inside joints	Inflammation of joints, causing joint pain and damage and possible loss of mobility	Anti-inflammatory drugs; drugs that suppress the immune system
Type 1 diabetes	Insulin-producing cells of the pancreas	Loss of ability to produce insulin, causing too much sugar in the blood and tissue and organ damage	Insulin injections

Table 24.1: (continued)

Autoimmune Disease	Object of Immune Attack	Results of Immune Attack	Treatment(s)
Multiple sclerosis	Myelin in the brain and spinal cord	Loss of nerve function, causing muscle weakness, fatigue, visual problems, pain, and other symptoms	Corticosteroid drugs; hormones that control the immune system
Systemic lupus erythematosus	Joints, heart, lungs, or other organs	Inflammation of joints or organs, causing serious joint or organ damage and pain	Corticosteroid drugs; drugs that suppress the immune system

The causes of autoimmune diseases are not known for certain. One way autoimmunity may develop is through "molecular mimicry." This occurs when a person is infected with pathogens bearing antigens similar to the person's own molecules. When the immune system mounts an attack against the pathogens, it also attacks body cells with the similar molecules. Some people inherit genes that increase their risk for an autoimmune disease. Female sex hormones may also increase the risk. This may explain why autoimmune diseases are more common in females than males and why they usually begin after puberty.

Immunodeficiency Diseases

Immunodeficiency occurs when one or more components of the immune system are not working normally. As a result, the ability of the immune system to respond to pathogens and other threats is decreased. A person with immunodeficiency may suffer from frequent, life-threatening infections. In other words, an individual with a compromised immune system (for example, a person with AIDS) may be unable to fight off and survive infections by microorganisms that are usually benign. Immunodeficiency can be present at birth or acquired after birth.

Congenital Immunodeficiency

Congenital immunodeficiency is present at birth and usually caused by a genetic disorder. Such disorders are relatively rare. For example, thymic aplasia—a genetic disorder characterized by an absent or abnormal thymus—occurs in about 1 out of 4,000 births. People with thymic aplasia are unable to produce normal T cells. They have frequent infections and increased risk of autoimmune diseases.

Acquired Immunodeficiency

Acquired immunodeficiency occurs when immune function declines in a person who was born with a normal immune system. There are many possible causes for declining immune function. Age is one cause. The immune system naturally becomes less effective as we get older, starting in middle adulthood. This helps explain why older people are more susceptible to disease. Other possible causes of declining immune function include obesity, alcoholism, and illegal drug abuse. In developing countries, malnutrition is a common cause.

Many medications can interfere with normal immune function and cause immunodeficiency. Immune suppressive drugs are deliberately given to people with autoimmune diseases and transplanted organs. Many other drugs have immune suppression as a side effect. Chemotherapy drugs for cancer are especially likely to suppress the immune system.

Several kinds of cancer attack cells of the immune system and cause immunodeficiency. For example, in chronic lymphatic leukemia, abnormal B cells that can't fight infection grow out of control and crowd out healthy B cells. Certain pathogens can also attack cells of the immune system. In fact, the virus known as HIV is the most common cause of immunodeficiency in the world today.

HIV and AIDS

HIV, or human immunodeficiency virus, is the virus that causes AIDS. AIDS stands for acquired immune deficiency syndrome. It is a late stage in the progression of an HIV infection.

HIV Transmission

HIV is transmitted, or spread, through direct contact of mucous membranes or the bloodstream with a body fluid containing HIV. Body fluids that can contain HIV include blood, semen, vaginal fluid, preseminal fluid, and breast milk. Transmission of the virus can occur through sexual contact or use of contaminated hypodermic needles. HIV can also be transmitted through a mother's blood to her baby during late pregnancy or birth or through breast milk after birth. In the past, HIV was transmitted through blood transfusions. Because donated blood is now screened for HIV, the virus is no longer transmitted this way.

HIV and the Immune System

HIV destroys helper T cells. Recall that helper T cells are needed for normal humoral and cell-mediated immunity. When HIV enters a person's bloodstream, proteins on the coat of the virus allow it to fuse with the host's helper T cells. The virus injects its own DNA into the host's helper T cells and uses the T cells' "machinery" to make copies of itself. The copies of the virus bud off from the host's cells, destroying the cells in the process. Copies of the virus go on to infect other helper T cells throughout the body.

During the first several weeks after HIV infection, the immune system tries to fight off the virus. As shown in **Figure** 24.13, the initial immune response temporarily reduces the number of virus copies in the blood. However, the immune system is unable to destroy the virus, and it continues to multiply in the lymphatic system. How is HIV able to evade the immune system? There are at least two ways:

- The virus undergoes frequent mutations that keep changing the antigens on its coat. This prevents antigen-specific lymphocytes from developing that could destroy the virus.
- The virus uses the host's cell membranes to form is own coat. This covers up viral antigens so they cannot be detected by the host's immune system.

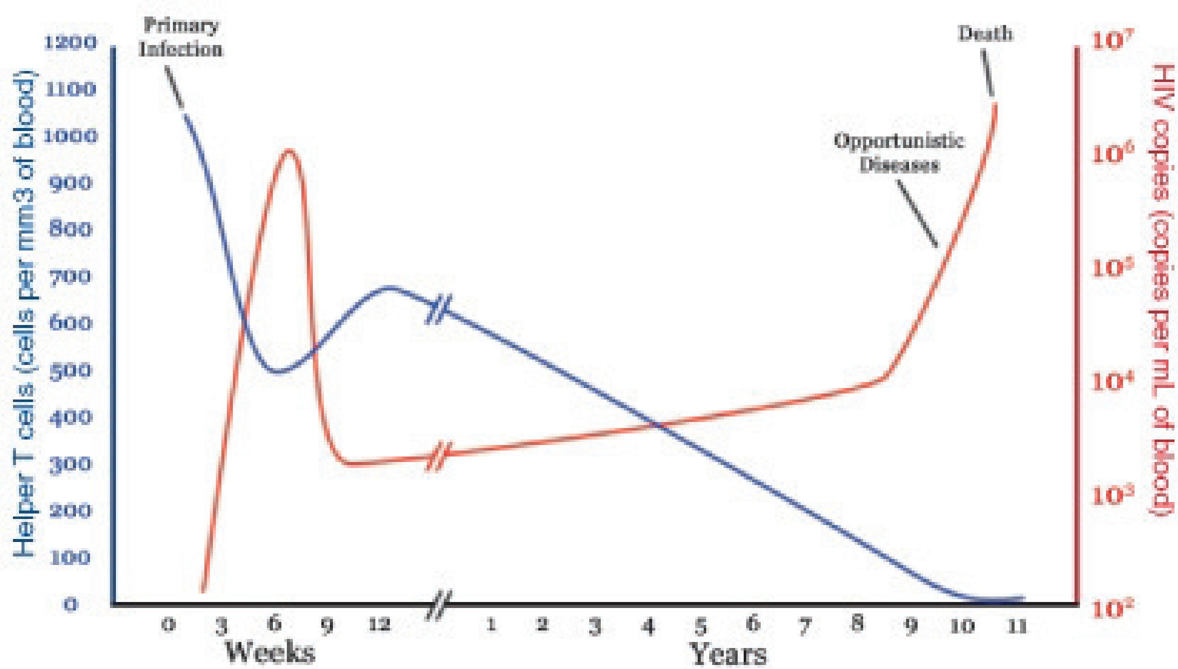


Figure 24.13: Average numbers of helper T cells and HIV copies in untreated HIV infections. (14)

Over the next several years, helper T cells continuously decline in the blood, while copies of the virus keep increasing. As the number of helper T cells declines, so does the ability of the immune system to make an immune response. The HIV-infected person starts showing symptoms of a failing immune system, such as frequent infections.

Treatment with antiviral medications can slow down the increase in virus copies, although they do not eliminate the virus altogether. The medications usually lengthen the time between infection with HIV and the development of symptoms. However, currently there is no cure for HIV infection or AIDS and no vaccine to prevent infection, although this is a field of intense study by biomedical scientists.

AIDS

AIDS is not a single disease but a collection of symptoms and diseases. It is the result of years of damage to the immune system by HIV. AIDS is diagnosed when helper T cells fall to a very low level and the infected person develops one or more opportunistic diseases.

Opportunistic diseases are infections and tumors that are rare in people with a healthy immune system but common in immunodeficient people. Opportunistic diseases include pneumocystis pneumonia and Kaposi's sarcoma, a type of cancer. The diseases are called opportunistic because they take advantage of the "opportunity" to infect a person with a damaged immune system that can't fight back. Opportunistic diseases are often the direct cause of death of people with AIDS.

AIDS was first identified in 1981. Since then it has killed more than 25 million people worldwide, many of them children. The hardest hit region is sub-Saharan Africa, where antiviral medications are least available. The worldwide economic toll of AIDS is also enormous.

Lesson Summary

- Allergies occur when the immune system makes an inflammatory response to a harmless antigen, called an allergen.
- Autoimmune diseases occur when the immune system fails to distinguish self from nonself and attacks the body's own cells.
- In an immunodeficiency disease, the immune system does not work normally and cannot defend the body.
- HIV is a virus that attacks cells of the immune system and eventually causes AIDS. It is the chief cause of immunodeficiency in the world today.

Review Questions

1. Describe anaphylaxis.
2. What is an autoimmune disease?
3. List three possible causes of acquired immunodeficiency.
4. Name two ways HIV can be transmitted.
5. Assume that you touch poison sumac and still have not developed a rash 12 hours later. Can you safely assume you are not allergic to the plant? Why or why not?

6. Rheumatic fever is caused by a virus that has antigens similar to molecules in human heart tissues. When the immune system attacks the virus, it also attacks the heart. What type of immune system disease is rheumatic fever? Explain your answer.
7. Draw a timeline to show the progression of an untreated HIV infection. Show how the numbers of HIV copies and helper T cells change through time.
8. Why are opportunistic infections a sign of immunodeficiency?

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Vocabulary

acquired immunodeficiency Immunodeficiency that occurs when immune function declines in a person who was born with a normal immune system.

AIDS Acquired immune deficiency syndrome; a late stage in the progression of an HIV infection.

allergen Any antigen that causes an allergic reaction.

allergic rhinitis A common immediate hypersensitivity reaction; affects mainly mucous membranes lining the nose; often called hay fever.

allergy A disease in which the immune system makes an inflammatory response to a harmless antigen.

anaphylaxis An allergic response in which there is a sudden, massive release of histamines throughout the body. This causes collapse of the circulatory system and severe constriction of the breathing passages. Without emergency treatment, anaphylaxis is likely to be fatal.

antihistamines Drugs that reduce or eliminate the effects of histamines.

autoimmune diseases Diseases that occur when the immune system fails to recognize the body's own molecules as self and attacks the body's cells as though they were foreign invaders.

delayed hypersensitivity reaction When an antigen causes allergy symptoms hours or days after exposure.

epinephrine The "fight-or-flight" hormone that your adrenal glands normally produce when you are in danger; suppresses non-emergency body processes, including the immune response.

HIV The human immunodeficiency virus, the virus that causes AIDS.

immediate hypersensitivity reaction When exposure to an antigen causes immediate allergy symptoms.

immunodeficiency Occurs when one or more components of the immune system are not working normally; as a result, the ability of the immune system to respond to pathogens and other threats is decreased.

molecular mimicry Occurs when a person is infected with pathogens bearing antigens similar to the person's own molecules; when the immune system mounts an attack against the pathogens, it also attacks body cells with the similar.

opportunistic diseases Infections and tumors that are rare in people with a healthy immune system but common in immunodeficient people; includes pneumocystis pneumonia and Kaposi's sarcoma, a type of cancer.

Points to Consider

You read in this lesson that some types of cancer attack cells of the immune system and cause immunodeficiency. Cancer has previously been described as resulting from a loss of regulation of the cell cycle.

- Why do you think immunodeficiency may lead to some cancers?
- Can you think of a relationship between pathogens, the immune system, and the development of cancer?

24.4 Lesson 24.4: Environmental Problems and Human Health

Lesson Objectives

- Explain how carcinogens cause cancer and list ways that cancer can be treated or prevented.
- Identify causes of air pollution and describe how air pollution affects human health.
- Define bioterrorism and explain how bioterrorism threatens human health.

Introduction

Cancer is one of many human diseases that can be caused by environmental problems. For example, air pollution may increase the risk of lung cancer. It can also cause or worsen asthma, cardiovascular diseases, and other health problems. Bioterrorism is another potential threat to human health. It may lead to severe environmental problems that have the potential to poison large numbers of people or cause epidemics of deadly diseases.

Carcinogens and Cancer

A carcinogen is anything that can cause cancer. Cancer is a disease in which abnormal body cells divide of control. Most carcinogens cause cancer by inducing mutations.

Carcinogens

Carcinogens may be pathogens, chemical substances, or radiation. Carcinogens often occur in nature. For example, some viruses are important carcinogens, causing as many as 15 percent of all human cancers. Different viruses cause different cancers. The human papilloma virus (HPV) is the main cause of cancer of the cervix in females. The hepatitis B virus can cause liver cancer, and the Epstein-Barr virus can cause cancer of the lymph nodes.

Other natural carcinogens include ultraviolet (UV) radiation from the sun. UV radiation is the leading cause of skin cancer. Radon is a natural radioactive gas that seeps into buildings from the ground. Exposure to radon can cause lung cancer. Asbestos can also cause lung cancer. Asbestos is a mineral previously used for insulation and many other purposes. Today, it is largely banned because of its link to cancer.

Humans are exposed to many artificial carcinogens in the environment, including those in tobacco smoke. In fact, tobacco smoke may be the key source of human carcinogen exposure. It contains dozens of carcinogens including nicotine and formaldehyde, which is used to preserve dead bodies. As you will read below, other pollutants in the air can cause cancer as well.

Other artificial carcinogens are or were found in foods. Some food additives, such as certain food dyes, have proven to be carcinogens. Cooking foods at very high temperatures also causes carcinogens to form. For example, a carcinogen called acrylamide forms when carbohydrates are cooked at very high temperatures. It is found in foods such as French fries and potato chips. Barbecued or broiled meats also contain several carcinogens.

How Cancer Occurs

Carcinogens generally cause cancer by inducing mutations in genes that control cell division or other aspects of the cell cycle. The mutations typically occur in two types of genes: tumor-suppressor genes and proto-oncogenes (see chapter titled *Molecular Genetics*). Briefly:

- Tumor-suppressor genes are genes that normally repair damaged DNA or prevent cells with badly damaged DNA from dividing (**Figure A** 24.14). If mutations occur in these genes, they may no longer be able to prevent cells with damaged DNA from dividing (**Figure B** 24.14).
- Proto-oncogenes are genes that normally help regulate cell division. Mutations can turn them into oncogenes. Oncogenes are abnormal genes that stimulate the division of cells with damaged DNA.

Cells that divide uncontrollably form a tumor. A tumor is an abnormal mass of tissue. Tumors may be benign or malignant. Benign tumors remain localized and generally do not harm health. Malignant tumors are cancer. There are no limits on their growth, so they can invade and damage neighboring tissues. Cells from malignant tumors can also break away from the tumor, enter the circulation, and start growing in another part of the body. This is called metastasis.

Types of Cancer

Cancer is usually classified according to the type of tissue where the cancer begins. Common types of cancer include:

- **Carcinoma**: tumor of epithelial tissues, such as lung tissue.
- **Sarcoma**: tumor of connective tissues, such as bone.
- **Lymphoma**: tumor of lymphatic cells, such as T cells.

Specific cancers are generally named for the organs where the cancers begin. Relatively common cancers include lung, prostate, bladder, and breast cancers. These and several

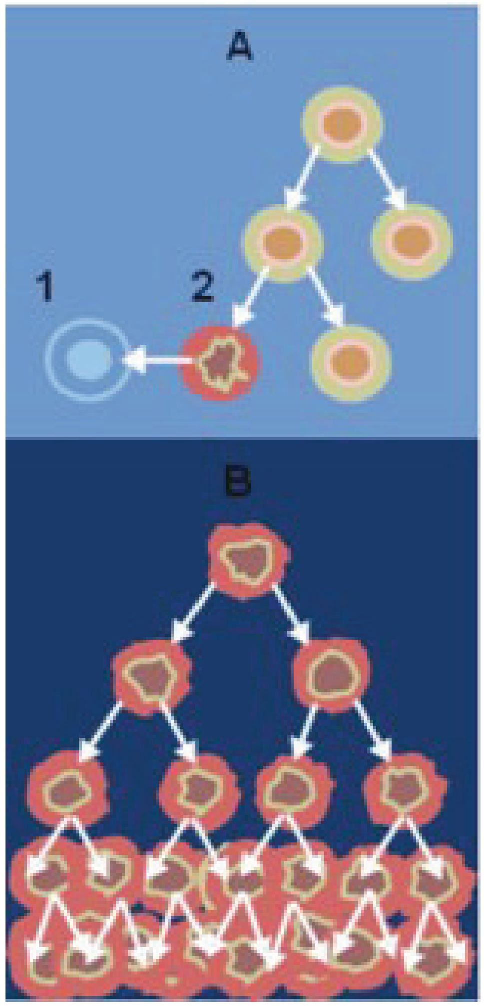

Figure 24.14: A cell with damaged DNA normally is not allowed to divide, so the damage is not passed on to other cells. **Figure B:** If a cell with damaged DNA is allowed to divide, it results in many more damaged cells. (10)

other cancers are listed in the **Table** 24.2. The figure shows which cancers are most common and which cause the most deaths in U.S. adults.

Table 24.2: **Common Cancers among Adult Males and Females in the United States**

Adult Males		Adult Females	
Most Common Cancers (percent of all cancers)	Most Common Causes of Cancer Deaths (percent of all cancer deaths)	Most Common Cancers (percent of all cancers)	Most Common Causes of Cancer Deaths (percent of all cancer deaths)
Prostate cancer(33%)	Lung cancer(31%)	Breast cancer(32%)	Lung cancer(27%)
Lung cancer(13%)	Prostate cancer(10%)	Lung cancer(12%)	Breast cancer(15%)
Colorectal cancer(10%)	Colorectal cancer(10%)	Colorectal cancer(11%)	Colorectal cancer(10%)
Bladder cancer(7%)	Pancreatic cancer(5%)	Endometrial cancer(6%)	Ovarian cancer(6%)

(*Source:* http://en.wikipedia.org/wiki/Cancer, *License:* Creative Commons)

Cancer can also occur in children and teens, but it is rare. Most childhood cancers occur during the first year of life. The most common type of infant cancer is leukemia. It makes up about 30 percent of cancers at this age. With prompt treatment, there is a good chance that an infant with cancer will survive.

Cancer Treatment and Prevention

Most cancers can be treated and some can be cured. The general goal of treatment is to remove the tumor without damaging the rest of the body. Cancer may be treated with a combination of surgery, chemotherapy, and/or radiation. In the past, chemotherapy drugs caused serious side effects. Many of today's chemotherapy drugs target specific molecules in tumors. This reduces damage to normal body cells and causes fewer side effects.

The outcome of cancer treatment depends on factors such as the type of cancer and its stage. The stage of cancer refers to the extent to which the cancer has developed. Generally, early diagnosis and treatment lead to the best chances of survival. That's why it's important for people to be aware of the following warning signs of cancer:

- A change in bowel or bladder habits
- A sore that does not heal
- Unusual bleeding or discharge from any place
- A lump in the breast or other parts of the body
- Chronic indigestion or difficulty in swallowing

- Obvious changes in a wart or mole
- Persistent coughing or hoarseness

Having warning signs of cancer does not mean that you have cancer, but you should see a doctor to be sure. Getting recommended tests for particular cancers, such as colonoscopies for colon cancer, can also help detect cancers early, when chances of a cure are greatest.

Many cancers can be prevented, or at least their risk can be reduced. You can help reduce your risk of cancer by avoiding specific carcinogens and maintaining a healthy lifestyle. Carcinogens you can avoid or limit your exposure to include tobacco smoke, sexually transmitted viruses, improperly cooked foods, and UV radiation. Other lifestyle choices you can make to reduce your risk of cancer include being physically active, eating a low-fat diet, and maintaining a normal weight.

Air Pollution and Illness

An estimated 4.6 million people die each year because of air pollution. Worldwide, air pollution causes more deaths than traffic accidents do. Air pollution harms the respiratory and cardiovascular systems. Both outdoor and indoor air can be polluted and contribute to illness and death.

Outdoor Air Pollution

The concentration of pollutants in outdoor air is indicated by the Air Quality Index. The Air Quality Index (AQI) is a measure of certain pollutants in the air in a given location. The health risks associated with different values of the AQI are shown in the **Table** 24.3 . When the AQI is high, you should limit the time you spend outdoors, especially the time you spend exercising. Avoiding exposure to air pollution can help limit its impact on your health. As you can see from **Table** 24.3, people with certain health problems, including asthma, need to be even more careful about limiting their exposure to air pollution.

Table 24.3: **Air Quality and Health Risk**

Air Quality Index(AQI)	Quality of Air in Terms of Human Health
0–50	Good
51–100	Moderate
101–150	Unhealthy for sensitive groups[1]
151–200	Unhealthy for everyone
201–300	Very unhealthy
301–500	Hazardous

[1] Sensitive groups include people with asthma, heart disease, or other diseases worsened by air pollution.

(*Source:* http://en.wikipedia.org/wiki/Air_Quality_Index, *License:* Creative Commons)

AQI reports to the public generally refer to levels of ground-level ozone and particulates. Ozone is a gas that forms close to the ground when high concentrations of air pollutants are heated by sunlight. Ozone damages both respiratory and cardiovascular systems. For example, it can cause asthma and decrease lung function. It can also convert cholesterol in arteries to plaque, causing cardiovascular disease. In addition, ozone may increase inflammation, which is a symptom of many diseases.

Particulates are tiny particles of solids or liquids suspended in the air. The most concentrated particulate pollution tends to be in the air over densely populated metropolitan areas in developing countries. The primary cause is the burning of fossil fuels by motor vehicles and factories. Particulates settle in airways and lungs and damage the respiratory tract. They can cause asthma and lung cancer. Extremely small particulates may pass through the lungs to the bloodstream and contribute to plaque formation in arteries.

Indoor Air Pollution

Indoor air quality refers to pollutants in the air inside buildings. Indoor air may be more polluted than outdoor air, although with different pollutants. Typical pollutants in indoor air include allergens, mold, bacteria, carbon monoxide, and radon.

Mold and bacteria can be allergens and also cause respiratory system infections. For example, a type of pneumonia, known as Legionnaire's disease, is caused by bacteria that can spread through air conditioning systems. The disease is not common, but it kills many of the people who contract it.

Carbon monoxide is a gas produced by cars, furnaces, and other devices that burn fuel. It replaces oxygen in the blood and quickly leads to death. Initial symptoms of carbon monoxide poisoning include headache, listlessness, and other flu-like symptoms. Loss of consciousness and death can occur within hours. An estimated 40,000 Americans annually seek medical attention for carbon monoxide poisoning. It is also the most common type of fatal poisoning in the U.S. Carbon monoxide is colorless and odorless, but it can be detected with carbon monoxide detectors like the one in **Figure** 24.15.

Sick building syndrome (SBS) is a combination of symptoms associated with working in a particular building, typically an office building. It is most common in new and remodeled buildings. It is usually caused by inadequate ventilation. Chemicals released by new building materials may also contribute to the poor air quality. Generally, conditions improve by increasing ventilation. Symptoms of SBS vary widely. They may include headaches, eye irritation, dry cough, dizziness, and asthma.

Figure 24.15: Home carbon monoxide detector (13)

Bioterrorism

Bioterrorism is terrorism by intentional release or spread of pathogens. As shown in **Tables** 24.4, 24.5, and 24.6, pathogens used in bioterrorism may include bacteria, viruses, or toxins. Toxins are poisons produced by organisms such as bacteria. The agents may be naturally occurring pathogens or pathogens that have been modified by humans to make them more effective agents of bioterrorism. The agents can spread in a variety of ways, including through air, food, water, direct contact, or cuts in the skin. They have the potential to cause epidemics of deadly human diseases.

Table 24.4: **Classification of Category A Bioterrorism Agents Based Upon Threat to Public Health**

Agent	Type of Pathogen	Mode of Transmission
Anthrax	Bacteria	Air, food, cuts in skin
Smallpox	Virus	Air, direct contact
Botulinum	Toxin	Food, cuts in skin

Table 24.5: **Classification of Category B Bioterrorism Agents Based Upon Threat to Public Health**

Agent	Type of Pathogen	Mode of Transmission
Brucellosis	Bacteria	Milk, direct contact
Ricin	Toxin	Air, food, water
Cholera	Bacteria	Food, water

Table 24.6: **Classification of Category C Bioterrorism Agents Based Upon Threat to Public Health**

Agent	Type of Pathogen	Mode of Transmission
Hantavirus	Virus	Air
Tuberculosis	Bacteria	Air

Agents of Bioterrorism

Bioterrorism agents are classified on the basis of their threat to public health, as shown in the tables above. Category A agents (**Table** 24.4) include anthrax and smallpox. Agents in this category pose the greatest threat. They spread easily and cause serious illness or death. Category B agents (**Table** 24.5) are considered less of a threat. They do not spread as easily and are less likely to cause death. Category C agents (**Table** 24.6) are pathogens that are likely to be engineered for bioterrorism in the future. They are easy to produce and have the potential to cause serious illness or death.

Recent Bioterrorism Incidents

Two recent bioterrorism incidents in the U.S. received a great deal of media attention. They heightened public awareness of the threat of bioterrorism. In 2001, letters containing anthrax spores were mailed to several news media offices and two U.S. Senate offices. A total of 22 people were infected, and 5 of them died of anthrax. In 2003, deadly ricin toxin was detected in a letter intended for the White House. The letter was intercepted at a mail-handling facility off White House grounds. Fortunately, the ricin did not cause illness or death.

Lesson Summary

- Carcinogens cause cancer by inducing mutations in genes that normally control cell division or other aspects of the cell cycle.
- Both indoor and outdoor air may contain pollutants that can cause human illness and death.
- In bioterrorism, pathogens are intentionally released or spread and have the potential to cause disease epidemics.

Review Questions

1. What is a carcinogen?
2. How do carcinogens cause cancer?
3. Identify three ways cancer can be treated.
4. List four warning signs of cancer.
5. How can you use the Air Quality Index to protect your health from air pollution?
6. The bacterium that causes plague is classified as a Category A bioterrorism agent. What can you conclude about the bacterium from this classification?
7. Explain why ozone is usually a worse problem in the summer than in the winter in North America.
8. Compare and contrast pollutants in indoor and outdoor air, including their effects on human health.

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Vocabulary

air quality index (AQI) A measure of certain pollutants in the air in a given location.

bioterrorism Terrorism by intentional release or spread of pathogens.

cancer A disease in which abnormal body cells divide of control.

carbon monoxide A gas produced by cars, furnaces, and other devices that burn fuel; replaces oxygen in the blood and quickly leads to death.

carcinogen Anything that can cause cancer; may be pathogens, chemical substances, or radiation.

carcinoma A tumor of epithelial tissues, such as lung tissue.

lymphoma A tumor of lymphatic cells, such as T cells.

oncogenes Abnormal genes that stimulate the division of cells with damaged DNA.

ozone A gas that forms close to the ground when high concentrations of air pollutants are heated by sunlight.

particulates Tiny particles of solids or liquids suspended in the air; primarily formed by the burning of fossil fuels by motor vehicles and factories.

proto-oncogenes Genes that normally help regulate cell division.

sarcoma A tumor of connective tissues, such as bone.

sick building syndrome (SBS) A combination of symptoms associated with working in a particular building, typically an office building.

tumor An abnormal mass of tissue.

tumor-suppressor genes Genes that normally repair damaged DNA or prevent cells with badly damaged DNA from dividing.

Points to Consider

High levels of certain hormones can increase the risk of some types of cancer. For example, high levels of estrogen can increase the risk of breast cancer. Estrogen is a female sex hormone.

- What are sex hormones?
- How do sex hormones normally affect the body?
- How are male and female sex hormones different?

Image Sources

(1) *http://en.wikipedia.org/wiki/Image:Herpes_simpex_virus.jpg* *http://en.wikipedia.org/wiki/Image:Amanita_phalloides_1.jpg* *http://upload.wikimedia.org/wikipedia/commons/0/08/Giardia_lamblia_SEM_8698_lores.jpg*. Creative Commons.

(2) *Phagocytosis by a macrophage.*. Creative Commons.

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