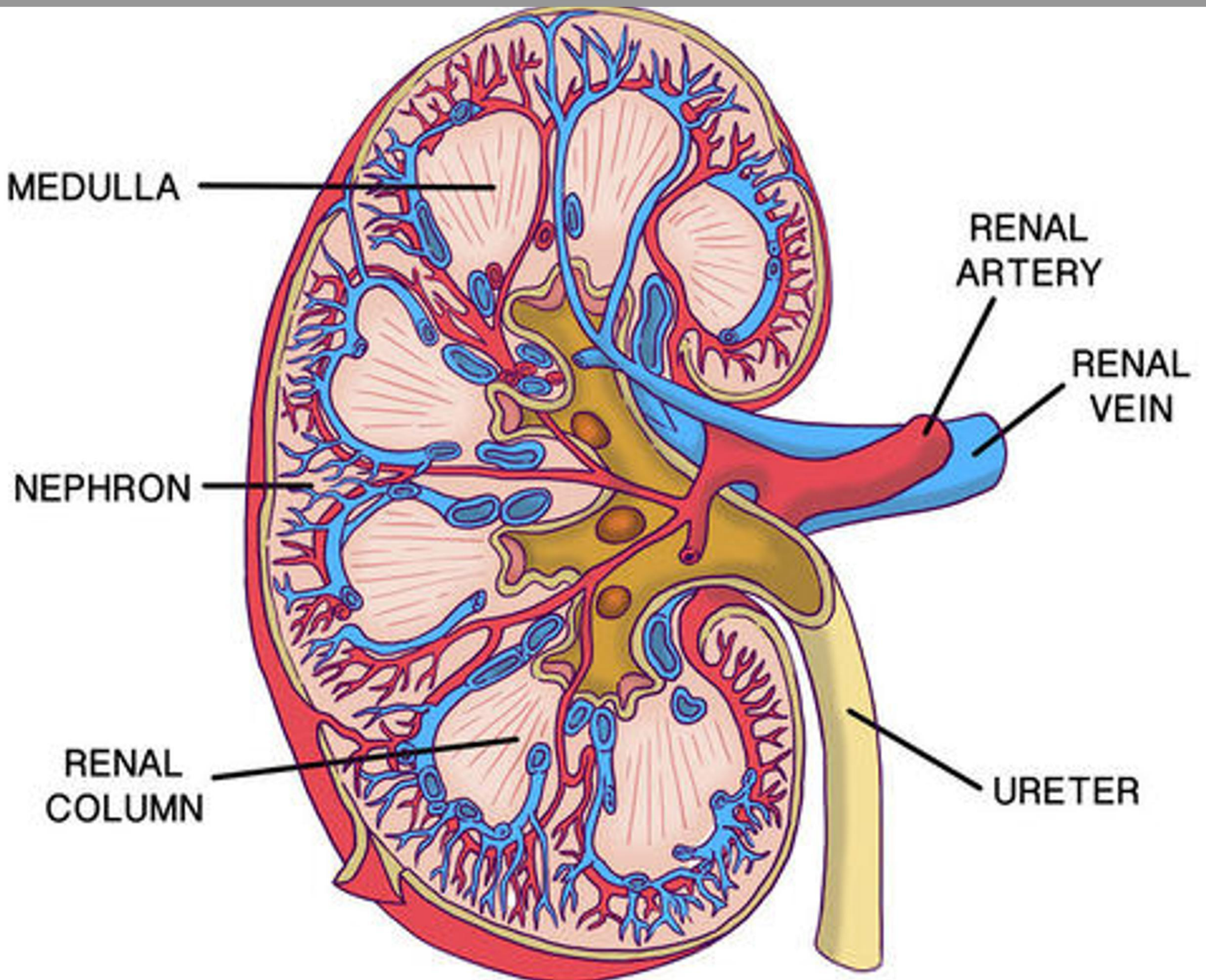
Human Physiology 110 Renal and Immune Systems



Human Physiology 110: Renal and Immune Systems

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Contents

CONCEPT 1 Excretion

Learning Objectives

- Define excretion.
- Identify organs of the excretory system.

What do you do with your waste?

Toxic waste must be disposed of properly or there can be serious consequences. Now, your waste should not be as colorful or toxic as shown here (if it is, get yourself to a doctor as soon as possible), but it still needs to be removed from you. And that is the role of the excretory system. The excretory system gets rid of waste and excess water.

Excretion

If you exercise on a hot day, you are likely to lose a lot of water in sweat. Then, for the next several hours, you may notice that you do not pass **urine** as often as normal and that your urine is darker than usual. Do you know why this happens? Your body is low on water and trying to reduce the amount of water lost in urine. The amount of water lost in urine is controlled by the **kidneys**, the main organs of the excretory system.

Excretion is the process of removing wastes and excess water from the body. It is one of the major ways the body maintains homeostasis. Although the kidneys are the main organs of excretion, several other organs also excrete wastes. They include the large intestine, liver, skin, and lungs. All of these organs of excretion, along with the kidneys, make up the **excretory system**. The roles of the excretory organs other than the kidney are summarized below:

- The large intestine eliminates solid wastes that remain after the digestion of food.
- The liver breaks down excess amino acids and toxins in the blood.
- The skin eliminates excess water and salts in sweat.
- The lungs exhale water vapor and carbon dioxide.

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Summary

- Excretion is the process of removing wastes and excess water from the body. It is one of the major ways the body maintains homeostasis.
- Organs of excretion make up the excretory system. They include the kidneys, large intestine, liver, skin, and lungs.

Review

1. What is excretion?
2. List organs of the excretory system and their functions.

CONCEPT 2 Urinary System

Learning Objectives

- Explain how the urinary system filters blood and excretes wastes.
- Summarize the role of the kidneys.
- Describe the structure and function of the nephron.
- Identify the relationship between the renal artery, the glomerulus, Bowman's capsule, and the renal tubule.

How is it determined what's waste and what's not?

Shown above is a major process of maintaining homeostasis. Getting rid of waste and excess water. Such a basic process is actually very complex. It involves an intricate exchange of material through the kidney.

Urinary System

The **kidneys** are part of the **urinary system**, which is shown in **Figure** 2.1. The main function of the urinary system is to filter waste products and excess water from the blood and excrete them from the body.

Kidneys and Nephrons

The kidneys are a pair of bean-shaped organs just above the waist. A cross-section of a kidney is shown in **Figure** 4.1. The function of the kidney is to filter blood and form urine. **Urine** is the liquid waste product of the body that is excreted by the urinary system. **Nephrons** are the structural and functional units of the kidneys. A single kidney may have more than a million nephrons!

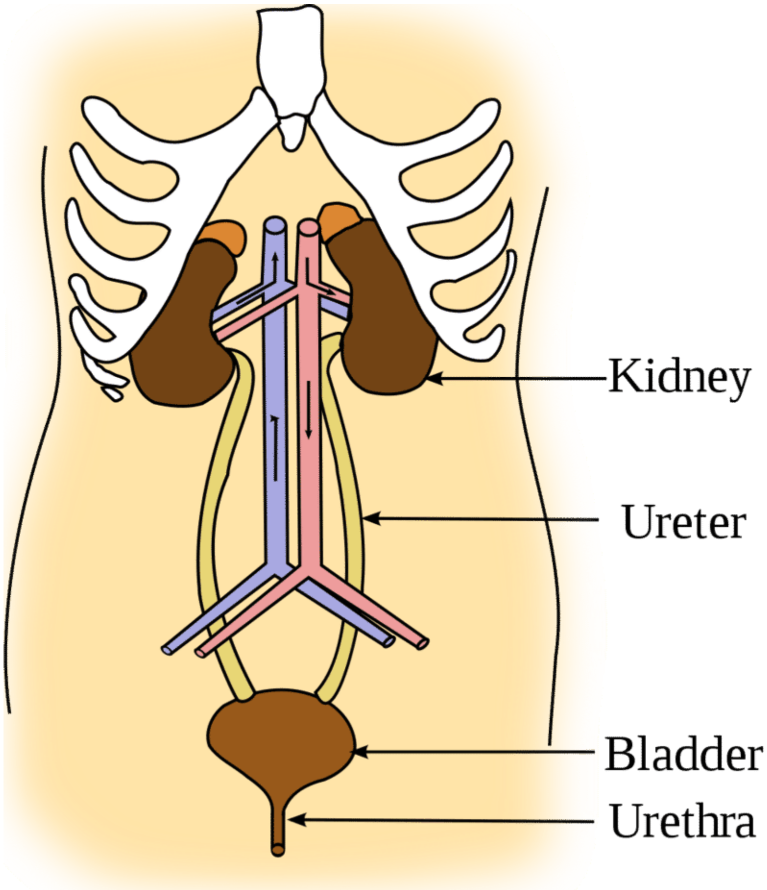


FIGURE 2.1
The kidneys are the chief organs of the urinary system.

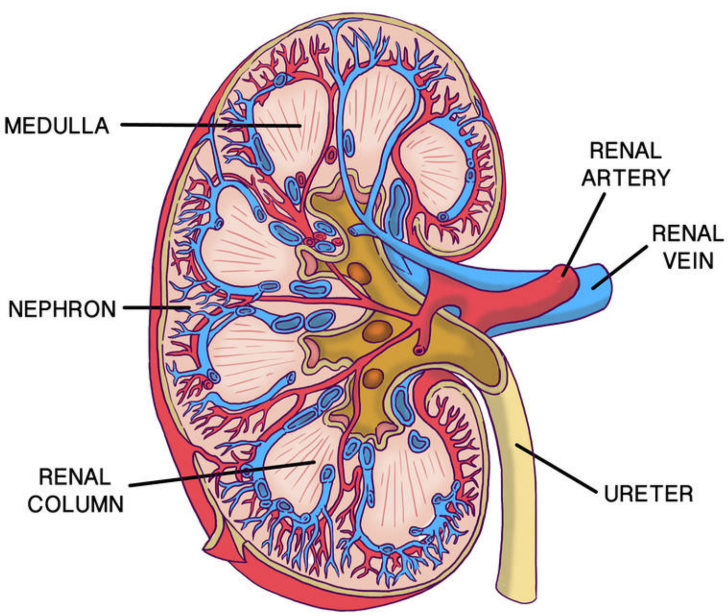


FIGURE 2.2
Each kidney is supplied by a renal artery and renal vein.

As shown in **Figure** 2.3, each nephron acts as a tiny filtering plant. It filters blood and forms urine in the following steps:

1. Blood enters the kidney through the **renal artery**, which branches into capillaries. When blood passes through capillaries of the **glomerulus** of a nephron, blood pressure forces some of the water and dissolved substances in the blood to cross the capillary walls into **Bowman's capsule**.
2. The filtered substances pass to the **renal tubule** of the nephron. In the renal tubule, some of the filtered substances are reabsorbed and returned to the bloodstream. Other substances are secreted into the fluid.
3. The fluid passes to a collecting duct, which reabsorbs some of the water and returns it to the bloodstream. The fluid that remains in the collecting duct is urine.

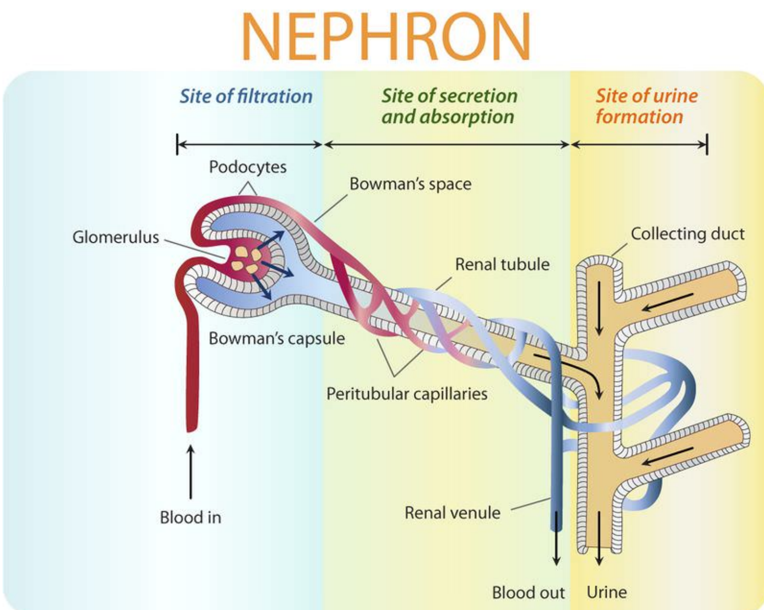
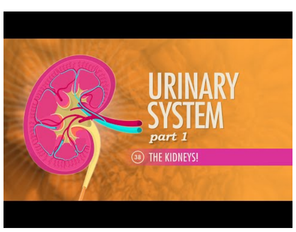


FIGURE 2.3
The parts of a nephron and their functions are shown in this diagram.

Excretion of Urine

From the collecting ducts of the kidneys, urine enters the **ureters**, two muscular tubes that move the urine by peristalsis to the bladder (see **Figure** 2.1). The **bladder** is a hollow, sac-like organ that stores urine. When the bladder is about half full, it sends a nerve impulse to a sphincter to relax and let urine flow out of the bladder and into the urethra. The **urethra** is a muscular tube that carries urine out of the body. Urine leaves the body through another sphincter in the process of **urination**. This sphincter and the process of urination are normally under conscious control.



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Summary

- The kidneys filter blood and form urine. They are part of the urinary system, which also includes the ureters, bladder, and urethra.
- Each kidney has more than a million nephrons, which are the structural and functional units of the kidney.
- Each nephron is like a tiny filtering plant.

Review

1. Describe how nephrons filter blood and form urine.
2. State the functions of the ureters, bladder, and urethra.

References

1. Courtesy of National Cancer Institute/SEER Training Modules. Kidney location in body . Public Domain
2. Laura Guerin. kidney cutaway . CC BY-NC 3.0
3. Hana Zavadska. In-depth diagram of nephron . CC BY-NC 3.0

CONCEPT 3 Excretory System Diseases

Learning Objectives

- Identify kidney diseases.
- Define kidney stone.
- Define diabetes and describe dialysis.

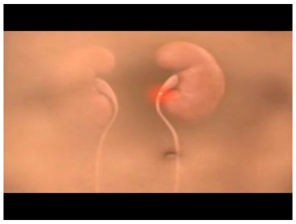
How do you block the flow of urine?

Kidney stones. Imagine having that travel through your excretory system. OK, that's not a kidney stone, but you get the idea. Kidney stones can be more than a few millimeters in diameter. Painful? Sometimes extremely uncomfortable. And how does a stone leave the kidney? The same way urine does.

Kidney Disease and Dialysis

A person can live a normal, healthy life with just one kidney. However, at least one kidney must function properly to maintain life. Diseases that threaten the health and functioning of the kidneys include kidney stones, infections, and diabetes.

- **Kidney stones** are mineral crystals that form in urine inside the kidney. Kidney stones can form when substances in the urine, such as calcium, oxalate, and phosphorus, become highly concentrated. They may be extremely painful. If they block a ureter, they must be removed so urine can leave the kidney and be excreted. A kidney stone may not cause symptoms until it moves around within your kidney or passes into your ureter. A stone may stay in the kidney or travel down the urinary tract. Kidney stones vary in size. A small stone may pass on its own, causing little or no pain. A larger stone may get stuck along the urinary tract and can block the flow of urine, causing severe pain or bleeding.



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- Bacterial infections of the urinary tract, especially the bladder, are very common. Bladder infections can be treated with antibiotics prescribed by a doctor. If untreated, they may lead to kidney damage.
- Uncontrolled **diabetes** may damage capillaries of nephrons. As a result, the kidneys lose much of their ability to filter blood. This is called **kidney failure**. The only cure for kidney failure is a kidney transplant, but it can be treated with dialysis. **Dialysis** is a medical procedure in which blood is filtered through a machine (see **Figure** 3.1).

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Summary

- Kidney diseases include kidney stones, infections, and kidney failure due to diabetes.
- Kidney failure may be treated with dialysis.

Review

1. Tom was seriously injured in a car crash. As a result, he had to have one of his kidneys removed. Does Tom need dialysis? Why or why not?
2. What are kidney stones? How do they form?

References

1. Jodi So. Dialysis machine illustration . CC BY-NC 3.0

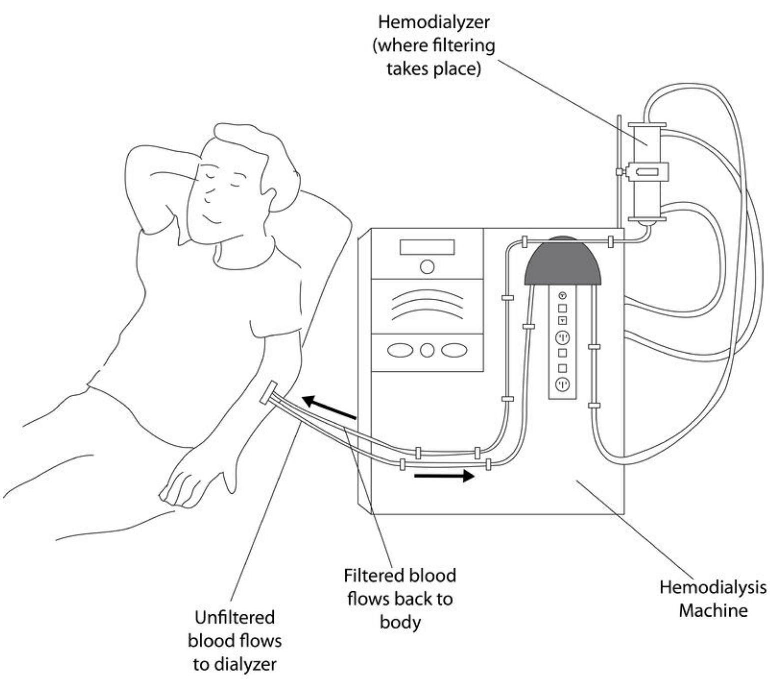


FIGURE 3.1
A dialysis machine filters a patient's blood.

Concept 4 Kidneys

Learning Objectives

- Describe the roles of the kidneys.
- Explain how the kidneys help maintain homeostasis.
- Describe additional roles of the kidneys.

Why is a bean-shaped organ so important?

Shown above are the isolated kidneys from many little mice. OK, they're really just kidney beans. But this is what the important kidney looks like. Why is it so important? Your kidneys filter and remove wastes from your blood.

The Kidneys

The kidneys are a pair of bean-shaped organs just above the waist. They are important organs with many functions in the body, including producing hormones, absorbing minerals, and filtering blood and producing urine.

A cross-section of a kidney is shown in **Figure** 4.1. The function of the kidney is to filter blood and form urine. **Urine** is the liquid waste product of the body that is excreted by the urinary system. Wastes in the blood come from the normal breakdown of tissues, such as muscles, and from food. The body uses food for energy. After the body has taken the nutrients it needs from food, some of the wastes are absorbed into the blood. If the kidneys did not remove them, these wastes would build up in the blood and damage the body.

Kidneys and Nephrons

The actual removal of wastes from the blood occurs in tiny units inside the kidneys called nephrons. **Nephrons** are the structural and functional units of the kidneys. A single kidney may have more than a million nephrons! This is further discussed in the *Urinary System* concept.

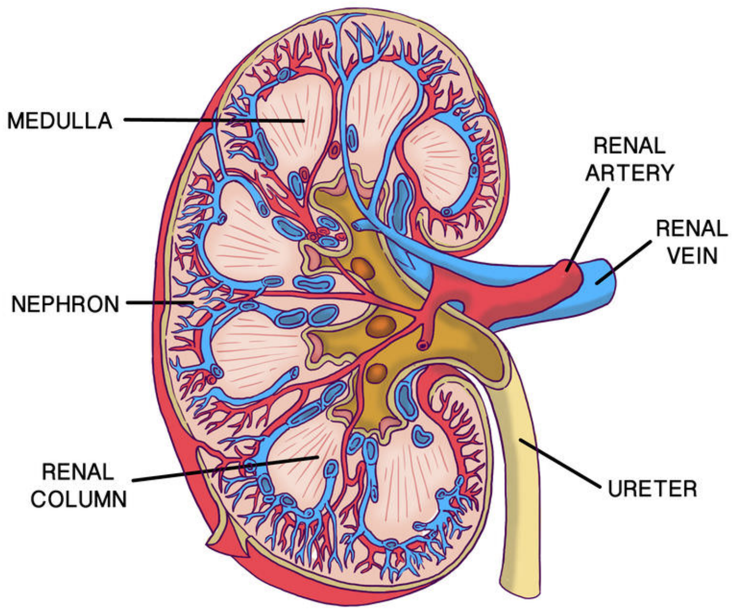


FIGURE 4.1
Each kidney is supplied by a renal artery and renal vein.

Kidneys and Homeostasis

The kidneys play many vital roles in **homeostasis**. They work with many other organ systems to do this. For example, they work with the circulatory system to filter blood, and with the urinary system to remove wastes.

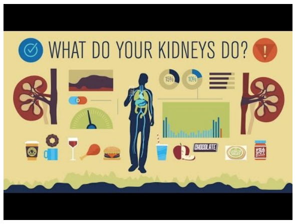
The kidneys filter all the blood in the body many times each day and produce a total of about 1.5 liters of **urine**. The kidneys control the amount of water, ions, and other substances in the blood by excreting more or less of them in urine. The kidneys also secrete **hormones** that help maintain homeostasis. **Erythropoietin**, for example, is a kidney hormone that stimulates bone marrow to produce red blood cells when more are needed. They also secrete renin, which regulates blood pressure, and calcitriol, the active form of vitamin D, which helps maintain calcium for bones. The kidneys themselves are also regulated by hormones. For example, **antidiuretic hormone** from the hypothalamus stimulates the kidneys to produce more concentrated urine when the body is low on water.

Other Functions

In addition to filtering blood and producing urine, the kidneys are also involved in maintaining the water level in the body, and regulating red blood cell levels and blood pressure.

- As the kidneys are mainly involved in the production of urine, they react to changes in the body's water level throughout the day. As water intake decreases, the kidneys adjust accordingly and leave water in the body instead of helping remove it through the urine, maintaining the water level in the body.
- The kidneys also need constant pressure to filter the blood. When the blood pressure drops too low, the kidneys increase the pressure. One way is by producing angiotensin, a blood vessel-constricting protein. This protein

also signals the body to retain sodium and water. Together, the constriction of blood vessels and retention of sodium and water help restore normal blood pressure.
- When the kidneys don't get enough oxygen, they send out a signal in the form of the hormone erythropoietin, which stimulates the bone marrow to produce more oxygen-carrying red blood cells.



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Summary

- The kidneys maintain homeostasis by controlling the amount of water, ions, and other substances in the blood.
- Kidneys also secrete hormones that have other homeostatic functions.

Review

1. What is the nephron? How many nephrons are in each kidney?
2. Explain how the kidneys maintain homeostasis.
3. What is the role of antidiuretic hormone?

References

1. Laura Guerin. Kidney cutaway . CC BY-NC 3.0

CONCEPT 5 Barriers to Pathogens

Learning Objectives

- Define immune system.
- List common pathogens.
- Describe mechanical, chemical, and biological barriers.
- Explain the role of mucous membranes.

How does your body keep most enemies out?

Many would consider the moat around this castle, together with the thick stone castle walls, as the first line of defense. Their role is to keep the enemy out, and protect what's inside.

The First Line of Defense

Does this organism look like a space alien? A scary creature from a nightmare? In fact, it's a 1-cm long worm that lives in the human body and causes serious harm. It enters the body through a hair follicle of the skin when it's in a much smaller stage of its life cycle. Like this worm, many other organisms can make us sick if they manage to enter our body. Fortunately for us, our immune system is able to keep out most such invaders.

The **immune system** protects the body from worms, germs, and other agents of harm. The immune system is like a medieval castle. The outside of the castle was protected by a moat and high stone walls. Inside the castle, soldiers were ready to fight off any invaders that managed to get through the outer defenses. Like a medieval castle, the immune system has a series of defenses. In fact, it has three lines of defense. Only pathogens that are able to get through all three lines of defense can harm the body.

FIGURE 5.1

The body's first line of defense consists of different types of barriers that keep most pathogens out of the body. **Pathogens** are disease-causing agents, such as bacteria and viruses. These and other types of pathogens are described in **Figure** 5.2. Regardless of the type of pathogen, however, the first line of defense is always the same.

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 the body has. The outer layer of the skin is tough and very difficult for pathogens to penetrate.

Mucous membranes provide a mechanical barrier at body openings. They also line the respiratory, GI, urinary, and reproductive tracts. Mucous membranes secrete **mucus**, a slimy substance that traps pathogens. The membranes also have hair-like cilia. The **cilia** sweep mucus and pathogens toward body openings where they can be removed from the body. When you sneeze or cough, pathogens are removed from the nose and throat (see **Figure** 5.3). Tears wash pathogens from the eyes, and urine flushes pathogens out of the urinary tract.

Chemical Barriers

Chemical barriers destroy pathogens on the outer body surface, at body openings, and on inner body linings. Sweat, mucus, tears, and saliva all contain enzymes that kill pathogens. Urine is too acidic for many pathogens, and semen

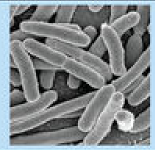
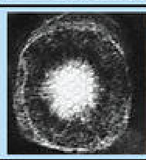
Type of pathogen		Description	Human diseases caused by pathogens of that type
Bacteria *Escherichia coli*		Single-celled organisms without a nucleus	Strep throat, staph infections, tuberculosis, food poisoning, tetanus, pneumonia, syphilis
Viruses *Herpes simplex*		Thread-like particles that reproduce by taking over living cells	Common cold, flu, genital herpes, cold sores, measles, AIDS, genital warts, chiken 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, tinea, candidiasis, histoplasmosis, mushroom poisoning
Protozoa *Giardia lamblia*		Single-celled organism with a nucleus	Malaria, "traveler's diarrhea" giardiasis, trypanosomiasis ("sleeping sickness")

FIGURE 5.2

Types of pathogens that commonly cause human diseases include bacteria, viruses, fungi, and protozoa. Which type of pathogen causes the common cold? Which type causes athlete's foot?

FIGURE 5.3

A sneeze can expel many pathogens from the respiratory tract. That's why you should always cover your mouth and nose and when you sneeze.

contains zinc, which most pathogens cannot tolerate. In addition, stomach acid kills pathogens that enter the GI tract in food or water.

Biological Barriers

Biological barriers are living organisms that help protect the body. Millions of harmless bacteria live on the human skin. Many more live in the GI tract. The harmless bacteria use up food and space so harmful bacteria cannot grow.

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Summary

- Barriers that keep out pathogens are the body's first line of defense.
- The first line of defense includes mechanical, chemical, and biological barriers.

Review

1. What is the role of the body's first line of defense?
2. Identify three types of barriers in the body's first line of defense. Give an example of each type of barrier.
3. Which type of pathogen causes the common cold? Which type causes athlete's foot?

References

1. Bruce Wetzel/Harry Schaefer/National Cancer Institute, colorized by Sam McCabe. Schistosome parasite . Public Domain
2. E coli: Rocky Mountain Laboratories, NIAID, NIH; Herpes simplex: CDC/Dr. Erskine Palmer; Death cap: GLJIVARSKO DRUSTVO NIS; Giarda lamblia: CDC/Janice Carr. Various pathogens, including E Coli, death cap mushrooms, Giarda lambia, and Herpes simplex . E coli, Herpes simplex, Giarda lamblia: Public Domain; Death cap: CC BY 2.0
3. James Gathany/Centers for Disease Control and Prevention. Sneezing individual . Public Domain

CONCEPT 6 Inflammatory Response and Leukocytes

Learning Objectives

- Explain the inflammatory response.
- Describe cytokines and histamines.
- Outline how nonspecific leukocytes help fight pathogens that enter the body.
- Define phagocytosis.

What happens when an enemy gets past the first line of defense?

For this running back to make it past the first line of defense, there usually has to be a hole or break in the line. He then runs into the secondary, or the second line of defense. Whenever the skin is broken, it is possible for pathogens to easily enter your body. They get past the first line of defense, and run into the second line of defense.

The 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 body's second line of defense.

Inflammatory Response

The cut on your hand may become red, warm, and swollen. These are signs of an **inflammatory response.** This is the first reaction of the body to tissue damage or infection. As explained in **Figure** 6.1, the response is triggered by chemicals called **cytokines** and **histamines**, which are released when tissue is injured or infected. The chemicals communicate with other cells and coordinate the inflammatory response. You can see an animation of the inflammatory response at this link: http://www.sumanasinc.com/webcontent/animations/content/inflammatory.html .

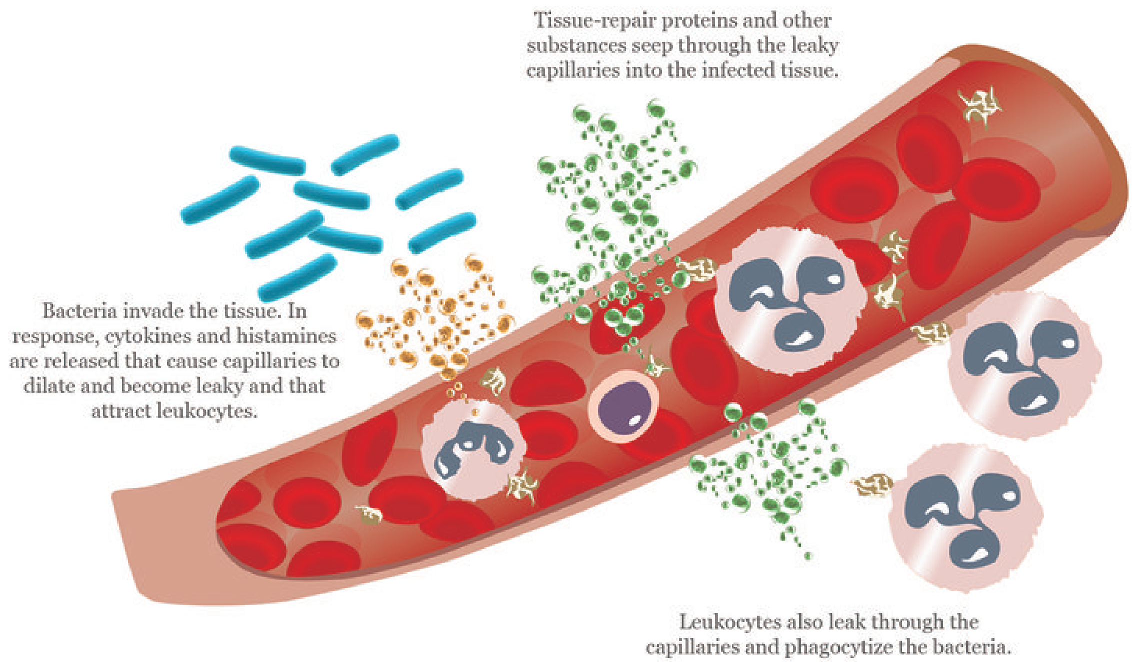

FIGURE 6.1

This drawing shows what happens during the inflammatory response. Why are changes in capillaries important for this response?

Leukocytes

The chemicals that trigger an inflammatory response attract leukocytes to the site of injury or infection. **Leukocytes** are white blood cells. Their role is to fight infections and get rid of debris. Leukocytes may respond with either a nonspecific or a specific defense.

- A **nonspecific defense** is the same no matter what type of pathogen is involved. An example of a nonspecific defense is **phagocytosis.** This is the process in which leukocytes engulf and break down pathogens and debris. It is illustrated in **Figure** 6.2. The immune system's first line of defense is also a nonspecific defense.
- A **specific defense** is tailored to a particular pathogen. Leukocytes involved in this type of defense are part of the immune response and are described in other concepts.

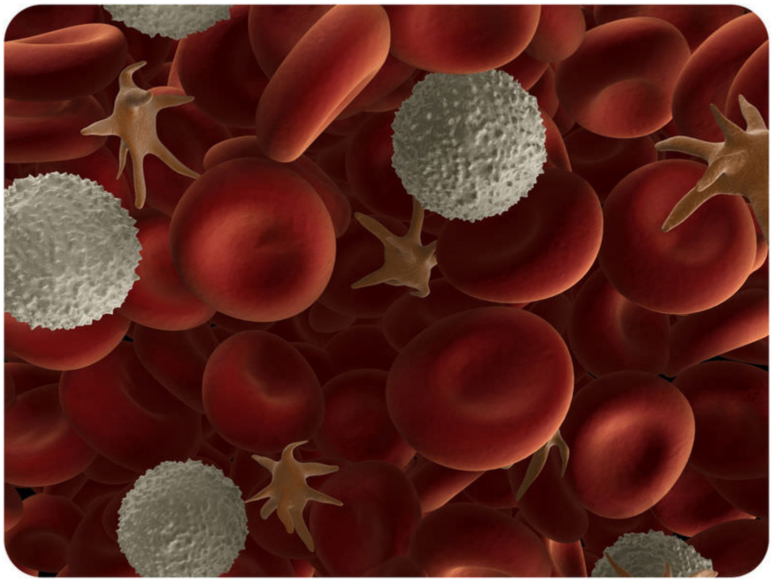

FIGURE 6.2
In this image, leukocytes (white) are attacking pathogens (star-shaped).

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Summary

- The second line of defense attacks pathogens that manage to enter the body.
- The second line of defense includes the inflammatory response and phagocytosis by nonspecific leukocytes.

Review

1. What is a nonspecific defense?
2. What is the body's second life of defense? When does it take effect?
3. Identify the roles of nonspecific leukocytes in the body's second line of defense.
4. Jera cut her finger. The next day, the skin around the cut became red and warm. Why are these signs of infection?

References

1. Image copyright Athanasia Nomikou, 2014, modified by CK-12 Foundation. Elements of an inflammatory response . Used under license from Shutterstock.com
2. Image copyright Sebastian Kaulitzki, 2014. Leukocytes attacking pathogens . Used under license from Shutterstock.com

CONCEPT 7 Lymphatic System

Learning Objectives

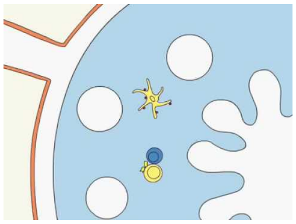
- Describe the lymphatic system and its roles in the immune response.
- Define lymph and lymph nodes.
- List and describe structures of the lymphatic system.
- Distinguish between B cells and T cells.
- Describe antigen recognition.

What happens when your tonsils cause more problems than they solve?

Almost all of us have had a sore throat at some time. Maybe you had your tonsils out when you were younger? Why? Your tonsils are two lumps of tissue that work as germ fighters for your body. But sometimes germs like to hang out there, where they cause infections. In other words, your tonsils can cause more problems than they solve. So, you have them taken out.

Lymphatic System

Like the immune systems of other vertebrates, the human immune system is adaptive. If pathogens manage to get through the body's first two lines of defense, the third line of defense takes over. The third line of defense is 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 response against that pathogen will be much faster and stronger.



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The immune response mainly involves the lymphatic system. The **lymphatic system** is a major part of the immune system. It produces leukocytes called lymphocytes. **Lymphocytes** are the key cells involved in the immune response. They recognize and help destroy particular pathogens in body fluids and cells. They also destroy certain cancer cells.

Structures of the Lymphatic System

Figure 7.1 shows the structures of the lymphatic system. They include organs, lymph vessels, lymph, and lymph nodes. Organs of the lymphatic system are the bone marrow, thymus, spleen, and tonsils.

- **Bone marrow** is found inside many bones. It produces lymphocytes.
- The **thymus** is located in the upper chest behind the breast bone. It stores and matures lymphocytes.
- The **spleen** is in the upper abdomen. It filters pathogens and worn out red blood cells from the blood, and then lymphocytes in the spleen destroy them.
- The **tonsils** are located on either side of the pharynx in the throat. They trap pathogens, which are destroyed by lymphocytes in the tonsils.

Lymphatic Vessels and Lymph

Lymphatic vessels make up a body-wide circulatory system. The fluid they circulate is lymph. **Lymph** is a fluid that leaks out of capillaries into spaces between cells. As the lymph accumulates between cells, it diffuses into tiny lymphatic vessels. The lymph then moves through the lymphatic system from smaller to larger vessels. It finally drains back into the bloodstream in the chest. As lymph passes through the lymphatic vessels, pathogens are filtered out at small structures called **lymph nodes** (see **Figure** 7.1). The filtered pathogens are destroyed by lymphocytes.

Lymphocytes

The human body has as many as two trillion lymphocytes, and lymphocytes make up about 25% of all leukocytes. The majority of lymphocytes are found in the lymphatic system, where they are most likely to encounter pathogens. The rest are found in the blood. There are two major types of lymphocytes, called **B cells** and **T cells.** These cells get their names from the organs in which they mature. B cells mature in bone marrow, and T cells mature in the thymus. Both B and T cells recognize and respond to particular pathogens.

Antigen Recognition

B cells and T cells actually recognize and respond to antigens on pathogens. **Antigens** are molecules that the immune system recognizes as foreign to the body. Antigens are also found on cancer cells and the cells of transplanted organs. They trigger the immune system to react against the cells that carry them. This is why a transplanted organ may be rejected by the recipient's immune system.

How do B and T cells recognize specific antigens? They have receptor molecules on their surface that bind only with particular antigens.

As shown in **Figure** 7.2, the fit between an antigen and a matching receptor molecule is like a key in a lock.

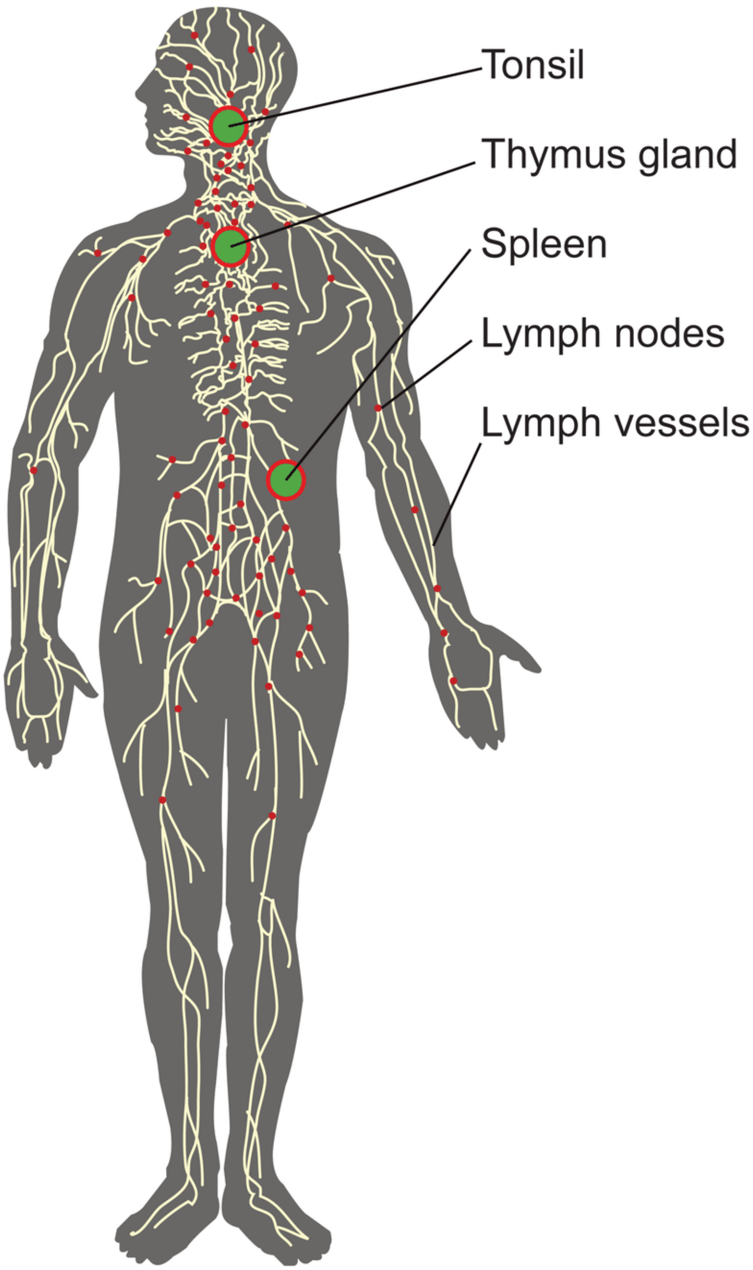


FIGURE 7.1
The lymphatic system consists of organs, vessels, and lymph.

Summary

- The body's third line of defense is the immune response. This involves the lymphatic system. This system filters pathogens from lymph and produces lymphocytes.
- Lymphocytes are the key cells in the immune response. They are leukocytes that become activated by a particular antigen. There are two major type of lymphocytes: B cells and T cells.

Review

1. What is the lymphatic system?

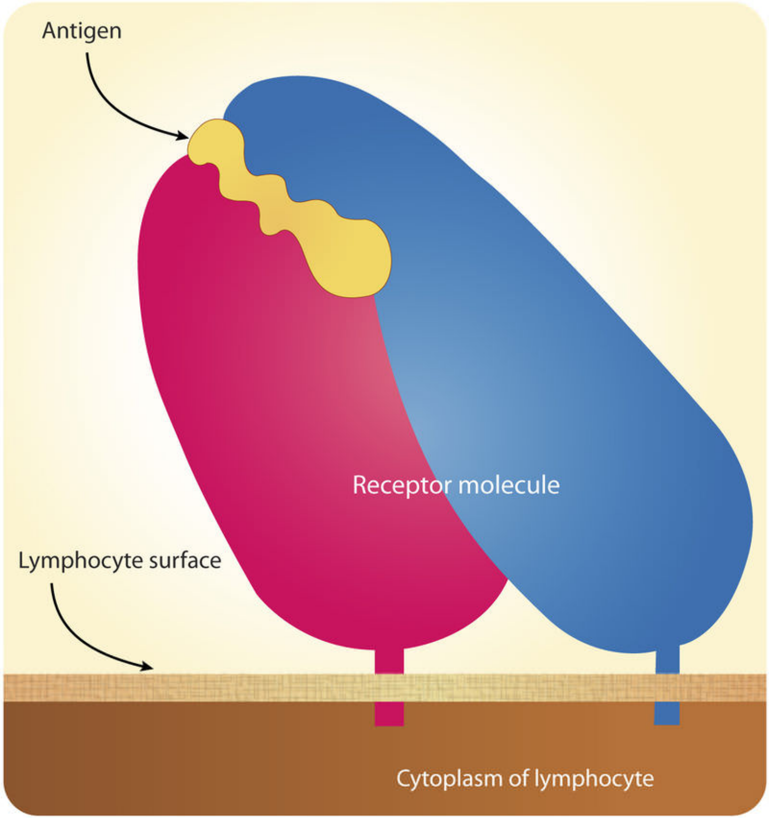
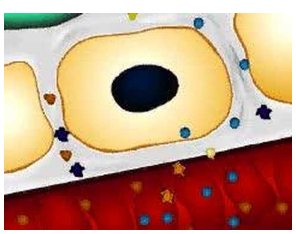


FIGURE 7.2
An antigen fits the matching receptor molecule like a key in a lock.

2. List three organs of the lymphatic system and their functions.
3. What are lymph nodes? What is their function?
4. What are the two major types of lymphocytes?
5. What are antigens, and how do lymphocytes "recognize" them?

Resources



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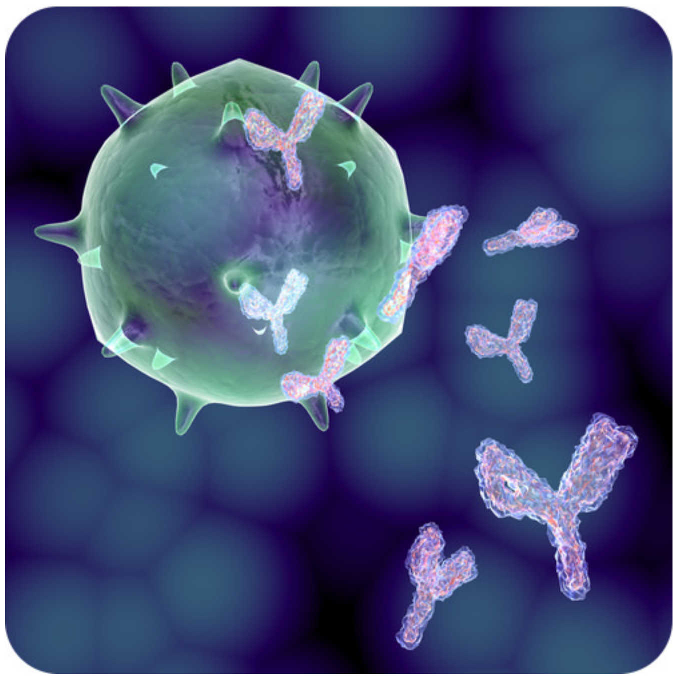
References

1. Mariana Ruiz Villarreal (LadyofHats) for CK-12 Foundation. Components of the lymphatic system . CC BY-NC 3.0
2. Hana Zavadska. Antigen receptor interaction . CC BY-NC 3.0

CONCEPT 8 Humoral Immune Response

Learning Objectives

- Describe the humoral immune response.
- List the steps that occur in a humoral immune response.
- Distinguish helper T cell from plasma cells and from memory cells.
- Describe antibodies and an antigen-antibody complex.



What are those Y-shaped things floating around the cell?

They are antibodies, which are large proteins. And they signal specific antigens for destruction. It does help that the antigens are usually attached to pathogens.

Humoral Immune Response

There are actually two types of immune responses: humoral and cell-mediated. The **humoral immune response** involves mainly **B cells** and takes place in blood and lymph.

B Cell Activation

B cells must be activated by an antigen before they can fight pathogens. This happens in the sequence of events shown in **Figure** 8.1. First, 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**. The helper T cell binds to the B cell at the antigen site and releases **cytokines** that "tell" or signal the B cell to develop into a **plasma cell**.

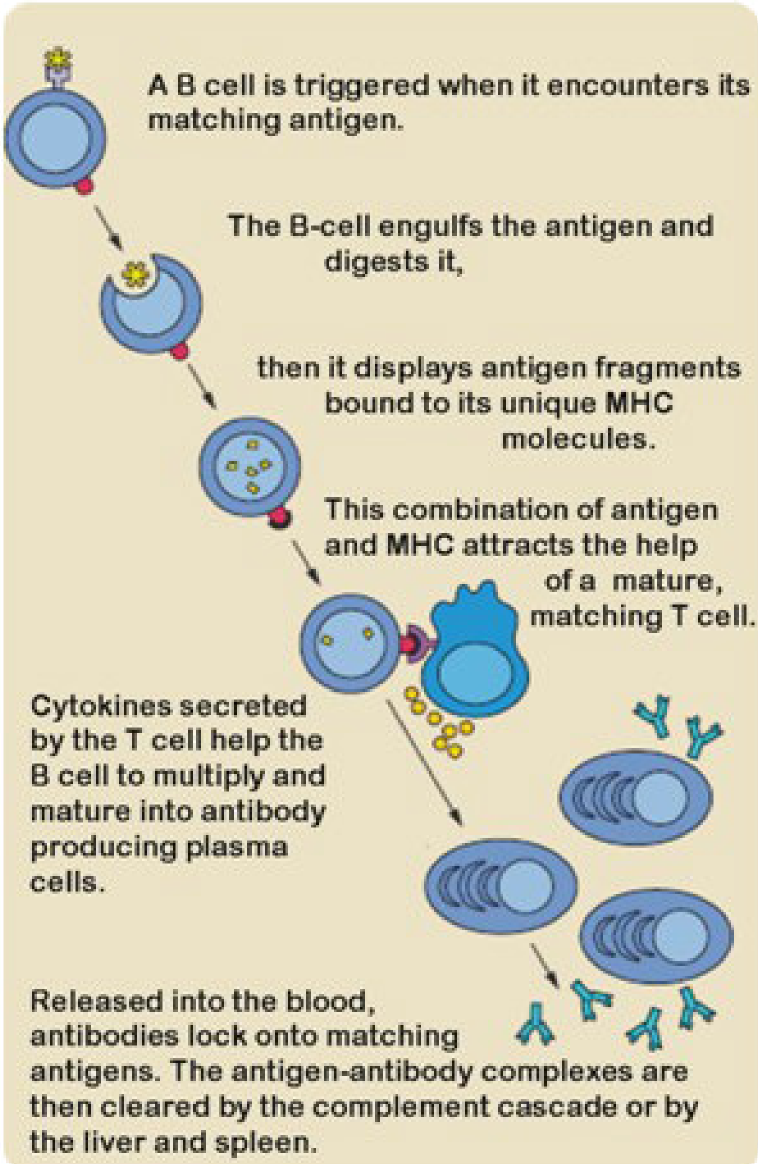


FIGURE 8.1

Activation of a B cell must occur before it can respond to pathogens. What role do T cells play in the activation process?

Plasma Cells and Antibody Production

Plasma cells are activated B cells that secrete antibodies. **Antibodies** are large, Y-shaped proteins that recognize and bind to antigens. Plasma cells are like antibody factories, producing many copies of a single type of antibody. The antibodies travel throughout the body in blood and lymph. Each antibody binds to just one kind of antigen. When it does, it forms an **antigen-antibody complex** (see **Figure** 8.2). The complex flags the antigen-bearing cell for destruction by **phagocytosis**.

Memory Cells

Most plasma cells live for just a few days, but some of them live much longer. They may even survive for the lifetime of the individual. Long-living plasma cells are called **memory cells.** They 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 again in the future.

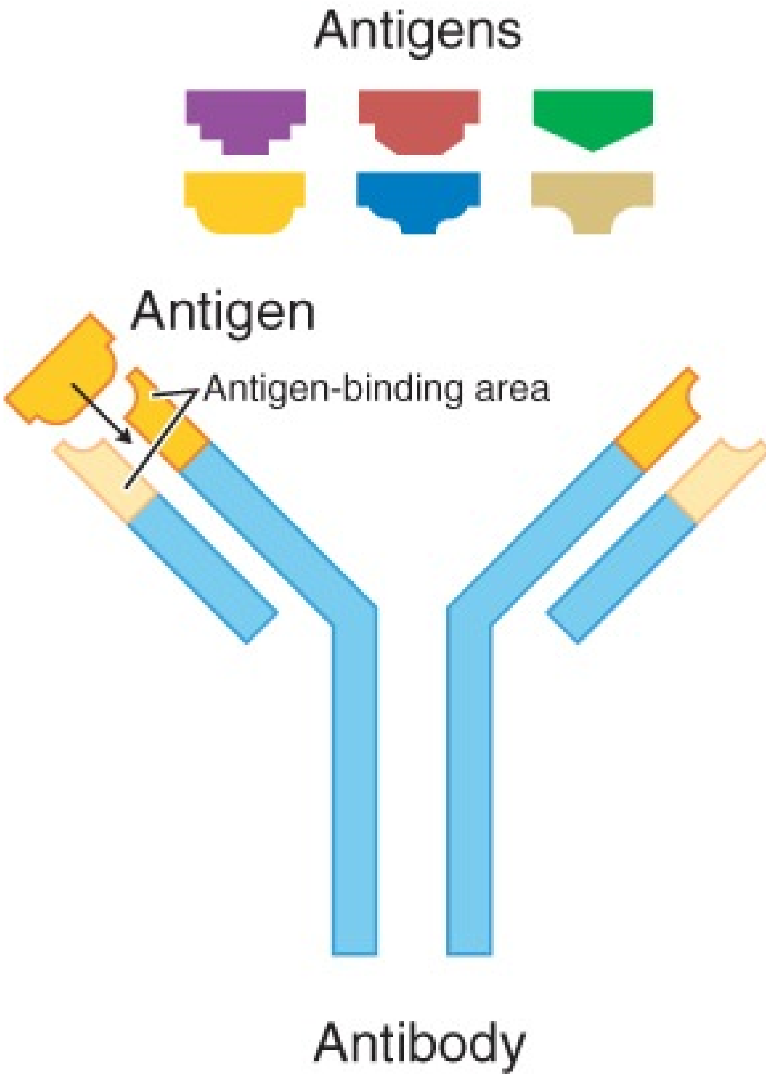
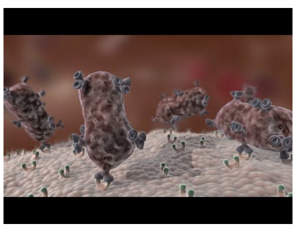


FIGURE 8.2
An antibody matches only one type of antigen.



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Summary

- Activated B cells produce antibodies to a particular antigen.
- Memory B cells remain in the body after the immune response is over and provide immunity to pathogens bearing the antigen.

Review

1. How do plasma cells help fight pathogens? Include the role of antibodies in your response.
2. If a disease destroyed a person's helper T cells, how might this affect the ability to launch an immune response?
3. What are memory cells? What is their role?

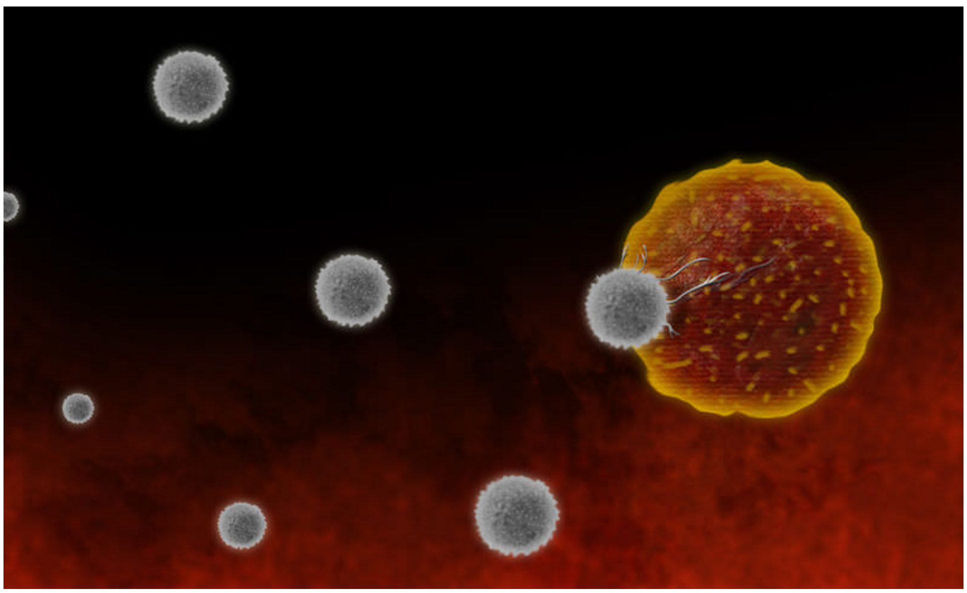
References

1. Courtesy of the National Institutes of Health and User:DO11.10/Wikimedia Commons. Activation of a B cell . Public Domain
2. User:Fvasconcellos/Wikimedia Commons. Single antibody illustrated . Public Domain

CONCEPT 9 Cell-Mediated Immune Response

Learning Objectives

- Describe the cell-mediated immune response.
- Identify the roles of T cells in a cell-mediated immune response.
- Summarize how T cells are activated.
- Distinguish between helper T cells, memory cells, cytotoxic T cells, and regulatory T cells.



Do cells really attack other cells?

They sure do. Depicted here is a group of T cells attacking a cancer cell. When they can, the T cells search out and destroy "bad" cells.

Cell-Mediated Immune Response

In addition to the humoral response, the other type of immune response is the **cell-mediated immune response**, which involves mainly **T cells**. It leads to the destruction of cells that are infected with viruses. Some cancer cells are also destroyed in this way. There are several different types of T cells involved in a cell-mediated immune response, including helper, cytotoxic, and regulatory T cells.

T Cell Activation

All three types of T cells must be activated by an antigen before they can fight an infection or cancer. T cell activation is illustrated in **Figure** 9.1. It begins when a B cell or nonspecific leukocyte engulfs a virus and displays its antigens. When the T cell encounters the matching antigen on a leukocyte, it becomes activated. What happens next depends on which type of T cell it is.

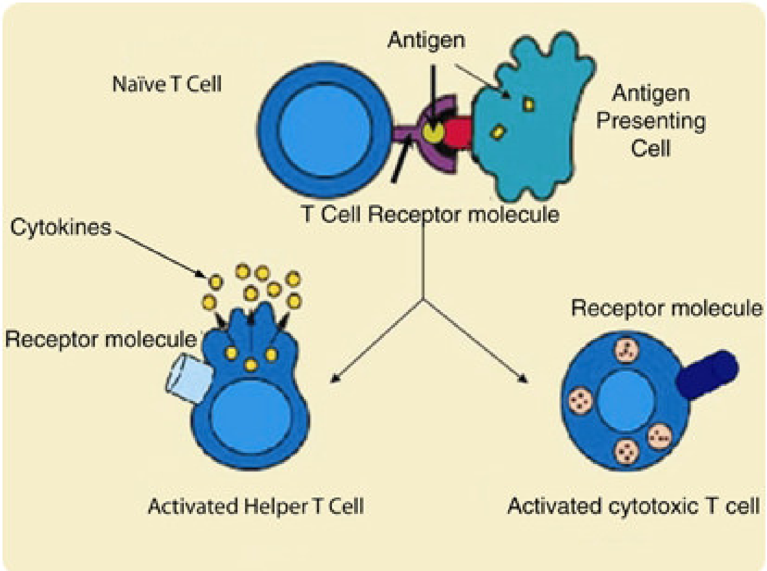


FIGURE 9.1
T cell activation requires another leukocyte to engulf a virus and display its antigen.

Helper T Cells

Helper T cells are like the "managers" of the immune response. They secrete **cytokines**, which activate or control the activities of other lymphocytes. Most helper T cells die out once a pathogen has been cleared from the body, but a few remain as **memory cells**. These memory cells are ready to produce large numbers of antigen-specific helper T cells like themselves if they are exposed to the same antigen in the future.

Cytotoxic T Cells

Cytotoxic T cells destroy virus-infected cells and some cancer cells. 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 to destroy. **Figure** 9.2 shows how a cytotoxic T cell destroys a body cell infected with viruses. This T cell releases toxins that form pores in the membrane of the infected cell. This causes the cell to burst, destroying both the cell and the viruses inside it.

After an infection has been brought under control, most cytotoxic T cells die off. However, a few remain as memory cells. If the same pathogen enters the body again, the memory cells mount a rapid immune response. They quickly produce many copies of cytotoxic T cells specific to the antigen of that pathogen.

Regulatory T Cells

Regulatory T cells are responsible for ending the cell-mediated immune response after an infection has been curbed. They also suppress T cells that mistakenly react against self antigens. What might happen if these T cells were not suppressed?

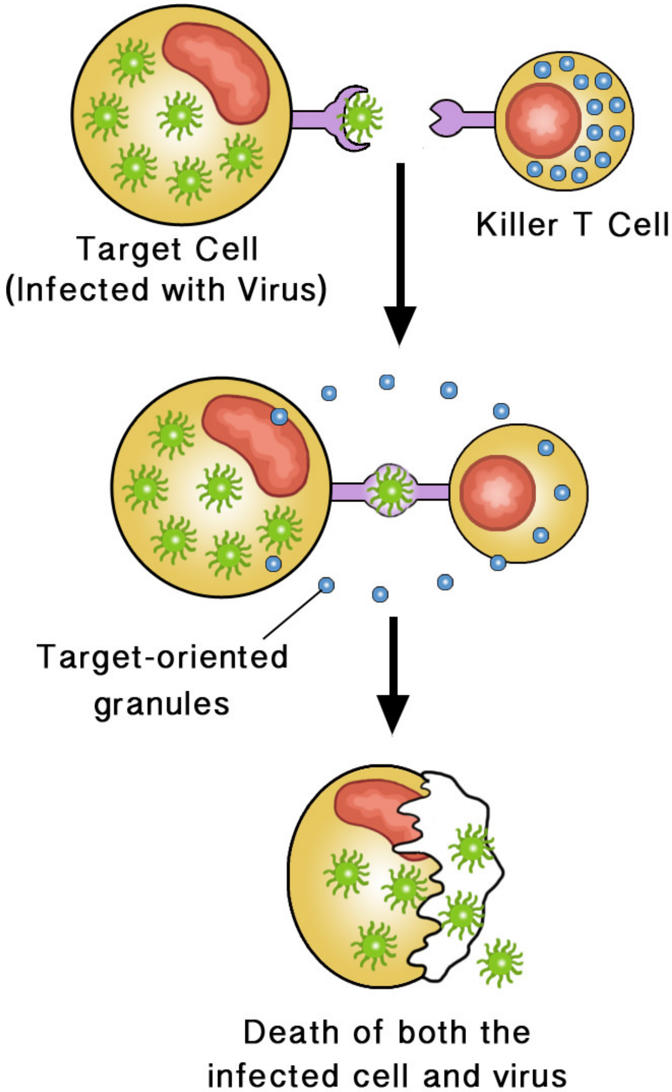
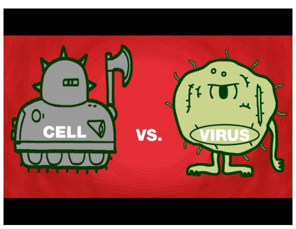


FIGURE 9.2

A cytotoxic T cell releases toxins that destroy an infected body cell and the viruses it contains.



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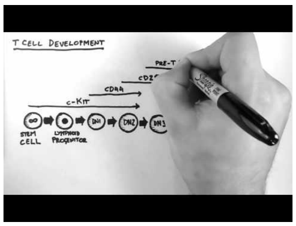
Summary

- Activated T cells destroy certain cancer cells and cells infected by viruses.
- Memory T cells remain in the body after the immune response and provide antigen-specific immunity to the virus.

Review

1. Describe one way that cytotoxic T cells destroy cells infected with viruses.
2. What are regulatory T cells?

Resources



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References

1. Courtesy of the National Institutes of Health and User:DO11.10/Wikimedia Commons. Mechanism for T cell activation . Public Domain
2. Laura Guerin. Cytotoxic T cell mechanism . CC BY-NC 3.0

CONCEPT 10 Immunity

Learning Objectives

- Define immunity.
- Distinguish between active and passive immunity.

Is giving shots to young children a good thing?

Many, if not most, children hated going to the doctor, as it often meant getting a shot. Why? The shot actually contained a weakened or dead pathogen. And putting some of that dead pathogen into you was a good thing.

Immunity

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

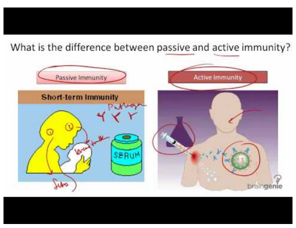
Active Immunity

Active immunity results when an immune response to a pathogen produces memory cells. As long as the memory cells survive, the pathogen will be unable to cause a serious infection in the body. Some memory cells last for a lifetime and confer permanent immunity.

Active immunity can also result from immunization. **Immunization** is the deliberate exposure of a person to a **pathogen** in order to provoke an immune response and the formation of memory cells specific to that pathogen. The pathogen is often injected. However, only part of a pathogen, a weakened form of the pathogen, or a dead pathogen is typically used. This causes an immune response without making the immunized person sick. This is how you most likely became immune to measles, mumps, and chicken pox.

Passive Immunity

Passive immunity results when **antibodies** are transferred to a person who has never been exposed to the pathogen. Passive immunity lasts only as long as the antibodies survive in body fluids. This is usually between a few days and a few months. Passive immunity may be acquired by a fetus through its mother's blood. It may also be acquired by an infant though the mother's breast milk. Older children and adults can acquire passive immunity through the injection of antibodies.



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Summary

- Immunity is the ability to resist infection by a pathogen.
- Active immunity results from an immune response to a pathogen and the formation of memory cells.
- Passive immunity results from the transfer of antibodies to a person who has not been exposed to the pathogen.

Review

1. What is immunity? What role do memory cells play in immunity?
2. How is active immunity different from passive immunity? Why does active immunity last longer?
3. Explain how immunization prevents a disease such as measles, which is caused by a virus.

CONCEPT 11 Allergies

Learning Objectives

- Define allergy.
- Identify common allergens.
- Describe anaphylaxis.

Have you ever started to sneeze and not known why?

A beautiful sea of flowers. A nice sight, unless you have an allergic reaction. It is not uncommon to have reactions to pollen.

Allergies

Your immune system usually protects you from pathogens and keeps you well. However, like any other body system, the immune system itself can develop problems. Sometimes it responds to harmless foreign substances as though they were pathogens. Sometimes it attacks the body's own cells. Certain diseases can also attack and damage the immune system and interfere with its ability to defend the body.

An **allergy** is a disease in which the immune system makes an inflammatory response to a harmless **antigen**. Any antigen that causes an allergy is called an **allergen.** Allergens may be inhaled or ingested, or they may come into contact with the skin. Two common causes of allergies are shown in **Figure** 11.1. Inhaling ragweed pollen may cause coughing and sneezing. Skin contact with oils in poison ivy may cause an itchy rash. Other common causes of allergies include dust mites, mold, animal dander, insect stings, latex, and certain food and medications. Symptoms of a common allergy such as pollen can include sneezing, a runny nose, nasal congestion and itchy, watery eyes.

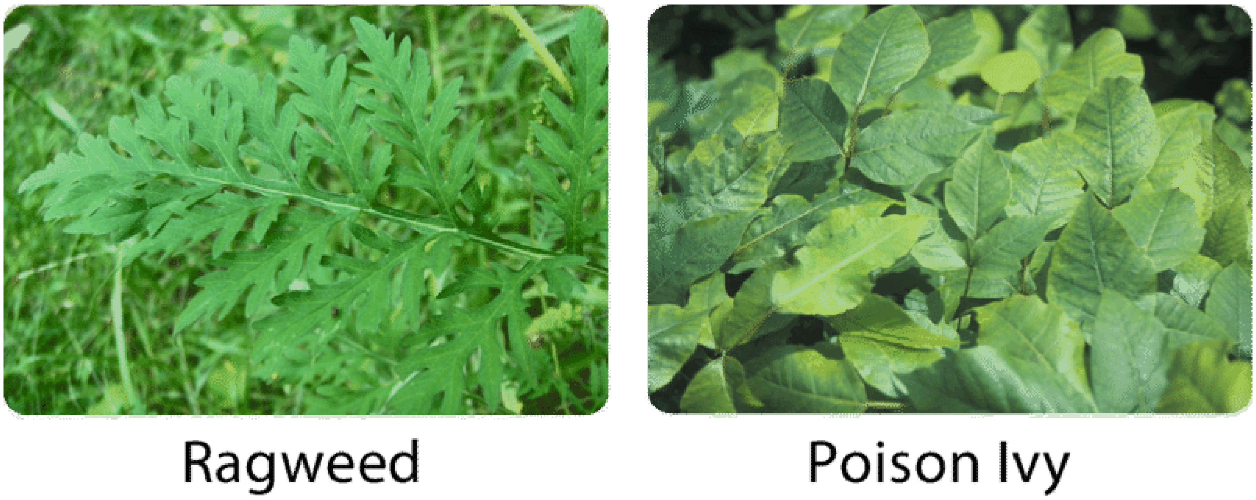
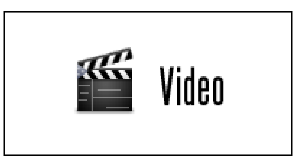


FIGURE 11.1
Ragweed and poison ivy are common causes of allergies. Are you allergic to these plants?

The symptoms of allergies can range from mild to severe. Mild allergy symptoms are often treated with **antihistamines**. These are drugs that reduce or eliminate the effects of the histamines that cause allergy symptoms. Recall that histamines trigger the inflammatory response. The most severe allergic reaction is called **anaphylaxis**. This is a life-threatening response caused by a massive release of histamines. It requires emergency medical treatment.



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Summary

- Allergies occur when the immune system makes an inflammatory response to a harmless antigen.
- An antigen that causes an allergy is called an allergen.

Review

1. What is an allergen? Give two examples.
2. Define anaphylaxis. What causes the symptoms of anaphylaxis?

3. Sometimes people with an allergy get allergy shots. They are injected with tiny amounts of the allergen that triggers the allergic reaction. The shots are repeated at regular intervals, and the amount of allergen that is injected each time gradually increases. How do you think this might help an allergy? Do you think this approach just treats allergy symptoms or might it cure the allergy?

References

1. Ragweed: Homer Edward Price; Poison ivy: John J. Mosesso/National Biological Information Infrastructure. Ragweed and poison ivy . Ragweed: CC BY 2.0; Poison ivy: Public Domain

CONCEPT 12 Autoimmune Diseases

Learning Objectives

- Describe how autoimmune diseases affect the body.
- List and describe common autoimmune diseases.

Joint pain. Not an uncommon problem as you grow older. Is it due to normal wear and tear on the joints? Possibly. But rheumatoid arthritis is an autoimmune disease, which means the body's immune system mistakenly attacks healthy tissue.

Autoimmune Diseases

Autoimmune diseases occur when the immune system fails to recognize the body's own molecules as "self," or belonging to the person. Instead, it attacks body cells as though they were dangerous pathogens. There are more than 80 known autoimmune diseases. Recall that regulatory T cells help regulate the immune system. When autoimmune disorders occur, these regulatory T cells fail in their function. This results in damage to various organs and tissues. The type of autoimmune disorder depends on the type of body tissue that is affected.

Some relatively common autoimmune diseases are listed in **Table** 12.1. These diseases cannot be cured, although they can be treated to relieve symptoms and prevent some of the long-term damage they cause.

TABLE 12.1: Autoimmune Diseases

Name of Disease	Tissues Attacked by Immune System	Results of Immune System Attack
Rheumatoid arthritis	tissues inside joints	joint damage and pain

TABLE 12.1: (continued)

Name of Disease	Tissues Attacked by Immune System	Results of Immune System Attack
Type 1 diabetes	insulin-producing cells of the pancreas	inability to produce insulin, high blood sugar
Multiple sclerosis	myelin sheaths of central nervous system neurons	muscle weakness, pain, fatigue
Systemic lupus erythematosus	joints, heart, other organs	joint and organ damage and pain

Why does the immune system attack body cells? In some cases, it's because of exposure to **pathogens** that have **antigens** similar to the body's own molecules. When this happens, the immune system not only attacks the pathogens, it also attacks body cells with the similar molecules.

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Summary

- Autoimmune diseases occur when the immune system fails to distinguish self from non-self. As a result, the immune system attacks the body's own cells.

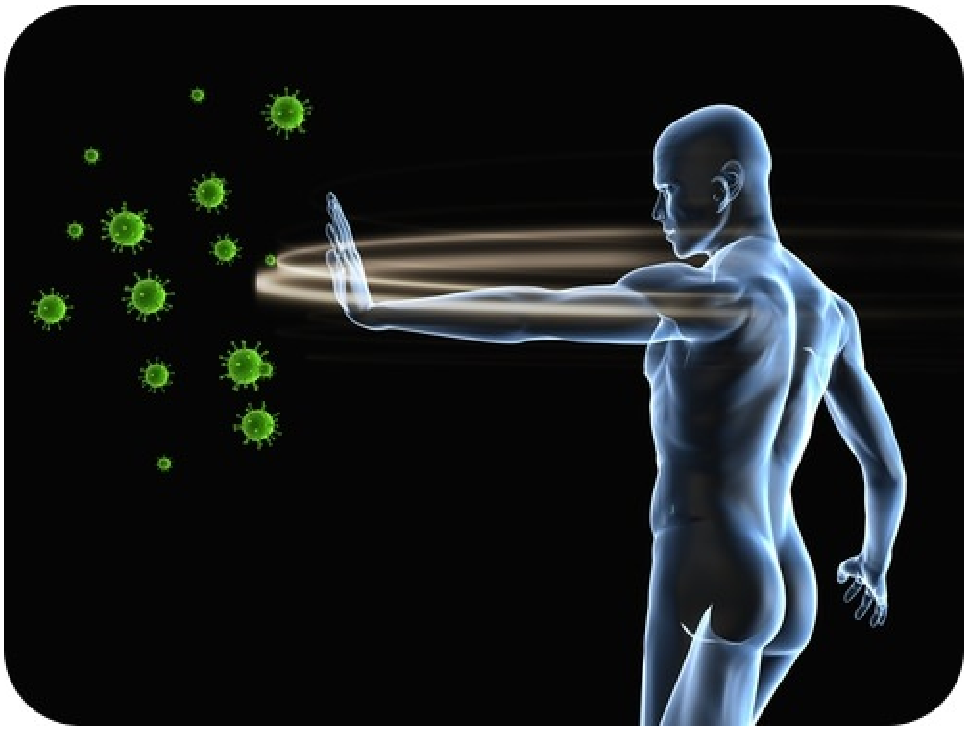
Review

1. What is an autoimmune disease? Name an example.
2. 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 may also attack the heart. What type of immune system disease is rheumatic fever? Explain your answer.
3. Can autoimmune disease be cured?

CONCEPT 13 Immunodeficiency

Learning Objectives

- Define immunodeficiency.
- List reasons for immunodeficiency.



Which is stronger?

You or little tiny pathogens? Usually you are. Normally your body can put up a strong defense against enemy pathogens. But what if it can't? What happens if your immune system is "sick"?

Immunodeficiency

Immunodeficiency occurs when the immune system is not working properly. As a result, it cannot fight off pathogens that a normal immune system would be able to resist. Most commonly, immunodeficiency diseases occur when T or B cells (or both) do not work as well as they should, or when your body doesn't produce enough antibodies.

Rarely, the problem is caused by a defective gene. Inherited immunodeficiency disorders that affect B cells include hypogammaglobulinemia, which usually leads to respiratory and gastrointestinal infections, and agammaglobulinemia, which results in severe infections early in life, and is often deadly.

More often, immunodeficiency is acquired during a person's lifetime. Immunodeficiency may occur for a variety of reasons:

- The immune system naturally becomes less effective as people get older. This is why older people are generally more susceptible to disease.

- The immune system may be damaged by other disorders, such as obesity or drug abuse.
- Certain medications can suppress the immune system. This is an intended effect of drugs given to people with transplanted organs. In many cases, however, it is an unwanted side effect of drugs used to treat other diseases.
- Some pathogens attack and destroy cells of the immune system. An example is the virus known as **HIV**. It is the most common cause of immunodeficiency in the world today.

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Summary

- In an immunodeficiency disease, the immune system does not work normally. As a consequence, it cannot defend the body.

Review

1. What is immunodeficiency?
2. List three possible reasons for acquired immunodeficiency.

CONCEPT 14 HIV and AIDS

Learning Objectives

- Explain how HIV is transmitted.
- Explain how HIV causes AIDS.
- Describe the relationship between HIV infection and helper T cells.
- Define AIDS.

How long can a person live with HIV?

Years ago, a diagnosis of an HIV infection was a death sentence. Not today. With the proper medical treatment, an individual can live well over 10 or 20 or more productive years with an AIDS diagnosis. One of the most famous individuals with HIV is Earvin "Magic" Johnson, a retired professional basketball player. He was diagnosed in 1991. Over 20 years later, he is still doing well.

HIV and AIDS

Human immunodeficiency virus (HIV) is a virus that attacks the **immune system**. An example of HIV is shown in **Figure** 14.1. Many people infected with HIV eventually develop **acquired immune deficiency syndrome (AIDS).** This may not occur until many years after the virus first enters the body.

HIV Transmission

HIV is transmitted, or spread, through direct contact of **mucous membranes** or body fluids such as blood, semen, or breast milk. As shown in **Figure** 14.2, transmission of the virus can occur through sexual contact or the use of contaminated hypodermic needles. It can also be transmitted through an infected mother's blood to her baby

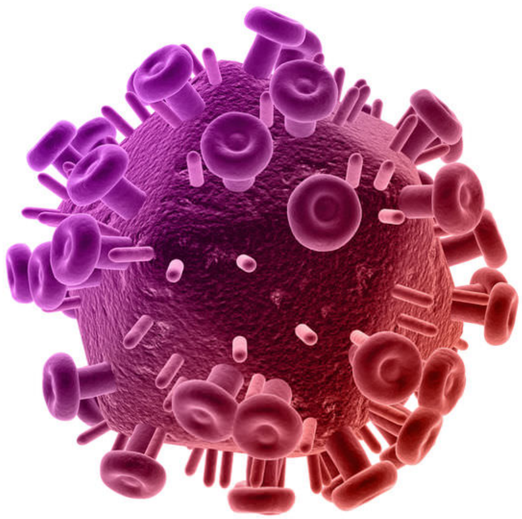

FIGURE 14.1
HIV is a virus that attacks cells of the immune system.

during late pregnancy or birth or through breast milk after birth. In the past, HIV was also transmitted through blood transfusions. Because donated blood is now screened for HIV, the virus is no longer transmitted this way. HIV is not spread through saliva, touching or in swimming pools.

HIV and the Immune System

HIV infects and destroys **helper T cells**. As shown in **Figure** 14.3, the virus injects its own DNA into a helper T cell and uses the T cell's "machinery" to make copies of itself. In the process the T cell is destroyed, and the virus copies go on to infect other helper T cells.

HIV is able to evade the immune system and keep destroying T cells. This occurs in two ways:

- The virus frequently mutates and changes its surface **antigens**. This prevents antigen-specific lymphocytes from developing that could destroy cells infected with the virus.
- The virus uses the plasma membranes of host cells to hide its own antigens. This prevents the host's immune system from detecting the antigens and destroying infected cells.

As time passes, the number of HIV copies keeps increasing, while the number of helper T cells keeps decreasing. The graph in **Figure** 14.4 shows how the number of T cells typically declines over a period of many years following the initial HIV infection. As the number of T cells decreases, so does the ability of the immune system to defend the body. As a result, an HIV-infected person develops frequent infections. Medicines can slow down the virus but not get rid of it, so there is no cure at present for HIV infections or AIDS. There also is no vaccine to immunize people against HIV infection, but scientists are working to develop one.

AIDS

AIDS is not a single disease but a set of diseases. It results from years of damage to the immune system by HIV. It occurs when helper T cells fall to a very low level and opportunistic diseases occur (see **Figure** 14.4). **Opportunistic diseases** are infections and tumors that are rare except in people with immunodeficiency. The diseases take advantage of the opportunity presented by people whose immune systems can't fight back. Opportunistic diseases are usually

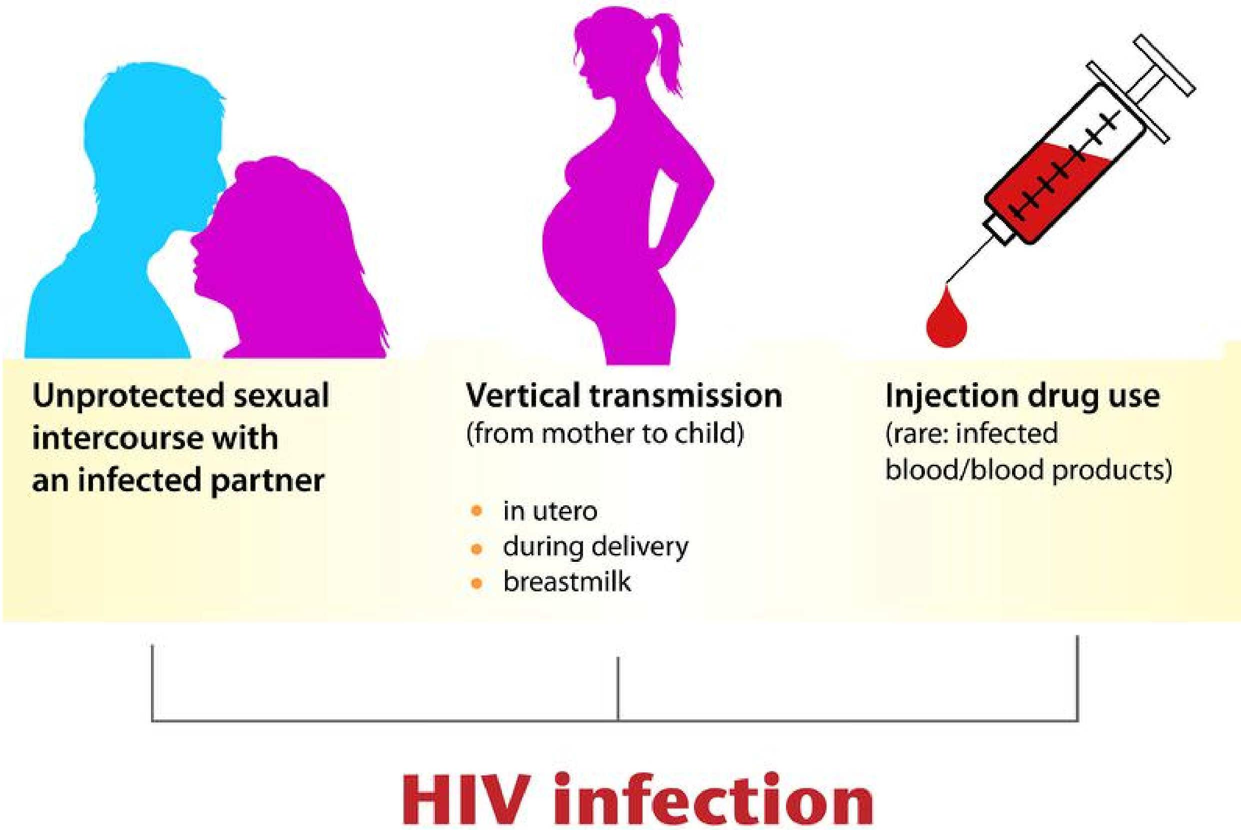

FIGURE 14.2
HIV may be transmitted in all of the ways shown here. Based on how HIV is transmitted, what can people do to protect themselves from becoming infected? What choices can they make to prevent infection?

the direct cause of death of people with AIDS.

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AIDS and HIV were first identified in 1981. Scientists think that the virus originally infected monkeys but then jumped to human populations, probably sometime during the early to mid-1900s. This most likely occurred in West Africa, but the virus soon spread around the world (see **Figure** 14.5). Since then, HIV has killed more than 25 million people worldwide. The hardest hit countries are in Africa, where medicines to slow down the virus are least available. The worldwide economic toll of HIV and AIDS has also been enormous.

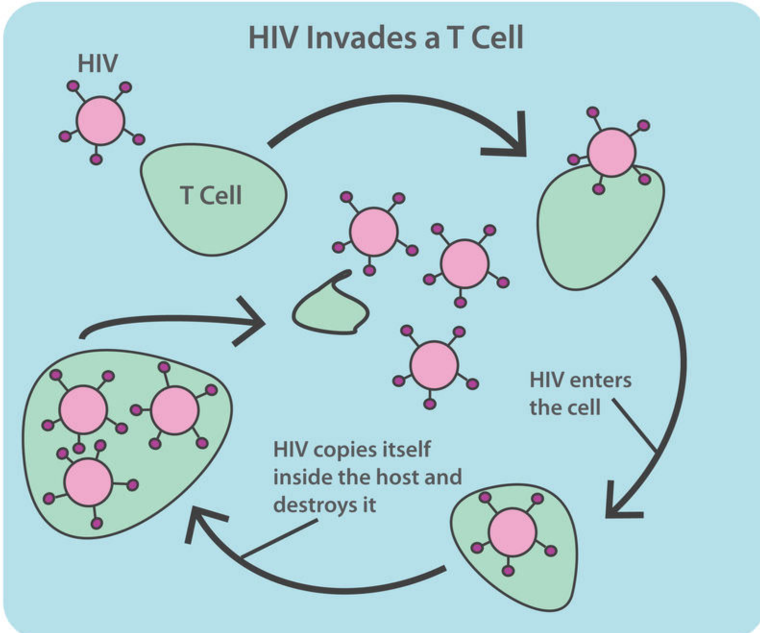


FIGURE 14.3
This diagram shows how HIV infects and destroys T cells.

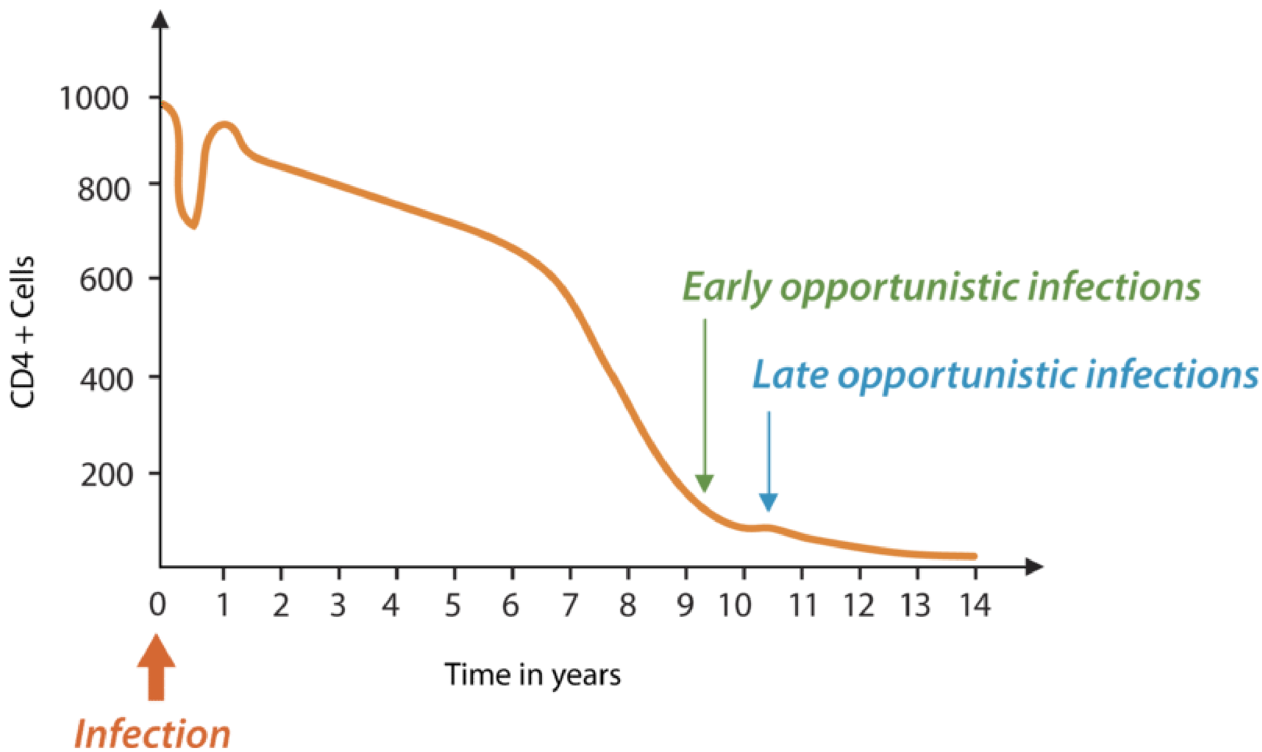


FIGURE 14.4
It typically takes several years after infection with HIV for the drop in T cells to cripple the immune system. What do you think explains the brief spike in T cells that occurs early in the HIV infection shown here?

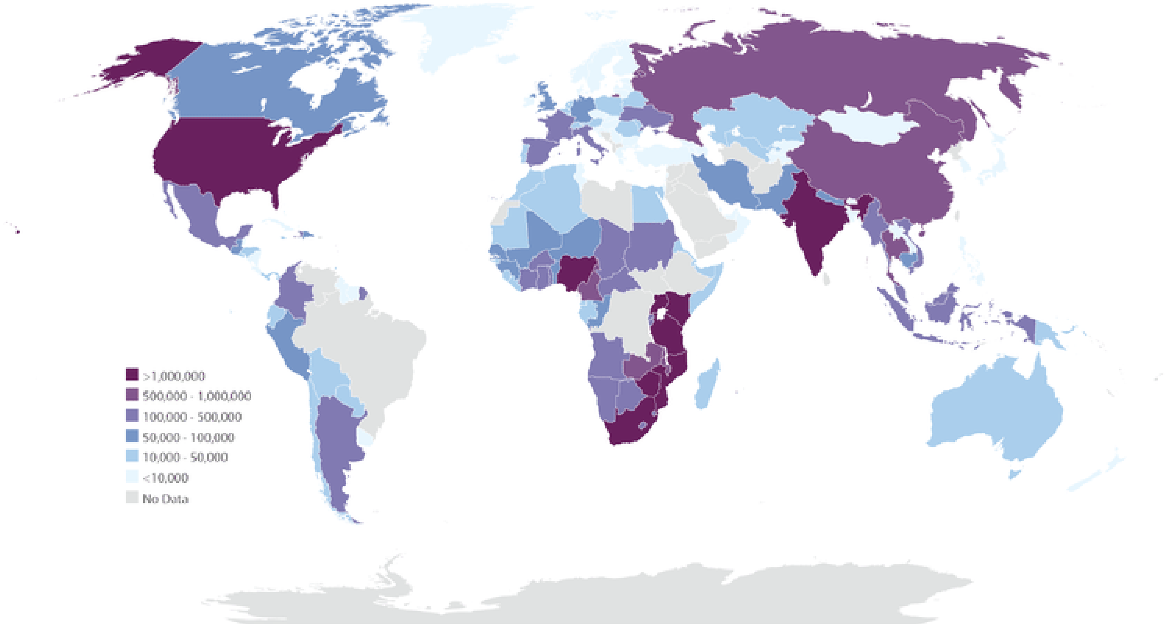


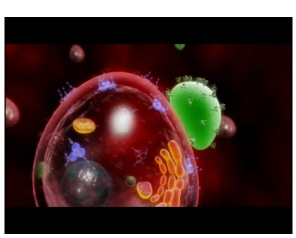
FIGURE 14.5

This map shows the number of people in different countries with HIV infections and AIDS in 2008. The rate of spread of the infection is higher Africa than in the U.S., yet the U.S. has a relatively large number of people with HIV infections and AIDS. Why might there be more survivors with HIV infections and AIDS in the U.S. than in Africa?

HIV Research: Beyond the Vaccine

Over the past 15 years, the number of people who die of AIDS each year in the United States has dropped by 70 percent. But AIDS remains a serious public health crisis among low-income African-Americans, particularly women. And in sub-Saharan Africa, the virus killed more than 1.6 million people in 2007 alone. Innovative research approaches could lead to new treatments and possibly a cure for AIDS. HIV/AIDS has been described as a disease of poverty. Individuals with poor access to health care are less likely to see a doctor early on in their HIV infection, and thus they may be more likely to transmit the infection. HIV is now the leading cause of death for African American women between 24 and 35 years old.

For patients who have access to drugs, infection with the virus has ceased to be a death sentence. In 1995, combinations of drugs called **highly active anti-retroviral therapy (HAART)** were developed. For some patients, drugs can reduce the amount of virus to undetectable levels. But some amount of virus always hides in the body's immune cells and attacks again if the patient stops taking his or her medication. Researchers are working on developing a drug to wipe out this hidden virus, which could mean the end of AIDS.



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Summary

- HIV is a virus that attacks cells of the immune system and eventually causes AIDS.
- AIDS is the chief cause of immunodeficiency in the world today.

Review

1. What is the relationship between HIV and AIDS?
2. Identify two ways that HIV can be transmitted.
3. What cells are affected by HIV?
4. What happens to the number of HIV copies and the helper T cells over time in an infected individual?
5. Draw a graph to show the progression of an untreated HIV infection. Include a line that shows how the number of HIV copies changes over time. Include another line that shows how the number of helper T cells changes over time.
6. What are opportunistic diseases?

References

1. Image copyright Sebastian Kaulitzki, 2014. HIV virus . Used under license from Shutterstock.com
2. Hana Zavadska and Laura Guerin. HIV modes of transmission . CC BY-NC 3.0
3. Rupali Raju. HIV mechanism for destroying T cells . CC BY-NC 3.0
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5. CK-12 Foundation, based on map created by User:Canuckguy/Wikipedia and data from the UNAIDS Global Report on the Global Aids Epidemic 2012. HIV global rates of infection . CC BY-NC 3.0