World War I was so horrifying an event in world history that it continues to overshadow the worst disease outbreak of the twentieth century. The 1918–1919 world-wide epidemic of Spanish flu, which broke out toward the end of the Great War, killed between 20 and 50 million people. The number of civilians and soldiers killed in WW1 is estimated to be near 15 million. In the United States, Spanish flu killed an estimated 675,000 people. Scientists now think that the flu virus was harbored in birds and then, for reasons unknown, “jumped” to humans and began to spread.

The 1918 Spanish flu disaster is the kind of history that could be repeated. A new and deadly influenza virus is now circulating among wild and domestic birds. Traveling with migratory birds, this so-called bird flu has already reached Turkey, Egypt, Nigeria, and Eastern Europe. This avian virus has killed more than 100 people, mainly in Southern Asia. To prevent its spread, public health authorities have had to kill millions of chickens, ducks, and other fowl.

As we write, the avian influenza virus does not have the ability to spread from one person to another, so all patients have been infected through close contact with an infected bird. But if avian flu mutates and becomes able to spread directly from one person to another, millions could die before a vaccine is developed.

Luckily humans, while susceptible to disease, are not completely defenseless. We have already seen that humans have general defenses against pathogens. A second, more specific, arm of this defense is found in the lymphatic system. The intricate interplay of antibodies, killer cells, and memory cells in the immune system are the focus of this chapter. Without the lymphatic system, humans would have died out long before the 1918 pandemic.
The Lymphatic System Is the Center of Our Immune Response

Learning Objectives

- Identify the structures of the lymphatic system.
- Describe the flow of lymph.

When nonspecific defenses such as those discussed in Chapter 9 prove inadequate, our body can employ more selective defenses against disease. This defense, called our immune response, is governed by the lymphatic system. The immune response is acquired, not innate, meaning that it is a conditioned or “learned” reaction of the lymphatic system.

The organs of the lymphatic system include the tonsils, spleen, thymus, lymph nodes, and the Peyer’s patch glands of the digestive system. Connecting these organs is a network of lymphatic vessels that collect lymph from the tissues and deposit it in the bloodstream.

The lymphatic system is composed of lymphatic vessels and lymphoid organs. Like the circulatory system, the lymphatic system touches most of the body and carries out both transportation and homeostatic services. You are probably familiar with the lymph nodes, those small, bean-shaped structures that you may feel alongside your Adam’s apple when you have a sore throat. You may be surprised to learn that you have lymph nodes elsewhere in your body, including your intestinal tract and chest. These lymph nodes function in concert with lymphatic tissue, organs, and vessels to (1) return excess fluid from the tissues to the bloodstream, (2) absorb fats from the intestine and transport them to the bloodstream, and (3) defend the body against specific invaders.

Your tissues are bathed in lymph, a clear fluid that is called interstitial fluid when it is found in the interstices between tissue cells. Chemically, lymph is quite similar to blood plasma, which makes sense because lymph originates in fluid that diffuses from the capillaries into the tissue. If you scrape your epidermis, say when you “skin your knee,” clear interstitial fluid will bead up on the exposed dermis. Normally, lymphatic vessels collect this fluid.

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for return to the bloodstream. When interstitial fluid is inside lymph vessels, we call it lymph (Figure 10.2).

**LYMPHATIC CAPILLARIES AND VESSELS RESEMBLE A PARALLEL CIRCULATORY SYSTEM**

The lymphatic system has many similarities to the circulatory system because both systems reach almost every cell in the body. Because interstitial fluid is so widespread, lymphatic capillaries (very small vessels) are also found throughout the body. Often the lymph in these capillaries is filled with ingested fats, turning the vessel milk white. When lymphatic veins and capillaries were first discovered, they were called "wee milked veins" for this reason.

In the circulatory system, capillaries are part of a closed system that takes blood from the heart to the tissue and back to the heart. In contrast, lymphatic capillaries are one-way tubes. They are part of an open system where vessels lead from the tissues to the bloodstream but not in the opposite direction.

Unlike the circulatory system, the lymphatic system has no central pump. Lymph flows through tissues and into lymphatic capillaries mainly because of the squeezing action of skeletal muscles. As muscles contract, they shorten and thicken, forcing excess fluid from the muscular tissue and surrounding organs into the lymphatic capillaries. Lymphatic capillaries allow fluid to enter but not to exit because their walls are composed of cells positioned with slight overlaps (Figure 10.3). Pressure from outside the vessel parts the cells so that fluid can enter the lumen (center) of the capillary. Fluid pressure inside the capillary presses the cells shut so that the fluid cannot escape. This action is rather like your front door. If you push on one side, the door will open, but if you push from the other side, it will only close tighter.
The long connective tissue flaps of lymphatic valves prevent lymph from flowing backwards into the lymphatic capillaries.

Lymphatic vessels transport their lymph to either the thoracic duct in the mediastinum, or to the right lymphatic duct, just posterior to the right clavicle (Figure 10.5). The right lymphatic duct drains the right side of the head and neck, the right arm, and the right thoracic area. Both ducts drain into the subclavian veins, allowing lymph to return to the bloodstream.

The main ducts of the lymphatic system are the thoracic and the right lymphatic ducts. The right lymphatic duct drains the right side of the head, the right shoulder and the upper portion of the right chest. Lymph collected from the entire rest of the body is drained into the thoracic duct. This arrangement causes concern for breast cancer patients, whose cancer may metastasize into the lymph. If this happens, it is easy to see how quickly those cells can be spread throughout the body via the lymphatic system.

**MEDIASTINAL TRUNK**

The central portion of the thoracic cavity between the lungs, housing the heart, major blood vessels, and lymphatics.

**RIGHT BRONCHIO-MEDIASTINAL TRUNK**

The right lymphatic duct drains the right side of the head and neck, the right arm, and the right thoracic area. Both ducts drain into the subclavian veins, allowing lymph to return to the bloodstream.

Lymphatic vessels transport their lymph to either the thoracic duct in the mediastinum, or to the right lymphatic duct, just posterior to the right clavicle (Figure 10.5). The right lymphatic duct drains the right side of the head, the right shoulder and the upper portion of the right chest. Lymph collected from the entire rest of the body is drained into the thoracic duct. This arrangement causes concern for breast cancer patients, whose cancer may metastasize into the lymph. If this happens, it is easy to see how quickly those cells can be spread throughout the body via the lymphatic system.

**LYMPHATIC ORGANS FILTER AND PROTECT**

Before lymph returns to the bloodstream, it must be filtered and cleaned. Otherwise, the lymph would dump the cellular debris and waste products it has picked up while flushing through the tissues into the bloodstream. This cleaning occurs in the lymphoid organs—the lymph nodes, tonsil, spleen, thymus gland, and bone marrow.

Lymph nodes are cleansing units. Lymph nodes are small, encapsulated glands that are strategically located to filter large volumes of lymph. The intestinal nodes are in the groin, the axillary nodes are in the armpit, the cervical nodes are in the neck, and the mesenteric lymph nodes form a chain at the center of the abdominal cavity. Nodes are filtering stations for lymph (Figure 10.5). Lymph enters a node via many passages but can leave by only one or two exits, forcing lymph to flow through the nodes in one direction.

Lymph nodes filter lymph that has been collected from nearby tissues, and they can tell us a good deal about the health of that region of the body. “Swollen glands” are lymph nodes that are enlarged due to localized or systemic infection, abscess formation, malignancy, or other, rarer causes. A bacterial infection can often be detected in the lymph because immune cells in lymph nodes will increase in number and produce antibodies. The population of lymphocytes will rise in the lymph node as these cells work to attack the pathogens. Swelling might be present even when the infection is not producing other symptoms. The particular lymph nodes that are swollen depend on the type of problem and the body parts involved, and identifying the location can help locate the infection.

Many infections can cause swollen lymph nodes, including mononucleosis, German measles, tuberculosis, mumps, ear infections, tonsillitis, an abscessed tooth, gingivitis (infection of the gums), large, untreated dental cavities, and various sexually transmitted diseases. Immune disorders that can cause swollen lymph nodes include rheumatoid arthritis and HIV.
I WONDER...

Mononucleosis ("mono") is an infection caused by the Epstein-Barr virus. Many children get a mild case, which can be mistaken for an ordinary cold. In a young adult, mono usually produces symptoms four to seven weeks after exposure. These symptoms can include sore throat, fever, headache, fatigue, and anorexia. Many symptoms concern the lymphatic system: swollen tonsils, white patches on the back of the throat, and swollen glands (lymph nodes) in the neck.

Epstein-Barr virus infects cells in the salivary gland, causing the saliva to carry a large quantity of virus. This explains why Epstein-Barr is often transmitted through kissing and is called the "kissing disease." Other, less romantic transfers can occur through coughing, sneezing, or sharing food utensils.

Mononucleosis is usually treated with rest and fluids. Because it is viral, antibiotics are not helpful, although they may be used to defeat a bacterial infection that may accompany mono.

The complications of mono include hepatitis (liver inflammation), jaundice, and a reduction of platelets, a formed element of the blood that initiates clotting. But the most serious complication is a ruptured spleen. The spleen is the lymphatic organ that filters and cleans whole blood, and it expands during an infection, just as the lymph nodes in their organization and function. You were born with two sets of tonsils: the pharyngeal tonsils in the nasopharynx, and the palatine tonsils, which are visible on either side of the pharyngeal opening. The main difference between tonsils and lymph nodes is that the tonsils are not entirely encapsulated. Instead, they are open to the fluids that pass through the pharynx. Infectious agents can be trapped in these organs, swellling the tonsil enough to almost shut off the pharynx.

Similar patches of lymphoid tissue are found in the lining of the small intestine. These egg-shaped masses, called mucosa-associated lymphoid tissue, or MALT, help filter fluid absorbed from the intestinal lumen.

The spleen is the largest collection of lymphoid tissue. The largest lymphatic organ is the spleen. The spleen is highlighted in yellow in this CT scan. Hodgkin’s disease Figure 10.7

Hodgkin’s disease is a cancer of the lymph nodes, usually contracted in people who have had mononucleosis or measles. Not much is yet understood about the causes of this disease, but once diagnosed, survival rates are high for patients with Hodgkin’s lymphoma. In this photo, a patient is undergoing radiotherapy on linear accelerator.

Cancers that can cause swollen glands include leukemia, Hodgkin’s disease, and non-Hodgkin’s lymphoma. Swollen lymph nodes may also be caused by certain medications or vaccinations. Cells of certain cancers, especially breast cancer, can be found in lymph nodes near the site of the primary tumor. As these cells metastasize, or migrate, to form new tumors, the number of lymph nodes containing cancer cells increases. This then is a good indicator of how advanced the cancer is.

When I was diagnosed with mononucleosis, why was I told not to jump around?

B-cells (B-lymphocytes) are a second infection site of Epstein-Barr, and one job of the spleen is to remove abnormal blood cells. During mononucleosis, the spleen must deal with a large number of abnormal blood cells, which cause the organ to swell and become tender. As with most swollen organs, stretching stresses the membranes and capsule of the spleen, making it susceptible to bursting upon impact or injury. A burst spleen causes internal bleeding. Symptoms of rupture include pain in the left upper part of the abdomen, a lightheaded feeling, a racing heart, bleeding elsewhere more easily than usual, and trouble breathing. A ruptured spleen is a medical emergency, entailing either quick repair surgery or a spleen removal.

Although few people with mononucleosis suffer a ruptured spleen, this life-threatening complication is worth avoiding. As the fatigue starts to abate, light exercise will help recovery, but the patient should avoid sports or other activities until a doctor grants permission...It's usually safe to resume activities about four to eight weeks after the first symptoms appear.

If you avoid a ruptured spleen, Epstein-Barr virus is unlikely to cause any long-term harm, and your new antibodies are quite likely to ensure that you never get the disease again.
The thymus produces mature immune cells

The thymus gland is located in the mediastinum of the thoracic cavity, behind the sternum and spanning over the upper portion of all the heart. It is composed of two lobes held together by connective tissue. (See Fig-ure 10.9.)

The primary function of the thymus is to produce mature, functional T cells, a distinct group of immune cells. The cortex of the thymus gland is involved in "training" T cells to distinguish self versus pathogens. It also produces thymic hormones that promote maturation of T cells.

The changing activity of the immune system with aging helps explains the recommendations the U.S. Centers for Disease Control and Prevention (CDC) has made for flu shots (Figure 10.10). The CDC currently recommends that flu shots be given to people age 50 and over, nursing home residents, children 6 months to 5 years, pregnant women, people with chronic health problems, and certain healthcare and daycare workers. But when vaccine becomes scarce, healthy people under 65 are urged to forgo the shot.

Bone marrow also produces mature immune cells

The final type of lymphatic tissue is bone marrow. (See Figure 10.9.) The thymus is largest at puberty and shrinks with age, losing function as it shrinks. One reason your parents or grandparents probably suffer more than you from a common cold or a passing virus is thymic atrophy.

As we now understand, the thymic system cleans and returns excess fluid to the circulatory system. It is also of paramount importance in maintaining homeostasis through its role in specific immunity.
THE IMMUNE SYSTEM IS A WORLD OF ASSASSINS

Two main classes of lymphocytes are involved in immunity: B cells and T cells. B cells (B lymphocytes) mature in the thymus gland in response to thymic hormones. T cells (T lymphocytes) mature in the bone marrow and spend most of their time inside lymph nodes. B cells produce antibodies that are specific to a particular pathogen. T cells (T lymphocytes) mature in the thymus gland in response to thymic hormones. T cells make up the majority of the circulating lymphocytes in the blood. T cells are responsible for stimulating B cells, as well as the direct destruction of antigens.

Lymphocytes have receptors on their cell membranes, waiting to detect the exact antigen, which fits the receptor like a lock and key (Figure 10.11). Each lymphocyte is specific to one antigen; it will ignore all others. During our lives, we are exposed to thousands of antigens. Amazingly, our lymphocytes develop a specific response to every one of them by mixing and matching receptor proteins that are created by genes of the immune system. Small changes in receptor shape on the surface of a T cell or B cell will cause that cell to react to a different antigen.

HUMORAL IMMUNITY IS MEDIATED BY ANTIBODIES

Antibodies are proteins produced by B lymphocytes and directed against specific pathogens or foreign tissue. When a lymphocyte encounters the matching antigen, it bonds to that antigen and the lymphocyte is stimulated. Depending on the type of lymphocyte, stimulation results in either humoral immunity or cell-mediated (cellular) immunity. T cells are responsible for cellular immunity, whereas both B cells and T cells are involved in humoral immunity.

Humoral immunity is the type of immunity that uses B cells and antibodies; the name “humoral” reflects the fact that this immunity takes place in the blood. Antibodies are proteins that remove antigens from the bloodstream, usually by causing them to agglutinate. Each B cell produces a different antibody that is directed toward a specific antigen. Because the B cell “wears” this antibody on its surface, the antibody is called a marker. When the surface antibody reacts with its specific antigen, the B cell is activated and begins to divide, making clones of itself. Because the antigen in effect “chooses” or selects which B cell will be cloned, this process is called clonal selection.

The cloned B cells produced during clonal selection are identical to the original, so they will link to the same antigen that started the cloning in the first place. As the cloned B cells are produced, two populations are created: plasma cells and memory cells. Mature antibody-producing B cells, called plasma cells, pump out an arsenal of antibodies, ensuring that the antigen is removed from the body (Figure 10.12). When the antigen is gone, the plasma cells undergo apoptosis and die.

The second variety of cloned B cells, called memory cells, contributes to a library of long-term immunity that we call the secondary immune response. For as long as 10 years, memory cells stand ready to go into action if the antigen ever reappears. If the pathogen reappears within that period, the memory cells quickly produce antibodies, ready to combat the pathogen before it can cause harm. Vaccinations and booster shots trigger the formation of memory cells, thus allowing us to fight pathogens that have never actually caused us to get sick. We have memory cells for a disease for which we never actually experienced the symptoms.

T Cells are traveling fighters. Because B cells reside in lymph nodes where they may not contact antigens, we have an alternative route to stimulation. Recall that T cells travel throughout the body in the bloodstream. Helper T cells patrol the blood in concentrations from 500 to 1,500 cells per cubic millimeter. The surface of helper T cells carries the same type of antigen-binding antibodies as B cells. When the proper antigen binds to a helper T cell, it is stimulated to clone. This cloning of helper T cells amplifies the message that there is a pathogen to be taken care of, greatly increasing the chances of stimulating the
activated by IL-2, which promotes T cell growth and stimulates macrophage function (Fig. 10.13). Activated helper T cells may activate the specific B cells that are directed against that same antigen. These B cells then begin to produce antibodies, just as they would do if they had encountered the antigen directly.

On the surface of a helper T cell is a protein complex called CD4, which serves as a docking station for a B cell while it is being stimulated to clone and produce antibodies. CD4 is attracted to Class II MHC (Major Histocompatibility Complex) molecules, which occur on the surface of B cells and other immune cells. The CD4/MHC interaction holds the T cell to the B cell, enhancing stimulation (Fig. 10.14).

Memory helper T cells, produced when cloned helper T cells differentiate, lie in wait in the blood, ready to jump quickly into action should the same antigen again threaten the body.

Some T lymphocytes differentiate into natural killer (NK) cells, which are actually part of our innate defense system. They are introduced here because they are produced exactly like the specific T cells of our specific immune defenses. NK cells function as our natural cancer screen, patrolling the body and identifying virally infected cells and tumor cells. After detection, NK cells kill the diseased cell via cell-to-cell contact. NK cells are not specific because they remove all foreign or infected cells in exactly the same way. They do not respond to immunization, and they do not seem to produce clones of memory cells.

Proper B cells. Much like B cells, cloned helper T cells may be activated to actively fight the invading antigen, or they may produce memory cells.

Activated helper T cells secrete compounds that stimulate other lymphocytes. Interleukin-2 (IL-2), the best known of these compounds, promotes T cell growth and stimulates macrophage functioning (Fig. 10.13). An activated helper T cell will activate the specific B cells that are directed against that same antigen. These B cells then begin to produce antibodies, just as they would do if they had encountered the antigen directly.

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Memory helper T cells, produced when cloned helper T cells differentiate, lie in wait in the blood, ready to jump quickly into action should the same antigen again threaten the body.
**Antibodies Are More Specific Than Your Social Security Number**

Antibodies are proteins secreted by plasma cells in response to antigen binding. Antibodies all have the same general shape: a double-Y shaped protein with one long chain and one short chain polypeptide. Because the vast majority of long chains are identical among antibodies of one class, the long chain is called the constant region. The tips of the long chain and the corresponding tips on the short chain identify each antigen, and because they change so much, they are called the variable region. It is the variable region that interacts with the antigen and causes agglutination. A large conglomerate of antigen and antibody marks the antigens for destruction by the macrophages. The antigen/antibody complex often activates complement as well, enhancing antigen destruction.

The five classes of antibodies (also called immunoglobulin) are IgG, IgM, IgA, IgD, and IgE (see Figure 10.15):

- **IgG**, by far the most common antibody, occurs in the circulating blood, lymph, and tissue extracellular fluid. Immunoglobins bind directly to an antigen, inactivating them almost immediately. (Figure 10.16)
- **IgM** is the first immunoglobin released in any immune response and is also the predominant immunoglobin produced in infants. IgM is a large polymer of five Y-shaped molecules that causes infected or foreign cells to clump together when IgM binds to them. Like IgG, IgM also aids in the release of complement.
- **IgA** can be a monomer, dimer (two subunits), or larger molecule composed again of the Y-shaped units. One form of IgA is found in secretions, such as saliva, and can bind to pathogens before they enter the bloodstream.
- **IgD**, found on mature B cells, binds antigens that stimulate B cell activation.
- **IgE** is the immunoglobin responsible for immediate allergic reactions, appears on the surface of basophils and mast cells, both of which release histamines and other chemicals implicated in allergic symptoms.

In the body, natural humoral immunity results when many different plasma cells are simultaneously stimulated to form antibodies. Each clone of plasma cells originates from a different B cell. Each of these plasma cells produces an antibody that responds to a slightly different portion of the invading pathogen. The resulting soup of antibodies is polyclonal, meaning that the antibodies are produced by many different plasma cells. Polyclonal antibodies are directed against one specific antigen, but they link to many different antigenic sites on that antigen.

Many different antibodies become attached to this antigen. Each antibody was produced by a different plasma cell clone. Having so many slightly different antibodies all directed against differing portions of the antigen ensures that no antigen will be left in the bloodstream.

Because antibodies are so specific, they are an interesting source of precisely targeted drugs. Most of these cutting-edge medical treatments propose to use “monoclonal antibodies.” As the words imply, monoclonal antibodies are antibodies that are formed from clones of a single activated cell. To make a monoclonal antibody, a plasma cell is removed from the body, then cloned in the laboratory, creating a large number of identical cells that all produce the same antibody (Figure 10.17). Monoclonal antibodies are specific, reacting to only one particular antigenic portion of the pathogen. It may be possible to use them to target cancer cells by combining an antibody specific to the tumor cell with either a radioactive particle or a cell-killing medicine. In either case, the idea would be to deliver the death knell directly to the tumor cells, without harming healthy cells.

The specificity of monoclonal antibodies is often used in medical tests. The pregnancy tests sold in drug stores use a monoclonal antibody directed against a protein found only in the urine of pregnant women. Because monoclonal antibodies are so specific, any reaction in the test proves that the woman is pregnant. (If there is no reaction, the test should be repeated within a few days, because the protein level could be too low to detect on the first test.)

**Cellular Immunity Is Mediated by Cells**

Cellular immunity is governed by the T cells that wander through the tissues in the blood. There are two large populations of T cells: helper T cells and cytotoxic T cells. Unlike B cells, which can directly detect the presence of an antigen using the
Monoclonal antibody production

**Figure 10.17**

- Mouse is immunized with antigen X.
- Spleen lymphocytes are removed from mouse.
- Mouse myeloma cells in tissue culture.
- Cells are mixed and fused to make hybridomas.
- Hybridoma cells are grown in tissue culture.
- Select for hybridomas that make antibody to antigen X.
- Individual hybridoma cells are cloned.
- Antibodies to antigen X are present.
- Specimen is saved.
- Monoclonal antibodies are purified.
- Cloned hybridoma cells are cultured in bulk.
- Desired antibodies are not found.
- Specimen is discarded.

Cytotoxic T cells are mainly responsible for cellular immunity. Just like B cells, cytotoxic T cells are activated when antigens bind to receptors on their surface. They are also stimulated to divide by cytokines released from helper T cells. Cytotoxic T cells respond specifically to altered HLA (human leukocyte antigen) proteins. The

**Macrophage presenting antigen**

*Figure 10.18*

When the macrophage phagocytoses an antigen, it breaks the antigen into antigenic subunits, which are attached to the MHC of the macrophage and presented on the surface of the macrophage membrane. Traveling T cells can easily locate these antigenic fragments and respond to them. In this way, the MHC increases the probability that T cells will encounter and respond to the antigen.
HLA complex is a marker that identifies the cell as belonging to the body and is what we identify when we “tissue type” a person and an organ before an organ transplant. HLA mismatches can trigger a rejection reaction that can destroy poorly matched transplanted organs.

Most cells with foreign HLA complexes are cancerous or virally infected, but cytotoxic T cells will remove any cell without the proper HLA antigens, even cells that are beneficial to the body. Cytotoxic T cells physically attach to the foreign HLA-carrying cell and release perforin molecules from their vacuoles. Perforin molecules are like little molecular darts that poke through the plasma membrane of the infected cell (Figure 10.19). A pore forms in the cell membrane, allowing salts and water to enter the cell, causing it to swell and burst.

Immunity can be Acquired Actively or Passively

ACTIVE IMMUNITY IS THE “TRAINABLE” IMMUNE SYSTEM

Most of us acquire immunity from experience. We are exposed to a pathogen, it invades our tissues, and our immune system counterattacks by making antibodies (as just described). This is natural active immunity: Your immune system is exposed to the antigen in the natural course of your life; it adapts and actively combats the pathogen.

The primary advantage of active immunity comes from the creation of memory cells, which arise days after the initial reaction to the pathogen. The body needs days to respond to the pathogen, stimulate the proper cells, and follow the chain through helper T cells to B cells to plasma cells to antibody production.

Then the body needs a few days of antibody production to elevate the antibody titer to an effective level.

Memory cells produced during the primary response remain in the body for years, lying dormant until the same antigen reappears, when the secondary response occurs. This secondary response to a particular antigen happens far faster than the first response because the immune system needs to stimulate and clone only the memory cells (see Figure 10.20). Secondary responses also require less energy from the body.

Although active immunity is a great way to prevent illness from a second exposure to a pathogen, the process we have described requires that you have previously been exposed to the pathogen gotten sick and recovered from it. It’s preferable to prevent illness from the outset, so we never get the disease; some pathogens, after all, are extremely fatal! Fortunately, immunity can be obtained through artificial means as well. In this case, we intentionally introduce a pathogen to the body rather than allow you to contract the pathogen naturally. These pathogens are attenuated so that they can stimulate a primary immune response without causing disease.

CONCEPT CHECK

List the three traits of specific immunity.

How are memory cells created in humoral immunity?

Compare the structure and activity of the five classes of antibodies.

Describe the role of the macrophage in cellular immunity.

Explain the significance of HLA in cellular immunity.
PASSIVE IMMUNITY GETS HELP FROM THE OUTSIDE

Passive immunity is the transfer of antibodies without stimulating the immune system. Although active immunity is helpful because the memory cells can launch a quick secondary response, passive immunity is also beneficial because you do not expend energy creating antibodies or producing clones. However, passive immunity is like giving an infantryman a gun with only one magazine. Introduced antibodies provide the recipient with immediate resistance to specific antigens. Once the antibodies are used or broken down, however, the body cannot create mor e, and the immune protection is lost. There are no memory cells because the antibodies were not created by active stimulation of the immune system.

La Leche is the nonprofit organization that promotes healthy prenatal and postnatal care for both the breast feeding. Passive immunity can also be administered artificially in gamma globulin shots, which are mixtures of many antibodies designed to match the pathogens the patient may contract. These are often given before travel to foreign countries, where new diseases may be encountered. Passive immunity generally lasts three to six months, long enough for most foreign vacations.

IN AUTOIMMUNE DISEASES, DEFENSE BECOMES OFFENSE

The immune system is a complicated network of cells and cell components that normally defend the body and eliminate infections of bacteria, viruses, and other pathogens. This sophisticated mechanism can go bad in autoimmune diseases, when the immune system mistakenly attacks the body’s own cells, tissues, and organs. “Auto” is Greek for “self,” so an autoimmune response is an immune response in which the body attacks itself.

The many autoimmune diseases have different effects depending on what tissue is under attack. In multiple sclerosis, the autoimmune attack is directed against nervous tissue. Immune cells break down the myelin sheath on neurons of the CNS, resulting in the breakdown of scar tissue on those cells. This impedes normal impulse transmission. Crohn’s disease is an autoimmune disease directed against the gut. Type 1 diabetes mellitus is an autoimmune disease that attacks the pancreas. If the pancreas is not functioning properly, cells of the body cannot absorb glucose as they should, resulting in all the myriad symptoms of diabetes. In diseases like systemic lupus erythematosus (lupus), the site of the attack may vary. In one person, lupus may affect the skin and joints, whereas in another it may affect the skin, kidney, and lungs. Arthritis is an extremely common autoimmune disease, attacking the joint capsules of the body, causing painfully deformed joints (Figure 10.23). Although arthritis is usually considered a disease of older people, 1 in 1000 children under the age of 16 show signs of juvenile rheumatoid arthritis.

The damage of autoimmune disease may be permanent. Once the insulin-producing cells of the pancreas are destroyed in Type 1 diabetes, they do not regenerate. Autoimmune diseases affect millions of Americans, and for reasons not understood, they strike more women than men. Some autoimmune diseases are also more frequent in certain minority populations. For example, lupus is more common in African American and Hispanic women than in Caucasian women of European ancestry. Rheumatoid arthritis and scleroderma affect a higher percentage of some Native American and Hispanic communities than the general U.S. population.

CONCEPT CHECK

Why is the secondary immune response so much more effective than the primary immune response?

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Viruses and Bacteria Cause Disease in Different Ways

Learning Objectives

- Define prokaryotic and eukaryotic.
- Outline the structure of a typical bacterium.
- Relate the structure of a virus to its function.
- Define the lytic and lysogenic life cycles of viruses.

**Viruses and Bacteria Cause Disease in Different Ways**

Throughout this chapter, we have been discussing viral and bacterial infection. It is important to recognize the differences between these two categories of pathogens. These differences emerge from the fact that one is a true cell, whereas the other is a bit of protein surrounding a few genes.

**Bacteria are single-celled wonders**

Bacteria are prokaryotic cells that can be found in the ground, in the water, even in the air, not to mention inside humans and our fellow animals. Bacteria are generally smaller than eukaryotic cells, ranging in size from the 100-nanometer mycoplasma to the average-sized 7-micron cyanobacterium. A bacterial giant was recently discovered in the seafloor off Namibia. *Thiomargarita namibiensis* (Figure 10.24), which means “Sulfur pearl of Namibia,” was discovered in 2000 by Dr. Andreas Teske of Woods Hole Oceanographic Institute. This spherical bacterium is roughly the size of a period in a 12-point font. (Most bacteria are barely visible with a light microscope.)

Like all prokaryotes, bacteria have no internal membranes, no division of labor, and no specialized area where DNA is stored. Any special function, such as photosynthesis or isolating the single, circular strand of DNA, is carried out by the cell membrane. Bacteria do have one organelle in common with eukaryotic cells, however. Bacterial cells transcribe and translate DNA just like eukaryotes, so they have ribosomes in their cytoplasm. These ribosomes are so similar to those in eukaryotic cells that some scientists think all cells may have a common origin.

**Photosynthesis**

Process of producing carbohydrates with solar energy, chlorophyll, carbon dioxide, and water.

**Bacteria are classified in three ways**

Being relatively simple organisms, bacteria were traditionally classified by shape and by the staining patterns of their cell wall. The shape of bacteria falls into two broad categories: spherical and rod-shaped. Terms for spherical bacteria include cocci for single spherical bacteria, streptococci for those that grow in chains, and staphylococci for those that grow in large masses. Bacilli (singular bacillus) are rod-shaped cells that can be oval, tapered, or curved. Spirochetes are long rod-shaped bacterial cells that twist about their long axis. The bacterium that causes Lyme disease is an example of a spirochete.

**Gram stain, the most common bacterial staining technique, was developed by Hans Christian Gram to distinguish two types of bacterial infections in the lungs. Bacteria are either gram-positive or gram-negative.** Gram-positive bacteria retain a purple color from the gram stain, whereas gram-negative bacteria pick up a red dye, safranin (Figure 10.25). *Staphylococcus aureus* (staph infections) and *Streptococcus pneumoniae* (strept infections), are both gram-positive, whereas *Escherichia coli* (E.coli) is gram-negative.

A third, more scientific way to classify bacteria reflects their genetics, not their appearance. Two
strains can be compared with DNA-DNA hybridization, which measures how closely the DNA of one species resembles that of the other. Alternatively, the study could focus on a particular common gene that changes slowly through time. A third technique can look at ribosomal RNA; in fact, a sub-branch of this investigation, called 16S RNA, has been used to track the evolutionary relationships of the entire tree of life, not just bacteria.

Before leaving the subject of bacteria, here’s something to ponder: Humans live in concert with more than 2,000 types of bacteria. If you could count the bacteria in your GI tract, their number would exceed the number of cells in your body. Your mouth probably houses more than 400 species of bacteria all by itself. Clearly, most of these bacteria are harmless or even helpful. Bacteria in your gut, to take just one example, produce vitamin K, which is essential in blood clotting. Without bacteria in your body, you would die. So before you spend money on antibacterial soap or cleanser, consider that most of the microbes you encounter are harmless, helpful, or easily controlled by your innate and adaptive defenses.

Antibiotics kill bacteria When we need to kill bacteria, we turn to antibiotics, drugs that interfere with cellular processes that bacterial cells undergo every day. Various antibiotics prevent protein synthesis by binding to the bacterial ribosomal RNA; others destroy essential metabolic pathways, and still others block DNA and RNA synthesis. Antibiotics also affect cell walls, which are found in bacteria but not in mammals; they either break them down or prevent new cell walls from forming.

Bacteria have fiendishly clever defenses against antibiotics. Although bacteria sometimes mutate to acquire antibiotic resistance, more commonly, they acquire a resistance gene from other bacteria. This antibiotic resistance is developing into a huge problem, as bacteria are rapidly becoming immune to many modern antibiotics. One gene, or a ring of genetic material including a few genes, may carry resistance to several antibiotics, and it may be transferred from one species of bacterium to another, not just among a single species. For a discussion of one source of antibiotic resistance, see the Ethics and Issues box.

Bacteria can become resistant to specific antibiotics through several mechanisms:

- The bacterial cell membrane permeability changes so that the antibiotic cannot enter.
- The antibiotic receptor protein on the bacterial surface changes so that the antibiotic cannot attach.
- The bacterial metabolism alters to pump the antibiotic out of the cell.
- The bacteria produce enzymes that destroy the antibiotic.

Viruses can reproduce, but they are not alive

Viruses are different from bacteria. Not only are they far smaller, but they lack most characteristics of life. Viruses cannot reproduce without a host cell; they do not metabolize, and they are not composed of cells. A virus is merely a snippet of nucleic acid (either DNA or RNA) contained inside a protein coat, called a capsid. There may be enzymes carried within the protein coat as well. Ebola, AIDS, smallpox, chickenpox, influenza, shingles, herpes, polio, rabies, and hantavirus are all viral diseases. Some viruses, called bacteriophages, attack bacteria (Figure 10.26). Because of their small size and ease of purification, bacteriophages are used in research and medicine to introduce genes into cells.

Are antibiotics being overused on the farm?

Americans love meat; in 2001, the average American ate about 220 pounds of beef, poultry, and pork. Meat consumption is rising in other countries as well; beef consumption in Brazil, for example, is increasing by nearly 5 percent per year.

Raising meat animals is a multibillion dollar industry, where profits rest on tiny margins. The cost of feed and the time to reach market weight must be minimized, and producers are eager to decrease costs by growing animals faster. Decades ago, scientists observed that feeding small, subtherapeutic doses of antibiotics to farm animals would speed weight gain. Today, low doses of antibiotics are led to most meat animals in developed countries. According to one estimate, such use accounts for 70 percent of all antibiotics used in the United States. Beyond speeding growth, these antibiotics also prevent disease in crowded animal facilities.

But how does routine feeding of antibiotics affect the bacteria that are the target of antibiotics? A subtherapeutic dose of antibiotic does not kill all bacteria in an animal, and the ones that survive are more likely to resist the drug. When these bacteria multiply, they may form antibiotic-resistant strains of common, and sometimes deadly, bacteria. In human medicine, low doses are rare. We take enough antibiotics to kill all the microbes, and we are told to finish all our pills in order to prevent antibiotic-resistant microbes from emerging. Antibiotic resistance is a real danger. More than 50 years after antibiotics were labeled "miracle drugs" for killing common bacteria like tuberculosis, streptococcus, and staphylococcus, resistant bacteria are overcoming antibiotic barriers. Could we return to the dreadful days of untreatable bacterial epidemics? Research indicates that feeding antibiotics does undermine the drugs. After poultry started receiving fluoroquinolone antibiotics in 1995, doctors began seeing patients with resistant campylobacter and salmonella infections. The Food and Drug Administration found that 20 percent of ground beef in a supermarket was contaminated with salmonella, and 84 percent of those bacteria were resistant to at least one antibiotic. Antibiotic-resistant bacteria have been seen in groundwater, surface water, and air near large animal operations.

The medical profession has repeatedly warned about overusing antibiotics. According to a 2002 analysis in the journal Clinical Infectious Diseases, “Many lines of evidence link antimicrobial-resistant human infections to foodborne pathogens of animal origin.” Cessing to feed subtherapeutic doses to food animals “will lower the burden of antimicrobial resistance in the environment, with consequent benefits to human and animal health.”

Farming trade organizations, however, argue that many factors are involved in creating antibiotic-resistant bacteria, including medical practices and evolution through natural selection. Furthermore, they say that after antibiotic feeding was banned in Denmark, animals got sicker, and farmers had to use more antibiotics to treat diseases. At root is an ethical question: Feeding antibiotics to animals may be profitable, but is this worth the hazard of resistance? Are we overusing antibiotics on the farm, or are public health officials overreacting to a reasonable use of cost-saving technology?
Viruses are cellular parasites. When they contact their preferred host cell, they inject their nucleic acid into the host and take over its functioning. The host cell becomes a viral factory, producing new viruses at an alarming rate.

Viral DNA may remain dormant in the host cell, as happens in viruses that have a “lysogenic cycle” of viral replication, or it may immediately affect the cell, as happens in viruses that have a “lysogenic cycle.” Lytic viruses cause the host cell to immediately become a viral factory, pumping out more viruses almost instantaneously. Because viruses are not living, they are not susceptible to antibiotics. There is no cell wall to break down, no metabolic pathways to destroy, and no protein synthesis to disrupt. This is why you are not given antibiotics when you are suffering from the flu. How- ever, a few drugs can counteract specific viruses. Acyclovir, for example, breaks down into a compound that inhibits the replication of herpes simplex virus. A wide range of compounds are being used to prevent the replication of HIV, the virus that causes AIDS. However, in most cases, when you contract a virus, all that modern medicine can do is treat the symptoms and wait for your immune system to contain and destroy the virally infected cells.

**Other Pathogens Carry Other Dangers**

Two other categories of pathogens can attack human beings in the proper conditions: fungi and prions. Fungi are eukaryotic organisms that play a major role in decay processes in the natural world. Those that you are most familiar with include mushrooms and molds. Fungal diseases in general are more common in warm, moist conditions. They can range from athlete’s foot, a skin infection, to yeast infections of the blood vessels that is predominantly found in patients with a compromised immune system due to an underlying disease.

Prions are misshapen proteins that cause mad cow disease (spongiform encephalopathy) in cattle and Creutzfeld-Jacob disease in humans. Prions have even entered the human food chain through the consumption of mad cow meat. Prions are impossible to destroy with conventional heat, acid, or most common sterilization methods. They are most likely the cause of Creutzfeld-Jacob disease in humans, which has so far been untreatable.

**Adenovirus and bacteriophage**

Note the comparative sizes of the bacterium and virus pictured here inside a typical human liver cell. Both the virus and the bacterium are simple structures, with no organelles or specialized compartments. The liver cell is far more complex.
fewer of the characteristics of life than viruses, but they do cause similar proteins to become deformed, resulting in a chain reaction of destruction. Prions can attack the brain in a wide range of mammals, ranging from deer to cats to humans. These diseases are fatal and untreatable but extremely rare.

AIDS and HIV Attack the Immune System

**Learning Objectives**

- Describe the structure of the AIDS virus.
- Explain the difference between HIV and AIDS.
- Describe the transmission modes of HIV.
- Describe the problems that AIDS vaccines have encountered.

**AIDS**

AIDS, or Acquired Immunodeficiency Syndrome, is a disease characterized by the progressive destruction of the immune system, leading to severe opportunistic infections and cancers. It is caused by the human immunodeficiency virus (HIV).

**HIV**

HIV is a retrovirus, a type of virus that uses RNA as its genetic material and can integrate into the DNA of the host cell, allowing it to replicate. This makes HIV particularly difficult to treat and eliminate.

**Transmission of HIV**

HIV is transmitted primarily through sexual contact, intravenous drug use, and from mother to child during pregnancy, childbirth, or breastfeeding.

**Immunodeficiency**

Once HIV infects the body, it attacks the immune system, particularly the CD4 T cells, which are crucial for regulating the immune response.

**Viral Replication**

HIV enters the body, infects a CD4 T cell, and integrates its genetic material into the cell's DNA. The virus then replicates within the host cell, producing new viral particles that can infect other cells.

**Antibodies**

Antibodies are produced to help neutralize the virus, but they cannot completely clear HIV from the body.

**Use of Antiviral Medications**

Antiretroviral therapy (ART) is used to treat HIV and help prevent the progression of the disease. However, it does not cure HIV and requires lifelong use.

**HIV's Impact on the Global Health Landscape**

HIV is currently treatable but not curable, and there is still a pressing need for effective vaccines and treatments to prevent its spread.

**AIDS**

AIDS is the advanced stage of HIV infection, characterized by severe immune system failure and an increased risk of opportunistic infections and certain cancers.

**HIV**

HIV is the virus that causes AIDS, but not all individuals with HIV will develop AIDS. The progression to AIDS varies greatly from person to person.

**Viral Load**

The viral load refers to the amount of HIV in the body. Lowering the viral load can slow the progression of the disease and reduce the risk of transmission.

**Antiretroviral Therapy**

Antiretroviral therapy (ART) is a combination of antiviral medications that can help reduce the viral load and improve the immune system.

**Drug Resistance**

HIV can develop resistance to antiretroviral medications over time, which can make it more difficult to control.

**Medical Advances**

Ongoing research aims to develop new treatments, including vaccines and curative therapies, to combat HIV and AIDS.

**Prevention and Education**

Preventing HIV transmission involves education about transmission modes, use of condoms, and access to antiretroviral medications.

**Conclusion**

Despite significant advances in treatment and prevention, HIV/AIDS remains a major global health challenge, requiring continued collaboration and innovation to address.
The number of viral particles in the blood is called the viral load. The viral load is high after the infection, then it drops as the CD4 T cells are infected, which reduces the amount of virus floating freely in the blood. The viral load increases again when the infected T cells start producing more virus. See Figure 10.29 for a summary of the process of HIV reproduction.

The infection pattern of HIV causes recognizable stages for patients (Figure 10.30). During the acute phase of HIV infection, the patient has a high viral load. The CD4 T cell count is normal (500–1100 per mm³), and the immune system is functioning normally. A small proportion of people complain of flu-like symptoms during this stage, but the majority of patients have no symptoms because the HIV virus is attacking their T cells.

The number of T cells remains higher than the viral load during this first attack of HIV. Eventually, however, the virus will gain the upper hand. Viral load will exceed the CD4 T cell count, and the patient will suffer chronic infections. This stage can begin a few months to several years after infection. The CD4 T cell count drops below 500 per mm³ to as low as 200 per mm³ as infection after infection attacks the body. The lymph nodes swell with each infection and remain swollen for prolonged periods, damaging the node tissue. With fewer CD4 cells to initiate the immune response, the patient is susceptible to many diseases that a healthy immune system defeats daily. One indicator disease for this stage of HIV infection is thrush, a yeast infection in the throat and mouth. Uninfected patients easily combat this fungus but not those with lowered T cell counts.

It can take anywhere from 1 to 15 years for HIV to develop into AIDS. Once chronic infection sets in, full-blown AIDS, defined as a CD4 count below 200 per mm³—is not far behind. The patient suffers a dramatic weight loss, the lymph nodes are damaged beyond their ability to function, and opportunistic infections like Pneumocystis carinii (an otherwise rare form of pneumonia), tuberculosis, or Kaposi’s sarcoma attack the body (Figure 10.31). The patient usually succumbs to one of these infections, so death is an indirect result of the HIV infection.
Health, Wellness, and Disease

CHAPTER 10

HIV treatment remains an uphill battle

Al though AIDS cannot be cured, we are getting better at controlling the virus and its symptoms. The current state-of-the-art treatment is called highly active antiretroviral therapy (HAART), which includes nucleoside analogs and protease inhibitors. Protease inhibitors block the enzyme protease needed to produce new viral particles. Nucleoside analogs like AZT are structurally similar to one of the four DNA nucleotides, and they prevent translation of the HIV proviruses in infected cells. The analogs are picked up during transcription and added to the growing mRNA molecule. The analogs either stop the formation of the new chain, inhibit reverse transcriptase from completing the chain, or prevent translation of the cDNA. When nucleotide analogs are present, the message is not usable, so production of viral proteins stops. These treatments are effective but demanding. The patient must take a complicated regime of pills throughout the day, and the side effects of these medications commonly include diarrhea, hepatitis, and diabetes.

HIV treatment remains an uphill battle
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controlling the virus and its symptoms. The current state-

AIDS is spreading in Eastern Europe and the Russian Federation, especially among drug injectors and prisoners. In Asia, 8 million people are infected, including 1 million infected during 2005. In the United States, about 1 million people are living with HIV, and about 42,000 people have AIDS.

AIDS is spreading in Eastern Europe and the Russian Federation, especially among drug injectors and prisoners. A similar danger exists today. Scientists say a deadly avian flu virus may spread from poultry to people, starting a global epidemic of a virus that spreads through the air (see discussion at the beginning of this chapter).

Although East Africa has been considered a focus of AIDS, scientists now concede that previous estimates of infection were overstated because they were based on women who visited prenatal clinics. Because these women were more active sexually than average, their high rates of HIV were not fully representative of all women. Despite the overreporting, the AIDS epidemic is thriving in southern Africa, where at least 20 percent of pregnant women in six countries carry the virus.

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Although our bodies have an excellent series of defenses against disease, epidemics still occur. Because epidemics can cross borders, combating them requires international leadership. Since 1948, the World Health Organization (WHO) has been the branch of the United Nations dedicated to ensuring that every human attains the highest possible level of health. (Figure 10.32) The policies of this organization are designed to enhance quality of life through improvements in physical, mental, and social well-being.

In collaboration with national health organizations such as the U.S. Centers for Disease Control and Prevention, WHO tries to keep tabs on epidemics. Researchers from WHO constantly model the spread of epidemics in an attempt to stay ahead of and predict viral outbreaks. WHO helps transfer samples of new diseases to safe labs where they can be quickly identified. The WHO also helps predict which strains of influenza (the "flu") are most likely to appear among humans each winter. Their predictions are based on past influenza strains and on hypotheses of how changing environmental conditions may affect the competitive advantages of particular strains. On this basis, the organization then selects which antigens to include in the "flu shot," and corporations and national medical systems make and administer the shots to at-risk individuals.

Common influenza remains a deadly nuisance, but smallpox was one of the greatest killers in history. At the end of the nineteenth century, the WHO directed a worldwide campaign to eradicate smallpox, the only viral disease ever eradicated from the human population. WHO is now in the midst of a campaign to eradicate polio, which attacks the motor neurons of the brain stem and spinal cord and causes paralysis in 1 of 200 cases (Figure 10.33). In 2002, the eradication program was working well, with only three Asian and three African countries reporting cases. Since then, the vaccination has been undermined by fear, rumors, and political manipulation. For 16 months, northern Nigeria refused to administer polio vaccines because Islamic leaders charged that the vaccine was a disguised sterilization campaign. The lapse in vaccinations caused a resurgence of polio. Between April 2005 and April 2006, 1,876 cases were seen worldwide, including 769 in Nigeria. The other cases in Africa were traced via genetic fingerprinting to the viral strain of the polio in Nigeria. Nigeria rescinded its ban on vaccination at the end of 2004, but 21 countries have been reinfected since 2003.

CONCEPT CHECK
What is one key role of the World Health Organization?
How does the WHO determine which strains of influenza are most threatening each year?

A rural clinic in a developing country (Figure 10.32) The World Health Organization provides vaccines for children in developing countries as part of their effort to eradicate crippling diseases. Often these vaccines are given in free health clinics such as the one in Haiti pictured here.

Infectious Disease is a Global Issue

LEARNING OBJECTIVES
Explain the importance of disease surveillance.
Describe one major program of the WHO during 2005.

In retrospect, many governments bungled the initial response to AIDS by denial or by staging lame, uncoordinated campaigns against infection. To date, no HIV vaccines work. Even though we have relied on vaccines to control viruses for a century, for the foreseeable future the battle against AIDS will focus on changing behavior and maximizing the use of imperfect medicines.
CHAPTER SUMMARY

1. The Lymphatic System is the Center of Our Immune Response

The lymphatic system returns interstitial fluid to the cardiovascular system, absorbs and transports fats, and provides specific immunity. The system is composed of lymphatic organs, lymphatic tissue, and lymphatic vessels. Lymph forms when portions of blood are forced through capillaries. This lymph bathes and cleans the tissues.

2. Cellular Immunity Relies on a Deadly Series of Cells

Cellular immunity is embodied in lymphocytes in the bloodstream and lymph nodes. Humoral immunity is carried out by B cells residing in the lymph nodes. Helper T cells detect a specific antigen and stimulate the proper B cell. That B cell then clones, producing plasma cells and memory cells. The plasma cells produce antibodies against the specific antigen. There are five classes of antibodies, on the basis of shape and chronology of appearance. When the pathogen has been cleared, memory cells lie in wait for a second invasion by the same pathogen.

3. Immunity Can Be Acquired Actively or Passively

Active immunity refers to immunity obtained through activating your own immune system and creating memory cells. Both immunizations and the natural course of getting sick and recovering cause a population of memory cells to form in the body. When the same antigen reappears, the memory cells immediately clone and eliminate the antigen. This secondary response is far faster than the primary immune response. Passive immunity occurs when antibodies are given to an individual rather than formed by that individual. Natural passive immunity occurs when a fetus or infant receives antibodies from the mother, through diffusion across the placenta and then breast milk.

4. Viruses and Bacteria Cause Disease in Different Ways

Bacteria and viruses cause most infectious diseases in humans. Bacteria are larger prokaryotic cells. They have a cell wall, a cell membrane, ribosomes, a circular piece of DNA anchored to the cell wall, and some intracellular fluid. Bacteria are classified by shape, gram staining, and genetic techniques. Viruses are small bits of nucleic acid covered in a protein coat, but they are not considered alive. Antibiotics kill bacteria by disrupting their cell membranes or other metabolic processes, but they have no effect on viruses. Pions and fungi also cause disease.

5. AIDS and HIV Attack the Immune System

AIDS is a blood-borne viral pathogen that leads to death via the AIDS. It is a retrovirus, infecting individuals through blood-to-blood contact that usually occurs during unprotected sex or use of contaminated needles. The cycle of HIV begins with introduction to the bloodstream. It then attaches to and invades a host CD4 T cell, where it copies its own RNA into cDNA. Next the viral genes are inserted into the host cell DNA. Symptoms are negligible at this point. Years later, the infected CD4 T cells begin to produce virus, increasing the viral load of the patient and decreasing the T cell count. AIDS is diagnosed when the CD4 T cell count drops below 200 per mm³ and the patient is suffering from opportunistic infections that healthy individuals’ immune systems easily fight off. Vaccine treatment for HIV remains out of reach, but researchers are getting closer to success.

6. Infectious Disease Is a Global Issue

The WHO is responsible for monitoring and predicting pandemics, and for helping national health organizations coordinate healthcare worldwide. Epidemics are often easier to prevent than to treat, so global monitoring is needed to track them to their source and start containment.

KEY TERMS

- cytokines p. 000
- antibodies p. 000
- apoptotic p. 000
- attenuated p. 000
- CD4 p. 000
- class II MHC (Major Histocompatibility Complex) p. 000
- phagocytes p. 000
- lymphocytes p. 000
- host cell p. 000
- immune response p. 000
- immunization p. 000
- interferons p. 000
- lymphatic system p. 000
- photosynthesis p. 000
- prokaryotic p. 000
- stem cells p. 000
- filter p. 000

CRITICAL THINKING QUESTIONS

1. Rheumatoid arthritis is an autoimmune disease. In autoimmune diseases, your immune system loses its ability to differentiate self from nonself and begins to attack your body. In rheumatoid arthritis, the attack affects cartilage in the joints. Using what you have learned about the immune response, what symptoms would you predict? How would the normal functioning of the immune system lead to these symptoms? What might a physiologist prescribe for rheumatoid arthritis?

2. Dengue fever is a tropical disease that, by 2005, had reached the Americas. In the Americas, the mosquito Aedes aegypti is the agent. Explain how a dengue fever vaccine might slow this epidemic. What characteristics would the vaccine need? What are the differences between the primary and secondary immune responses in terms of a dengue vaccine?

3. Compare a bacterium to a virus. Which is larger? How do their internal structures compare? How do their outer casings, or membranes, compare? What is the infectious pathway of most bacteria? How do viruses infect cells?

4. Herpes simplex (HS) is the name for a group of viruses that attack human cells. This virus is lyticogenic, causing cold sores (HS I) or genital warts (HS II). Both of these varieties display as open canker sores that periodically reappear. Reviewing the lysogenic cycle of viral infection, predict what is happening within an infected cell during the appearance of a cold sore.

5. The flu is a serious problem for the WHO. Why is this so? It seems like a minor inconvenience, leaving most of us ill for a mere few days. Why is influenza still a number one priority of the WHO? What can you say about the origin of a serious influenza epidemic?
14. ________ are directed against one specific antigen, but link to many different antigenic sites on that antigen.
   a. Monoclonal antibodies
   b. Polyclonal antibodies
   c. Genetically engineered antibodies

15. The type of immune cell causing the reaction seen here, where the pathogenic cell is attacked by released perforin, is the
   a. T helper cell.
   b. Cytotoxic T cell.
   c. HLA cell.
   d. Antigen-presenting cell.

16. True or False: The secondary immune response, occurring after initial exposure to the pathogen, is much faster than the primary response.

17. The type of immunity achieved by the infant via breast milk is
   a. Active artificial immunity.
   b. Passive artificial immunity.
   c. Passive natural immunity.
   d. Active natural immunity.

18. Which of the following is NOT characteristic of the activity of immune cells in an autoimmune disease?
   a. Attack the body’s own cells
   b. Cause erratic degeneration of joint tissue
   c. Destroy pancreatic cells
   d. Increase in number and specificity in the blood

19. The type of bacteria found in long chains of spherical organisms is
   a. Staphylococcus.
   b. Bacillus.
   c. Coccos.
   d. Streptococcus.

20. The phase of the viral life cycle depicted here is the
   a. Lytic phase.
   b. Lysogenic phase.
   c. Replication phase.
   d. Dormant phase.

HIV attaches to the CD4 protein complex of the ________, obtaining entry to the cell where it may lie dormant for many years.
   a. Cytotoxic T cell
   b. Helper T cell
   c. B cell
   d. Macrophage

SELF TEST

1. True or False: The lymphatic system is anatomically similar to the circulatory system, with a series of vessels that transport lymph to and from the heart.

2. Functions of the lymphatic system include all of the following EXCEPT
   a. Maintaining tissue fluid homeostasis.
   b. Absorbing fats from the intestinal tract.
   c. Defending against bacterial invasion via fever.
   d. Defending against specific invaders.

3. Identify the structure indicated as A on the diagram.
   a. Lymph node
   b. Tonsil
   c. Peyer’s patch
   d. Spleen

4. The structure indicated as B on that same diagram
   a. Produces lymphocytes.
   b. Filters blood.
   c. Cleans body fluids passing the organ.
   d. Has no known function, and can easily be removed without damage to the individual’s health.

5. The lymphatic organ labeled A in this photograph is the
   a. Spleen.
   b. Thymus.
   c. Tonsil.
   d. Inguinal lymph node.

6. The stem cells in red bone marrow produce
   a. Both red and white blood cells.
   b. B cells only.
   c. T cells only.
   d. Macrophage only.

7. Humoral immunity employs
   a. T cells.
   b. B cells.
   c. Antibodies.
   d. All of the above.

8. True or False: Specific immunity requires cells to demonstrate specificity, memory, and self-recognition.

9. The portion of this image labeled A is the
   a. Antigen.
   b. Random lymphatic cell.
   c. Specific receptor on lymphatic cell.
   d. Specific pathogen.

10. Vaccinations and booster shots are designed to assist in the formation and maintenance of
    a. Antibodies in the blood stream.
    b. Cloned B memory cells.
    c. Cloned T memory cells.
    d. Plasma cells.

11. The type of T cell that binds an antigen, clones to amplify the signal, and then stimulates the B cell that will produce the matching antibody is the
    a. Natural killer T cell.
    b. Thymic cell.
    c. APC cell.
    d. Helper T cell.

12. The activation of a T cell requires direct interaction between the pathogen and
    a. The CD4 protein complex of the T cell.
    b. The class II MHC molecules on the surface of the T cell.
    c. The CD4 protein complex of the B cell.
    d. The antigen-presenting cell.

13. The function of the antibody seen here is to
    a. Bind directly to the antigen.
    b. Trigger allergic responses.
    c. Agglutinate the pathogen.
    d. Stimulate B cell activation.

14. ________ are directed against one specific antigen, but link to many different antigenic sites on that antigen.
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