The Lymphatic System

CHAPTER OBJECTIVES

After studying this chapter, you should be able to:

1. Name the functions of the lymphatic system.
2. Explain what lymph is and how it forms.
3. Describe lymph flow through the body.
4. Name the principal lymphatic trunks.
5. Describe the functions of the tonsils and spleen.
6. Explain the unique role the thymus gland plays as part of the lymphatic system.
7. Describe the different types of immunity.
8. Explain the difference between blood and lymphatic capillaries.
9. Explain the difference between active immunity and passive immunity.
10. Define an antigen and an antibody.
KEY TERMS

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INTRODUCTION

The lymphatic system is intimately associated with the
blood and the cardiovascular system. Both systems trans-
port vital fluids throughout the body, and both have a sys-
tem of vessels that transport these fluids. The lymphatic
system transports a fluid called lymph through special
vessels called lymphatic capillaries and lymphatics. This
lymph eventually gets returned to the blood from where it
originated. In addition to fluid control, our lymphatic sys-
tem is essential to helping us control and destroy a large
number of microorganisms that can invade our bodies.
and cause disease and even death. The lymphatic system consists of lymph, lymph vessels, lymph nodes, and four organs. The organs are the tonsils, the spleen, the thymus gland, and Peyer’s patches. See Concept Map 15-1: The Lymphatic System. Figure 15-1 shows the vessels and organs of the lymphatic system.

THE FUNCTIONS OF THE SYSTEM AND THE STRUCTURE AND FUNCTIONS OF THE LYMPHATIC VESSELS

The primary function of this system is to drain from tissue spaces protein-containing fluid that escapes from the
blood capillaries. Other functions are to transport fats from the digestive tract to the blood, to produce lymphocytes and to develop immunities.

In our bodies where blood capillaries are close to the cells of tissues, the blood pressure in the cardiovascular system forces some of the plasma of blood through the single-celled capillary walls. When this plasma moves out of the capillaries and into the spaces between tissue cells, it gets another name and is called interstitial fluid. Most, but not all, of this fluid gets reabsorbed into the capillary by differences in osmotic pressure. However, some does not, and this interstitial fluid must be drained from the tissue spaces to prevent swelling or edema from occurring. It is the role of the lymphatic capillaries to drain this fluid. Once the interstitial fluid enters a lymphatic capillary, it gets a third name and is now called lymph.

In the villi of the small intestine, there are special lymphatic vessels called lacteals whose role is to absorb fats and transport them from the digestive tract to the blood. Fats from the intestine travel through the lymphatic system, which delivers them to the blood, when the lymph rejoins the blood at the right and left subclavian veins. Lymph in the lacteals looks milky because of the fat content and is called chyle.

Lymphatic Vessels

Lymphatic vessels originate as blind-end tubes that begin in spaces between cells in most parts of the body. The tubes, which are closed at one end, occur singly or in extensive plexuses and are called lymphatic capillaries (Figures 15-2 and 15-3). These vessels are not found in the central nervous system, red bone marrow, vascular tissue, or portions of the spleen. Lymphatic capillaries are much larger and more permeable than blood capillaries. Lymphatic capillaries will eventually unite to form larger and larger lymph vessels called lymphatics (LIM-fat-iks). Lymphatics resemble veins in structure but have thinner walls and more valves. The large number of valves helps to ensure that the lymph will not backflow but go in one direction only. Along lymphatics there are lymph nodes found at various intervals.

Lymphatics of the skin travel in loose subcutaneous connective tissue and generally follow the routes of veins. Lymphatics of the viscera generally follow the routes of arteries and form plexuses around the arteries. Eventually, all the lymphatics of the body converge into one of two main channels: either the thoracic duct (the main collecting channel), also known as the left lymphatic duct, or the right lymphatic duct.
FIGURE 15-2. (A) Diagrammatic view of lymphatics transporting fluid from interstitial spaces to the bloodstream. (B) Lymphatic capillaries begin as blind-end tubes next to tissue cells and blood capillaries.
Lymph Nodes

Lymph nodes are oval to bean-shaped structures found along the length of lymphatics (Figure 15-4). They are also known as lymph glands. They range in size from 1 to 25 mm in length (about 0.04 to 1 inch), looking like small seeds or almonds. The three regions of aggregations of nodes in the body are the groin, armpits, and neck. A lymph node contains a slight depression on one side called the hilum (HIGH-lum) where efferent (EE-fair-ent) lymphatic vessels leave and a nodal artery enters and a nodal vein leaves the node. Each lymph node or gland is covered by a capsule of fibrous connective tissue that extends into the node. These capsular extensions are called trabeculae (trah-BEK-yoo-lee). The capsular extensions divide the lymph node internally into a series of compartments that contain lymphatic sinuses and lymphatic tissue. Lymphatic vessels that enter the lymph node at various sites are called afferent (AFF-er-ent) lymphatic vessels.

The lymphatic tissue of the node consists of different kinds of lymphocytes and other cells that make up dense aggregations of tissue called cortical or lymphatic nodules (Figure 15-5). The lymph node surrounds a germinal center that produces lymphocytes. Lymphatic sinuses are spaces between these groups of lymphatic tissue. They contain a network of fibers and the macrophage cells (see Figure 15-4). The capsule, trabeculae, and hilum make up the stroma or framework of the lymph node.

As lymph enters the node through the afferent lymphatics, the immune response is activated. Any microorganisms or foreign substances in the lymph stimulate the germinal centers to produce lymphocytes, which are then released into the lymph. Eventually, they reach the blood and produce antibodies against the microorganisms. The macrophages will remove the dead microorganisms and foreign substances by phagocytosis.

LYMPH CIRCULATION

As the plasma of blood is filtered by the blood capillaries, it passes into the interstitial spaces between tissue cells and is now known as interstitial fluid. When this fluid passes from the interstitial spaces into the lymphatic capillaries, it is called lymph. Lymph is primarily water but it also contains plasma solutes such as ions, gases, nutrients, and some proteins and substances from tissue cells such as hormones, enzymes, and waste products.

The lymph, drained by the lymphatic capillaries and the lymphaticplexuses, is then passed to the lymphatic vessels that have a beaded appearance due to the one-way valves that prevent backflow movement. The lymphatics head toward lymph nodes. At the lymph nodes, afferent vessels penetrate the capsules at various positions on the node and the lymph passes through the sinuses of the nodes. In the node, antigenic microorganisms, foreign substances, or cancer cells stimulate lymphocytes to divide, and the immune response is...
activated. Macrophages phagocytize the attacked foreign substances. Efferent vessels leave nodes and pass on to other lymph nodes by either going with other efferent vessels into another node of the same group or passing on to another group of nodes. The efferent vessels will eventually unite to form **lymphatic trunks**.

This circulation of lymph through the various lymphatic vessels is maintained by normal skeletal muscle contractions. This action compresses the lymphatic vessels and because those vessels have one-way valves, the compression forces the lymph in one direction toward the subclavian veins. Normal movement helps circulate...
Another factor in lymph circulation is respiratory or breathing movements, which cause pressure changes in the thorax. Finally, smooth muscle contraction in the lymphatic vessel also pushes lymph along. However, if lymphatics become obstructed by blockage, then an excessive amount of interstitial fluid will develop in tissue spaces and result in swelling or edema.

Eventually, the efferent lymphatic vessels unite to form lymphatic trunks (Figure 15-6). The principal lymphatic trunks of the body are: the lumbar trunk, the intestinal trunk, the bronchomediastinal trunk, the intercostal trunk, the subclavian trunk, and the jugular trunk.

The lumbar trunk drains lymph from the lower extremities, the walls and viscera of the pelvis, the kidneys and adrenal glands, and most of the abdominal wall. The intestinal trunk drains lymph from the stomach, intestines, pancreas, spleen, and the surface of the liver. The bronchomediastinal trunk drains the thorax, lungs, heart, diaphragm, and the rest of the liver. The intercostal trunk also helps drain lymph from portions of the thorax. The subclavian trunk drains the upper extremities, that is, arms, hands, and fingers. Finally, the jugular trunk drains the head, and neck.

These principal trunks now pass their lymph into two main channels: the thoracic duct which is the main
Collecting duct of the system and is also known as the left lymphatic duct, and the right lymphatic duct (Figure 15-7). Ultimately, the thoracic duct empties all of its lymph into the left subclavian vein and the right lymphatic duct empties all of its lymph into the right subclavian vein, so the journey of the lymph is now completed. The lymph is drained back into the blood where it originally came from, and the cycle completes itself. This circulation repeats itself continuously, thus maintaining the proper levels of lymph, plasma, and interstitial fluids in the body.

**THE ORGANS OF THE LYMPHATIC SYSTEM**

The lymphatic system has four organs: the tonsils, spleen, thymus gland, and Peyer’s patches. Tonsils are masses of lymphoid tissue embedded in mucous membrane. There

**FIGURE 15-6.** The principal lymphatic trunks of the body.

**FIGURE 15-7.** Lymphatic trunks pass their lymph into two main collecting ducts, the thoracic duct and the right lymphatic duct. These ducts empty into the left and right subclavian veins, respectively.
are three groups of tonsils. The palatine (PAL-ah-tyne) tonsils are the ones commonly removed in a tonsillectomy. They are located in the tonsillar fossae between the pharyngopalatine and glossopalatine arches on each side of the posterior opening of the oral cavity. The pharyngeal (fair-in-JEE-al) tonsils are also known as the adenoids (ADD-eh-noydz). They are located close to the internal opening of the nasal cavity. When they become swollen, they can interfere with breathing. The lingual (LING-gwall) tonsils are located on the back surface of the tongue at its base.

In these positions, the tonsils form a protective ring of reticuloendothelial cells against harmful microorganisms that might enter the nose or oral cavity. Occasionally, they become chronically infected and need to be removed. However, this operation is not as common as it once was because of the understanding of how important these organs are in protecting the body and as being part of the immune system. Tonsils are more functional in children. As we age, the tonsils decrease in size and may even disappear in some individuals.

The spleen (SPLEEN) is oval in shape and is the single largest mass of lymphatic tissue in the body (Figure 15-8). It measures about 12 cm, or 5 inches, in length. It is found in the left upper corner of the abdominal cavity. It filters blood via the splenic artery and splenic vein, which enter the spleen at a slightly concave border called the hilum. The spleen phagocytizes bacteria and worn-out platelets and red blood cells. This action releases hemoglobin to be recycled. It also produces lymphocytes and plasma cells. The spleen stores blood and functions as a blood reservoir. During a hemorrhage, the spleen releases blood into the blood circulation route. Serious injury to the spleen may require its removal.

The thymus gland is a bilobed mass of tissue located in the mediastinum along the trachea behind the sternum. Its role in the endocrine system was discussed in Chapter 12. It reaches maximum size during puberty and
then decreases. In older individuals, the thymus becomes small and is difficult to detect because it is replaced with fat and connective tissue. It is involved in immunity. The thymus is a site for lymphocyte production and maturation. The thymus helps develop T lymphocytes in the fetus and in infants for a few months after birth. A number of its lymphocytes degenerate, but those that mature leave the thymus and enter the blood to travel to other lymphatic tissues where they and their descendents protect against foreign substances and harmful microorganisms.

**Peyer’s (PIE-erz) patches** (also known as aggregated lymphatic follicles) are found in the wall of the small intestine. They resemble tonsils. Their macrophages destroy bacteria. Bacteria are always present in large numbers in the intestine, and the macrophages prevent the bacteria from infecting and penetrating the walls of the intestine.

**IMMUNITY**

Immunity (im-YOO-nih-tee) is the ability of the body to resist infection from disease-causing microorganisms or pathogens (PATH-oh-jenz), damage from foreign substances, and harmful chemicals. Humoral immunity and cellular immunity are the results of the body’s lymphoid tissue. The bulk of our lymphoid tissue is located in the lymph nodes. However, as mentioned, it is also found in the spleen, the tonsils, in the small intestine, and in infants for a few months after birth. A number of its lymphocytes degenerate, but those that mature leave the thymus and enter the blood to travel to other lymphatic tissues where they and their descendents protect against foreign substances and harmful microorganisms.

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**ANTIGENS AND ANTIBODIES**

**Antigens** (AN-thih-jenz) are foreign proteins that gain access to our bodies via cuts and scrapes, through the respiratory system, through the digestive or circulatory systems, or through the urinary and reproductive systems. They cause the immune system to produce high molecular weight proteins, called **antibodies** or **immunoglobulins** (im-yoo-noh-GLOB-yoo-linz), to destroy the foreign invader.

These foreign proteins can be the flagella or cell membranes of protozoans, the flagella or cell membrane of bacteria, the protein coat of a virus, or the surface of a fungal spore. The B lymphocyte and the plasma cell recognize these antigens and produce antibodies that bind with the specific antigen. This binding causes the foreign cells to agglutinate (stick together) and precipitate within the circulatory system or tissues. Then the phagocytic white blood cells like neutrophils and macrophages come along and eat them up by phagocytosis, eliminating them from the body. Thus, we have an internal defense system to protect us from foreign microbes. Antibodies are formed in response to an enormous number of antigens. Antibodies have a basic structure consisting of four amino acid chains linked together by disulfide bonds. Two of the chains are identical, with about 400 amino acids, and are called the heavy chains; the other two chains are half as long, identical, and are called the light chains. When united, the antibody molecule is made of two identical halves, each with a heavy and light chain. The molecule has a Y shape and the tips of the Y are the antigen-binding sites. The binding site varies, thus allowing the antibody to bind with the enormous number of antigens. The stem of the Y is always constant. (See Figure 15-9.)

Five types of antibodies make up the gamma globulins of plasma proteins. **Immunoglobulin G (IgG)** is found in tissue fluids and plasma. It attacks viruses, bacteria, and toxins. It also activates **complement**, a set of enzymes that attack foreign antigens. **Immunoglobulin A (IgA)** is found in exocrine gland secretions, nasal fluid, tears, gastric and intestinal juice, bile, breast milk, and urine. **Immunoglobulin M (IgM)** develops in blood plasma as a response to bacteria or antigens in food. **Immunoglobulin D (IgD)** is found on the surface of B lymphocytes and is important in B cell activation. **Immunoglobulin E (IgE)** is also found in exocrine gland secretions and is associated with allergic reactions, attacking allergy-causing antigens. The most abundant antibodies are IgG, IgA, and IgM.

When B lymphocytes come in contact with antigens and produce antibodies against them, this is called **active immunity**. It can be acquired naturally, as when we...
are exposed to a bacterial or viral infection, or it can be acquired artificially, as when we receive a vaccine. A vaccine contains either killed pathogens or live, but very weak pathogens. It does not matter whether the antigen is introduced to the body on its own or through a vaccine, the immune response is the same. The advantage of vaccines is that we do not experience the major symptoms of the disease, which would occur in the primary response to the pathogen, and the weakened antigen stimulates antibody production and immunologic memory. Future exposure keeps us immune to the pathogen. Vaccines are currently available against measles, smallpox, polio, tetanus, chickenpox, pneumonia, diphtheria, and various strains of flu.

Passive immunity can be conferred naturally when a fetus receives its mother’s antibodies through the placenta and they become part of the fetal circulatory route. This immunity lasts for several months after birth. Passive immunity can be conferred artificially by receiving gamma globulin, breast milk, or immune serum. This is used after exposure to hepatitis. These donated antibodies provide immediate protection, but it only lasts 2 to 3 weeks. Other immune serums include antivenom for snakebites or botulism and rabies serum.

Like the B lymphocytes, T lymphocytes are activated to form clones by binding with an antigen. But T cells are not able to bind with free antigens. The antigens must first be engulfed by macrophages, processed internally, and then displayed on their surface to the T cells. Thus, antigen presentation is a major role for macrophages and is absolutely necessary for activation and clonal response of the T cells.

CELLS OF THE IMMUNE RESPONSE AND OTHER DEFENSES

The lymphocytes of the body are the precursors of a whole range of cells that are involved in the immune response. The following is a list of those cells and their functions.

- **B cells** are lymphocytes found in the lymph nodes, spleen, and other lymphoid tissue where they replicate, induced by antigen-binding activities. Their clones or progeny form plasma cells and memory cells.

- **Plasma cells** are formed by replicating B cells that enter tissue, and produce huge numbers of the same antibody or immunoglobulin.

- **Helper T cells** are T cells that bind with specific antigens presented by macrophages. They stimulate the production of killer T cells and more B cells to fight the invading pathogen. They release lymphokines.

- **Killer T cells** kill virus-invaded body cells and cancerous body cells. They are also involved in graft rejections.

- **Suppressor T cells** slow down the activities of B and T cells once the infection is controlled.
Memory cells are descendents of activated T and B cells produced during an initial immune response. They will exist in the body for years, enabling it to respond quickly to any future infections by the same pathogen.

Macrophages engulf and digest antigens. They then present parts of these antigens in their cell membranes for recognition by T cells. This antigen-presentation function is crucial for normal T-cell responses.

In addition to these cells, certain chemicals are produced in the immune response that also help keep us healthy. The lymphokines (LIM-foh-kynz) are chemicals released by the sensitized T lymphocytes. There are a number of these chemicals. Chemotactic factors attract neutrophils, basophils, and eosinophils to the infected area. Macrophage migration-inhibiting factor (MIF) keeps macrophages in the local area of infection and inflammation. Helper factors stimulate plasma cells to produce antibodies. Interleukin-2 stimulates proliferation of T and B cells. Gamma interferon helps make tissue cells resistant to viruses, activates macrophages, and causes killer T cells to mature. Perforin causes cells to break down. Suppresser factors suppress antibody formation by T cells.

Activated macrophages also release chemicals called monokines (MON-oh-kynz). One is interleukin-1, which stimulates T-cell proliferation and causes fever. The body produces fever or elevated temperatures as a response to attempt to kill the invading pathogen by changing its environment. The other is tumor necrosis factor (TNF), which kills tumor cells and attracts the granular leukocytes to the area. Blood-borne proteins, called complement, cause the breakdown or lysis of microorganisms and enhance the inflammatory response.

In addition to these cellular and chemical barriers inside the body, the body has an external covering and other protective mechanisms. The skin’s epidermis is a mechanical barrier to pathogens and toxins. It also has a so-called acid mantle (acidic pH) that inhibits bacterial growth. Sebum from the sebaceous glands has antifungal and antibacterial qualities. Tears from the lacrimal glands and saliva contain lysozyme, which destroys bacteria. Mucous membranes lining the digestive, respiratory, urinary, and reproductive tracts trap microorganisms and dust and prevent them from entering the circulatory system. In the nose and throat, the mucus-dust package is brought up to the throat to be swallowed by the action of cilia on the free edge of the epithelial tissue. The hydrochloric acid in the stomach then destroys most pathogens. Even the hairs in our nose have a role to trap large particles and filter them out before they enter the respiratory system. Refer to Figure 15-10 for an overview of the body’s defense mechanisms.
CHAPTER 15 The Lymphatic System

**Primary Immune Response**

First-time contact: primary immune response

**Secondary Immune Response**

Secondary immune response: subsequent contact with same antigen stimulates rapid divisions of B lymphocytes.

**Nonspecific Defense Systems**
- Skin; mucous membranes; phagocytes; natural killer cells; interferon; complement
- Actions: guard against nearly any foreign agent; act to impede or destroy foreign agents

**Specific Defense Systems**

**Phagocytes**
- Engulf antigens and present them to helper T lymphocytes.

**Helper T Lymphocytes**
- Secrete lymphokines
- Activate and stimulate divisions of T lymphocytes, B lymphocytes, and plasma cells

**T Lymphocytes**
- Produce killer T lymphocytes and memory T lymphocytes
- Actions: destroy infected cells by disturbing the cell's plasma membrane

**B Lymphocytes**
- Produce plasma cells and memory B lymphocytes

**Plasma Cells**
- Secrete antibodies
- Actions: aid in destruction of bacteria and some viruses by the process of agglutination

**Memory B Lymphocytes**

**Memory T Lymphocytes**

**FIGURE 15-10. Overview of the body's defense mechanisms.**
At birth, the thymus gland is fairly large but decreases in size as we age. It eventually is replaced with adipose tissue, thus losing its ability to produce new mature T cells. The number of T cells in the body remains fairly stable, however, due to their constant replication in secondary lymphatic tissues. With advancing age, we become more susceptible to infections because our immune response decreases. Older adults also tend to produce more antibodies against their own body cells, resulting in autoimmune deficiencies.

As the aging process progresses, T cells become less responsive to antigens and fewer of them respond to infections. Since the T-cell population decreases as we age, B cells also become less responsive, so antibody levels do not increase as rapidly in response to antigens. It is therefore recommended that vaccinations be administered to older adults before the age of 60. Older adults also should be encouraged to receive yearly influenza shots because they are more susceptible to the flu.

With decreased immunity as we age, latent pathogens can be reactivated; for example, the chickenpox virus that erupts in children can remain in the body in a latent state within nerve cells. As we age, the virus can leave the nerve cells and enter the skin cells, resulting in painful lesions known as shingles.

The increased susceptibility of older adults to various types of cancers is also assumed to be related to the immune system’s decreased response to cancer cells.

Individuals with an interest in the lymphatic system can pursue careers related to the study of the immune response.

- **Immunologists** are physician specialists who study reactions of tissues of the body's immune system to stimulation from antigens.
- **Oncologists** are physicians who specialize in the treatment and study of any abnormal growth of new tissue, benign or malignant. Such a physician is an authority on cancerous diseases.
- **Cytotechnologists** are individuals who work in a clinical laboratory utilizing microscopy in examining cell samples for signs of cancer.
- **Lymphedema therapists** are individuals who utilize massage therapy, exercises, and bandaging to relieve the swellings caused by blockage of the lymphatic vessels. They also train patients with lymphedema on how to care for themselves, utilizing water massage or hydrotherapy and exercise.
ALLERGIES

Allergies (AL-er-jeez) are hypersensitive reactions to common, normal, usually harmless environmental substances referred to as allergens. Some examples are house dust, pollen, and cigarette smoke. The reactions to the allergens can damage body tissues. Over 20 million Americans have allergic reactions to inhaled allergens. When the nose is affected, we refer to it as hay fever. In the lungs, it is referred to as asthma. If the eyes are affected, it is called allergic conjunctivitis. If the material is swallowed and affects the digestive tract, it can result in diarrhea, vomiting, or cramps. Contact on the skin can result in contact dermatitis. Hives can develop when certain foods cause allergic reactions or when drugs, animal hairs, or insect stings are encountered.

When exposed to a certain allergen, antibody IgE is produced and attaches to basophils and mast cells. These cells release histamine and prostaglandins. Histamine causes the secretion of mucus from mucous membranes and causes capillaries to become more permeable. Prostaglandins cause smooth muscle to constrict, as in the bronchioles of the lungs. Such an inflammatory response produces a runny nose, sneezing, difficult breathing, and congestion as with asthma and hay fever.

Severe allergic reactions can result in anaphylactic shock, culminating in death. Some individuals are overly sensitive to bee stings and certain drugs, resulting in severe bronchial constriction, mucus production, and breathing difficulties. This lowers blood pressure and can lead to death. This severe allergic reaction is called anaphylaxis.

Treatment can use desensitization, which is exposure to minute amounts of the allergen over time, or the use of antihistamines, bronchial dilators, or steroids.

LYMPHOMA

Lymphoma (lim-FOH-mah) is a tumor of lymphatic tissue, which usually is malignant. It begins as an enlarged mass of lymph nodes, usually with no accompanying pain. The enlarged nodes will compress surrounding structures, causing further complications. The immune response becomes depressed, and the individual becomes susceptible to opportunistic infections. Lymphomas are classified into two groups: Hodgkin’s disease and non-Hodgkin’s lymphomas. The name Hodgkin’s disease was named after an English physician in 1832 who first described a group of patients with lymph node swellings in the neck. The disease usually manifests itself in the 20s or 30s, more commonly in men than in women. The disease tends to involve the reticulum cells of the lymph node rather than the lymphocytes. Treatment with drugs and radiation is effective for most people with lymphomas.

LYMPHADENITIS

Lymphadenitis (lim-fad-en-EYE-tis) is an inflammation of lymph nodes or glands. They become enlarged and tender. When microorganisms are being trapped and attacked in the lymph nodes, they enlarge. Hence, a swollen lymph gland is indicative of an infection. Very often when you visit a physician when you are ill, the doctor will feel for swollen lymph nodes in the neck region.

LYMPHANGITIS

Lymphangitis (lim-fan-JYE-tis) is an inflammation of the lymphatic vessels with accompanying red streaks visible in the skin.

BUBONIC PLAGUE

Bubonic plague (boo-BON-ik PLAYGH) is a disease of the lymphatic system with historical implications. It is caused by the bacterium Klebsiella pestis transmitted to humans by the bite of the Asiatic rat flea Xenopsylla cheopis. The bacteria grow in the lymph nodes, causing them to enlarge, forming dark swellings called buboes. The bacteria also get into the bloodstream, causing septicemia. Without treatment, death follows quickly in about 80% of cases. In the Middle Ages, bubonic plague (continues)
epidemics wiped out a third of the population of Europe. Before effective treatment with antibiotics, like penicillin, bubonic plague outbreaks occurred throughout the world. Fortunately, few cases ever occur today.

**AIDS**

AIDS, or acquired immune deficiency syndrome, is caused by infection with the human immunodeficiency virus (HIV). This virus is transmitted by contact with body fluids containing the virus through sexual contact, including anal intercourse, through contaminated needles, during birth from an infected mother, or by receiving contaminated blood in a transfusion. The infection has three stages: initial symptoms, a latency period, and full-blown AIDS. Initial symptoms include weakness, fever, night sweats, weight loss, and swollen lymph glands in the neck region. These symptoms mimic the flu and last only a few days. The latency period may last 5 to 10 years with no symptoms. Full-blown AIDS occurs with the onset of opportunistic infections that can be fatal. Some such infections are pneumonia, skin cancer, diarrhea, tuberculosis, toxoplasma affecting the nervous system, and fungal infections in the lungs and throat.

The virus attacks the T cells, compromising the immune response. It invades the T cells, reproducing more viruses in the T cells, and eventually destroys the T cells. Hence, a person with the virus has the T-cell count constantly monitored by a physician. The virus also invades macrophages but does not destroy them utilizing them to produce more viral cells. Some common AIDS-related symptoms include weight loss due to diarrhea, persistent swollen lymph glands, chronic low-grade fever, fatigue, night sweats, and, occasionally, memory loss and confusion.

Research is constantly going on to try to understand and combat this dreaded disease. Some individuals have the virus but never develop any symptoms; others get exposed repeatedly but never become infected. By studying the genetics and backgrounds of these individuals, scientists may find a cure in the future. Meanwhile, drugs are used to combat the virus. Older drugs like AZT blocked viral replication but had serious side effects. New drugs, called protease inhibitors, inhibit the HIV from becoming functional, thus crippling the virus. Combinations of drugs, called the AIDS cocktail, have extended the life of many infected individuals by stemming the growth and activity of the virus, thus giving new hope for controlling and eventually curing AIDS.

**BONE MARROW TRANSPLANT**

Bone marrow transplants are done to treat various disorders of the human body including disorders of the lymphatic system such as leukemia, lymphomas, and immunological deficiencies. Red bone marrow contains blood cells in all stages of development, since its role is hematopoiesis. Red bone marrow from a healthy donor is transplanted intravenously into an ill recipient after chemotherapy and body radiation treatment. The bone marrow from the donor will produce whatever blood cells are needed by the recipient dependent upon the specific disease experienced by the patient.

**CANCER AND LYMPH NODES**

Cancer cells can be spread by growing in lymph nodes and being transported throughout the body by the lymphatic circulatory system. The cancer cells originally came from a tumor from which they metastasized and entered lymphatic vessels. The vessels carry them to lymph nodes where they become trapped and reproduce. Some escape from the lymph nodes and are carried by the lymphatics to the blood circulatory system, which then carries them to other parts of the body where they develop into more tumors. For example, when a woman develops advanced breast cancer, the axillary lymph nodes are also removed in addition to the cancerous breast in a radical mastectomy to prevent the possible spread of the cancer from the lymph nodes.
SYSTEMIC LUPUS ERYTHEMATOSUS (SLE)

Systemic lupus erythematosus (SLE) is a chronic inflammatory disease in which cells and tissues are damaged by the immune system. One of the symptoms is a red butterfly shaped rash over the nose and cheeks. The exact cause of the disease is not known but a viral infection may disrupt the normal functioning of the immune system. Eight times as many women than men develop SLE. There also appears to be a genetic connection. In addition to severe inflammation of blood vessels, there can be kidney involvement leading to renal disease. Other systems of the body that can be affected are the respiratory and the nervous system. Symptoms first appear between the ages of 15 and 25. These symptoms may go into remission but periodic, unpredictable flare-ups will occur. If a patient survives this condition for 10 years or more, the survival rate can be as high as 90%. Death results from kidney failure, heart disease, central nervous system involvement with severe neurological abnormalities, and infections. Treatment involves the careful and monitored use of steroids, and antimalarial drugs to treat skin rashes and joint pain. Patients are also recommended to protect themselves from direct exposure to the rays of the sun by using sunscreen, and to avoid stressful situations. Avoiding fatigue and getting lots of rest also help prevent periodic flare-ups.

BODY SYSTEMS WORKING TOGETHER TO MAINTAIN HOMEOSTASIS: THE LYMPHATIC SYSTEM

Integumentary System
- The skin’s epidermis is a mechanical barrier to microorganisms.
- The acid pH mantle of the skin inhibits the growth of most bacteria.
- Sebum, produced by the sebaceous glands of the skin, has antifungal properties.
- Lymphatic vessels drain interstitial fluid from the dermis of the skin preventing edema.

Skeletal System
- Lymphocytes are produced in red bone marrow.

Muscular System
- Contraction of muscles compresses lymphatics and helps push the flow of lymph toward the right and left lymphatic ducts.

Nervous System
- Undue stress may suppress the immune response.
- The nervous system innervates large lymphatic vessels and helps regulate the immune response.

Endocrine System
- The thymus gland confers immunologic competence on the T lymphocytes.
- Hormones stimulate the production of lymphocytes.

Cardiovascular System
- Blood plasma is the source of interstitial fluid, which becomes lymph when drained by lymphatic capillaries.
- The lymphatic system returns this fluid to the bloodstream via the right and left subclavian veins, connecting with the right and left lymphatic ducts.

Digestive System
- Lacteals in the villi of the small intestine absorb fats.
- The hydrochloric acid in the gastric juice destroys most pathogens.
- The digestive system digests and absorbs nutrients for lymphatic tissues.
- Peyer’s patches in the wall of the small intestine destroy bacteria.

Respiratory System
- The tonsils are located in the pharynx.
- Breathing and contraction of the respiratory muscles maintain lymph flow through lymphatics.
- Immune system cells receive their oxygen and get rid of carbon dioxide waste via the respiratory system.
Urinary System
● The kidneys maintain homeostasis by regulating the amounts of extracellular fluid.
● Electrolyte and acid-base levels of the blood are maintained by the urinary system for lymphoid tissue function.
● Urine can flush out certain microorganisms from the body.

Reproductive System
● The acid environment of the female vagina and male urethra prevent bacterial growth.
● In the female reproductive tract, the immune system does not attack the male sperm as a foreign antigen, ensuring the possibility of fertilization.

**HEALTH ALERT**

**Splenomegaly**

Splenomegaly is an abnormal enlargement of the spleen that can develop from infections with diseases such as scarlet fever, syphilis, typhoid fever, and typhus fever. Infections with a microscopic blood fluke worm of the genus *Schistosoma* in Japan and in Africa can also cause splenomegaly. Eggs of the parasite get carried by the bloodstream and lodge in the spleen, causing irritation. This results in a swollen abdomen caused by the enlarged spleen.

**StudyWARE™ Connection**

Watch an animation on cancer metastasizing on your StudyWARE™ CD-ROM.

**HEALTH ALERT**

**Splenic Anemia**

Splenic anemia is also characterized by an abnormal enlargement of the spleen caused by hemorrhages that develop from the stomach and fluid accumulating in the abdomen. This condition usually requires the surgical removal of the spleen.
2. Efferent lymphatics exit the lymph node at the hilum, a slight depression on one side. Blood vessels and nerves also exit and enter at the hilum.

3. Afferent lymphatics enter the lymph node at various locations on the node.

4. Capsular extensions of the node, called trabeculae, divide the node internally into a series of compartments with germinal centers.

5. The germinal centers produce lymphocytes.

**LYMPH CIRCULATION**

1. Plasma, filtered by the blood capillaries, passes into interstitial tissue spaces and is now called interstitial fluid.

2. When this fluid passes into lymphatic capillaries, it is called lymph.

3. The lymph now passes into larger lymphatic vessels called lymphatics, which have many valves to prevent backflow of lymph and have lymph nodes along their lengths.

4. Afferent lymphatics enter the lymph nodes, and efferent lymphatics leave the nodes.

5. Circulation of lymph is maintained by muscular contractions, which compress lymphatics and push the lymph along.

6. Eventually, efferent lymphatics unite to form six lymphatic trunks.

7. The lumbar trunk drains the lower extremities and pelvis.

8. The intestinal trunk drains the abdominal region.

9. The bronchomediastinal trunk and the intercostal trunk drain the thorax.

10. The subclavian trunk drains the upper extremities.

11. The jugular trunk drains the head and neck.

12. These trunks drain their lymph into two main collecting ducts: the main duct, called the thoracic duct, and the right lymphatic duct.

13. The thoracic duct empties its lymph into the left subclavian vein. The right lymphatic duct drains into the right subclavian vein. This process returns lymph to the blood vessels from whence it originated.

**THE ORGANS OF THE LYMPHATIC SYSTEM**

1. The three groups of tonsils are the palatine tonsils (commonly removed in a tonsillectomy); the
pharyngeal tonsils, or adenoids; and the lingual tonsils.

2. The tonsils are composed of reticuloendothelial cells that protect the nose and oral cavity from pathogens.

3. The spleen is the single largest mass of lymphatic tissue in the body. It phagocytizes worn-out red blood cells and platelets. It destroys bacteria. It produces lymphocytes and plasma cells and functions as a blood storage organ.

4. The thymus gland is the site for T lymphocyte production and maturation.

5. Peyer’s patches resemble tonsils but are found in the walls of the small intestine where their macrophages destroy bacteria.

**IMMUNITY**

1. Immunity is the ability to resist infection from microorganisms, damage from foreign substances, and harmful chemicals.

2. Humoral immunity and cellular immunity are produced by the body’s lymphoid tissues.

3. Lymphoid tissue produces two main groups of lymphocytes: the B lymphocyte cells and the T lymphocyte cells.

4. The B cells produce antibodies and provide humoral immunity, which is effective against circulating bacterial and viral infections.

5. The T cells are responsible for providing cellular immunity, which is effective against intracellular viruses, fungi, parasites, cancer cells, and foreign tissue implants.

6. B cells that enter tissues and become specialized cells are known as plasma cells.

**ANTIGENS AND ANTIBODIES**

1. An antigen is a foreign protein that gains access to our bodies. Some examples are the cell membrane or flagella of protozoans, the protein coat of a virus, the surface of a fungal spore, and the flagella or cell membranes of bacteria.

2. The B lymphocytes recognize antigens and produce antibodies, which bind to specific antigens, causing the foreign antigens to agglutinate and precipitate.

3. Phagocytic white blood cells then eat up the invading microorganism.

4. The antibody molecule has a Y shape. The binding sites are the tips of the Y.

5. Antibodies are also called immunoglobulins (Ig). There are five types that make up the gamma globulins of blood plasma: IgG found in tissue fluids and plasma; IgA found in exocrine gland secretions, nasal fluid, tears, gastric and intestinal juice, bile, breast milk, and urine; IgM found in plasma as a response to bacteria in food; IgD found on the surface of B cells; and IgE associated with allergic reactions found in exocrine gland secretions.

6. Active immunity occurs when B cells contact antigens and produce antibodies against them. It is acquired naturally when we are exposed to a viral or bacterial infection. It is acquired artificially when we receive a vaccine.

7. Passive immunity occurs naturally when a fetus receives antibodies from its mother through the placenta. Passive immunity is conferred artificially by receiving gamma globulin or immune serum via injection. Passive immunity is short-lived.

8. T cells cannot bind with free antigens like B cells. They must go through antigen presentation via macrophages. They engulf the antigen, process it internally, and then display the antigen on the surface of the macrophage.

**CELLS OF THE IMMUNE RESPONSE AND OTHER DEFENSES**

1. B cells, found in lymphoid tissue, induce antigen-antibody-binding activities. Their replication produces clones that form plasma cells and memory cells.

2. Plasma cells produce huge amounts of antibodies.

3. Helper T cells bind with specific antigens presented by macrophages. They release lymphokines and stimulate the production of killer T cells and more B cells.

4. Killer T cells attack virus-invaded body cells and cancer cells. They also reject body grafts.

5. Suppressor T cells slow down the activity of B and T cells once the infection is controlled.

6. Memory cells are the descendants of activated B and T cells that remain in the body.
for years, allowing the body to respond to future infections.

7. Macrophages engulf and digest antigens and present them to T cells for recognition.

8. Lymphokines are chemicals released by T cells: chemotactic factors attract neutrophils, eosinophils, and basophils; MIF keeps macrophages in the inflamed and infected area; helper factors stimulate plasma cells to produce antibodies; interleukin-2 stimulates proliferation of T and B cells; gamma interferon makes tissue cells resistant to viruses, activates macrophages, and matures killer T cells; suppressor factors stop antibody production by T cells.

9. Monokines are chemicals produced by macrophages: interleukin-1 stimulates T-cell production and fever; TNF kills tumor cells and attracts granular leukocytes; complement causes the lysis of microorganisms and enhances the inflammatory response.

10. Skin is a mechanical barrier, and its acid mantle inhibits bacterial growth. Sebum has antibacterial and antifungal properties.

11. Lysozyme, in tears and saliva, attacks bacteria.

12. Mucous membranes trap microorganisms and debris.

13. Hydrochloric acid in the stomach destroys most microorganisms.

REVIEW QUESTIONS

1. Name the functions of the lymphatic system.

2. Compare the anatomy of a vein to a lymphatic vessel.

3. Discuss what factors keep lymph flowing in a one-way direction without the aid of a pumping organ?

4. Name the major lymphatic trunks of the body and what they drain.

5. Beginning at a lymph capillary, describe the flow of lymph, ending at the two main collecting ducts, and name the vessels of the system.

6. Name the five types of antibodies that make up the gamma globulins of plasma proteins.

7. Give examples of active and passive immunity.

Critical Thinking Questions

FILL IN THE BLANK

Fill in the blank with the most appropriate term.

1. At a lymph node, ____________ vessels penetrate the capsule while ____________ vessels pass on to another node and unite to form lymph trunks.

2. The ____________ tonsils are the ones commonly removed by a tonsillectomy.

3. The ____________ is the largest single mass of lymphatic tissue in the body.

4. The ____________ confers immunologic competency on the T cells. As we age, it disintegrates and may disappear in adults.

5. If interstitial fluid builds up between tissue cells, ____________ or swelling will develop.

MATCHING

Place the most appropriate number in the blank provided.

B cells 1. Immunoglobulin
T cells 2. Vaccine
Adenoid 3. Macrophage
Antibody 4. Gamma globulin
Blood storage 5. Lysis of microorganisms
Active immunity 6. Humoral immunity
Passive immunity 7. Lymphokines
Antigen presentation 8. Pharyngeal tonsils
Helper T cells 9. Lingual tonsils
Complement 10. Spleen
11. Cellular immunity
12. Palatine tonsils

Search and Explore

- Write about a family member or someone you know that has one of the common diseases, disorders, or conditions introduced in this chapter, and tell about the disease.
- Visit the National Cancer Institute at http://www.cancer.gov. Choose a cancer related to this chapter from the A to Z List of Cancers. Give an oral presentation about your findings.
Quinn, a 20-year-old man, visits an outpatient clinic. He appears to be weak and lethargic. Quinn tells the health care provider that he feels like he has a bad case of the flu. He states he has night sweats that drench the bed, and that he has lost around 10 pounds since becoming ill. He seems anxious and admits that he has had unprotected sex with two male partners over the last few months. The care provider examines Quinn and documents that he has a fever and swollen lymph nodes in his neck.

**Questions**

1. Based on this information, what disorder might Quinn have?
2. How is this disorder transmitted from one person to another?
3. Why must the care provider continually monitor the T-cell count?
4. What complications can individuals with this disorder eventually develop?
5. What is the prognosis for individuals with this condition?
LABORATORY EXERCISE:

THE LYMPHATIC SYSTEM

Materials needed: A microscope slide of a lymph node, an anatomic model of the head or throat showing the location of the tonsils, a fotal pig for dissection, a dissecting pan, and a dissection kit.

1. Examine a microscope slide of a lymph node. Notice that the lymph node is enclosed by a sheath of tissue called the capsule. The outer part of the node is called the cortex and the inner part is called the medulla. Within the medulla, note the darker nodules where the germinal centers that produce the lymphocytes are found. Remember that afferent vessels bring lymph into the node, and efferent lymphatic vessels take lymph out of the node. Compare your slide to Figure 15-5 in your text.

2. Your instructor will supply you with an anatomic model. Locate the three tonsils. The palatine tonsils are on the sides of the oral cavity. The lingual tonsils are at the back of the tongue, and the pharyngeal tonsils or adenoids are in the nasopharynx.

3. You will dissect a fetal pig in Chapter 16. You will then find and identify the spleen located near the stomach in the abdominal cavity. Remember, we located the thymus gland when we dissected the throat region in the lab on the endocrine system. Review this also when you perform your dissection on the digestive system.