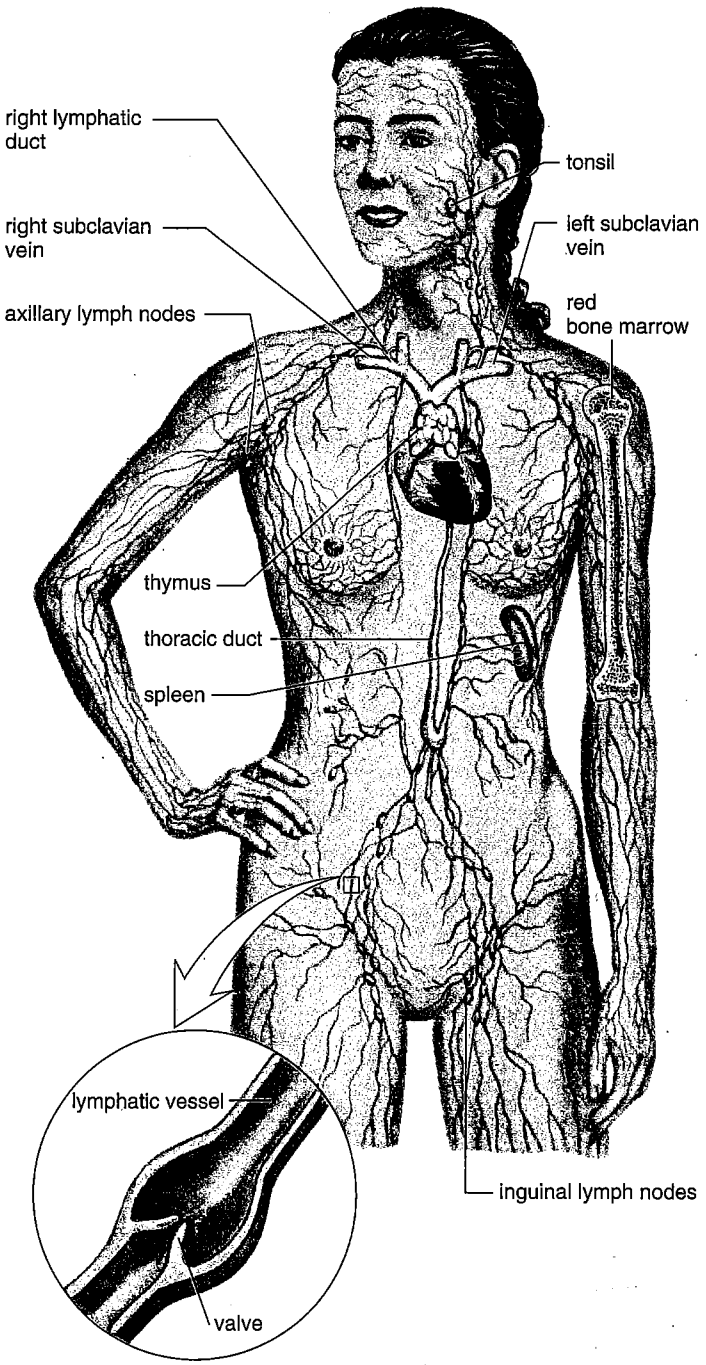

Figure 14.1 Lymphatic system.
Lymphatic vessels drain excess fluid from the tissues and return it to the cardiovascular system. The enlargement shows that lymphatic vessels, like cardiovascular veins, have valves to prevent backward flow. The lymph nodes, tonsils, spleen, thymus gland, and red bone marrow are the main lymphoid organs that assist immunity.

[1]After glycerol and fatty acids are absorbed, they are rejoined and packaged as lipoprotein droplets, which enter the lacteals.

14.1 The Lymphatic System

The **lymphatic system** consists of lymphatic vessels and the lymphoid organs. This system, which is closely associated with the cardiovascular system, has three main functions that contribute to homeostasis: (1) lymphatic capillaries take up excess tissue fluid and return it to the bloodstream; (2) lacteals receive lipoproteins[1] at the intestinal villi and transport them to the bloodstream (see Fig. 5.6); and (3) the lymphatic system works with the immune system to help defend the body against disease.

Lymphatic Vessels

Lymphatic vessels are quite extensive; most regions of the body are richly supplied with lymphatic capillaries (Fig. 14.1). The construction of the larger lymphatic vessels is similar to that of cardiovascular veins, including the presence of valves. Also, the movement of lymph within these vessels is dependent upon skeletal muscle contraction. When the muscles contract, the lymph is squeezed past a valve that closes, preventing the lymph from flowing backwards.

The lymphatic system is a one-way system that begins with lymphatic capillaries. These capillaries take up fluid that has diffused from and not been reabsorbed by the blood capillaries. **Edema** is localized swelling caused by the accumulation of tissue fluid. This can happen if too much tissue fluid is made and/or not enough of it is drained away. Once tissue fluid enters the lymphatic vessels, it is called **lymph.** The lymphatic capillaries join to form lymphatic vessels that merge before entering one of two ducts: the thoracic duct or the right lymphatic duct. The thoracic duct is much larger than the right lymphatic duct. It serves the lower extremities, the abdomen, the left arm, and the left side of both the head and the neck. The right lymphatic duct serves the right arm, the right side of both the head and the neck, and the right thoracic area. The lymphatic ducts enter the subclavian veins, which are cardiovascular veins in the thoracic region.

Lymph flows one way from a capillary to ever-larger lymphatic vessels and finally to a lymphatic duct, which enters a subclavian vein.

Lymphoid Organs

The **lymphoid organs** of special interest are the lymph nodes, the tonsils, the spleen, the thymus gland, and the red bone marrow (Fig. 14.2).

Lymph nodes, which are small (about 1–25 mm in diameter) ovoid or round structures, are found at certain points along lymphatic vessels. A lymph node is composed

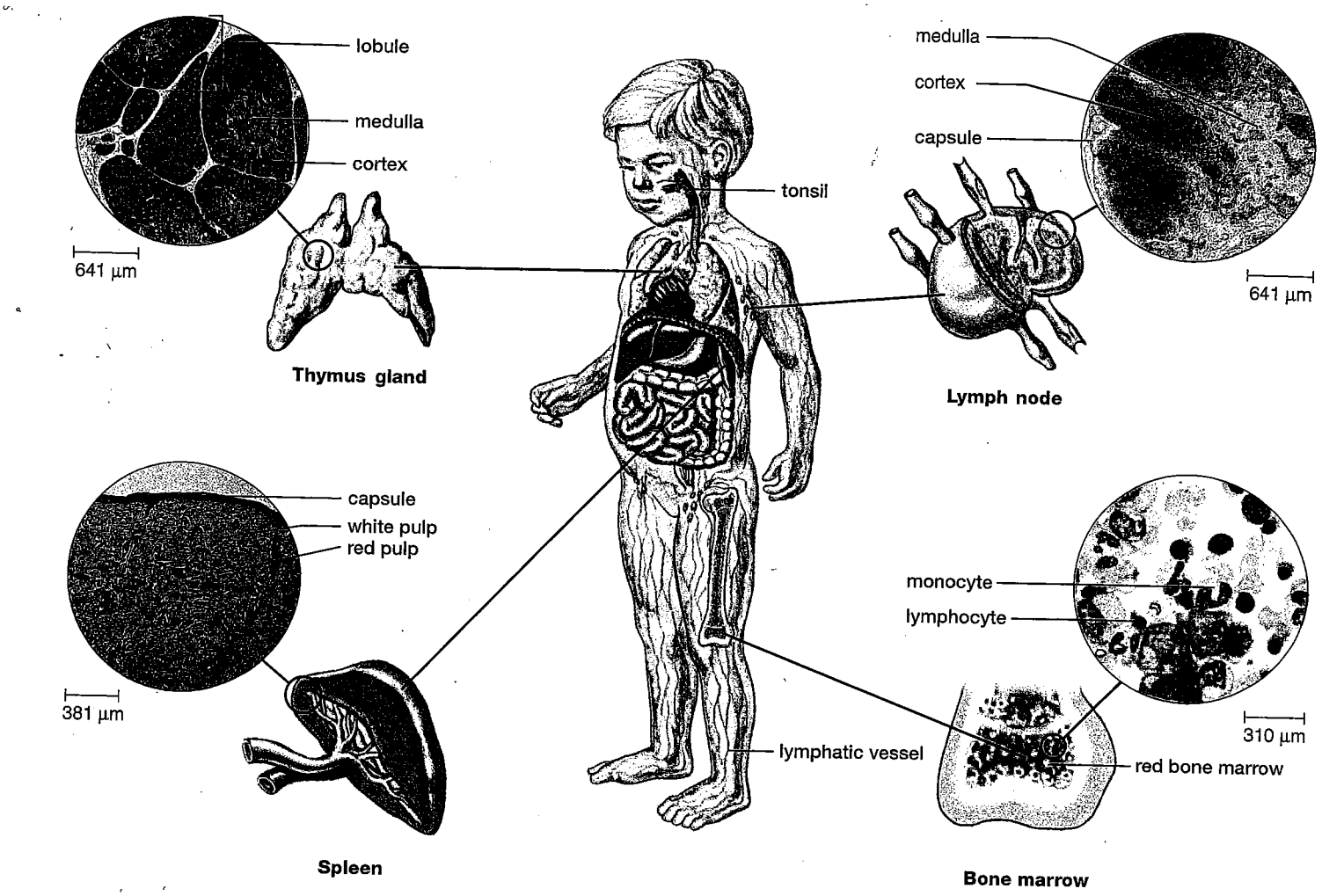

Figure 14.2 **The lymphoid organs.**
The lymphoid organs include the lymph nodes, the tonsils (not shown in an enlargement), the spleen, the thymus gland, and the red bone marrow, all of which contain lymphocytes.

of a capsule surrounding two distinct regions known as the cortex and medulla, which contain many lymphocytes. The cortex contains nodules where lymphocytes congregate when they are fighting off a pathogen. Macrophages, concentrated in the medulla, work to cleanse the lymph. Lymph nodes are named for their location. Inguinal nodes are in the groin, and axillary nodes are in the armpits. Physicians often feel for the presence of swollen, tender lymph nodes in the neck as evidence that the body is fighting an infection. This is a noninvasive, preliminary way to help make such a diagnosis.

The **tonsils** are patches of lymphatic tissue located in a ring about the pharynx (see Fig. 14.1). The well-known pharyngeal tonsils are also called adenoids, while the larger palatine tonsils, located on either side of the posterior oral cavity, are more apt to be infected. The tonsils perform the same functions as lymph nodes inside the body, but because of their location, they are the first to encounter pathogens and antigens that enter the body by way of the nose and mouth.

The **spleen** is located in the upper left region of the abdominal cavity just beneath the diaphragm. It is much larger than a lymph node, about the size of a fist. Whereas the lymph nodes cleanse lymph, the spleen cleanses blood. The spleen is composed of a capsule surrounding tissue known as white pulp and red pulp. The white pulp is involved in filtering out bacteria and any debris; the red pulp is involved in filtering old worn-out red blood cells.

The spleen's outer capsule is relatively thin, and an infection or a blow can cause the spleen to burst. Although its functions are replaced by other organs, a person without a spleen is often slightly more susceptible to infections and may have to receive antibiotic therapy indefinitely.

The **thymus gland** is located along the trachea behind the sternum in the upper thoracic cavity. This gland varies in size, but it is larger in children and shrinks as we get older.

The thymus is divided into lobules by connective tissue. The T lymphocytes mature in these lobules. The interior (medulla) of the lobule, which consists mostly of epithelial cells, stains lighter than the outer layer (cortex). The thymus gland produces thymic hormones, such as thymosin, that are thought to aid in maturation of T lymphocytes. Thymosin may also have other functions in immunity.

Red bone marrow is the site of origin for all types of blood cells, including the five types of white blood cells pictured in Figure 13.10. The marrow contains stem cells that are ever capable of dividing and producing cells that then differentiate into the various types of blood cells (see Fig. 13.14). In a child, most bones have red bone marrow, but in an adult it is present only in the bones of the skull, the sternum (breastbone), the ribs, the clavicle, the pelvic bones, and the vertebral column. The red bone marrow consists of a network of connective tissue fibers, called reticular fibers, which are produced by cells called reticular cells. These and the stem cells and their progeny are packed around thin-walled sinuses filled with venous blood. Differentiated blood cells enter the bloodstream at these sinuses.

Lymphoid organs have specific functions that assist immunity. Lymph is cleansed in lymph nodes; blood is cleansed in the spleen. All blood cells are made in red bone marrow. Most white blood cells mature in the red bone marrow, but T lymphocytes mature in the thymus.

14.2 Nonspecific Defenses

The **immune system** includes the cells and tissues that are responsible for immunity. **Immunity** is the body's ability to defend itself against infectious agents, foreign cells, and even abnormal body cells, such as cancer cells. Thereby, the internal environment has a better chance of remaining stable. Immunity includes nonspecific and specific defenses. The four types of nonspecific defenses—barriers to entry, the inflammatory reaction, natural killer cells, and protective proteins—are effective against many types of infectious agents.

Barriers to Entry

Skin and the mucous membranes lining the respiratory, digestive, and urinary tracts serve as mechanical barriers to entry by pathogens. Oil gland secretions contain chemicals that weaken or kill certain bacteria on the skin. The upper respiratory tract is lined by ciliated cells that sweep mucus and trapped particles up into the throat, where they can be swallowed or expectorated (coughed out). The stomach has an acidic pH, which inhibits the growth of or kills many types of bacteria. The various bacteria that normally reside in the intestine and other areas, such as the vagina, prevent pathogens from taking up residence.

Inflammatory Reaction

Whenever tissue is damaged, a series of events occurs that is known as the **inflammatory reaction.** The inflamed area has four outward signs: redness, heat, swelling, and pain. Figure 14.3 illustrates the participants in the inflammatory reaction. **Mast cells,** which occur in tissues, resemble basophils, one of the types of white cells found in the blood.

When an injury occurs, damaged tissue cells and mast cells release chemical mediators, such as **histamine** and **kinins,** which cause the capillaries to dilate and become more permeable. The enlarged capillaries cause the skin to redden, and the increased permeability allows proteins and fluids to escape into the tissues, resulting in swelling. The swollen area, as well as the kinins, stimulate free nerve endings, causing the sensation of pain.

Neutrophils and monocytes migrate to the site of injury. They are amoeboid and can change shape to squeeze through capillary walls and enter tissue fluid. Neutrophils, and also mast cells, phagocytize pathogens. The engulfed pathogens are destroyed by hydrolytic enzymes when the endocytic vesicle combines with a lysosome, one of the cellular organelles.

As they leave the blood and enter the tissues, monocytes differentiate into **macrophages,** large phagocytic cells that are able to devour a hundred pathogens and still survive. Some tissues, particularly connective tissue, have resident macrophages, which routinely act as scavengers, devouring old blood cells, bits of dead tissue, and other debris. Macrophages can also bring about an explosive increase in the number of leukocytes by liberating colony-stimulating factors, which pass by way of blood to the red bone marrow, where they stimulate the production and the release of white blood cells, primarily neutrophils. As the infection is being overcome, some neutrophils may die. These—along with dead cells, dead bacteria, and living white blood cells—form pus, a whitish material. Pus indicates that the body is trying to overcome the infection.

When a blood vessel ruptures, the blood forms a clot to seal the break. The chemical mediators (e.g., histamine and kinins) and antigens move through the tissue fluid and lymph to the lymph nodes. Now lymphocytes are activated to react to the threat of an infection. Sometimes inflammation persists, and the result is chronic inflammation that is often treated by administering anti-inflammatory agents such as aspirin, ibuprofen, or cortisone. These medications act against the chemical mediators released by the white blood cells in the area.

The inflammatory reaction is a "call to arms"—it marshals phagocytic white blood cells to the site of bacterial invasion and stimulates the immune system to react against a possible infection.