Lymphoid Cells and Tissues

In order to understand the basic aspects of the lymphatic system's role in the body, we investigate the components of lymphoid organs—lymphoid cells and lymphoid tissues—before considering the organs themselves.

Lymphoid Cells

Infectious microorganisms that manage to penetrate the body's epithelial barriers quickly proliferate in the underlying loose connective tissues. These invaders are fought off by the inflammatory response, by phagocytes (macrophages), and by lymphocytes.

Lymphocytes, the main warriors of the immune system, arise in red bone marrow (along with other formed elements). They then mature into one of the two main varieties of immunocompetent cells—**T cells (T lymphocytes)** or **B cells (B lymphocytes)**—that protect the body against antigens. (*Antigens* are anything the body perceives as foreign, such as bacteria and their toxins, viruses, mismatched RBCs, or cancer cells.) Activated T cells manage the immune response and some of them directly attack and destroy foreign cells. B cells protect the body by producing **plasma cells,** daughter cells that secrete antibodies into the blood (or other body fluids). Antibodies immobilize antigens until they can be destroyed by phagocytes or other means. The precise roles of the lymphocytes in immunity are explored in Chapter 21.

Lymphoid **macrophages** play a crucial role in body protection and in the immune response by phagocytizing foreign substances and by helping to activate T cells. So, too, do the spiny-looking **dendritic cells** found in lymphoid tissue. Last but not least are the **reticular cells,** fibroblastlike cells that produce the reticular fiber **stroma** (stro'mah), which is the network that supports the other cell types in the lymphoid organs (Figure 20.3).

Lymphoid Tissue

Lymphoid (lymphatic) tissue is an important component of the immune system, mainly because it (1) houses and provides a proliferation site for lymphocytes and (2) furnishes an ideal surveillance vantage point for lymphocytes and macrophages. Lymphoid tissue, largely composed of a type of loose connective tissue called **reticular connective tissue,** dominates all the lymphoid organs except the thymus. Macrophages live on the fibers of the reticular network, and in the spaces of the network are huge numbers of lymphocytes that have squeezed through the walls of postcapillary venules coursing through this tissue. The lymphocytes reside temporarily

? *How is reticular connective tissue classified?*

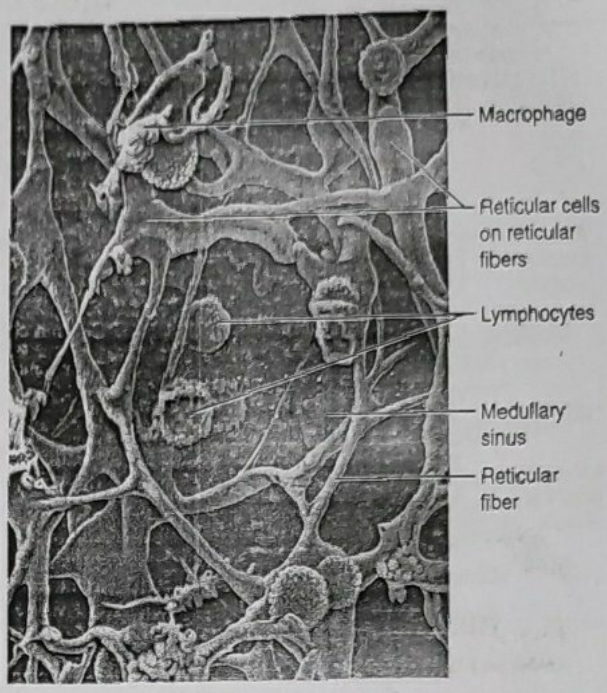

FIGURE 20.3 **Reticular tissue in a human lymph node.** Scanning electron micrograph (1100×).

in the lymphoid tissue (Figure 20.3), and then leave to patrol the body again. The cycling of lymphocytes between the circulatory vessels, lymphoid tissues, and loose connective tissues of the body ensures that lymphocytes reach infected or damaged sites quickly.

Lymphoid tissue comes in various "packages." **Diffuse lymphatic tissue,** consisting of a few scattered reticular tissue elements, is found in virtually every body organ, but larger collections appear in the lamina propria of mucous membranes and in lymphoid organs. **Lymphoid follicles (nodules)** represent another way lymphoid tissue is organized. Like diffuse lymphatic tissue, they lack a capsule, but follicles are solid, spherical bodies consisting of tightly packed reticular elements and cells. Follicles often have lighter-staining centers, called **germinal centers.** Follicular dendritic cells and B cells predominate in germinal centers, and these centers enlarge dramatically when the B cells are dividing rapidly and producing plasma cells. In many cases, the follicles are found forming part of larger lymphoid organs, such as lymph nodes. However, isolated aggregations of lymphatic follicles occur in the intestinal wall as Peyer's patches and in the appendix.

? What is the benefit of having fewer efferent than afferent lymphatics in lymph nodes?

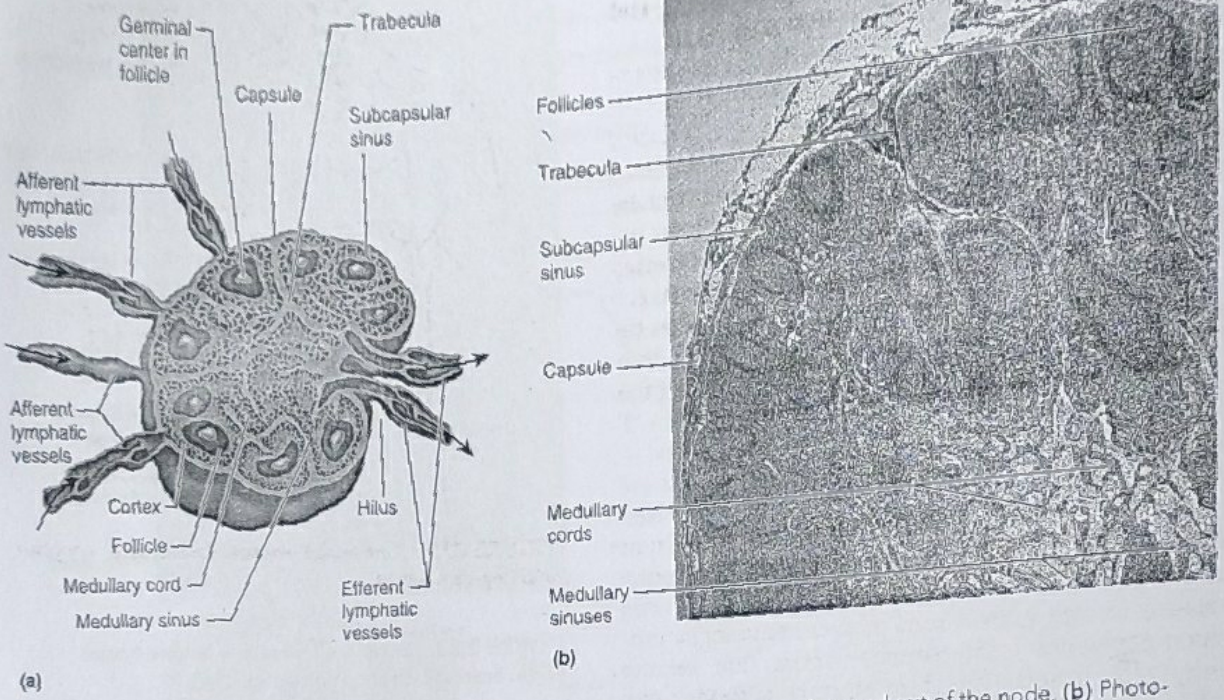

FIGURE 20.4 **Lymph node.** (a) Longitudinal view of the internal structure of a lymph node and associated lymphatics. Notice that several afferent lymphatics converge on its convex side, whereas fewer efferent lymphatics exit at its hilus. Arrows indicate the direction of lymph flow into and out of the node. (b) Photomicrograph of part of a lymph node (60×).

Lymph Nodes

The principal lymphoid organs in the body are the **lymph nodes**, which cluster along the lymphatic vessels of the body. As lymph is transported back to the bloodstream, it is filtered through the lymph nodes. There are hundreds of these small organs, but because they are usually embedded in connective tissue, they are not ordinarily seen. Large clusters of lymph nodes occur near the body surface in the inguinal, axillary, and cervical regions, places where the lymphatic collecting vessels converge to form trunks (see Figure 20.2a).

Lymph nodes have two basic functions, both concerned with body protection. (1) They act as lymph "filters." Macrophages in the nodes remove and destroy microorganisms and other debris that enter the lymph from the loose connective tissues, effectively preventing them from being delivered to the blood and spreading to other parts of the body. (2) They help activate the immune system. Lymphocytes, also strategically located in the lymph nodes, monitor the lymphatic stream for the presence of *antigens* and mount an attack against them. Let's look at how the structure of a lymph node supports these defensive functions.

Structure of a Lymph Node

Lymph nodes vary in shape and size, but most are bean shaped and less than 2.5 cm (1 inch) in length. Each node is surrounded by a dense fibrous **capsule** from which connective tissue strands called **trabeculae** extend inward to divide the node into a number of compartments (Figure 20.4). The node's internal framework or stroma of reticular fibers physically supports the ever-changing population of lymphocytes.

A lymph node has two histologically distinct regions, the **cortex** and the **medulla**. The superficial

Having fewer efferents causes lymph to accumulate in lymph nodes, allowing more time for its cleansing. ■

part of the cortex contains densely packed follicles, many with germinal centers heavy with dividing B cells. Dendritic cells nearly encapsulate the follicles and abut the deeper part of the cortex, which primarily houses T cells in transit. The T cells circulate continuously between the blood, lymph nodes, and lymph, performing their surveillance role.

Medullary cords, which are thin inward extensions from the cortical lymphoid tissue, contain both types of lymphocytes plus plasma cells and they define the medulla. Throughout the node are **lymph sinuses,** large lymph capillaries spanned by crisscrossing reticular fibers. Numerous macrophages reside on these reticular fibers and phagocytize foreign matter in the lymph as it flows by in the sinuses. Additionally, some of the lymph-borne antigens in the percolating lymph leak into the surrounding lymphoid tissue, where they activate lymphocytes to mount an immune attack against them.

Circulation in the Lymph Nodes

Lymph enters the convex side of a lymph node through a number of **afferent lymphatic vessels.** It then moves through a large, baglike sinus, the **subcapsular sinus,** into a number of smaller sinuses that cut through the cortex and enter the medulla. The lymph meanders through these sinuses and finally exits the node at its **hilus** (hi'lus), the indented region on the concave side, via **efferent lymphatic vessels.** Because there are fewer efferent vessels draining the node than afferent vessels feeding it, the flow of lymph through the node stagnates somewhat, allowing time for the lymphocytes and macrophages to carry out their protective functions. Lymph passes through several nodes before it is completely cleansed.

HOMEOSTATIC IMBALANCE

Sometimes lymph nodes are overwhelmed by the agents they are trying to destroy. For example, when large numbers of bacteria are trapped in the nodes, the nodes become inflamed, swollen, and tender to the touch, a condition often referred to (erroneously) as swollen glands. Such infected lymph nodes are called *buboes* (bu'boz). (Buboes are the most obvious symptom of bubonic plague, the "Black Death" that killed much of Europe's population in the late Middle Ages.) Lymph nodes can also become secondary cancer sites, particularly in metastasizing cancers that enter lymphatic vessels and become trapped there. The fact that cancer-infiltrated lymph nodes are swollen but not painful helps distinguish cancerous lymph nodes from those infected by microorganisms.

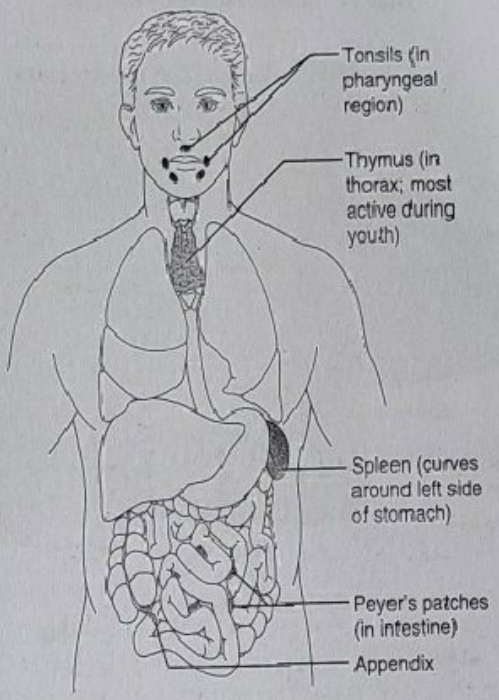

FIGURE 20.5 **Lymphoid organs.** Tonsils, spleen, thymus, and Peyer's patches.

Other Lymphoid Organs

Lymph nodes are just one example of the many types of **lymphoid organs** or aggregates of lymphatic tissue in the body. Others are the spleen, thymus gland, tonsils, and Peyer's patches of the intestine (Figure 20.5), as well as bits of lymphatic tissue scattered in the connective tissues. The common feature of all these organs is their tissue makeup: All are composed of *reticular connective tissue.* Although all lymphoid organs help protect the body, only the lymph nodes filter lymph. The other lymphoid organs and tissues typically have efferent lymphatics draining them, but lack afferent lymphatics.

Spleen

The soft, blood-rich **spleen** *is* about the *size* of a fist and is the largest lymphoid organ. Located in the left side of the abdominal cavity just beneath the diaphragm, it curls around the anterior aspect of the stomach (Figures 20.5 and 20.6). It is served by the large *splenic artery* and *vein,* which enter and exit the *hilus* on its slightly concave anterior surface.

The spleen provides a site for lymphocyte proliferation and immune surveillance and response. But perhaps even more important are its blood-cleansing functions. Besides extracting aged and defective

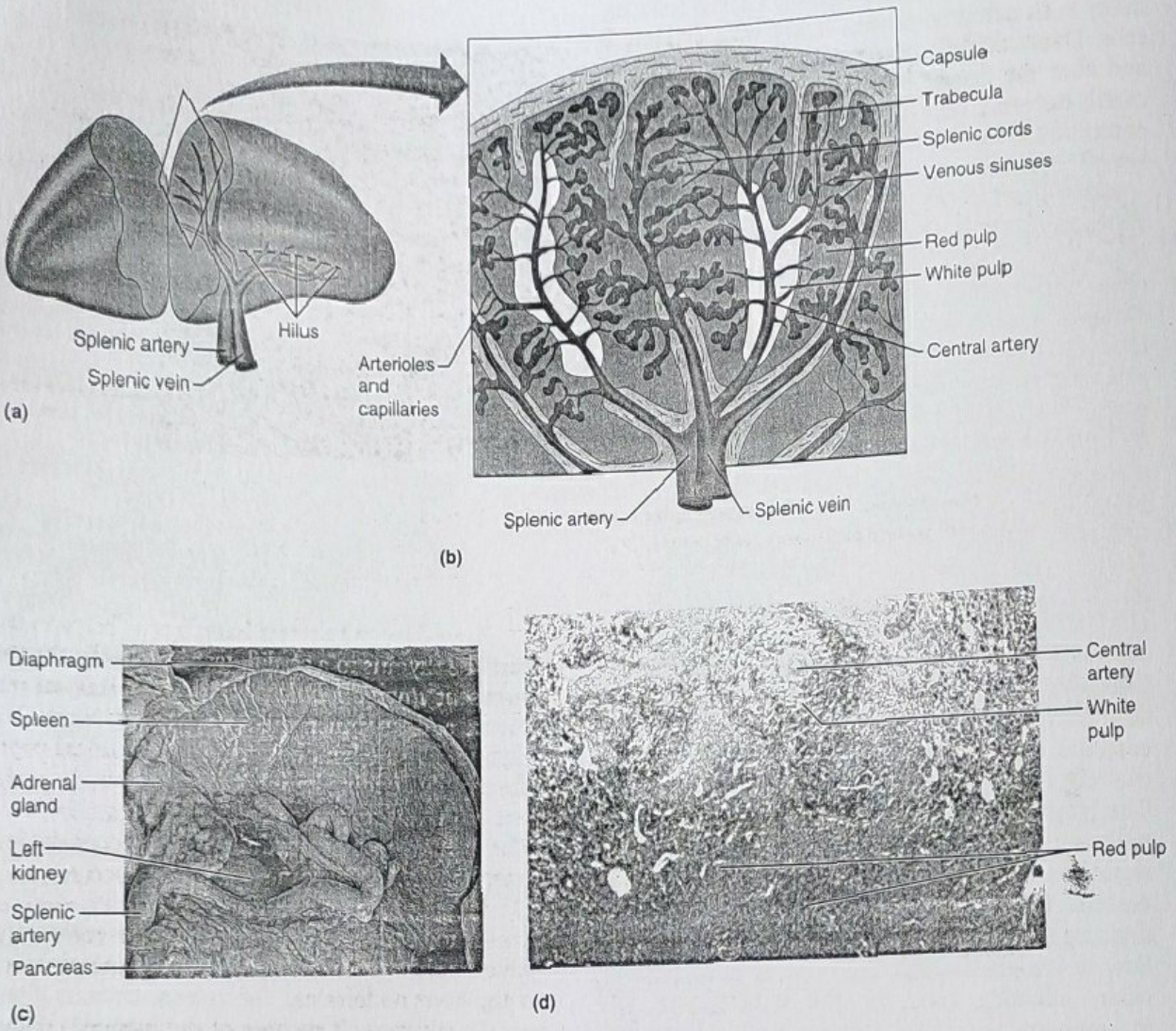

FIGURE 20.6 **The spleen.** (a) Gross structure. (b) Diagram of the histological structure. (c) Photograph of the spleen in its normal position in the abdominal cavity, anterior view. (d) Photomicrograph of spleen tissue showing white and red pulp regions (30×).

blood cells and platelets from the blood, its macrophages remove debris and foreign matter from blood flowing through its sinuses. The spleen also performs three additional, and related, functions.

1. It stores some of the breakdown products of red blood cells for later reuse (for example, it salvages iron for making hemoglobin) and releases others to the blood for processing by the liver.
2. It is a site of erythrocyte production in the fetus (a capability that normally ceases after birth).
3. It stores blood platelets.

Like lymph nodes, the spleen is surrounded by a fibrous capsule, has trabeculae that extend inward, and contains both lymphocytes and macrophages. Consistent with its blood-processing functions, it also contains huge numbers of erythrocytes. Areas composed mostly of lymphocytes suspended on reticular fibers are called **white pulp.** The white pulp clusters or forms "cuffs" around the *central arteries* (small branches of the splenic artery) in the organ and forms what appear to be islands in a sea of red pulp. **Red pulp** is essentially all remaining splenic tissue, that is, the venous sinuses (blood sinusoids) and the **splenic cords,** regions of reticular connective tissue exceptionally rich in macrophages. Red pulp is most concerned with disposing of worn-out red blood cells and bloodborne pathogens, whereas white pulp is involved with the immune functions of the spleen. The naming of the pulp regions reflects their appearance in fresh spleen tissue rather than their staining properties. Indeed, as can

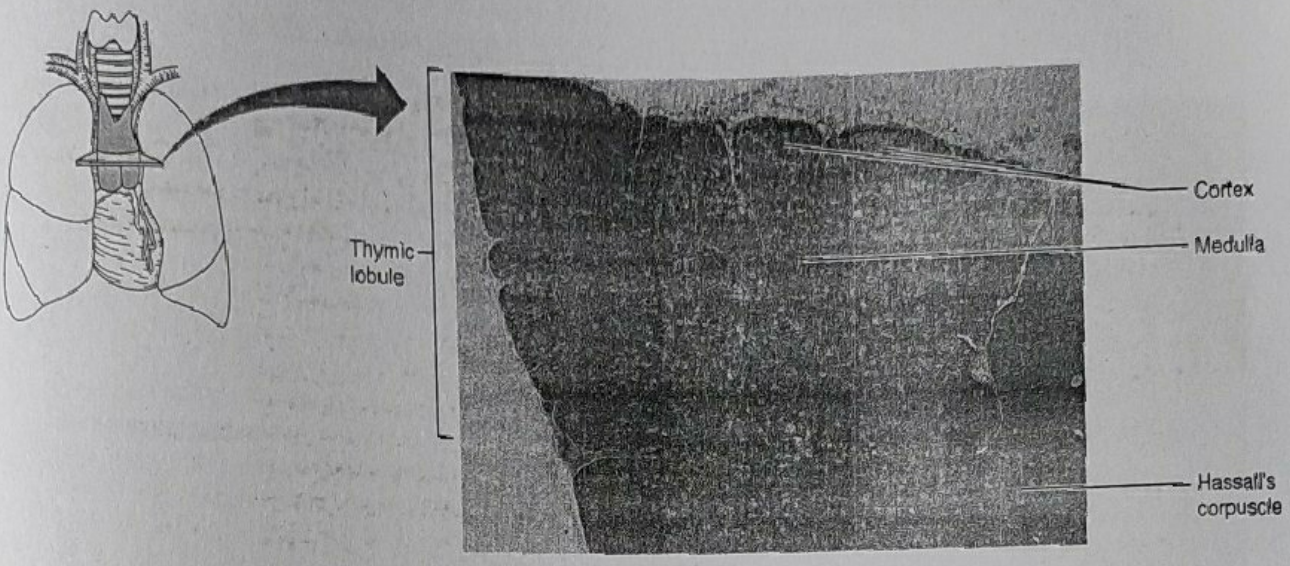

FIGURE 20.7 **The thymus.** The photomicrograph of a portion of the thymus shows its lobules with cortical and medullary regions (20×).

be seen in the photomicrograph in Figure 20.6d, the white pulp takes on a purplish hue and sometimes appears darker than the red pulp.

HOMEOSTATIC IMBALANCE

Because the spleen's capsule is relatively thin, a direct blow or severe infection may cause it to rupture, spilling blood into the peritoneal cavity. Under such conditions the spleen must be removed quickly (a procedure called a *splenectomy*) and the splenic artery tied off to prevent life-threatening hemorrhage and shock. Surgical removal of the spleen seems to create few problems because the liver and bone marrow take over most of its functions. In children younger than 12, the spleen will regenerate if a small part of it is left in the body. ●

Thymus

The bilobed **thymus** (thi'mus) has important functions primarily during the early years of life. It is found in the inferior neck and extends into the superior thorax, where it partially overlies the heart deep to the sternum (see Figures 20.5 and 20.7). By secreting the hormones thymosin and thymopoietin, the thymus causes T lymphocytes to become immunocompetent; that is, it enables them to function against specific pathogens in the immune response. Prominent in newborns, the thymus continues to increase in size during childhood, when it is most active. During adolescence its growth stops, and it starts to atrophy gradually. By old age it has been replaced almost entirely by fibrous and fatty tissue and is difficult to distinguish from surrounding connective tissue.

To understand thymic histology, it helps to compare the thymus to a cauliflower head—the flowerets represent *thymic lobules*, each containing an outer cortex and an inner medulla (Figure 20.7). Most thymic cells are lymphocytes. In the cortical regions the rapidly dividing lymphocytes are densely packed, but a few macrophages are scattered among them. The lighter-staining medullary areas contain fewer lymphocytes plus some bizarre structures called **Hassall's** or **thymic corpuscles.** Hassall's corpuscles appear to be areas of degenerating cells, but their significance is unknown. Because the thymus lacks B cells, it has no follicles.

The thymus differs from other lymphoid organs in two other important ways. First, it functions strictly in T lymphocyte maturation and thus is the only lymphoid organ that does not *directly* fight antigens. In fact, the so-called *blood-thymus barrier* keeps blood-borne antigens from leaking into the cortical regions to prevent premature activation of the immature lymphocytes. Second, the stroma of the thymus consists of epithelial cells rather than reticular fibers. These **thymocytes** secrete the hormones that stimulate the lymphocytes to become immunocompetent.

Tonsils

The **tonsils** are the simplest lymphoid organs. They form a ring of lymphatic tissue around the entrance to the pharynx (throat), where they appear as swellings of the mucosa (Figure 20.5). The tonsils are named according to location. The paired **palatine tonsils** are located on either side at the posterior end of the oral cavity. These are the largest of the tonsils and the ones most often infected. The **lingual tonsils,** paired lumpy collections of lymphoid follicles, lie at the base