21. Lymphatic System

The lymphatic system serves two major functions for the body:

1. Assist the body in defense against foreign invaders, toxins, cancer cells, etc. Lymphatic tissues and organs transport and house phagocytic cells and lymphocytes to aid in the body’s defense.

2. Transport of fluid from the interstitial spaces to the bloodstream. Hydrostatic and osmotic pressures result in the movement of fluid out of the circulatory system at the arterial ends of the capillaries. Much of the fluid is reabsorbed at the venous ends of the capillaries, but the balance must be returned to the bloodstream as well or the blood volume will drop. Fluid is absorbed from the interstitial compartment by the lymphatic system and later returned to the venous circulation.

Notice that both of these functions involve supporting other systems of the body–the immune system and the cardiovascular system.

I. Lymph and Lymph Vessels

Lymph and lymphatic capillaries
You should already be aware that the body contains interstitial fluid in the spaces between and around cells. You should also be aware that throughout most of the body, fluid from the blood leaks through capillaries into the interstitial fluid. A slight pressure gradient drives interstitial fluid into capillaries of the lymphatic system, which are found throughout most of the body (Fig. 21.1). Once fluid enters these vessels it is known as lymph. Over the course of a day, about three liters of fluid are absorbed into lymph capillaries. The main ingredient of lymph is, of course, water. Lymph also contains small solutes (such as sodium and potassium) and a small amount of protein. Leukocytes and foreign particles are also found in lymph.

Lymph capillaries (Fig. 21.2) are found throughout the body in most places where capillary beds are found. Notable exceptions are in the bones, bone marrow, and central nervous system. Lymph capillaries are more permeable than blood capillaries, and they easily take in fluid and particles as large as proteins. Pressure in the interstitial fluid is generally somewhat higher than pressure in the lymph capillaries, and this pressure opens flaps on the lymph capillaries to allow fluid and particles into the lymph capillaries. Should pressure inside the lymph capillaries exceed that of the interstitial fluid, the flaps shut to prevent backflow out of the lymph capillaries. When tissue becomes inflamed, interstitial pressure may rise sufficiently to force particles such as viruses and bacteria into the lymph capillaries.

Lacteals are lymph capillaries found in the villi of the small intestine (see Chapter 26). They absorb lipids and lipid-soluble vitamins from the intestine and transport them to the bloodstream.

Lymphatic vessels, trunks, and ducts
From lymph capillaries, lymph travels toward the heart via increasingly larger vessels. Lymphatic vessels are similar in structure to veins; they have the same three tunics as veins and they have valves. Why are valves critically important to the lymphatic vessels?
Lymphatic vessels converge to form **lymphatic trunks**, which drain major body regions, such as the head, the arms, the abdominal organs, and the legs. The lymphatic trunks eventually lead to one of two large **lymphatic ducts** (Fig. 21.3): The **right lymphatic duct** drains the right arm, the right side of the head, and the right side of the thorax. The right lymphatic duct empties lymph into the venous circulation at the right subclavian vein. The **thoracic duct** drains the rest of the body. The thoracic duct empties lymph into the venous circulation at the left subclavian vein.

Flow through the lymphatic system occurs at a much lower rate than flow through the circulatory system. Movement of fluid is accomplished primarily by contraction of skeletal muscles and changes in pressure of the thoracic cavity (caused by breathing), combined with assistance from the valves. Compare the rate of flow through the lymphatic system (about three liters of fluid per day) with the rate of flow through the cardiovascular system.

**II. Overview of Lymphatic Tissue and Organs**

In addition to lymphatic vessels and lymph, the lymphatic system contains clusters of tissue and organs. The various tissues and organs are categorized as either primary or secondary lymphatic structures.

**Primary lymphatic structures** are involved in the formation and maturation of lymphocytes.

**Secondary lymphatic structures** are not involved in lymphocyte or maturation. They are sites where immune responses are initiated.

**III. Primary Lymphatic Structures**

**Red bone marrow**
Red bone marrow tissue is considered a primary lymphatic structure. As you learned earlier in the semester (and in A&P I), red bone marrow is the site of hemopoiesis. Both B- and T-lymphocytes are formed in the red bone marrow.

**Thymus**
The **thymus** is located in the superior portion of the mediastinum. After T-lymphocytes are formed in the red bone marrow they must travel to the thymus in order to properly mature. The “T” in the phrase “T-lymphocyte” or “T cell” comes from the fact that these cells mature in the thymus. The thymus grows throughout childhood, then it slowly atrophies though adult life. This atrophy may explain to some degree why older persons are often more susceptible to infection.
IV. Secondary Lymphatic Structures

Secondary lymphatic structures house lymphocytes and other cells of the immune system. They are composed largely of reticular connective tissue. There are four key cell types in the lymphatic system:

1. Lymphocytes direct the specific immune response against specific antigens.
2. Macrophages that phagocytize pathogens.
3. Dendritic cells present antigens to T-lymphocytes.
4. Reticular cells produce a fibrous network in the lymphoid organs.

Secondary lymphatic structures provide an environment for the proliferation of lymphocytes. They also provide strategically-placed surveillance points for lymphocytes and macrophages to look for pathogens. Pathogens that enter the body are likely to invade the interstitial spaces or blood and end up in the lymphatic system.

A secondary lymphatic structure that is enclosed by a capsule is considered an organ; these include the spleen and lymph nodes. Other secondary lymphatic structures have incomplete capsules or lack capsules altogether; these structures are not considered proper organs.

Lymph nodes
Lymph nodes are rather small, round structures found along the lymphatic vessels. They act to filter the lymph as it travels through the vessels. While they are found throughout most of the body, lymph nodes are concentrated in the inguinal, axillary, and cervical regions of the body (Fig. 21.1). Phagocytic cells in the nodes remove microorganisms and debris from the lymph, and lymphocytes monitor the lymph for specific antigens that may require a specific immune response.

Lymph nodes are generally less than 1” in length (Fig. 21.6). Each node is surrounded by an outer capsule made of connective tissue. Extensions of the capsule, called trabeculae, extend into the lymph node and make compartments within the node. The outer layer of the lymph node, or cortex, contains numerous lymphatic nodules (discussed in more detail later). The inner portion of the node is called the medulla.

Multiple afferent lymphatic vessels bring lymph to each lymph node. The lymph makes its way to the medulla, where lymph flows into lymph sinuses, which are spanned by networks of reticular fibers. These networks provide an environment in which many macrophages and lymphocytes reside, as they monitor the lymph for invaders. One side of each node has an indented area, called the hilum. At the hilum, an efferent lymphatic vessel allows lymph to exit the lymph node.

Spleen
The spleen is located below the diaphragm, and it curls around the left margin of the stomach (Fig. 21.7). It receives a rich supply of blood, and it is generally deep red in color. Functions of the spleen are as follows:
1. Like the lymph nodes, the spleen is a site of lymphocyte proliferation and immune system surveillance. Unlike the lymph nodes, the spleen is monitoring the blood, rather than lymph.
2. The spleen aids in the removal from the bloodstream and breakdown of aged and defective
erythrocytes and platelets. Iron is stored in the spleen and released when needed by other parts of the body.

3. The spleen is a storage site for platelets.

Areas of the spleen that consist primarily of lymphocytes are referred to as **white pulp**. These areas are the primary sites for the spleen’s immune system functions. The rest of the spleen has a high density of erythrocytes and makes up the **red pulp**. Arteries and veins enter and exit the spleen at the **hilum**. While the spleen has efferent lymphatic vessels, it lacks afferent lymphatic vessels.

The **capsule** of the spleen is quite delicate, and injury to the spleen can be detrimental because of the potential for extensive internal bleeding. A damaged spleen can generally be removed without serious complications, since other lymphoid organs and the liver can handle the functions of the spleen.

**Tonsils**

The **tonsils** are found in the walls of the pharynx (Fig. 21.8). They are not completely surrounded by a capsule, and thus they are not considered true lymphatic organs. There are three main tonsils: the **palatine tonsils**, the **lingual tonsils**, and the **pharyngeal tonsil** (also called the adenoids). Being located in the pharynx, they monitor the entrance to both the respiratory and digestive systems.

**Lymphatic nodules and MALT**

**Lymphatic nodules** (or **follicles**) are dense, spherical bodies of lymphoid tissue. Groups of nodules make up **diffuse lymphatic tissue**, which is found throughout most organs in the body. Nodules are found in the lymphoid organs, including the lymph nodes, spleen, and tonsils. There are also some other places in the body where specific collections of lymphatic follicles are found: **Peyer’s patches** are aggregates of follicles found in the wall of the small intestine. The **appendix** also contains many follicles.

The term **MALT** (**mucosa-associated lymphatic tissue**) is used to refer to the various lymphoid tissues and organs associated with the digestive and respiratory tracts (this includes the Peyer’s patches, lymph nodes, etc.).

Why is it important to have lymphoid tissues concentrated along the digestive and respiratory tracts?