The Lymphatic System

Lymphatics and Lymphatic Organs
The lymphatic system has two major functions. The primary function is to drain excess fluid (lymph) from the interstitial space of all tissues in the body. Recall that plasma fluid is lost into the interstitial spaces of tissues at capillary beds. As blood moves from wider arterioles into narrower capillaries, the fluid pressure forces some of the fluid across the capillary walls (capillaries are “leaky”). Most of this fluid is drawn back into the capillary later because of osmosis, but not all of it. The fluid that stays behind, now called lymph, has to be drained out and returned to the blood, otherwise the tissues would swell with the extra fluid (edema) and blood pressure would drop since it has less volume.
The smallest of the lymphatic vessels are the **lymphatic capillaries**, found closely associated with capillary beds. The lymphatic vessels are extremely permeable to many different substances: water, proteins, white blood cells, and even pathogens and cancer cells. They have this permeability because their walls are made of “minivalves” – overlapping endothelial cells and “hinge” open like a trap door when fluid pressure outside the capillary becomes high. This ensures that the correct amount of fluid remains in the interstitial space at all times. With the proper amount of fluid, the pressure isn’t enough to push the minivalves open but as fluid collects in the interstitial space, pressure builds up, forcing the minivalves open, and allowing some fluid to enter. Since the capillaries actually open up, fluid (and lots of other stuff) enters the lymphatic capillaries easily.
Lymph is drawn through the lymphatic capillaries and into a series of ever-widening lymphatic collecting vessels that merge to form fewer, and wider, vessels as the fluid gets nearer the subclavian veins. Eventually, all of the lymph moves into two large **lymphatic ducts**, which drain the lymph back into the bloodstream at the left and right subclavian veins.

There are two lymphatic ducts, and each drains into one subclavian vein. The **right lymphatic duct** drains the upper-right quadrant of the body: the right side of the head, the right upper limb, and the right upper part of the torso. The **thoracic duct** drains everything else: the entire left side of the body as well as the right lower limb and the lower part of the right half of the torso.

Lymph movement is different from blood movement in a few ways. First, the lymphatic system does not have a specialized “pump” like the circulatory system does (the heart). Instead, lymph movement is slowly “milked” through the lymphatic vessels by skeletal muscles. The changing pressure in the chest as a result of breathing also helps this movement, but it’s slow and low-pressure. Second, the lymphatic system has “open” circulation – it has a beginning and an end. Lymph moves from tissue space to the subclavian veins, but it does not circulate further.
Lymphatics

- Secondary function: Immunity
  - Lymph nodes

Since the lymphatic capillaries are so permeable, lots of undesirable “hitchhikers” that can’t cross blood vessel membranes and enter the blood directly can enter the lymph: bacteria, viruses, metastatic cancer cells, etc. Using the lymphatic vessels, they can then move either to the bloodstream or other parts of the body. This is a big problem! Fortunately, though, the lymph doesn’t just shunt directly back to the bloodstream. Along the way, it passes through thousands of “processing stations” called lymph nodes. Inside the lymph nodes, the lymph is filtered and examined by white blood cells. Pathogens are identified and destroyed.
Lymph Nodes

- Basic structure
- Superficial clusters
- Functions & Cells
- Afferent & efferent vessels

In the interest of time, we’re going to forego a detailed discussion about the anatomy of a lymph node, but there are some basics you need to be familiar with. Lymph nodes range in size from very small to about an inch in length. They tend to be kidney-shaped, with lymph entering them through afferent lymphatic vessels entering the convex side and leaving through less-numerous efferent lymphatic vessels exiting the concave side. There are lymph nodes all throughout the body, but they are especially numerous in the cervical, axillary, and inguinal regions. These superficial clusters of lymph nodes ensures that all lymph is well-processed before it enters the torso (and approaches the subclavian veins).

The two main types of cells found inside the lymph nodes are lymphocytes and macrophages. The lymphocytes are responsible for identifying pathogens (both new pathogens and ones that have been seen before) and provoking an immune response when they are detected. The macrophages are responsible for destroying pathogens non-selectively. (They also help some of the lymphocytes identify the pathogens).

Since there are more afferent vessels than efferent vessels, lymph moves slowly through the lymph node. This gives the white blood cells more time to process it.
In addition to the lymph nodes, there are some other organs (called lymphoid organs) that contribute to the body’s defenses but do not process lymph. We lump them into the lymphatic system as well, though, because they contain large numbers of lymphocytes that do battle with pathogens. The tonsils are an example. Once thought to be basically useless, the tonsils are now recognized as important organs in trapping and destroying pathogens that would otherwise invade our digestive and respiratory systems through the oral and nasal cavities. They are found beneath the mucous membranes of these cavities and so they are part of a collection of lymphoid tissues called mucosa-associated lymphoid tissues (MALTs). Other MALTs are found lining parts of the small intestine and the lungs.

The ring of tonsils consists of three different areas. The palatine tonsils are the ones that flank the opening of the throat. They’re the only ones easily visible from the outside, and the ones that people usually mean when they refer to “the tonsils.” The lingual tonsils are found at the base of the tongue and the pharyngeal tonsils (or “adenoids”) are found in the roof the nasal cavity.
Name those tonsils!
The spleen is an organ that has a wealth of important functions, only one of which is associated with immunity. Structurally, a single large artery (the splenic artery, a branch of the celiac trunk) enters the spleen medially. The artery and its branches are surrounded by a lot of reticular tissue, called “pulp.” Inside the spleen, the blood leaves the branches of the splenic artery and percolates through the pulp to the periphery. At the periphery, it enters veins that will eventually form the splenic vein, which leaves the spleen. There are numerous lymphocytes and macrophages in the pulp of the spleen which filter the blood, identifying and destroying any pathogens they find. In this sense, the spleen acts a lot like a lymph node, but it processes blood instead of lymph.

There are some other important functions as well:

• Prenatally, new blood cells are formed in the spleen. Why? Fetuses don’t have much bone marrow because their skeletons are mostly-cartilage during development.

• Old red blood cells are broken down (by macrophages) and their parts recycled.

• The spleen can act as an “emergency reservoir” for blood when blood pressure is low. When blood pressure drops, smooth muscle surrounding the spleen contracts, making the spleen smaller. This squeezes additional blood into general circulation and effectively reduces the volume of the circulatory system (more blood filling a smaller space means higher blood pressure).
Other Lymphatic Organs

- Thymus
- Peyer’s patches

The thymus is a site of lymphocyte production (not in adults) and maturation. It also produces a hormone called thymosin, which helps regulate lymphocyte development.

Peyer’s patches are another MALT. They’re associated with the lower small intestine and are similar, both structurally and functionally, to the tonsils.
Some of the general symptoms of lymphatic system disease include edema (swelling) of tissues since the fluid is not removed, decreased blood pressure since blood volume is decreased and a suppressed immune system since less lymph is getting processed by the lymph nodes.
**Pathology**

- Bubonic plague

*Bubonic plague* is a bacterial infection that has caused many thousands of deaths throughout history. When the bubonic plague bacteria get into human lymph nodes, the bacteria take up residence and begin reproducing at a very fast rate, causing massive swelling of the lymph node. Without treatment, death usually soon follows from lymphatic system failure. The plague is usually treated with antibiotics.
Elephantiasis is lymphatic system disorder usually caused by a parasitic roundworm. The worm causes a skin infection which indirectly results in blockage of the body’s lymphatics. Lymph cannot be transported back to the blood supply, so it pools in the tissues. The legs and male scrotum show more edema than more superior tissues, largely due to gravity.