

## Chapter 22a Lymphatic System

**The function** of the lymphatic system is to **maintain blood volume** by picking up fluid from the interstitial environment and returning it to circulation. This amounts to about 3 liters of fluid each day. This also promotes mixing of the ECF divisions (plasma and interstitial fluid) and enhances delivery of substances to cells.

The lymphatic system also **transports fats** (and fat soluble vitamins) that have been absorbed from the GI tract. AND, it **houses the body's defenses**. This includes cells, tissues and organs that are responsible for defending the body against environmental threats (pathogens) and internal threats such as cancer cells. The lymphatic capillaries intercept invading microbes when collecting interstitial fluid which is then exposed to defense cells in the nodes.

### Anatomy Overview

- Lymph is the fluid of the lymphatic system. It contains leukocytes, proteins (though less than the blood), fats and microbes (if any are present)
- Lymphatic vessels transport the lymph, also called "lymphatics." This network extends from the lymphatic capillaries to the subclavian veins where the lymph enters circulation.
- Lymphatic tissues are either diffuse tissues or nodules.
  - Diffuse lymphatic tissue is MALT...mucosa associated lymphatic tissue. This includes lymphocytes scattered along tracts, including the respiratory tract (BALT), digestive tract (GALT), urinary tract and reproductive tract.
  - The lymphatic nodules are aggregates of lymphocytes and macrophages. They are found in the walls of the pharynx (tonsils), the appendix, and the ileum (Peyer's Patches)
- Lymphatic organs differ from tissues in that they have a CT capsule. This includes bone, lymph nodes, thymus and spleen.
  - The primary lymphatic organs are the bone and the thymus. They are primary because this is where lymphocytes mature. The B-lymphocytes mature in bone, and the T-lymphocytes mature in the thymus. After they mature they circulate!
  - The secondary lymphatic organs are where most of the immune responses occur, and they contain mature B and T cells. These are the lymph nodes and the spleen.

### Lymphatic Vessels

The lymphatic vessels are found closely associated with blood vessels. However, unlike blood vessels it is not a closed-circuit system...the lymphatic vessels are a one-way system that have a definitive beginning and end. They begin at the capillaries and end at the two main ducts that empty into the subclavian veins.

The LYMPHATIC CAPILLARIES are found everywhere in the body except for the CNS, cartilage, cornea, bone and marrow. They are highly permeable and they collect

interstitial fluid, which is excess filtrate from the blood capillaries and leaked plasma proteins.

In contrast to blood capillaries, the lymphatic capillaries:

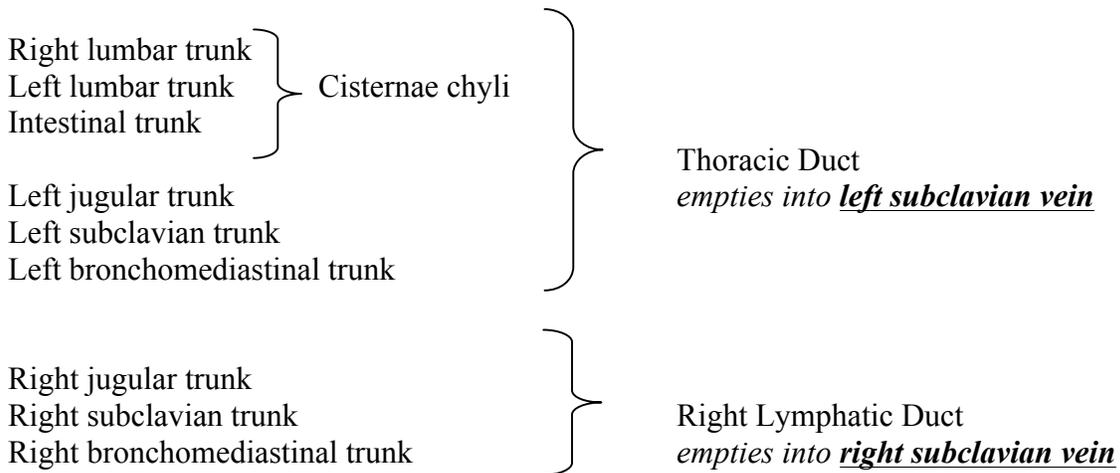
- Are blind-ended “pockets” (terminal lymphatics)
- Have large diameters, for less resistance
- Have thinner walls with little to no basement membrane (less pressure)
- Endothelial cells overlap to form one-way valves
- Tethered to surrounding tissue by protein filaments...this prevents collapse

The capillaries are called **LACTEALS** in the GI tract.

The COLLECTING VESSELS receive lymph from the capillaries. They run together with arteries and veins...often bound up in the same CT. They also have the same tunics as veins, but have thinner walls and more valves. The valves form bulges along the vessel, giving it a beaded appearance.

There are both superficial and deep collecting vessels, relating to how close they are to the surface. The superficial lymphatics are subcutaneous and in areolar CT of mucous membranes (GI, respiratory, urinary, reproductive tracts), and serous membranes (pleural, pericardial, peritoneal). Everything else is a deep lymphatic vessel...and these are larger vessels associated with deep arteries and veins.

The LYMPHATIC TRUNKS are formed where large collecting vessels converge.



### The Lymphatic Vessels and Flow

The lymphatic vessels have 1-way valves that rely on pumps to move the lymph. The pumps are the skeletal muscle pump and the respiratory pump. The skeletal muscles squeeze the lymphatic vessels when they are contracted. The respiratory muscles change the volume of the thoracic cavity to move air in/out of lungs. This causes changes in pressure, which is transmitted to the lymphatic vessels for pumping action.

There are two other things that also help...the pulse pressure of nearby arteries, and the smooth muscle contractions in response to stretching.

## Lymphocytes

We'll go through this in more detail when we cover the immune system. For now, recall that T-lymphocytes, B-lymphocytes and NK cells are "immune cells."

- T-cells (80% of circulating lymphocytes) are antigen specific "cell mediated immunity"
- B-cells (10-15% of circulating lymphocytes) are antigen specific "humoral immunity." They produce antibodies (immunoglobulins)
- NK cells (5-10% of circulating lymphocytes) attack foreign cells, virus-infected cells and cancer cells. Not specific!

Lymphocytes are everywhere! They wander among lymphatic and connective tissues (loose CT, blood, lymph). They are produced in the red bone marrow and lymphatic tissues/organs. LYMPHOPOIESIS is the production of lymphocytes from stem cells in the red bone marrow. The resident stem cells stay in the bone marrow and produce NK and B-cells. Some lymphoid stem cells migrate to the thymus (T-cells). The T and B-cells proliferate in the peripheral tissues once they are activated/stimulated by a specific antigen. Most memory cells last up to 4 years, and some can last 20+ years.

**Lymphoid Nodules (follicles)** are loose CT dominated by lymphocytes and some macrophages. The follicles do not have a CT capsule, so not organs. They are found in the respiratory mucosa as tonsils. The tonsils are large nodules along the pharynx, meant to intercept pathogens brought in through food, beverage and breathing.

- Pharyngeal tonsil – *nasopharynx*
- Pair of Palatine tonsils – *inferior/posterior oral cavity*
- Pair of Lingual tonsils – *base of tongue*

A disorder of the tonsils leads to infection and swelling called "tonsillitis."

The nodules in the intestinal wall are "Peyer's Patches" and in the appendix. These are collectively called GALT (gut associated lymphoid tissue.) this is an ideal place for contacting bad stuff that comes in through the intestinal wall.

## Lymphatic Organs

The lymphatic organs are the lymph nodes, thymus and the spleen.

The function of the **lymph nodes** are to cleanse lymph and active T & B-cells. The collagen fibers of the CT capsule extend inward, forming *trabeculae*. The *hilus* is where the blood vessels and nerves enter the organ...the *efferent lymphatic vessels* exit at the hilus. The *afferent lymphatic vessels* enter opposite the hilus. Because there are more inlets than outlets, this builds up pressure.

The lymph flows through the subscapular sinus to the outer cortex to the sinuses of the deep cortex to the sinuses of the medulla out through the efferent vessels.

- B-cells are in the outer cortex (germinal center contains B-cells, dendritic cells and macrophages)
- Deep cortex contains T-cells and dendritic cells
- Medulla contains B-cells and macrophages

The fixed macrophages clean and filter lymph as it passes through on its way back into circulation. It removes microbes, dead or dysfunctional cells and cell debris. If any present antigens activate B & T-cells then you have an immune response!

The lymph nodes are clustered in a few strategic areas...the cervical nodes, axillary nodes and inguinal nodes. They are also found along the mesenteries (gut) and along airways leading to the lungs. The goal is to catch anything before it gets into circulation.

When someone says they have “swollen glands”, they are so totally wrong. They really mean that they have infected lymph nodes!

The **thymus** is located in the superior mediastinum, right above the heart. It is active in children up until about age 2 as the immune system is developing, and then begins to atrophy as the immune system takes hold and thrives! The collagen fibers of the CT capsule extend inward to form left and right lobes, and form septae that divide the lobes into lobules. Each little globby is a lobule.

The lobules contain the cortex and medulla. T-cells proliferate/develop in the cortex and migrate to the medulla to mature. They then leave the thymus via the medullary blood vessels. T-cell activity is regulated by thymosins...the hormone secreted by the thymus!

Unlike other lymphoid tissues/organs, the thymus consists of reticular epithelial cells that form the blood-thymus barrier. This separates the cortex from the medulla, protecting immature T-cells from being exposed to antigens in the blood. The cells also secrete thymosins...thymosin, thymopoietin, thymulin.

The **spleen** is the largest collection of lymphoid tissue in the body. It is lateral to the stomach on the left side...liver is on the right. Blood comes in to the spleen via the splenic artery and it leaves through the renal vein. Along the way the blood is exposed to macrophages and lymphocytes...the spleen CLEANS AND FILTERS BLOOD!

The pathway goes like this:

*Splenic artery to trabecular arteries that pass through the white pulp (lymphocytes and macrophages are here), then go to the capillaries that feed into the red pulp, which then leads to the sinusoids then small veins to trabecular veins to splenic vein.*

Note that the spleen cleans and filters blood...it removes abnormal blood cells and debris via macrophages, and stores  $Fe^{++}$  recycled from RBCs. The spleen initiates the immune response as antigens in the blood are presented to T & B-cells when they pass through the pulp.

Some diseases and infections cause the spleen to enlarge such as TB and leukemia. A rupture of the spleen causes internal hemorrhage. This is extremely difficult to repair, so the spleen is removed. You can live without a spleen because other lymphatic organs perform the same functions...such as the liver and red bone marrow. Note that these people would be at a higher risk for bacterial infection.

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