

1. Lymphatic system
 - a. Includes: lymph, lymphatic vessels, lymphatic tissue, lymphatic nodules, and lymphatic organs (lymph nodes, tonsils, the spleen, and the thymus).
 - b. Major functions of the lymphatic system are fluid balance, fat absorption, and defense.
2. Lymphatic vessels
 - a. Return excess tissue fluid to the vascular system.
 - i. As blood flows thru systemic capillaries, a small amt of fluid is exuded into the interstitial space. This fluid loss maintains the presence and composition of tissue and intracellular fluid, but too much fluid loss is bad.
 - b. Return approximately 3L of fluid to the vascular system per day.
 - i. Ensures that blood volume is sufficient.
 - c. Also return any leaked plasma proteins back to the bloodstream.
 - d. Fluid within lymphatic vessels is known as lymph. Lymph is similar to plasma except it contains fewer proteins. It contains water, nutrients, ions, gases, wastes, and hormones.
 - e. 1-way system flowing toward the heart.
 - f. Types of lymphatic vessels include: lymphatic capillaries, lymphatic collecting vessels, lymphatic trunks, and lymphatic ducts.
3. Lymphatic capillaries
 - a. Blind capillaries found almost everywhere blood capillaries are found, i.e., everywhere tissue fluid is formed.
 - b. Areas w/o lymphatic capillaries include bones, teeth, and CNS. Little ISF is found w/i bones and teeth. CNS ISF drains into the cerebrospinal fluid.
 - c. Composed of simple squamous epithelial cells that overlap and are loosely attached to another. This makes the lymphatic capillaries quite permeable (much more so than blood capillaries) and ensures that fluid is able to enter but not leave. Fluid enters easily, as do proteins, WBCs, pathogens, and cancer cells. S
 - d. Specialized lymphatic capillaries, known as lacteals, are present in the intestinal mucosa where they assist in absorption of dietary fat. Lymph within lacteals is known as chyle.
4. Lymphatic collecting vessels
 - a. Receive lymph from lymphatic capillaries.
 - b. Similar to veins (tunics with similar proportions) but contain more valves.
 - c. Superficial and deep lymphatic collecting vessels.
 - d. Pass thru lymph nodes, where lymph is “cleaned” of pathogens and cancer cells.
5. Lymphatic trunks
 - a. Formed by the union of the largest lymphatic vessels forms lymphatic trunks.
 - b. Jugular trunks drain the head and neck
 - c. Subclavian trunks drain the upper limbs, superficial thoracic wall, and mammary glands
 - d. Bronchomediastinal trunks drain thoracic organs and the deep thoracic wall
 - e. Intestinal trunks drain the intestines, stomach, pancreas, spleen, and liver
 - f. Lumbar trunks drain the lower limbs, pelvic and abdominal walls, pelvic organs, gonads, kidneys, and adrenal glands.
6. Lymphatic ducts
 - a. Formed by the union of lymphatic trunks.
 - b. 2 lymphatic ducts: the right lymphatic duct and the thoracic duct.
7. Right lymphatic duct
 - a. Drains lymph from the right arm and the right side of the head and thorax.
 - b. Receives lymph from the R jugular, R subclavian, and R bronchomediastinal trunks.
 - c. Empties into the R internal jugular vein.
8. Thoracic duct
 - a. Drains lymph from the rest of the body.
 - b. Receives lymph from the L jugular, L subclavian, L bronchomediastinal, intestinal, and lumbar trunks.
 - c. Empties into the left internal jugular vein.
 - d. Note that there is much variability in the formation and emptying of the lymphatic ducts.
9. 4 factors responsible for lymph flow:
 - a. Skeletal muscle pump

- b. Respiratory pump
 - c. Contraction of smooth muscle in the lymphatic vessel walls
 - d. Compression of lymphatic vessels by pulsations of nearby arteries.
 - e. Inability to move lymph (perhaps due to blockage of a lymphatic vessel) can result in an excess of ISF accumulation, i.e., edema.
10. Cells of lymphatic tissue
- a. Main lymphoid cells are: lymphocytes, macrophages, dendritic cells, and reticular cells.
11. Lymphocytes
- a. Produced in red bone marrow and within lymphoid organs.
 - b. 2 main types: T lymphocytes and B lymphocytes.
 - c. T lymphocytes attack virus-infected and cancerous cells, and, more importantly, coordinate and control the immune response.
 - d. B lymphocytes become plasma cells, which secrete immune proteins (antibodies).
12. Macrophages
- a. Phagocytes derived from monocytes,
 - b. Swallow and destroy foreign particles and help activate the immune response.
13. Dendritic cells
- a. Immune cells that swallow foreign material (antigens) and present it to lymphocytes in order to activate the immune response.
14. Reticular cells
- a. Fibroblast-like cells that produce the reticular fibers that form the framework (a.k.a. the stroma) upon which lymphoid organs and tissues are constructed.
15. Lymphoid tissue
- a. Formed from aggregations of lymphoid cells.
 - b. Provides a storage and proliferation site for lymphocytes as well as a site for lymphocytes and macrophages to be on the lookout for pathogens or cancer cells.
 - c. 2 main types of lymphoid tissue: diffuse lymphatic tissue and lymphoid follicles.
16. Diffuse lymphatic tissue
- a. Collection of scattered reticular tissue elements and associated lymphocytes.
 - b. Has no clear boundary and blends w/ other tissues.
 - c. Found w/i lymph nodes and the spleen
 - d. Especially prominent in the mucous membranes lining the urinary, reproductive, respiratory, and digestive tracts.
 - i. Prime locations for pathogen entry
 - ii. Referred to as mucosa associated lymphatic tissue (or MALT).
 - iii. 2 major subdivisions of MALT are:
 - 1. GALT (gut associated lymphatic tissue in the digestive tract)
 - 2. BALM (bronchus associated lymphatic tissue in the respiratory tract).
17. Lymphoid follicles (a.k.a. lymphoid nodules)
- a. Solid, spherical bodies consisting of tightly packed reticular tissue and lymphoid cells.
 - b. Numerous in the loose connective tissue of the digestive, respiratory, urinary, and reproductive tracts.
 - c. Often form parts of larger lymphoid organs and are found in the distal small intestine and appendix.
 - d. Peyer's patches are aggregates of lymphoid follicles found in the distal ileum (last portion of the small intestine).
 - e. Similar lymphoid aggregates are common within the appendix.
 - f. These sites are ideal to destroy bacteria attempting to invade the small intestine from the colon and anal canal.
 - g. They're also a good location for pathogen exposure and the subsequent generation of "memory cells."
 - h. The appendix also serves as a reservoir for the good bacteria that we need in the colon.
18. Lymphoid organs
- a. Characterized by large collections of lymphoid tissue surrounded by a connective tissue capsule.
 - b. Principal lymphoid organs are the lymph nodes.

- c. Other lymphoid organs include: tonsils, thymus, and spleen.

19. Lymph nodes

- a. Clustered along lymphatic vessels and filter the lymph flowing through them.
- b. Hundreds of lymph nodes w/i the body.
- c. Most are deep, but large, superficial clusters appear in the inguinal, cervical, and axillary regions.
- d. Surrounded by a dense connective tissue capsule.
- e. Extending inward from the CT capsule are strands of CT known as trabeculae. They divide the node into compartments.
- f. Reticular fibers within the node support its population of lymphocytes and macrophages.
- g. 2 distinct regions: a cortex and a medulla.
- h. Lymph node cortex consists of a subcapsular sinus (beneath the capsule) and cortical sinuses, which are separated by diffuse lymphatic tissue, trabeculae, and lymphatic nodules.
- i. The inner medulla consists of diffuse lymphatic tissue (the medullary cords) separated by medullary sinuses.
- j. Afferent lymphatic vessels bring “unfiltered” lymph to the lymph nodes.
- k. Lymph empties into the subcapsular sinus and then flows thru the cortical and medullary sinuses. As it does so, it’s scrutinized by the resident macrophages (which will ingest foreign particles and pathogens) and lymphocytes (which can proliferate and mount a serious immune response).
- l. Medullary sinuses drain into the efferent lymph vessels, which take “filtered” lymph away.
- m. Efferent vessels leave at an indentation in the node known as the hilum.
- n. Typically there are more afferent than efferent vessels - creating a bottleneck that forces lymph to flow slowly giving lymphocytes and macrophages time to perform surveillance.
- o. Also note that the efferent vessels of one node can become the afferent vessels of another.
- p. Since lymph nodes are the only organs that filter lymph, they are the only ones with afferent lymphatic vessels. Other organs will have only efferent lymphatic vessels.
- q. Lymph node’s blood supply is important for gas and nutrient supply, and also to outfit the node with the lymphocytes needed to monitor the lymph and induce an immune response. An artery typically enters the hilum and then proceeds towards the cortex where it branches and gives rise to capillaries and venules. Lymphocytes typically exit the venules and enter the cortical sinuses. Blood then exits the lymph node via a vein that departs at the hilum.

20. Spleen

- a. Largest lymphoid organ.
- b. Sits just below the diaphragm slightly behind the stomach and above the kidney.
- c. Surrounded by a CT capsule and divided by inward extending trabeculae (constructed by reticular cells and fibers).
- d. Primary function is blood modulation – removal of aged/malformed RBCs, pathogens, and other undesirables.
- e. Also provides a site of lymphocyte proliferation and immune surveillance and response.
- f. Other functions include: monocyte storage, platelet storage, and fetal RBC production.
- g. Splenic artery enters the spleen at its hilum it branches into trabecular arteries which run deep into the spleen. They then branch into central arteries. They then branch into arterioles which are usually surrounded by a sheath of lymphocytes – this arrangement is referred to as the white pulp of the spleen. The lymphocytes there will scrutinize the blood for pathogens.
- h. Splenic arterioles empty into splenic capillaries (a.k.a. splenic sinuses), which are large, twisty, incomplete sinusoids. They run btwn the splenic cords, which consist of macrophages, lymphocytes, plasma cells, granulocytes, and platelets. This is the red pulp. Aged RBCs, pathogens, and foreign matter are removed by macrophages.

21. Thymus

- a. Found in the superior mediastinum.
- b. Contains a thin connective tissue capsule and has trabeculae that partition it into lobules.

- c. Functions primarily in fetus and infancy where it plays a major role in T lymphocyte maturation.
 - d. Lymphocytes that survive the maturation process are able to respond to foreign substances but do not attack the body's healthy cells.
 - e. Lacks B lymphocytes as it is only involved in the maturation of T lymphocytes.
 - f. Special Regulatory T cells that help prevent autoimmune diseases develop in unique structures called thymic corpuscles.
 - g. Prominent in infants but stops growing during adolescence. It then becomes more and more fibrotic and fatty during adulthood.
 - h. Unique in that it is the only lymphoid organ that does not directly fight antigens. Also, its stroma is composed of epithelial cells as opposed to reticular fibers.
22. Tonsils
- a. Form a ring of lymphatic tissue at the entrance to the pharynx.
 - b. 3 main tonsils: palatine, pharyngeal, and lingual.
 - i. Palatine tonsils
 - 1. Paired and located on either side of the posterior end of the oral cavity.
 - 2. Largest and most often infected.
 - ii. Lingual tonsil
 - 1. Collection of lymphoid follicles lying at the base of the tongue.
 - iii. Pharyngeal tonsil
 - 1. Found in the posterior wall of the nasopharynx.
 - 2. Referred to as the adenoids if enlarged.
 - c. Tonsils are unique among lymphoid organs in that they are not fully encapsulated. Their surface is overlain by epithelium.
 - d. Contain deep invaginations known as crypts.
 - e. Strategy is to basically "invite" bacteria into the crypts and then destroy them. It's a risky approach that can occasionally backfire, but wide exposure to bacteria/viruses results in the creation of a lot of "memory immune cells" that can swiftly deal with invaders later in life.