1. Lymphatic system
   a. Includes: lymph, lymphatic vessels, lymphatic tissue, lymphatic nodules, and lymphatic organs (lymph nodes, tonsils, spleen, and thymus).
   b. Major functions of the lymphatic system are fluid balance, fat absorption, and defense.

2. Lymphatic vessels = Return excess tissue fluid to the vascular system.
   a. 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 ISF and ICF.
   b. Return 3L of excess tissue fluid (and any leaked plasma proteins) to the blood per day.
   c. 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.
   d. 1-way system flowing toward the heart.
   e. Types of lymphatic vessels include: lymphatic capillaries, lymphatic collecting vessels, lymphatic trunks, and lymphatic ducts.

3. Lymphatic capillaries = Blind vessels found next to blood capillaries (where ISF is formed).
   a. Area w/o lymphatic capillaries = red bone marrow.
   b. Composed of loosely attached, overlapping simple squamous epithelial cells.
   c. Quite permeable (more than blood capillaries)
   d. Fluid enters but doesn’t leave. Proteins, WBCs, pathogens, & cancer cells may also enter.
   e. 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 = receive lymph from lymphatic capillaries.
   a. Similar to veins (tunics with similar proportions) but contain more valves.
   b. Pass thru lymph nodes, where lymph is “cleaned” of pathogens and cancer cells.

5. Lymphatic trunks = formed by the union of the largest lymphatic vessels.
   a. Jugular trunks drain the head and neck
   b. Subclavian trunks drain the upper limbs, superficial thoracic wall, and mammary glands
   c. Bronchomediastinal trunks drain thoracic organs and the deep thoracic wall
   d. Intestinal trunks drain the intestines, stomach, pancreas, spleen, and liver
   e. Lumbar trunks drain the lower limbs, pelvic and abdominal walls, pelvic organs, gonads, kidneys, and adrenal glands.

6. Lymphatic ducts =formed by the union of lymphatic trunks.
   a. 2 lymphatic ducts: the right lymphatic duct and the thoracic duct.

7. Right lymphatic duct = Drains lymph from the right arm and the right side of the head and thorax.
   a. Receives lymph from the R jugular, R subclavian, and R bronchomediastinal trunks.
   b. Empties into the R internal jugular vein.

8. Thoracic duct = Drains lymph from the rest of the body.
   a. Receives lymph from the L jugular, L subclavian, L bronchomediastinal, intestinal, and lumbar trunks and empties into the left internal jugular vein.
   b. Note that there is much variability in the formation and emptying of the lymphatic ducts.

9. Factors responsible for lymph flow include:
   i. Gravity
   ii. Skeletal muscle pump
   iii. Respiratory pump
   iv. Contraction of smooth muscle in the lymphatic vessel walls
   v. Compression of lymphatic vessels by pulsations of nearby arteries.
   b. Inability to move lymph results in an excess of ISF accumulation, i.e., edema.

10. Cells of lymphatic tissue = 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.
12. Macrophages = Phagocytes derived from monocytes,
   a. Swallow and destroy foreign particles and help activate the immune response.
13. Dendritic cells = Immune cells that swallow foreign material (antigens) and present it to lymphocytes in order to activate the immune response.
14. Reticular cells = 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. Primary Lymphatic Structures = sites of lymphocyte formation and maturation
   a. Red bone marrow – site of T and B cell production. Also the site of B cell maturation.
   b. Thymus – site of T cell maturation.
16. 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/infancy where it is the site of T lymphocyte maturation.
   d. Secretes hormones involved in T cell maturation.
   e. Lymphocytes that survive the maturation process are able to respond to foreign substances but do not attack the body’s healthy cells.
   f. Lacks B lymphocytes as it is only involved in the maturation of T lymphocytes.
   g. Stops growing during adolescence and becomes fibrotic and fatty during adulthood.
   h. Unique in that it is the only lymphoid organ that does not directly fight antigens.
17. Secondary Lymphatic Structures = not involved in lymphocyte formation.
   a. House lymphocytes and other immune cells.
   b. Often the site of immune response initiation.
   c. Lymph nodes, spleen, tonsils and MALT.
18. Lymph nodes
   a. Clustered along lymphatic vessels and filter the lymph flowing through them.
   b. Hundreds of lymph nodes w/i the body. Most are deep, but large, superficial clusters are located in inguinal, cervical, and axillary regions.
   c. Surrounded by a dense CT capsule. Extending inward from it are trabeculae that divide the node into compartments.
   d. Reticular fibers within the node support its population of lymphocytes and macrophages.
   e. 2 distinct regions: a cortex and a medulla.
   f. Lymph node cortex consists of a subcapsular sinus (beneath the capsule) and cortical sinuses, separated by diffuse lymphatic tissue, trabeculae, and lymphatic nodules.
   g. Medulla has diffuse lymphatic tissue (medullary cords) separated by medullary sinuses.
   h. Afferent lymphatic vessels bring “unfiltered” lymph to the lymph nodes.
   i. Lymph empties into the subcapsular sinus and then flows thru the cortical and medullary sinuses. As it does so, it’s scrutinized by macrophages (which ingest foreign particles and pathogens) and lymphocytes (which proliferate and mount an immune response).
   j. Medullary sinuses drain into efferent lymph vessels, which take “filtered” lymph away.
   k. Efferent vessels leave at an indentation in the node known as the hilum.
   l. 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.
   m. Also note that the efferent vessels of one node can become the afferent vessels of another.
   n. 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.
   o. Lymph node 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 cortical sinuses. Blood exits the lymph node via a vein at the hilum.
19. Spleen
   a. Largest lymphoid organ. Below diaphragm, behind the stomach, above the L. kidney.
b. Surrounded by a CT capsule and divided by inward extending trabeculae (constructed by reticular cells and fibers).
c. Primary function is blood modulation – removal of old/malformed RBC’s and pathogens.
d. Also provides a site of lymphocyte proliferation and immune surveillance and response.
e. Other functions include: monocyte storage, platelet storage, and fetal RBC production.
f. Splenic artery enters the spleen at its hilum and it branches into smaller arteries which run deep into the spleen. They then branch into arterioles which are usually surrounded by a sheath of lymphocytes – this tissue is the white pulp of the spleen. Lymphocytes/macrophages scrutinize the blood for pathogens.
g. 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 are removed by macrophages.

20. Tonsils = Form a ring of lymphatic tissue at the entrance to the pharynx.
a. 3 main tonsils: palatine, pharyngeal, and lingual.
b. Palatine tonsils are paired and located on either side of the posterior oral cavity. They are the largest and most often infected.
c. Lingual tonsil is a collection of lymphoid follicles lying at the base of the tongue.
d. Pharyngeal tonsil is found in the posterior wall of the nasopharynx and is referred to as the adenoids if enlarged.
e. Tonsils are unique among lymphoid organs in that they are not fully encapsulated. Their surface is overlain by epithelium.
f. Contain deep invaginations known as crypts.
g. Strategy is to “invite” bacteria into the crypts and then destroy them. It’s a risky approach that can 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.

21. MALT
a. Mucosa-associated lymphatic tissue.
b. Can be diffuse lymphatic tissue, i.e., a collection of scattered reticular tissue and lymphocytes that has no clear boundary and blends w/ other tissues.
c. Very prominent in the mucous membranes lining the urinary, reproductive, respiratory, and digestive tracts.
   i. Prime locations for pathogen entry
   ii. 2 major subdivisions of MALT are:
      1. GALT (gut associated lymphatic tissue in the digestive tract)
      2. BALT (bronchus associated lymphatic tissue in the respiratory tract).
d. Can also be lymphatic nodules (a.k.a. lymphatic follicles)
   i. Solid, spherical bodies made of tightly packed reticular and lymphoid cells.
   ii. Numerous in the loose CT of the digestive, respiratory, urinary, and reproductive tracts.
   iii. Abundant in ileum and appendix.
   iv. Peyer’s patches are aggregates of lymphoid follicles found in the distal ileum. These destroy bacteria attempting to invade the small intestine from the colon and anal canal.
   v. Similar lymphoid aggregates are common within the appendix. The appendix also serves as a reservoir for the good bacteria that we need in the colon.