Lymphatic System

“Great things are done by a series of small things brought together.” ~Van Gogh
“Many of the truths we cling to depend greatly on our point of view.”
Lymphatic System: Overview

- Venous system
- Arterial system
- Heart
- Lymph duct
- Lymph trunk
- Lymph node
- Lymphatic system
- Lymphatic collecting vessels, with valves
- Lymphatic capillary
- Blood capillaries
- Tissue cell
- Venule
- Loose connective tissue around capillaries
- Arteriole
- Blood capillaries
- Lymphatic capillary
- Tissue fluid
Lymphatic Structures

- Tonsils (in pharyngeal region)
- Thymus (in thorax; most active during youth)
- Spleen (curves around left side of stomach)
- Peyer’s patches (in intestine)
- Appendix
- Lymph Nodes

- Tonsils
- Spleen
- Thymus
- MALT
- Appendix
- Liver
- Lymph Nodes
Lymphatic Functions

• **Maintain fluid balance by:**
  – Returning fluid that has escaped from the bloodstream in the capillaries
  – Returning proteins to the bloodstream that have leaked out from the capillaries

• **Immunity**
  the lymph organs house phagocytic cells & lymphocytes, which play essential roles in the **body’s defense mechanism**

• **Absorption & Transport of Lipids**
  from the G.I. tract when fatty food are ingested & digested, they are absorbed into lymphatic vessels in the small intestines

• **One of the body's many natural defenses against infection**
**Lymph**

- ___________________ fluid derived from blood plasma that has leaked from the capillaries into the interstitial fluid
- Most lymph is made in the liver & intestines
- Contain varying concentrations of WBCs, proteins & fats…
- ___________
  - ___________________ Fatty Lymph fluid absorbed from the intestine
  - Consists of Emulsified (Free) fatty acids & lymph
Composition & Characteristics of Lymph

- Similar to blood plasma, but with fewer proteins
- Alkaline, clear & colorless
  - Mostly water
  - Albumins & globulins
  - Salts
  - Urea
  - Lymphocytes & Monocytes

(lymph in lacteals in the small intestine can appear milky white due to the presence of absorbed fats)
Lymph & Interstitial Fluid

• Although we think of fluids in the body as occupying completely separate compartments (blood, intracellular fluid, interstitial fluid, etc), they actually move from one compartment to another & they ultimately have the same source.

• What we call “Plasma” in the blood stream we call “Cytosol” in the cells, “Interstitial Fluid” in tissues & “Lymph” in the lymphatic vessels.

• All of these fluid compartments are interconnected & loss of fluid volume from one will affect the others.
Lymph & Interstitial Fluid

• **Recall**
  • when blood enters the capillaries some of the plasma is forced out under hydrostatic pressure & becomes interstitial fluid
  • Most of that fluid (90%) reenters the blood capillaries
  • The remaining 10% is drained by lymph capillaries & at that point is referred to as lymph
  • As much as 3 Liters of fluid each day is collected by the lymphatic system & returned to the bloodstream
Lymphoid Cells ➔ Lymphocytes

• arise from red bone marrow & mature into immune cells that protect the body against foreign cells & substances:
  • **T-Lymphocytes** (T cells)
    – __________________ foreign cells such as bacteria or viruses
    – mature in the __________________ (behind the breast bone)
  • **B-Lymphocytes** (B cells)
    – produce plasma cells which secrete ______________ against foreign cells
    – mature in the __________________
Other Leukocytes

- **Macrophages**
  - Protect the body by phagocytizing foreign substances & by activating T lymphocytes
- **Dendritic cells**
  - found in lymphoid tissue
  - play a role in T lymphocyte activation
- **Reticular cells**
  - produce the stroma (Matrix), which is the network that supports the other cell types in the lymphoid tissue
Cell Mediated Immune Response

- By Macrophages, Lymphocytes
- Protection Against Microbes & Antigens (anything foreign to the body)
- What is the Lifespan of various Lymphocytes? see Text
Lymphocyte

• All lymphocytes originate in the bone marrow as immature cells called?

Answer: __________________

• Both Reside in the **Lymphatic Nodes**

  - **Sore Throat** → notice enlargement of lymph nodes in your neck, a sign that your body is fighting the infection
Principal Lymphatic Functions

• ______________ & ____________________ interstitial fluid, including plasma protein to the blood → Helps maintain fluid balance/Homeostasis

• __________ lipids from the intestine & transport them to the blood, triglycerides combine with cholesterol, lipoprotein & phospholipids to form globules called ______________________

• **Defend the body** against disease by lymphocyte production & action
**Lymphatic System**

- Soaks up leaked interstitial fluid & plasma proteins that leak from capillary beds into interstitium like a sponge
- Receives _____ liters/daily & return it to the circulatory system, transports **ADEK**, dietary lipids & carry out immune responses
- Increases capillary pressure, interstitial fluid protein, capillary permeability
- Decreases Plasma Colloid Osmotic Pressure (Albumin, Globulin)
Lymphatic Vessels

• Lymphatic vessels are widespread in the body, woven between tissue cells
• Contain ___________________________ that prevent backflow
• Pump fluid in only 1 directional flow towards the ________________
Lacteals

• Networks of ___________________________ in the lining of the small intestine absorb digested fats from the small intestine (similar to those of the circulatory system)

• Parts of the body without lacteals:
  – teeth, bones, bone marrow & the CNS
Lymphatic Capillaries & their characteristics

• Unlike capillaries of the circulatory system that are within a closed system, lymph capillaries are ____________________________________________, meaning that they have an end that is not connected to another vessel.
• Endothelial cells forming the walls of the lymphatic vessels are not tightly joined.
• The edges of adjacent cells overlap each other loosely, forming **Mini-valves**.
Lymphatic Capillaries & their characteristics

• When fluid pressure in the interstitial space is high, the mini-valves are forced open & fluid enters the lymph capillaries.

• Then, as fluid pressure builds up inside the lymph capillaries, the mini-valves are forced closed from the inside, preventing leaking of the lymph back into the interstitial space.

• Endothelial cells of lymphatics are attached to surrounding tissue cells by collagen fibers.
Lymphatic Capillaries

- Filaments anchored to connective tissue
- Endothelial cell
- Flaplike minivalve
- Fibroblast in loose connective tissue
Lymph transport through Lymphatic vessels

• _______-pressure vessels that use the same mechanisms as veins to return the lymph to the circulatory system:

• __________________________________

• __________________________________

• __________________________________

• _________________ Contractions & Movement

• _________________ Contractions
  – Smooth muscles in the walls of lymphatic trunks & thoracic duct
Lymphatic Vessels

- Larger Lymphatic Vessels have the same 3 layers (tunics) as circulatory vessels, but there are some important structural differences.
- **Closely resemble**
- The major differences between veins & lymph vessels:
  - The walls of the lymphatic vessels are ______________.
  - Lymphatic vessels have __________ internal valves than veins.
  - The lymphatic vessels **anastomose** ________!
Large Lymphatic Ducts

- ____________________ Duct
  - Anterior to L1/L2 (lumbar spine)
  - Drains digestive organs

2 large lymphatic ducts are located in the thoracic region of the body

- ____________________ Duct
  - Drains lymph from right arm & right side of head, neck & thorax (the RUQ)
  - Empties into the Right Subclavian Vein

- ____________________ Duct
  - the larger of the 2 ducts
  - It collects lymph from the rest of the body & empties into the Left Subclavian Vein
Lymphatic System: Overview
Lymphatic Trunks

- Right jugular trunk
- Right lymphatic duct
- Right subclavian trunk
- Right subclavian vein
- Right bronchomediastinal trunk
- Brachiocephalic veins
- Superior vena cava
- Azygos vein
- Cisterna chyli
- Right lumbar trunk
- Left jugular trunk
- Internal jugular veins
- Left subclavian trunk
- Left subclavian vein
- Left bronchomediastinal trunk
- Entrance of thoracic duct into left subclavian vein
- Esophagus
- Trachea
- Rib
- Thoracic duct
- Hemiazygos vein
- Left lumbar trunk
- Inferior vena cava
- Intestinal trunk
Inflammation

Inflammatory Response

• 1. _______________
• 2. _______________
• 3. _______________

• Micro-organisms/MO’s that penetrate endothelial barriers are fought by the inflammatory process
Lymph Nodes

- Over 600 Solid, spherical bodies of **Reticular Tissue**, shaped like kidney beans 1-2 cm
- Convex side ________ (IN) vessels, Concave side is the **HILUS** ________ (OUT) vessels
- ______ Afferent vessels, ______ Efferent vessels
- Found embedded in connective tissues: inguinal, axillary, cervical & others sites
Lymph Nodes

- Capsule, Cortex & Medulla, Lobules & Trabecula
- Filtering cells, debris & MO & Monitoring stations for antigens
- __________ B & T Lymphocytes
- __________ B Lymphocytes & Macrophages
- When overwhelmed with MO’s → swollen glands
- 2nd CA sites swollen, but not tender
Lymph Nodes

• The principle lymphoid organs in the body, which act as filters to remove & destroy microorganisms & other debris from the lymph before it is transported back to the bloodstream

• Each lymph node is surrounded by a fibrous capsule (septum), which extends inward, dividing the node into several sections called nodules
Lymph Nodes

- Around each nodule are open spaces called **Cortical Sinuses**, filled with the Lymph & also lined with **Phagocytic Reticuloendothelial Cells** (Macrophages)
- Lymph enters the cortical sinuses from **several Afferent lymph vessels**, circulates through the sinuses & gets filtered by the B-cells & macrophages
- Lymph flows out **few Efferent lymph vessels**
- Lymph nodes range in size, but most < 1 inch in length
Lymph Nodes

• See Text

• Benefit of more Afferent vessels than Efferent vessels? “Hotel California”

• “You can check out, but you can never leave”
Lymph nodes

• Widely distributed throughout the body
• ___________________ lymph nodes
  located under skin just anterior to external ear flap
  (known as the auricle)
• ___________________ lymph nodes
  located in neck alongside the sternocleidomastoid
  muscles
• ___________________ lymph nodes
  located in the axillary (armpit) region
• ___________________ lymph nodes
  located in the inguinal (groin) region
Structure of a Lymph Node

Figure 20.4a, b
Clinical Note

• *What do swollen lymph nodes indicate?*

• Swollen lymph nodes can be symptomatic of any of a number of causes

• Palpation can indicate the cause, as can the presence or absence of pain

• Painful, Swollen nodes usually indicate infection

• Painless swollen nodes may indicate a tumor or cancer
Lymphoid Tissue & Organs

- Mostly Loose **Reticular Connective Tissue**
  - Large number of Reticular Protein Fibers in the tissue matrix
- Most of the lymph organs, with the exception of the thymus (glandular), are composed largely of this reticular tissue
- Tissue is arranged differently to form the various lymphatic organs, which serve specific purposes
Lymphatic Flow

• ______________ (collect excess interstitial fluid) → ____________________________
  (receive lymph from the lymph capillaries) → ____________________________ (formed from the merging of collecting vessels)

• → Right Lymphatic & Thoracic Ducts) → Right & Left ___________________________Veins
  (lymph reenters bloodstream)
Spleen

- ___________ Lymphoid Organ
- Shaped like a loose fist ~½ lb.
- Located in the ________ directly below the diaphragm
- Has Hilus, Splenic artery & vein
Spleen

• Surrounded by a fibrous capsule & contains 2 internal areas of tissue:
  • White pulp
  • Red pulp
White pulp

- tissue areas within the spleen that are composed primarily of lymphocytes suspended on reticular fibers
- form small clusters within the splenic tissue
- Because of the presence of the lymphocytes, the white pulp areas are **involved with the immune functions** of the spleen
- site of lymphocyte proliferation
Red pulp

- most of the spleen tissue is made up of red pulp areas, which are rich in blood vessels & macrophages
- The red pulp areas are mainly involved in removing old erythrocytes & any blood-borne pathogens
- Stores & Recycles breakdown products of erythrocytes for later use, such as Heme (Fe) to needed to make more new hemoglobin
Spleen

• Site of erythrocyte production in the fetus (this stops after birth)
• Storage of blood platelets
  ◦ Malaria or Mono can also cause splenomegaly
• Enlargement of the spleen seen with: Rheumatoid Arthritis, Systemic Lupus, Sickle Cell Anemia, Leukemia & Lymphomas
Structure of the Spleen

Figure 20.6a-d
Clinical Note

- Spleen lies in the **LUQ** & is easily ruptured by blows to the left side.
- If ruptured, it can release large amounts of blood into the abdominal cavity including any bacteria that it had filtered out.
- This can lead to severe internal hemorrhaging & bacterial infections of internal organs.
- **Splenectomy**
  - Removal of a traumatized spleen → Liver takes over function (> risk of Bacterial infection, if younger than age 12 regeneration is possible).
- If injured and not removed mortality rate is about **90%**.
Thymus

- Encapsulated, Bi-lobed glandular organ
- Trabeculae divide lobes into lobules
- Located atop the Heart within the
  ________________________
- ________________________in size & function with age
- 70 g infant ➔ 3 g in elderly
- Fibrous Fatty in Elderly
- T-cells w/in Cortex
- Macrophages w/in Medulla
- T-cells proliferate throughout our lifetime
Thymus

- During adolescence its growth stops & it starts to atrophy
- While it is active, its cells (thymocytes) secrete hormones (thymosin & thymopoietin) that cause T lymphocytes to become immunocompetent (enables them to recognize foreign cells & substances)
- While it is functional, the thymus gland does not directly fight infections, making it different from other lymph organs
MALT

- **Lymphatic Tissue**
  Collective Name for all small lymphoid tissues in the body: Appendix, Peyer’s patches, Tonsils & lymphoid follicles in the walls of the respiratory passageways

- **MALT** protects the digestive & respiratory tracts from foreign matter that constantly enter

- Distal Ileum & Appendix
Tonsils/Adenoids “Ring of Fire”

- the simplest lymphoid organs & form a **ring of lymphoid tissue** around the openings to the pharynx, they appear as swellings of the mucosa that gather & remove many of the pathogens entering the pharynx in food or inhaled air
Tonsils/Adenoids “Ring of Fire”

- ______________________
  (paired, lie at the base of the tongue)
- **Pharyngeal**
  (____________________, __________________________ located in the posterior wall of the nasopharynx)
- ______________________
  (paired lateral to pharyngeal) on either side of the pharynx directly behind the nasal cavity
  – Largest & most frequently infected
Clinical Note

- when the pharyngeal tonsils become infected & inflamed they are referred to as Adenoids as they swell forwards into the nasal cavity, they can interfere with normal breathing & are often removed
- Tonsil removal “Tonsillectomy”
Peyer’s Patches

- Nodes of lymphatic tissue located within Small Intestine
- Clusters of lymphoid follicles that are found in the wall of the distal portion of the small intestine & the appendix (located in the RLQ of the abdominal cavity), also contains small masses of lymphoid follicles
- The lymph tissue in these areas serve 2 strategic purposes:
  - Destruction of bacteria, which occur in large numbers in the intestine
  - Generation of “memory” lymphocytes for long-term immunity
Swollen lymph nodes → **Bubonic Plague**

Also known as **Black Death**

Disease caused by bacteria (Yersinia pestis)

Transferred from rats to humans by bites from the rat flea

The bacteria localize in the lymph nodes, causing them to enlarge

Without treatment, the bacteria can spread throughout the body, rapidly causing death in 70 – 90% of those infected!

In the 14th century, the plague killed 200 million victims & constituted the largest death toll from any known epidemic

Today, only about 15 cases are reported annually in the US & current antibiotic treatments are usually effective
Lymphatic Vessel Disorders

- Lymphedema
- Lymphangitis
- Elephantiasis
- Lymphoma
Lymphangitis

- Inflammation of the superficial lymphatic vessels, most often due to a streptococcus infection
- Red streaks are present along the inflamed vessels & are accompanied by rubor, dolor, calor, tumor & functio laesa
- Lymph nodes in the area are often enlarged & tender
- Treatment consists of antibiotics & elevating the affected part of the body so that local lymphatics can drain
Lymphedema

- abnormal accumulation of fluid in the interstitial space because of a blockage of uptake by the lymphatic vessels
- In other words, the interstitial fluid can’t enter the lymphatic capillaries and become lymph, or the larger collecting vessels are blocked & the lymph backs up through the lymph capillaries & out into the interstitial space
- Causes include blockage by tumors, infection & interference with lymph flow following surgery
Elephantiasis

- (lymphatic filariasis)
- Severe Swelling of Lymphatic Vessels due to blockage by roundworms (filaria)
- Swelling can become so severe that the overlying tissues can become deformed & the lower limbs can resemble an elephant’s leg
- Lymphatic blockage of Lymph flow can be due to parasitic worms, recurrent attacks of a bacterial infection that causes inflammation of the lymphatic vessels (streptococcal lymphangitis)
- When the lymphatic obstruction is large enough, back pressure in the lymphatic channels produces dilation of the superficial vessels → resulting in Extreme Swelling
- Without medical intervention, the cycle continues until the affected area is Grotesquely Enlarged →
- Death of surrounding tissues may also occur from an obstructed blood supply (Gangrene)
- Skin usually develops a thickened, pebbly, ulcerated & darkened appearance
- Fever, chills & Malaise
Lymphoma

• Any tumor of the lymphatic tissue (Benign or Malignant)

**Symptoms:** Night sweats or unexplained fever, Loss of appetite, unexplained weight loss and fatigue

• **Children**
  – may develop a cough or breathlessness
  – may also complain of abdominal pain or you may notice a lump in your child's abdomen or persistent itching of the skin all over the body

• **Divided into 2 groups:**
  – Hodgkin’s lymphoma
  – Non-Hodgkin lymphoma
Hodgkin’s Lymphoma/Disease

- Malignancy of the lymph nodes
- The Diagnostic Sign is the presence of large, deformed B lymphocytes known as *Reed-Sternberg cells* in the lymph nodes
- The lymphoma usually begins in a single lymph node in the neck, axillary region, or groin & spreads to nearby lymph nodes
- **Signs/Symptoms:** include swollen, non-painful lymph nodes, fatigue, persistent fever & night sweats
- It is categorized into stages based on the degree of metastasis (spreading)
  - Stages “1” or “2” mean that the cancer is in one or a few lymph nodes
  - Stage “5” means it has spread throughout the body
  - The lower the stage, the better the prognosis for survival
  - Patients with stage 1 Hodgkin’s lymphoma have a 90% survival rate 5 years after diagnosis
Non-Hodgkin Lymphoma

- All cancers of lymphatic tissue Except Hodgkin’s disease
- Involves uncontrolled growth & metastasis (spread) of immature lymphocytes, with nonpainful swelling of lymph nodes, spleen & Peyer’s patches… Eventually it may spread to other tissues
- **Signs/Symptoms:**
  - fever, night sweats & rapid weight loss
  - 1<sup>st</sup> sign NHL is a painless swelling of a lymph node in the neck, armpit or groin
    - There are low-grade & high-grade varieties
    - The high-grade type is more common in younger people, grows more quickly, but responds better to chemotherapy
    - The low-grade type is more common in the elderly & though it doesn’t spread as rapidly it is more resistant to treatment, so it is often fatal
**Sentinel Node**

- the very 1\textsuperscript{st} lymph node that filters fluid draining away from the area of concern (Infections & Cancer)
- **Sentinel** = guard, watchdog or protector
Edema
excess accumulation of interstitial fluid in tissue spaces due to obstruction (infected node or blocked vessel) filtration faster than reabsorption

Metastasis
spreading via lymphatic or blood vessels
All malignant tumors eventually exhibit metastasis
1° → 2° tumors- seeding
• Infected enlarge not firm, movable, very tender
• Cancerous enlarged, firm, non-tender
Lymphatic Learning Objectives

• Describe the general characteristics & functions of the LS
• Describe the location of the major lymphatic pathways
• Describe the formation of tissue fluid & lymph
• Describe major functions of the lymph nodes, thymus & spleen
• Define immunity
• Relate the role of the LS to immunity