Page 1: Introduction

Page 2: Goals
- To list the cells of the immune system and describe their major functions.
- To compare the function of primary and secondary lymphoid organs.
- To describe the structure and functions of the lymphatic system and the flow of lymph.
- To describe how the structures of the lymph nodes and spleen reflect their functions of filtering lymph and blood.
- To describe the structure and functions of MALT.
- To describe the structure and functions of the thymus.

Page 3: Anatomy Overview
- The immune system consists of specialized immune cells and lymphoid organs and tissues.
- Many of the immune cells are leukocytes and their close relatives.
- Lymphoid organs and tissues include the bone marrow, lymph nodes, spleen, and thymus.

Page 4: Immune Cells: Leukocytes
- Leukocytes can be classified on the basis of histological staining.
- Leukocytes travel through the blood and enter tissues when they are needed.
- Leukocytes originate in the bone marrow.
- Neutrophils, the most abundant leukocytes, have pale-staining granules and multi-lobed nuclei, and they are phagocytic cells.
- Eosinophils have red-staining granules and bi-lobed nuclei, kill parasitic worms, and participate in allergic diseases.
- Basophils have blue-staining granules that contain histamine.
- Monocytes are agranular and become macrophages when they enter tissues.
- Lymphocytes are agranular and include B cells and T cells.

Page 5: Immune Cells: Functions
- Phagocytes engulf and destroy pathogens, dead cells, and debris.
- Antigen-presenting cells (APCs) process and present antigens to T cells.
- Effector cells of adaptive immunity, B cells and T cells, carry out the functions of adaptive immunity.
- Other cells, including some non-leukocytes, perform various other functions in host defenses.

Page 6: Primary and Secondary Lymphoid Organs
- Like all leukocytes, both B and T cells originate in bone marrow.
- B and T cells mature in the primary lymphoid organs: B cells in the bone marrow and T cells in the thymus.
• Secondary lymphoid organs include lymph nodes, the spleen, and Peyer’s patches in the small intestine, appendix, and tonsils. These are the sites where mature B and T cells are activated by antigen.

Page 7: Lymphatic Vessels
• The lymphatic system consists of lymphatic vessels, lymph, and lymph nodes.
• Lymph is excess extracellular fluid collected from tissues into lymphatic vessels.
• Lymphatic vessels channel lymph through a series of lymph nodes, where it is cleansed of antigens and microorganisms and eventually returned to the circulatory system.

Page 8: Flow of Lymph
• Lymphatic capillaries, the smallest lymph vessels, are blind sacs lined by overlapping endothelial cells.
• When fluid builds up in the tissues, the overlapping endothelial cells open like a valve to allow the fluid to enter the lymph capillaries.
• Plasma proteins, pathogens, antigens, and dendritic cells can also enter the lymphatics from the tissues in lymph.
• Lymph is filtered through lymph nodes found in clusters along lymph vessels.

Page 9: Lymphatic Vessel Summary
• Lymphatic vessels return excess tissue fluid and any leaked proteins to the bloodstream.
• Lymphatic vessels transport pathogens, antigens, and dendritic cells from the tissues to the lymph nodes.
• Special lymphatic capillaries in the intestine, called lacteals, transport absorbed fat to the blood.
• Lymphatic vessels, together with the lymph and lymph nodes, form the lymphatic system.

Page 10: Lymph Node: Functions
• Lymph nodes are secondary lymphoid organs found in clusters along the lymphatic vessels.
• Lymph nodes filter the lymph by removing antigens and other debris.
• Lymph nodes provide a site for the activation of B and T cells by antigens.

Page 11: Lymph Node: Vessels
• Afferent lymphatic vessels bring lymph to the lymph nodes.
• Lymph leaves the lymph nodes through the efferent lymphatic vessels.

Page 12: Lymph Node: Structure
• Lymph nodes have a capsule, subcapsular sinus, and trabeculae.
• Lymphoid follicles in the outer cortex contain B cells.
• Germinal centers form within follicles and are sites where B cells are proliferating in response to antigen.
• T cells are found primarily in the deep cortex, where dendritic cells present antigens to them.
• Medullary cords contain B and T cells, macrophages, and plasma cells.
Lymph enters through the afferent lymphatic vessels into the subcapsular sinus, flows through cortical sinuses into the medullary sinuses, and leaves the node through the efferent lymphatics.

**Page 13: Spleen: Functions**
- The spleen removes pathogens, aged erythrocytes, and platelets from the blood.
- The spleen is the site for B and T cell interaction with antigens in the bloodstream.
- The spleen stores platelets and breakdown products of red blood cells.

**Page 14: Spleen: Structure**
- Multiple branches of the splenic artery and vein enter and leave the spleen at the hilum.
- In capillaries and the venous sinuses, macrophages remove worn-out erythrocytes and blood-borne antigens.
- The spleen has an external capsule and trabeculae.
- The spleen consists of red and white pulp, named for their color in fresh tissue.
- The red pulp is the site of erythrocyte processing. It contains venous sinuses and splenic cords that are rich in macrophages.

**Page 15: Spleen: Red and White Pulp**
- The white pulp surrounds the central arteries. It contains B and T cells, macrophages, and lymphoid follicles.
- B and T cells enter the spleen and travel to the white pulp, where they interact with antigens as they do in the lymph nodes.

**Page 16: MALT Guards the Mucosae**
- Mucosa-associated lymphoid tissues (MALT) are collections of lymphoid tissue strategically distributed throughout the mucosae.
- MALT contains both B cells (in follicles) and T cells.

**Page 17: Tonsils**
- The palatine, pharyngeal, and lingual tonsils respond to microorganisms entering the body through the oral or nasal cavities.
- Tonsils can become overwhelmed by bacteria, becoming sites that harbor, rather than kill, the organisms.

**Page 18: Appendix**
- The vermiform appendix is a blind sac stemming from the wall of the first part of the large intestine.
- The appendix contains a large concentration of lymphoid follicles.
- A ruptured appendix can be life-threatening.

**Page 19: Peyer’s Patches**
- Peyer’s patches are found in the mucosa of the distal portion of the small intestine. Peyer’s patches sample and respond to intestinal microorganisms.
**Page 20: The Thymus**
- The thymus is a bi-lobed organ located in the anterior mediastinum.
- The thymus is the site for differentiation of T cell precursors into mature T cells.
- Thymic epithelial cells influence T cell development and secrete thymic hormones.
- The thymus produces fewer T cells as we age.

**Page 21: Summary**
- The immune system consists of immune cells and lymphoid organs and tissues.
- Neutrophils and macrophages are phagocytes. Dendritic cells, macrophages, and B cells are antigen-presenting cells.
- The primary lymphoid organs, where lymphocytes mature, are the bone marrow and thymus. B cells differentiate in the bone marrow, whereas T cells differentiate in the thymus.
- Mature lymphocytes encounter antigens and become activated in the secondary lymphoid organs, which include the lymph nodes, mucosa-associated lymphoid tissue (MALT), and the spleen.
- Lymph containing pathogens and antigens is drained from tissues and carried in lymphatic vessels to lymph nodes, where antigens are removed and held for interaction with lymphocytes.
- Antigens are removed from blood as it passes through the spleen.

**Study Questions**

1. (Goal 1, Page 4.) Cells of the Immune System: Characteristics of Leukocytes and Their Functions.
   A. Identify the five types of leukocytes by placing the name of each cell in the box beneath it.

   ![Leukocytes](image)

   B. Complete the following table by placing the name of each type of leukocyte in the correct box.

<table>
<thead>
<tr>
<th>Leukocytes</th>
<th>Characteristics and Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A large cell with a U-shaped nucleus and no prominent cytoplasmic granules. It becomes a macrophage when it enters tissue.</td>
</tr>
<tr>
<td></td>
<td>The least common leukocyte. It has large, dark-blue-staining granules that contain histamine. It mediates inflammatory responses.</td>
</tr>
</tbody>
</table>
A cell with a bi-lobed nucleus and prominent red-staining granules containing enzymes. It eliminates parasites such as worms and plays a role in allergic diseases.

Smaller than a monocyte, this cell has a round nucleus and no cytoplasmic granules. It could be a B or T cell.

The nucleus of this cell has many lobes and pale-staining cytoplasmic granules. It is the most common leukocyte and eliminates pathogens.

2. (Goal 2, Page 6) Where do B and T lymphocytes originate?
3. (Goal 2, Page 6) Name the two primary lymphoid organs and the type of lymphocyte that matures in each organ.
4. (Goal 2, Page 6) Name the secondary lymphoid organs and describe what happens to lymphocytes in these organs.
5. (Goal 2, Page 6) Compare and contrast the function of the primary lymphoid organs to the function of the secondary lymphoid organs.
6. (Goal 3, Page 7) List the three principle components of the lymphatic system.
7. (Goal 3, Page 7) Relate where lymph comes from and how it is collected.
8. (Goal 3, Page 7) Describe lymph movement once it enters the lymphatic system. Which structure filters lymph?
9. (Goal 3, Page 8) Explain the properties of lymph capillaries that enable them to drain excess fluid located in the extracellular space.
10. (Goal 3, Page 8)
    A. List other substances/cells that can enter a lymph capillary.
    B. Label the blood capillary, dendritic cell, lymph capillary, and pathogen in the diagram below.
11. (Goal 3, Page 9) Lymphatic Vessel Summary.

**Fill-in-the-blanks.** Fill in each blank with the correct term.

Lymph _________________ return excess fluid and any leaked proteins to the bloodstream.

Lymphatic vessels transport, ________________, ________________, and ________________ cells from the tissue to the lymph nodes. ________________ are special lymphatic capillaries in the intestine that absorb fat. Lymphatic vessels, lymph, and lymph nodes form the _________________ system.

12. (Goal 4, Page 10) State the function of a lymph node.

13. (Goal 4, Page 10) List the two immune cells that are activated in a lymph node.

14. (Goal 4, Page 11) Explain how lymph enters and leaves a lymph node.

15. (Goal 4, Page 12)
   A. Describe the anatomy of a lymph node.
   B. Label the following structures on the lymph node diagram below: afferent lymphatic vessel, capsule, deep cortex, efferent lymphatic vessel, germinal center, lymphoid follicle, and trabeculae.
16. (Goal 4, Page 12) Complete the following table using the following lymph node locations: germinal centers, outer cortex, deep cortex, and medullary cords.

<table>
<thead>
<tr>
<th>Location in Lymph Node</th>
<th>Cell Types</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B cells located in lymphoid follicles.</td>
</tr>
<tr>
<td></td>
<td>Form within follicles; sites where B cells proliferate in response to antigen.</td>
</tr>
<tr>
<td></td>
<td>Both B and T cells, macrophages, and plasma cells.</td>
</tr>
<tr>
<td></td>
<td>Antigen presented to T cells by dendritic cells.</td>
</tr>
</tbody>
</table>
17. (Goal 4, Page 12) Describe the flow of lymph as it enters via the afferent lymph vessels until it leaves via the efferent lymph vessels.
18. (Goal 4, Page 13) Relate the three primary functions of the spleen.
19. (Goal 4, Page 14) Explain the anatomical characteristics of the spleen.
20. (Goal 4, Pages 14 and 15)
   A. Compare and contrast white pulp and red pulp.
   B. Label red pulp and white pulp in the diagram below.

![Diagram of the spleen with labeled parts]

21. (Goal 4, Pages 10-15) Discuss how the structures of the lymph nodes and spleen reflect their functions of filtering lymph and blood.
22. (Goal 5, Page 16) Define and list characteristics of MALT.
23. (Goal 5, Page 16) List three general locations where MALT is found.
24. (Goal 5, Page 17) List the location of the tonsils and their function.
25. (Goal 5, Page 18) Describe the appendix. Relate why a ruptured appendix can be life threatening.
26. (Goal 5, Page 19) Relate the location and function of Peyer’s patches.
27. (Goal 6, Page 20) Describe the characteristics and location of the thymus gland.
28. (Goal 6, Page 20) Relate the function of the thymus gland and what happens to it as a person ages.

**Summary**

**Fill-in-the-blanks.** Fill in each blank with the correct term.

The immune system consists of immune cells and lymphoid organs and tissues. Neutrophils are macrophages that are _____________________. Dendritic cells, macrophages, and B cells are _________________-presenting cells.
The primary lymphoid organs where lymphocytes mature are the ______________________ and ______________________. B cells differentiate in the bone marrow, whereas T cells differentiate from bone marrow-derived precursor cells in the thymus.

Mature lymphocytes encounter __________________ and become activated in the secondary lymphoid organs, which include ________________________________, __________________________________, and __________________________________.

Lymph containing pathogens and antigens drained from tissues is carried in lymphatic vessels to ______________________, where antigens are removed and held from interaction with lymphocytes.

Antigens are removed from blood as it passes through the ______________________.