CHAPTER 10 – BLOOD AND LYMPHATIC SYSTEM

OBJECTIVES

On completion of this chapter, you will be able to:

- Describe the blood.
- Describe the formed elements in blood.
- Name the four blood types.
- Describe and state the functions of the lymphatic system.
- Describe the accessory organs of the lymphatic system.
- Describe the immune system response.
- Analyze, build, spell, and pronounce medical words.
- Comprehend the drug highlighted in this chapter.
- Describe diagnostic and laboratory tests related to blood and the lymphatic system.
- Identify and define selected abbreviations.
- Describe each of the conditions presented in the Pathology Spotlights.
- Review the Pathology Checkpoint.
- Complete the Study and Review section and the Chart Note Analysis.

OUTLINE

I. Anatomy and Physiology Overview

Blood and lymph are two of the body’s main fluids and are circulated through two separate but interconnected vessel systems. **Blood** is circulated by action of the heart, through the circulatory system (arteries, veins, and capillaries). **Lymph** does not actually circulate like blood, but is propelled in one direction, away from its source, through increasingly larger lymph vessels, to drain into large veins of the circulatory system located in the neck region.

A. **Blood** – fluid consisting of formed elements and plasma. The purpose of blood is to transport respiratory gases, chemical substances, and cells that act to protect the body from foreign substances. Average blood volume, which depends on body weight, is approximately 5 qt or 5 L.

1. **Formed Elements (Table 10–1, p. 287) (Fig. 10–1, p. 287)** – in blood are the **erythrocytes** (red blood cells), **thrombocytes** (platelets), and **leukocytes** (white blood cells). They constitute about 45% of total blood volume and along with plasma make up whole blood.

   a. **Erythrocytes or Red Blood Cells (RBC) (Fig. 10–1, p. 287)** – doughnut-shaped (biconcave) cells without nuclei. They transport oxygen (most of which is bound to hemoglobin contained in the cell) and carbon dioxide. There are approximately 5 million erythrocytes per cubic millimeter of blood, with a life span of 80 to 120 days. They are formed in red bone marrow.
b. **Thrombocytes (Fig. 10–1, p. 287)** – commonly called **platelets**, these disk-shaped cells play an important role in the clotting process by releasing **thrombokinase**, which in the presence of calcium, reacts with **prothrombin** to form **thrombin**. There are approximately 200,000 to 500,000 thrombocytes per cubic millimeter of blood. Thrombocytes are fragments of certain giant cells called **megakaryocytes**, which are formed in the red bone marrow.

c. **Leukocytes or White Blood Cells (WBC) (Fig. 10–1, p. 287)** – sphere-shaped cells containing nuclei of varying shapes and sizes. Leukocytes are the body’s main defense against the invasion of **pathogens**. In a normal body state, at the time pathogens enter the tissue, the leukocytes leave the blood vessels through their walls and move in an amoebalike motion to the area of infection, where they ingest and destroy the invader. There are approximately 8,000 leukocytes per cubic millimeter of blood. There are five types of white blood cells:

- **Neutrophils** – formed in red bone marrow and contribute to the body’s nonspecific defenses.
- **Eosinophils** – formed in red bone marrow and contribute to the body’s nonspecific defenses.
- **Basophils** – formed in red bone marrow and contribute to the body’s nonspecific defenses.
- **Lymphocytes (lymphs)** – formed in lymph nodes and other lymphoid tissue; responsible for specific defenses against invading pathogens or foreign proteins.
- **Monocytes** – formed in red bone marrow and contribute to the body’s nonspecific defenses.

2. **Blood Groups (Table 10–2, p. 288) (Fig. 10–2, p. 289)** – the **ABO** system is used in blood typing and blood transfusions. The four main blood types identified in this system are types A, B, AB, and O. Differences in blood are due to the presence or absence of certain protein molecules called **antigens**, which are located on the surface of red blood cells, and **antibodies**, which are located in the blood plasma.

3. **RH Factor** – is the presence of a substance called **agglutinogen**, which is located in the red blood cells. About 85% of the population have the **Rh factor** and are **Rh positive**. The other 15% lack the Rh factor and are called **Rh negative**. Blood groups may not be compatible because mixing can lead to agglutination (blood clumping). For a transfusion to be successful, ABO and Rh blood groups must be compatible between the donor and the recipient. In order to assure that agglutination does not take place, a type and crossmatch of the blood must be performed. Sensitization can
occur between an Rh-negative mother and an Rh-positive fetus. Sensitization can also occur if the Rh-negative woman has had a previous miscarriage, induced abortion, or ectopic pregnancy. Rh antibodies produced in maternal blood may cross the placenta and destroy fetal cells, producing hemolytic disease of the newborn (HDN). Hemolytic disease can, for the most part, be prevented if the Rh-negative woman has not already made antibodies against the Rh factor from an earlier pregnancy or blood transfusion. Rh immunoglobulin (Rhogam) is a product that can safely prevent sensitization of an Rh-negative mother. It suppresses her ability to respond to Rh-positive red cells. It is given at 28 weeks of pregnancy and a second dose within 72 hours after delivery if the baby is Rh-positive.

4. **Plasma** – fluid part of blood, which is clear and straw-colored. It is the circulation medium of blood cells, providing nutritive substances to various body structures and removing waste products of metabolism from body structures. Plasma comprises about 55% of the total volume of blood and is composed of water (91%), and chemical compounds (9%). There are four major plasma proteins:
   a. **Albumin**
   b. **Globulin**
   c. **Fibrinogen**
   d. **Prothrombin**

B. **Lymphatic System** (Figs. 10–3 and 10-4, pp. 291, 292) – a vessel symptom apart from, but connected to, the circulatory system. The purpose is to return **lymph**, a clear, colorless, alkaline fluid that is about 95% water, from tissue spaces to the bloodstream. Lymph contains proteins, salts, organic substances, and water. The three main functions of the lymphatic system are:
   1. Transports proteins and fluids, lost by capillary seepage, back to the bloodstream.
   2. Protects the body against pathogens by phagocytosis and immune response.
   3. Serves as the pathway for the absorption of fats from the small intestines into the bloodstream.

C. **Accessory Organs** – these organs are not a part of the lymphatic system, but are closely related to it in their functions (Fig. 10–4, p. 292).
   1. **Spleen** – a soft, dark red oval body lying in the upper left quadrant of the abdomen. It is the major site of erythrocyte destruction and serves as a reservoir for blood. The spleen plays an essential role in the immune response and acts as a filter, removing microorganisms from blood.
   2. **Tonsils** (Fig. 10–5, p. 293) – lymphoid masses located in depressions of the mucous membranes of the face and pharynx.
The tonsils filter bacteria and aid in the formation of white blood cells. They consist of the:

a. Palatine Tonsil
b. Pharyngeal Tonsil (adenoid)
c. Lingual Tonsil

3. **Thymus** – located in the mediastinal cavity, the thymus plays an essential role in the formation of antibodies and the development of the immune response in the newborn. It manufactures infection-fighting T cells, which are important in the body’s immune response and helps distinguish normal T cells from those that attack the body’s own tissue. T cells are important in the body’s cellular immune response.

4. **Immune System** – the immune system consists of:
   a. Tissues
   b. Organs
   c. Physiologic processes used by the body to identify abnormal cells, foreign substances, and foreign tissue cells that have been transplanted into the body.

The average, healthy human body is equipped with natural defenses that assist it in fighting off disease and cancer. These natural defenses are:

- Intact skin
- Cleansing action of the body’s secretions, such as tears and mucus
- White blood cells
- Body chemicals, such as hormones, enzymes
- Antibodies

5. **Immune Response Overview** – the reaction of the body to foreign substances and the means by which it protects the body. Can be described as:
   a. **Humoral** (pertaining to body fluids or substances contained in them) **Immunity or Antibody-Mediated Immunity** – involves the production of plasma lymphocytes (B cells) in response to antigen exposure with subsequent formation of antibodies. Humoral immunity is a major defense against bacterial infections.
   - **Antigen** – a substance such as bacteria, toxins, or certain allergens that induces the formation of antibodies.

   - **Antibodies or Immunoglobulin (Table 10–3, p. 294)** – protein substances that are developed in response to a specific antigen. It is a complex glycoprotein produced by B lymphocytes in response to the presence of an antigen. Antibodies neutralize or destroy antigens in several ways. They can initiate destruction of the antigen by:
o Activating the complement system.
  o Neutralizing toxins released by bacteria.
  o Opsonizing (coating) the antigen.
  o Forming a complex to stimulate phagocytosis, promoting antigen clumping, or preventing the antigen from adhering to host cells.

b. Cellular Immunity or Cell-Mediated Immunity

involves the production of lymphocytes (T cells) that responds to any form of injury and natural killer (NK) cells that attack foreign cells, normal cells infected with viruses, and cancer cells. Cellular immunity constitutes a major defense against infections caused by viruses, fungi, and a few bacteria. It also helps defend against the formation of tumors. The phases associated with the body’s immune response to a foreign substance are:

- Recognition of the foreign substance or the invader (enemy).
- Activation of the body’s defense by producing more white blood cells that are designed to seek and destroy the invader (Table 10–4, p. 294).
  o T cells of the helper type identify the enemy and rush to the spleen and lymph nodes, where they stimulate the production of other cells to aid in the fight of the foreign substance.
  o T cells of the NK type are large granular lymphocytes that also specialize in killing cells of the body that have been invaded by foreign substances and fighting cells that have turned cancerous.
  o B cells reside in the spleen or lymph nodes and produce antibodies for specific antigens.
- The attack phase begins and the above defenders of the body produce antibodies and/or seek out to kill and/or remove the foreign invader by phagocytosis in which the macrophages squeeze out between the cells in the capillaries and crawl into the tissue to the site of the infection. Other white blood cells respond to infection by producing antibodies, which are released into the bloodstream and carried to the sight of infection. Later, both antibodies and invader may be eaten by the phagocytes.
- In the slowdown phase, the numbers of defenders return to normal.
II. Life Span Considerations
A. The Child – Plasma and blood cells are formed approximately the second week of life. At approximately the fifth week of development, blood formation occurs in the liver and later in the spleen, thymus, lymphatic system, and bone marrow. By 12 weeks the fetal liver is the chief producer of red blood cells, and bile is secreted by the gallbladder. At 16 weeks blood vessels are visible through the now-transparent skin. Fetal circulation provides oxygenation and nutrition to the fetus and disposes of carbon dioxide and other waste products. The thymus gland plays an important role in the development of the immune response in the newborn, and at birth weighs 10 to 15 g. At puberty, the thymus attains a weight of 40 g, after which it begins to undergo involution which replaces the thymus with adipose and connective tissue.

B. The Older Adult – with age, the lymphatic tissue shrinks, bone marrow becomes less productive, hemoglobin in red blood cells decreases, and the walls of peripheral vessels stiffen and lose elasticity. This results in:
   - Increase in peripheral resistance
   - Impairment of flow of blood
   - Increase in the workload of the left ventricle

The immune response declines with age, limiting the body’s ability to identify and fight foreign substances such as bacteria and viruses. The loss of thymus cortex results in the limiting ability to produce T and B lymphocytes. The incidence of autoimmune diseases also increases with aging. Failure of the immune response system to recognize mutant, or abnormal, cells could be the reason for the high incidence of cancer associated with increasing age.

III. Building Your Medical Vocabulary
A. Medical Words and Definitions – this section provides the foundation for learning medical terminology. Medical words can be made up of four types of word parts:
1. Prefix (P)
2. Root (R)
3. Combining Forms (CF)
4. Suffixes (S)

By connecting various word parts in an organized sequence, thousands of words can be built and learned. In the text, the word list is alphabetized so one can see the variety of meanings created when common prefixes and suffixes are repeatedly applied to certain word roots and/or combining forms. Words shown in pink are additional words related to the content of this chapter that have not been divided into word parts. Definitions identified with an asterisk icon (*) indicate terms that are covered in the Pathology Spotlights section of the chapter.

IV. Drug Highlights
A. **Anticoagulants** – used in inhibiting or preventing a blood clot formation. Hemorrhage can occur at almost any site in patients on anticoagulant therapy.

B. **Hemostatic Agents** – used to control bleeding and can be administered systemically or topically.

C. **Antianemic Agents (irons)** – Used to treat iron deficiency anemia. Oral iron preparations interfere with the absorption of oral tetracycline antibiotics. These products should not be taken within 2 hours of each other.

D. **Epoetin Alpha (EPO, Procrit)** – genetically engineered hemopoietin that stimulates the production of red blood cells. It is a recombinant version of erythropoietin and is indicated for treating anemia in patients with chronic renal failure and HIV-infected patients taking zidovudine (AZT).

E. **Other Agents** – agents used in treating folic acid and vitamin B₁₂ deficiencies.

V. **Diagnostic and Lab Tests**

A. **Antinuclear Antibodies (ANA)** – blood test to identify antigen–antibody reactions. ANA antibodies are present in a number of autoimmune diseases.

B. **Bleeding Time** – puncture of an ear lobe (Duke method), 1 to 3 minutes normal bleeding time, or forearm (Ivy method), 1 to 9 minutes normal bleeding time, to determine the time required for blood to stop flowing. Times greater than those noted may indicate thrombocytopenia, aplastic anemia, leukemia, decreased platelet count, hemophilia, and potential hemorrhage. Anticoagulant drugs delay the bleeding time.

C. **Blood Typing (ABO groups and Rh factor)** – blood test to determine an individual’s blood type and Rh factor.

D. **Bone Marrow Aspiration** – removal of bone marrow for examination. Used to determine aplastic anemia, leukemia, certain cancers, and polycythemia.

E. **CD4 Cell Count** – most widely used serum blood test to monitor the progress of AIDS. CD4 is a protein on the surface of cells that normally helps the body’s immune system fight disease; a count of less than 200/mm³ confirms AIDS diagnosis.

F. **Complete Blood Count (CBC)** – blood test that includes a hematocrit, hemoglobin, red and white blood cell count, and differential; usually part of a complete physical examination and a good indicator of hematologic system functioning.

G. **Enzyme-linked Immunosorbent Assay (ELISA)** – most widely used screening test for HIV. The latest generation of ELISA test are 99.5% sensitive to HIV. Because of occasional false-positive test, the ELISA must be repeated on the same blood sample twice. If positive a second time, the results should be confirmed by the Western blot test.

H. **Hematocrit (Het, HCT)** – test performed on whole blood to determine the percentage of red blood cells in the total blood volume.
I. **Hemoglobin (Hb, Hgb, HGB)** – blood test to determine the amount of iron-containing pigment of the red blood cells.

J. **Immunoglobulins (Ig)** – serum blood test to determine the presence of IgA, IgD, IgE, IgG, and/or IgM. Lymphocytes and plasma cells produce immunoglobulins in response to antigen exposure. Increased and/or decreased values may indicate certain disease conditions.

K. **Partial Thromboplastin Time (PTT)** – test performed on blood plasma to determine how long it takes for fibrin clots to form; used to regulate heparin dosage and to detect clotting disorders.

L. **Platelet Count** – test performed on whole blood to determine the number of thrombocytes present. Increased and/or decreased amounts may indicate certain disease conditions.

M. **Prothrombin Time (PT)** – test performed on blood plasma to determine the time needed for oxalated plasma to clot; used to regulate anticoagulant drug therapy and to detect clotting disorders.

N. **Red Blood Count (RBC)** – test performed on whole blood to determine the number of erythrocytes present. Increased and/or decreased amounts can indicate certain disease conditions.

O. **Sedimentation Rate (ESR)** – blood test to determine the rate at which red blood cells settle in a long, narrow tube. The distance the RBCs settle in 1 hour is the rate. Higher or lower rates can indicate certain disease conditions.

P. **Viral Load** – blood test that measures the amount of HIV in the blood. Results can range from 50 to over 1 million copies per milliliter (mL) of blood. Two tests that are used to measure viral load are bDNA and PCR.

Q. **Western Blot Test or Immunoblot Test** – used as a reference procedure to confirm the diagnosis of AIDS. In Western blot testing, HIV antigen is purified by electrophoresis (large protein molecules are suspended in a gel and separated from one another by running an electric current through the gel). If antibodies to HIV are present, a detectable antigen-antibody response occurs and a positive result is noted.

R. **White Blood Count (WBC)** – blood test to determine the number of leukocytes present. Increased level indicates infection and/or inflammation and decreased level indicates aplastic anemia, pernicious anemia, and malaria.

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**VI. Abbreviations (p. 311)**

**VII. Pathology Spotlights**

A. **Acquired Immunodeficiency Syndrome (AIDS)** – the final and most serious stage of HIV disease. The virus attacks the immune system and leaves the body vulnerable to a variety of life-threatening illnesses and cancers. The Centers for Disease Control and Prevention (CDC) defines AIDS as beginning when a person with HIV infection has a CD4 cell count below \(200/\text{mm}^3\). It is also defined by the opportunistic infections and cancers that occur in someone with HIV infection. AIDS, which is caused by HIV, attacks the immune...
system and leaves the body vulnerable to a variety of life-threatening illnesses. Initial manifestation of HIV infection presents symptoms of a mononucleosis-type illness and can take as little as a few weeks for minor symptoms to show up or as long as 10 years or more for more serious symptoms. Anyone can get HIV and AIDS particularly if any of the following is true:

- Sexually active and does not properly use a latex condom.
- Ignorant of a partner’s sexual and drug history.
- Injects drugs and shares needles with other people.
- Has had blood transfused between 1978 and 1985, or a blood transfusion or operation in a developing country at any time.

There is no cure for AIDS, but several treatments can delay the progression of the disease. They include:

- **Antiviral Therapy** – suppresses the replication of the HIV virus.
- **Highly Active Antiretroviral Therapy (HAART)** – reduces the number of HIV particles in the blood stream (as measured by a blood test called the viral load).
- **Medications** – to prevent opportunistic infections.

### B. Allergic Rhinitis (Fig. 10–19, p. 313)

- A collection of symptoms in the nose and eyes after exposure to certain airborne particles. Symptoms include coughing, headache, sneezing, and itching nose, mouth, and eyes. When the symptoms are caused by pollens, the allergic rhinitis is commonly known as hay fever. This same reaction occurs with allergy to mold, animal dander, dust, and similar inhaled allergens. To diagnose allergic rhinitis the following are important:
  1. **The history of the person’s symptoms.**
  2. **Allergy testing** – can reveal the specific allergens to which a person is reacting. Most common forms are:
      a. Intradermal skin testing
      b. Scratch test
      c. Patch test

  The goal of treatment is to reduce the inflammation that causes allergy symptoms. Effective treatments include:
  - Avoidance or reducing exposure of the allergens
  - Antihistamines
  - Decongestants
  - Nasal corticosteroid sprays
  - Allergy shots (immunotherapy)

### C. Anaphylaxis (Fig. 10–20, p. 313)

- A type of allergic reaction that is sudden and severe and affects the whole body. It is a response to a substance to which a person has become very sensitive. Histamine is released causing constriction of the airways, resulting in wheezing, difficulty breathing, and gastrointestinal symptoms. Shock can occur as a result of lowered blood pressure and blood volume. Hives and angioedema (hives on the lips, eyelids, throat and/or tongue) often occur, and angioedema could be severe enough to cause obstruction of the
airway. Anaphylaxis is an emergency condition that requires immediate professional medical attention. Treatment includes:

1. If indicated, cardiopulmonary resuscitation (CPR) should be initiated.
2. Epinephrine should be given by injection without delay.
3. If the person is in shock, IV fluids and medications that support the actions of the heart and circulatory system are given.
4. Antihistamines and corticosteroids can be given to further reduce symptoms.

D. Anemia (Figs. 10–21 and 10–22, pp. 314, 315) – characterized by a reduction in the number of circulating red blood cells per cubic millimeter, the amount of hemoglobin per100 mL of blood, or the volume of packed red blood cells (hematocrit) per 100 mL of blood. Symptoms are due to tissue hypoxia or lack of oxygen. General symptoms include pallor, fatigue, dizziness, headaches, decreased exercise tolerance, tachycardia, and shortness of breath (SOB). There are many types of anemia including:

1. **Iron Deficiency Anemia** – occurs when there is:
   a. An increased iron requirement such as during adolescence and in girls at the onset of menses
   b. Impaired absorption of iron with malabsorption syndromes and chronic disease.
   c. Hemorrhage that causes a loss of blood.

2. **Other types** of anemias include hemolytic, pernicious, vitamin B\(_{12}\) deficiency, folic acid deficiency, sickle cell (Fig. 10–23, p. 316), and thalassemia. Anemia is treated according to the type involved but can include supplemental iron preparations, iron-rich foods, injections of iron, injections of vitamin B\(_{12}\), folic acid supplementation, blood transfusions, or medications such as epoetin alfa.

E. Leukemia (Fig. 10–24, p. 317) – any of a group of diseases of the blood involving uncontrolled increase of white blood cells (leukocytes). Common types of leukemia include:

1. **Chronic Lymphocytic Leukemia (CCL)** – a malignancy of the lymphocytes characterized by a slow, progressive increase of these cells in the blood and the bone marrow. The incidence rate of CCL is about 2 per 100,000 and increases with age; 90% of cases are found in people over 50 years old and many cases are detected during routine blood testing.

2. **Acute Lymphocytic Leukemia (ALL)** – is a cancer of the lymph cells. It is characterized by large numbers of immature white blood cells that resemble lymphoblasts. These cells can be found in the blood, the bone marrow, the lymph nodes, the spleen, and other organs. ALL causes the blood cell to lose its ability to mature and specialize (differentiate) its function. These malignant cells multiply rapidly and replace the normal cells. Bone marrow failure occurs as malignant cells replace normal bone marrow.
elements. The person becomes susceptible to bleeding and infection because the normal blood cells are reduced in number. ALL is responsible for 80% of the acute leukemias of childhood, with the peak incidence occurring between ages 3 and 7. It also accounts for 20% of all adult leukemias. Most cases have an unknown etiology, but radiation, toxins, some chemotherapy agents, and abnormalities in chromosomes can contribute to this type of leukemia.

VIII. Pathology Checkpoint

IX. Study and Review (pp. 319–324)

X. Practical Application: SOAP: Chart Note Analysis