

CHAPTER 19

LECTURE OUTLINE

I. INTRODUCTION

- A. Blood inside blood vessels, interstitial fluid around body cells, and lymph inside lymph vessels constitute one's internal environment.
- B. To obtain nutrients and remove wastes, cells must be serviced by blood and interstitial fluid.
 - 1. Blood, a connective tissue, is composed of plasma and formed elements.
 - 2. Interstitial fluid bathes body cells.
- C. The branch of science concerned with the study of blood, blood-forming tissues, and the disorders associated with them is called hematology.

II. FUNCTIONS OF BLOOD

- A. Blood transports oxygen, carbon dioxide, nutrients, heat, wastes, and hormones.
- B. It helps regulate pH, body temperature, and water content of cells.
- C. It prevents blood loss through clotting and combats toxins and microbes through certain phagocytic white blood cells or specialized plasma proteins.

III. PHYSICAL CHARACTERISTICS OF BLOOD

- A. Physical characteristics of blood include a viscosity greater than that of water; temperature, 38°C (100.4°); and a pH of 7.35 to 7.45.
- B. Blood constitutes about 8% of body weight; volume ranges from 4 to 6 liters.
- C. Blood samples for laboratory testing may be obtained by venipuncture, finger-stick, or arterial stick (Clinical Connection)

IV. COMPONENTS OF BLOOD

- A. Blood consists of 55% plasma and 45% formed elements (Figure 19.1a).
- B. Blood plasma consists of 91.5% water and 8.5% solutes.
 - 1. Principal solutes include proteins (albumins, globulins, fibrinogen), nutrients, enzymes, hormones, respiratory gases, electrolytes, and waste products.
 - 2. Table 19.1 summarizes the chemical composition of plasma.
- C. Formed Elements
 - 1. The formed elements in blood include erythrocytes (red blood cells or RBCs), leukocytes (white blood cells or WBCs), and thrombocytes (platelets) (Figure 19.2).

2. The percentage of total blood volume occupied by red blood cells is called the hematocrit. A hematocrit measures the percentage of red blood cells in whole blood.
 - a. A significant drop in hematocrit indicates anemia, due to a lower than normal number of RBCs.
 - b. In polycythemia the percentage of RBC is abnormally high with a higher than normal hematocrit.

V. FORMATION OF BLOOD CELLS

- A. Blood cells are formed from pluripotent hematopoietic stem cells (Figure 19.3).
 1. Originating from the pluripotent stem cells are the myeloid stem cells and lymphoid stem cells.
 - a. Myeloid stem cells give rise to RBCs, platelets, and all WBCs except for lymphocytes.
 - b. Lymphoid stem cells give rise to lymphocytes.
 2. Myeloid stem cells differentiate into progenitor cells or precursor cells (blast cells) which will develop into the actual formed elements of blood.
 3. Lymphoid stem cells differentiate into pre-B and prothymocytes which develop into B-lymphocytes and T-lymphocytes, respectively.
- B. This process of hemopoiesis (or hematopoiesis) is stimulated by several hematopoietic growth factors. These hematopoietic growth factors stimulate differentiation and proliferation of the various blood cells.
 1. Erythropoietin increases the number of RBC precursors.
 2. Thrombopoietin increases the number of platelet precursors.
 3. Cytokins (colony-stimulating factors and interleukins) increase the number of WBC precursors.
- C. Bone marrow examination is a way to diagnose blood diseases. (Clinical Connection)
- D. Growth factors, available through recombinant DNA technology, hold great potential for use in patients who cannot normally form the blood cells. (Clinical Connection)

VI. RED BLOOD CELLS

- A. Red blood cells or erythrocytes (RBCs) contain the oxygen-carrying protein hemoglobin and number about 5.4 million cells/microliter of blood.
- B. RBCs anatomy
 1. are biconcave discs without nuclei that contain hemoglobin (Figure 19.4a).

2. The cytosol of RBCs contains hemoglobin molecules; these important molecules are synthesized before loss of the nucleus during RBC production and constitute about 33% of the cell's weight

C. RBC Physiology

1. The function of the hemoglobin in RBCs is to transport oxygen and some carbon dioxide. Hemoglobin molecules are specialized components of the red blood cell plasma membrane that combine with oxygen (as oxyhemoglobin) or with carbon dioxide (as carbaminohemoglobin) in this transport process (Figure 19.4).
2. Hemoglobin also functions in blood pressure regulation.
 - a. The gaseous hormone NO binds to hemoglobin.
 - b. Hemoglobin can release NO
 - c. Released NO causes vasodilation which improves blood flow and enhances oxygen delivery to the area.

D. RBC Life Cycle

1. Red blood cells only live about 120 days because of the wear and tear on their plasma membranes as they squeeze through blood capillaries.
2. In the RBC life cycle, after phagocytosis of worn-out RBCs by macrophages, hemoglobin is recycled (Figure 19.5); the globin portion is split from the heme with the amino acids being reused for protein synthesis. The iron in the heme portion is reclaimed with the rest of the heme molecule; the rest becomes a component of bile in the digestive process.
3. Under normal conditions plasma contains almost no free iron. If the amount of iron present in the body builds up, iron overload results causing diseases of the liver, heart, pancreatic islets, and gonads. Iron overload also permits iron dependent microbes to flourish (Clinical Connection).

E. Erythropoiesis: Production of RBCs

1. Erythrocyte formation, called erythropoiesis, occurs in adult red bone marrow of certain bones (Figure 19.3).
2. The main stimulus for erythropoiesis is hypoxia (Figure 19.6).
3. A reticulocyte count (average 0.5 - 1.5% of all RBCs) is a diagnostic test that indicates the rate of erythropoiesis and is useful in diagnosing and treating anemia. (Clinical Connection)

VII. WHITE BLOOD CELLS

A. Types of White Blood Cells

1. Leukocytes (white blood cells or WBCs) are nucleated cells and do not contain hemoglobin. Two principal types are granular (neutrophils, eosinophils, basophils) and agranular (lymphocytes and monocytes) (Figure 19.7).
 - a. Granular leukocytes include eosinophils, basophils, and neutrophils based on the straining of the granules.
 - b. Agranular leukocytes do not have cytoplasmic granules and include the lymphocytes and monocytes, which differentiate into macrophages (fixed and wandering).
2. Leukocytes have surface proteins, as do erythrocytes. They are called major histocompatibility antigens (MHC), are unique for each person (except for identical siblings), and can be used to identify a tissue.

B. Function of WBCs

1. White blood cells usually live for only a few hours or a few days. Normal blood contains 5,000-10,000 leukocytes/mm³.
 - a. Leukocytosis refers to an increase in the number of WBCs.
 - b. Leukopenia refers to an abnormally low number of WBCs.
2. The general function of leukocytes is to combat inflammation and infection.
 - a. WBCs leave the blood stream by emigration (Figure 19.8).
 - b. Some WBCs, particularly neutrophils and macrophages, are active in phagocytosis.
 - c. The chemical attraction of WBCs to a disease or injury site is termed chemotaxis.
 - d. Different WBCs combat inflammation and infection in different ways.
 - 1) Neutrophils and wandering or fixed macrophages (which develop from monocytes) do so through phagocytosis.
 - 2) Eosinophils combat the effects of histamine in allergic reactions, phagocytize antigen-antibody complexes, and combat parasitic worms.
 - 3) Basophils develop into mast cells that liberate heparin, histamine, and serotonin in allergic reactions that intensify the inflammatory response.

- 4) B lymphocytes, in response to the presence of foreign substances called antigens, differentiate into tissue plasma cells that produce antibodies.
- 5) T lymphocytes destroy foreign invaders directly.
 - i. A differential white blood cell count is a diagnostic test in which specific white blood cells are enumerated. Because each type of WBC plays a different role, determining the percentage of each type in the blood assists in diagnosing the condition.
 - ii. Table 19.2 shows the significance of elevated or depressed counts of the various WBCs.

VIII. PLATELETS

- A. Thrombopoietin stimulates myeloid stem cells to produce platelets.
 1. Myeloid stem cells develop into megakaryocyte-colony-forming cells that develop into megakaryoblasts (Figure 19.2).
 2. Megakaryoblasts transform into megakaryocytes which fragment.
 3. Each fragment, enclosed by a piece of cell membrane, is a platelet (thrombocyte).
- B. Normal blood contains 250,000 to 400,000 platelets/mm³. Platelets have a life span of only 5 to 9 days; aged and dead platelets are removed by fixed macrophages in the spleen and liver.
- C. Platelets help stop blood loss from damaged vessels by forming a platelet plug. Their granules also contain chemicals that promote blood clotting.
- D. A complete blood count (CBC) is a test that screens for anemia and various infections. It usually includes counts of RBCs, WBCs, and platelets per μL of whole blood; hematocrit and differential white blood cell count. The amount of hemoglobin in grams per ml is also determined (Clinical Connection)
- E. Table 19.3 summarizes the formed elements in blood.

IX. STEM CELL TRANSPLANTS FROM BONE MARROW AND CORD BLOOD

- A. Bone marrow transplants may be used to treat several types of anemia, leukemia, and numerous other blood disorders. However, residual host T cells can reject the transplant and transplanted T cells can attack the host.
- B. Cord blood transplants are from the host so transplant rejection is not an issue.

X. HEMOSTASIS

- A. Hemostasis refers to the stoppage of bleeding. When blood vessels are damaged or ruptured, the hemostatic response must be quick, localized to the region of damage, and carefully controlled.
- B. It involves vascular spasm, platelet plug formation, and blood coagulation (clotting).
 - 1. In vascular spasm, the smooth muscle of a blood vessel wall contracts to stop bleeding.
 - 2. Platelet plug formation involves the clumping of platelets around the damage to stop the bleeding (Figure 19.9).
 - 3. A clot is a gel consisting of a network of insoluble protein fibers (fibrin) in which formed elements of blood are trapped (Figure 19.10).
 - 4. The chemicals involved in clotting are known as coagulation (clotting) factors; most are in blood plasma, some are released by platelets, and one is released from damaged tissue cells (Table 19.4).
 - 5. Blood clotting involves a cascade of reactions that may be divided into three stages: formation of prothrombinase (prothrombin activator), conversion of prothrombin into thrombin, and conversion of soluble fibrinogen into insoluble fibrin (Figure 19.11).
 - 6. The clotting cascade can be initiated by either the extrinsic pathway or the intrinsic pathway.
- C. Normal coagulation requires vitamin K and also involves clot retraction (tightening of the clot) and fibrinolysis (dissolution of the clot).
 - 1. The fibrinolytic system dissolves small, inappropriate clots and clots at a site of damage once the damage is repaired.
 - 2. Plasmin (fibrinolysin) can dissolve a clot by digesting fibrin threads and inactivating substances such as fibrinogen, prothrombin, and factors V, VIII, and XII.
- D. Homeostatic Control Mechanisms
 - 1. Clots are generally localized due to fibrin absorbing thrombin into the clot, clotting factors diffusing through blood, and the production of prostacyclin, a powerful inhibitor of platelet adhesion and release.
 - 2. Substances that inhibit coagulation, called anticoagulants, are also present in blood. An example is heparin.
 - 3. Patients who are at increased risk of forming blood clots may receive an anticoagulant drug such as heparin or warfarin. To prevent clots in donated blood, a

substance that removes Ca^{+2} such as EDTA or CPD may be added to the blood
(Clinical Connection)

4. Despite the anticoagulating and fibrinolytic mechanisms, blood clots sometimes form within the cardiovascular system.
5. Clotting in an unbroken blood vessel is called thrombosis.
6. A thrombus (clot), bubble of air, fat from broken bones, or piece of debris transported by the bloodstream that moves from its site of origin is called an embolus.
7. At low doses aspirin inhibits vasoconstriction and platelet aggregation thereby reducing the chance of thrombus formation. Thrombolytic agents are injected into the body to dissolve clots that have already formed. Streptokinase or tissue plasminogen activator (TPA) are thrombolytic agents (Clinical Connection)

XI. BLOOD GROUPS AND BLOOD TYPES

- A. The surfaces of red blood cells contain genetically determined blood group antigens, called agglutinogens or isoantigens.
 1. Blood is categorized into different blood groups based on the presence or absence of various isoantigens.
 2. Within a blood group there may be two or more different blood types.
 3. Major blood groups are the ABO and Rh groups. Other blood groups include the Lewis, Kell, Kidd, and Duffy systems.
- B. ABO Group**
 1. In the ABO system, agglutinogens (antigens) A and B determine blood types (Figure 19.12).
 2. Plasma contains agglutinins (antibodies), designated as a and b, that react with agglutinogens that are foreign to the individual.
 3. Table 19.5 indicates the incidence of ABO and Rh blood types.
- C. Rh Blood Group**
 1. In the Rh system, individuals whose erythrocytes have Rh agglutinogens are classified as Rh⁺. Those who lack the antigen are Rh⁻.
 2. The incidence of ABO and Rh blood types is seen in Table 19.5.
- D. A disorder due to Rh incompatibility between mother and fetus is called hemolytic disease of the newborn; it is treatable, but also preventable (Clinical Connection).
- E. Transfusions

1. Knowledge of blood types is essential to safe transfusion of blood and may also be used in proving or disproving paternity, linking suspects to crimes, or as a part of anthropology studies to establish a relationship among races.
 2. The interactions of the blood types of the ABO system are summarized in Table 19.6.
- F. Typing and Cross-Matching Blood for Transfusion
1. The Rh and ABO blood groups may be detected by a simple medical test, blood typing, in which a sample of blood is mixed with serum containing agglutinins to each of the major agglutinogens (AB, B, and Rh).
 2. Typing is the determination of blood types, whereas cross-matching is the mixing of donor and recipient blood for compatibility.

XII. DISORDERS: HOMEOSTATIC IMBALANCES

- A. Anemia is a condition in which the oxygen-carrying capacity of the blood is reduced; it is a sign, not a diagnosis and is usually characterized by a decreased erythrocyte count or hemoglobin deficiency. Kinds of anemia include iron-deficiency, pernicious, hemorrhagic, hemolytic, Thalassemia, and aplastic.
- B. Sickle-cell disease is an inherited disorder due to an abnormal kind of hemoglobin. RBCs show a characteristic sickle shape (Figure 19.14), rupture easily, and show a reduced oxygen carrying capacity which results in hemolytic anemia.
- C. Hemophilia is an inherited deficiency of clotting in which bleeding may occur spontaneously or after only minor trauma.
- D. Acute leukemia is a malignant disease of blood-forming tissues characterized by uncontrolled production and accumulation of immature leukocytes. In chronic leukemia, there is an accumulation of mature leukocytes in the bloodstream because they do not die at the end of their normal life span.

XIII. MEDICAL TERMINOLOGY - Alert students to the medical terms associated with blood.