Chapter 17: Blood

Objectives:
1. Describe the composition and physical characteristics of whole blood. Explain why it is classified as a connective tissue.
2. List six functions of blood.
3. Discuss the composition and functions of plasma.
4. Describe the structure, function and production of erythrocytes.
5. Describe the chemical makeup of hemoglobin.
6. List the classes, structural characteristics, and functions of leukocytes. Also, describe leukocyte genesis.
7. Describe the structure and function of platelets.
8. Give examples of disorders caused by abnormalities of each of the formed elements. Explain the mechanism of each disorder.
9. Describe the process of hemostasis. List factors that limit clot formation and prevent undesirable clotting.
10. Give examples of hemostatic disorders. Indicate the cause of each condition.
11. Describe the ABO and Rh blood groups. Explain the basis of transfusion reactions.
12. Describe fluids used to replace blood volume and the circumstances for their use.
13. Explain the diagnostic importance of blood testing.
14. Describe changes in the sites of blood production and in the type of hemoglobin produced after birth.
15. Name some blood disorders that become more common with age.

I. Overview of Blood Circulation
   A. Blood leaves the heart via arteries that branch repeatedly until they become capillaries
   B. Oxygen (O\textsubscript{2}) and nutrients diffuse across capillary walls and enter tissues
   C. Carbon dioxide (CO\textsubscript{2}) and wastes move from tissues into the blood
   D. Oxygen-deficient blood leaves the capillaries and flows in veins to the heart
   E. This blood flows to the lungs where it releases CO\textsubscript{2} and picks up O\textsubscript{2}
   F. The oxygen-rich blood returns to the heart

II. Composition of Blood
   A. Blood is the body’s only fluid tissue
B. It is composed of liquid plasma and formed elements
C. Formed elements include:
   1. Erythrocytes, or red blood cells (RBCs)
   2. Leukocytes, or white blood cells (WBCs)
   3. Platelets
D. Hematocrit – the percentage of RBCs out of the total blood volume

III. Components of Whole Blood
A. Physical Characteristics and Volume
   1. Blood is a sticky, opaque fluid with a metallic taste
   2. Color varies from scarlet to dark red
   3. The pH of blood is 7.35–7.45
   4. Temperature is 38°C
   5. Blood accounts for approximately 8% of body weight
   6. Average volume
      a. 5–6 L for males
      b. 4–5 L for females

IV. Functions of Blood
A. Transports:
   1. Oxygen from the lungs and nutrients from the digestive tract
   2. Metabolic wastes from cells to the lungs and kidneys for elimination
   3. Hormones from endocrine glands to target organs
B. Maintains:
   1. Appropriate body temperature by absorbing and distributing heat
   2. Normal pH in body tissues using buffer systems
   3. Adequate fluid volume in the circulatory system
C. Prevents blood loss by:
   1. Activating plasma proteins and platelets
   2. Initiating clot formation when a vessel is broken
D. Prevents infection by:
   1. Synthesizing and utilizing antibodies
   2. Activating WBCs to defend the body against foreign invaders

V. Blood Plasma (55% of blood volume)
A. 90% Water
B. Blood plasma contains over 100 solutes, including:
   1. Proteins
a. albumin
b. globulins
c. clotting proteins
2. Lactic acid
3. urea
4. creatinine
5. Organic nutrients
   a. glucose
   b. carbohydrates
   c. amino acids
6. Electrolytes
   a. sodium
   b. potassium
   c. calcium
   d. chloride
   e. bicarbonate
7. Respiratory gases
   a. oxygen
   b. carbon dioxide

VI. Formed Elements (45% of Blood Volume)
   A. Erythrocytes
      1. Biconcave discs
      2. anucleate
      3. essentially no organelles
      4. Filled with hemoglobin (Hb)
         a. protein that functions in gas transport
         b. Hb is composed of
            1) protein globin
            2) heme group (iron)
            3) Each Hb molecule can transport four molecules of oxygen
   B. Structure of Hemoglobin
      1. Hemoglobin (Hb)
         a. Oxyhemoglobin – Hb bound to oxygen
         b. Deoxyhemoglobin – Hb after oxygen diffuses into tissues (reduced Hb)
         c. Carbaminohemoglobin – Hb bound to carbon dioxide
   C. Production of Erythrocytes
      1. Hematopoiesis – blood cell formation
         a. Hematopoiesis occurs in the red bone marrow of the:
1) Axial skeleton and girdles
2) Epiphyses of the humerus and femur

2. Erythropoiesis (formation of red blood cells)
   a. Requires:
      1) Proteins
      2) lipids
      3) carbohydrates
      4) Iron,
      5) vitamin B_{12}
      6) folic acid

3. The life span of an erythrocyte is 100–120 days
4. Old RBCs become rigid and fragile, and their Hb begins to degenerate
5. Dying RBCs are engulfed by macrophages
6. Heme and globin are separated and the iron is salvaged for reuse
   a. Heme is degraded to a yellow pigment called bilirubin
   b. The liver secretes bilirubin into the intestines as bile
   c. Globin is metabolized into amino acids and is released into the circulation

VII. Erythrocyte Disorders
A. Anemia
   1. blood has abnormally low oxygen-carrying capacity
   2. It is a symptom rather than a disease itself
   3. Blood oxygen levels cannot support normal metabolism
   4. Signs/symptoms include
      a. fatigue
      b. paleness
      c. shortness of breath
      d. chills
B. Hemorrhagic anemia
   1. result of acute or chronic loss of blood
C. Hemolytic anemia
   1. prematurely ruptured RBCs
D. Aplastic anemia
   1. destruction or inhibition of red bone marrow
E. Sickle-cell Anemia
   1. Results from a defective gene coding for an abnormal Hb
   2. Defect causes RBCs to become sickle-shaped in low oxygen situations
VIII. Leukocytes (WBCs)
A. Only blood components that are complete cells
B. Are less numerous than RBCs
C. Make up 1% of the total blood volume
D. Leukocytosis – WBC count over 11,000 / mm$^3$
E. Normal response to bacterial or viral invasion
F. Percentages of Leukocytes
   1. Granulocytes
      a. neutrophils
         1) body’s bacteria slayers
      b. eosinophils
         1) account for 1–4% of WBCs
         2) Lead the body’s counterattack against parasitic worms
         3) Lessen the severity of allergies
      c. basophils
         1) Account for 0.5% of WBCs and:
         2) Are functionally similar to mast cells
         3) Have large, purplish-black (basophilic) granules that contain histamine
            a) Histamine – inflammatory chemical that acts as a vasodilator and attracts other WBCs (antihistamines counter this effect)
      d. Are larger and usually shorter-lived than RBCs
      e. Have lobed nuclei
      f. Are all phagocytic cells
   2. Agranulocytes
      a. lymphocytes
         1) Account for 25% or more of WBCs and:
         2) Are found mostly enmeshed in lymphoid tissue (some circulate in the blood)
         3) Are two types of lymphocytes
            a) T cells
               1. function in the immune response
            b) B cells
               1. give rise to plasma cells, which produce antibodies
      b. monocytes
         1) Account for 4–8% of leukocytes
         2) Largest leukocytes
3) Leave the circulation, enter tissue, and differentiate into macrophages
   c. Lack visible cytoplasmic granules
   d. Are similar structurally
   e. Functionally distinct and unrelated cell types
   f. Have spherical (lymphocytes) or kidney-shaped (monocytes) nuclei

3. Macrophages
   a. Are highly mobile and actively phagocytic
   b. Activate lymphocytes to mount an immune response

IX. Leukocytes Disorders: Leukemias
   A. Leukemia refers to cancerous conditions involving WBCs
   B. Leukemias are named according to the abnormal WBCs involved
   C. Myelocytic leukemia – involves myeloblasts
   D. Lymphocytic leukemia – involves lymphocytes
   E. Acute leukemia involves blast-type cells and primarily affects children
   F. Chronic leukemia is more prevalent in older people
   G. Immature WBCs are found in the bloodstream in all leukemias
   H. Bone marrow becomes totally occupied with cancerous leukocytes
   I. The WBCs produced, though numerous, are not functional
   J. Death is caused by internal hemorrhage and overwhelming infections
   K. Treatments
      a. irradiation
      b. antileukemic drugs
      c. bone marrow transplants

X. Platelets
   A. Fragments of megakaryocytes
   B. Platelets function in the clotting mechanism by forming a temporary plug that helps seal breaks in blood vessels
   C. Platelets not involved in clotting are kept inactive by prostacyclin
   D. Hemostasis
      1. A series of reactions for stoppage of bleeding
      2. During hemostasis, three phases occur in rapid sequence
         a. Vascular spasms – immediate vasoconstriction in response to injury
         b. Platelet plug formation
1) Platelets do not stick to each other or to blood vessels
2) Stick to exposed collagen fibers and form a platelet plug
3) Release serotonin and ADP, which attract still more platelets
4) Plug is limited to the immediate area of injury by prostacyclin
c. Coagulation (blood clotting)
   a. A set of reactions in which blood is transformed from a liquid to a gel
3. Thromboembolic Conditions
   a. Thrombus – a clot that develops and persists in an unbroken blood vessel
      1) Thrombi can block circulation, resulting in tissue death
   b. Coronary thrombosis – thrombus in blood vessel of the heart
   c. Embolus – a thrombus freely floating in the blood stream
      1) Pulmonary emboli can impair the ability of the body to obtain oxygen
      2) Cerebral emboli can cause strokes
4. Hemostasis Disorders: Bleeding Disorders
   1) Hemophiliias – hereditary bleeding disorders caused by lack of clotting factors

XI. Human Blood Groups
   A. RBC membranes have glycoprotein antigens on their external surfaces
   B. These antigens are:
      1. Unique to the individual
      2. Recognized as foreign if transfused into another individual
      3. Promoters of agglutination and are referred to as agglutinogens
   C. Presence or absence of these antigens is used to classify blood groups
   D. Humans have 30 varieties of naturally occurring RBC antigens
   E. The antigens of the ABO and Rh blood groups cause vigorous transfusion reactions when they are improperly transfused

XII. ABO Blood Groups
   A. Two antigens (A and B) on the surface of the RBCs
   B. Two antibodies in the plasma (anti-A and anti-B)
   C. Agglutinogens and their corresponding antibodies cannot be mixed without serious hemolytic reactions
   D. Rh Blood Groups
1. Presence of the Rh agglutinogens on RBCs is indicated as Rh⁺
2. Anti-Rh antibodies are not spontaneously formed in Rh⁻ individuals
3. If an Rh⁻ individual receives Rh⁺ blood, anti-Rh antibodies form
4. A second exposure to Rh⁺ blood will result in a typical transfusion reaction
5. Hemolytic Disease of the Newborn
   a. Rh⁺ antibodies of a sensitized Rh⁻ mother cross the placenta and attack and destroy the RBCs of an Rh⁺ baby
   b. Rh⁻ mother becomes sensitized when exposure to Rh⁺ blood causes her body to synthesize Rh⁺ antibodies
   c. The drug RhoGAM can prevent the Rh⁻ mother from becoming sensitized
   d. Treatment of hemolytic disease of the newborn involves pre-birth transfusions and exchange transfusions after birth
E. Transfusion Reactions
1. Transfusion reactions occur when mismatched blood is infused
2. Donor’s cells are attacked by the recipient’s plasma agglutinins causing:
   a. Diminished oxygen-carrying capacity
   b. Clumped cells that impede blood flow
   c. Ruptured RBCs that release free hemoglobin into the bloodstream
F. Blood Typing
1. When serum containing anti-A or anti-B agglutinins is added to blood, agglutination will occur between the agglutinin and the corresponding agglutinogens
2. Positive reactions indicate agglutination

XIII. Developmental Aspects
A. Before birth, blood cell formation takes place in the fetal yolk sac, liver, and spleen
B. By the seventh month, red bone marrow is the primary hematopoietic area
C. Blood cells develop from mesenchymal cells called blood islands
D. Age-related blood problems result from disorders of the heart, blood vessels, and the immune system
E. Increased leukemias are thought to be due to the waning deficiency of the immune system
F. Abnormal thrombus and embolus formation reflects the progress of atherosclerosis