Chapter 17: Blood

This chapter begins a new unit. In this unit, the first four chapters deal with transportation—one of the body's vital functions. It is important to emphasize to students that homeostasis of the internal environment (and therefore survival itself) depends on continual transportation to and from body cells. An examination of blood is a natural place to begin, because it is, after all, the major transportation fluid. This discussion is also a necessary precursor for a study of the cardiovascular, lymphatic, and immune systems, the subjects of Chapters 18 through 21.

Students tend to think of blood as a fairly simple fluid. However, it consists not only of one of the three major body fluids (plasma), but also formed elements, which include cells and specialized cell fragments (platelets). Finally, blood is more than a vital, complex transport medium for the body; it is also the keystone of the body's heat-regulating mechanism.

Objectives
After students have completed this chapter, they should be able to:

1. Describe the generalized functions of blood and explain how the packed cell volume is determined.
2. List the types of blood cells that are normally found in circulating blood and identify the most important function of each.
3. Discuss the normal appearance, size, shape, and number of erythrocytes in circulating blood.
4. Describe the structure and function of hemoglobin.
5. Describe the process of red blood cell formation (erythropoiesis) and destruction.
6. Discuss the generalized function, classification, normal appearance, size, shape, and number of leukocytes in circulating blood.
7. Compare and contrast granulocytes and agranulocytes.
8. Discuss the stages in development of granular and agranular leukocytes.
9. Discuss the appearance, size, shape, number, and function of platelets in circulating blood.
10. Discuss the important physical properties of platelets and their relationship to hemostasis.
11. Describe ABO and Rh blood grouping systems.
12. List the major plasma components and their generalized functions.
13. Explain the steps involved in blood coagulation and the factors that oppose and hasten clotting.

Lecture Outline

I. Introduction (p. 530)
   A. Homeostasis (dependent on continual transport to and from cells)

II. Composition of Blood (Fig. 17-1)
   A. Plasma (a major body fluid)—55% of blood
   B. Formed elements (blood cells)—45% of blood (Fig. 17-2)
   C. Blood volume
      1. Amount
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2. Measurement
   a. Direct method (only for experimental animals)
      1) Removal of all blood
   b. Indirect methods (used for humans)
      1) Injection of known amount of RBCs tagged with radioisotopes

III. Formed Elements of Blood (p. 531)
   A. Measurement of cells
      1. Hematocrit—packed cell volume (PCV) (Fig. 17-3)
         a. Normal for males: 45%
         b. Normal for females: 42%
         c. Polycythemia
   B. Red blood cells (erythrocytes) (Figs. 17-2, 17-4; Table 17-1)
      1. Anatomy
         a. Nucleus absent
         b. Biconcave disk
         c. 7.5 mm in diameter
         d. Filled with hemoglobin (Hb)
         e. Thin plasma membrane
         f. 5,500,000/mm$^3$ of blood in males
         g. 4,800,000/mm$^3$ of blood in females
      2. Function of red blood cells (p. 533)
         a. Transport of oxygen and carbon dioxide
      3. Hemoglobin (Hb) (Fig. 17-5)
         a. 200 million to 300 million molecules/RBC
         b. 4 oxygen molecules carried by each Hb molecule
         c. Normal Hb values:
            1) Males: 14 g to 16 g/100 ml blood
            2) Females: 12 g to 14 g/100 ml blood
         d. Anemia—less than 10 g/100 ml blood
      3. Formation of red blood cells (erythropoiesis) (Figs. 17-6, 17-7)
         a. Hemopoietic adult stem cells (hemocytoblast) go through stages to form erythrocytes

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b. Stimulus for RBC formation is erythropoietin, produced continually by liver

c. Stimulus for increased RBC formation is low oxygen levels in the kidney
   1) Erythropoietin stimulates the hemocytoblasts to produce more RBCs

4. Destruction of red blood cells (Fig. 17-8)
a. RBCs last about 120 days
b. Macrophage cells in the liver and spleen phagocytose the old cells
c. Most components are recycled

C. White blood cells (leukocytes) (Fig. 17-2; Table 17-1)

1. Granulocytes (granules in cytoplasm and lobed nuclei) (p. 538)
a. Neutrophils: 65%–75% of total WBCs (Fig. 17-9)
   1) Increase in numbers during acute infections
b. Eosinophils: 2%–5% of circulating WBCs (Fig. 17-10)
   1) Increase in numbers during allergic reactions and parasitic worm infections
c. Basophils: 0.5%–1% of total WBCs (Fig. 17-11)
   1) Increase in numbers during allergic reactions and periods of inflammation

2. Agranulocytes (no granules in cytoplasm and unlobed nuclei) (p. 536)
a. Lymphocytes: 20%–25% of total WBCs (Fig. 17-12)
   1) Two types are important in the immune response
      a) Thymic lymphocytes (T lymphocytes, or T cells)
      b) Bursal lymphocytes (B lymphocytes, or B cells)
b. Monocytes: 3%–8% of total WBCs (Fig. 17-13)
   1) Become macrophages in the tissues

3. White blood cell numbers (Table 17-2)
a. Normal: 5,000 to 9,000/mm³

4. Formation of white blood cells (Fig. 17-6)
a. Hemopoietic adult stem cells (hemocytoblasts) go through differentiation and then various stages to form each type of WBC
b. Red marrow tissue development for neutrophils, eosinophils, basophils, and some lymphocytes and monocytes
c. Lymphoid tissue development for most lymphocytes and monocytes

D. Platelets (thrombocytes) (Fig. 17-12)
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1. Characteristics
   a. 150,000 to 350,000/mm$^3$
   b. 2 to 4 mm in diameter
   c. Plasma membrane-bound particles of cytoplasm containing clotting factors

2. Functions of platelets
   a. Two roles:
      1) Hemostasis = stoppage of blood flow
         a) Platelet plug formed by platelets sticking together (sticky platelets)
      2) Coagulation = formation of fibrin clot (discussed later)

3. Formation and life span of platelets (Fig. 17-6)
   a. Hemopoietic adult stem cells (hemocytoblasts) form megakaryoblasts, which form megakaryocytes, which form membrane-bound cytoplasmic fragments (platelets)
   b. Average survival about 7 days

IV. Blood Types (Blood Groups) (p. 537)
   A. Definitions
      1. Blood type = type of agglutinogens present on the RBCs (Fig. 17-14)
         a. Agglutinogens are self-antigens
      2. Agglutinins (antibodies) (Fig. 17-14)
         a. Plasma antibodies that cause agglutination of RBCs with specific agglutinogens
      3. Transfusion reactions (agglutination) (Fig. 17-16)
         a. Reactions between agglutinogens and agglutinins of noncompatible blood; causes the RBCs to agglutinate (stick together)

   B. The ABO system (Figs. 17-14, 17-15, 17-16)
      1. One of several blood type systems
      2. Type A
         a. RBC has agglutinogens A; plasma has agglutinin anti-B
      3. Type B
         a. RBC has agglutinogens B; plasma has agglutinin anti-A
      4. Type AB
         a. RBC has agglutinogens A and B; plasma has no agglutinin anti A or B
      5. Type O
         a. RBC has no agglutinogens A or B; plasma has agglutinin anti-A and B

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C. The Rh system (p. 544)

1. One of several blood type systems

2. Type Rh-positive
   a. RBC has a protein called \(Rh\) on its plasma membrane
   b. Plasma has no anti-Rh agglutinin

3. Type Rh-negative
   a. RBC has no Rh protein on its plasma membrane
   b. Plasma has no anti-Rh agglutinin

4. Erythroblastosis fetalis (Fig. 17-17)
   a. If mother is Rh-negative and has been exposed to Rh-positive blood, her blood will have the anti-Rh agglutinin in the plasma
   b. If fetus is Rh-positive, mothers anti-Rh agglutinins will pass through the placenta and cause agglutination of fetal RBCs; this condition is called \textit{erythroblastosis fetalis}

V. Blood Plasma (p. 545)

A. Components (Fig. 17-1)

1. 91% water

2. 9% solutes
   a. Electrolytes
      1) Sodium, chloride, potassium, etc.
   b. Nonelectrolytes
      1) Proteins (7% of plasma)
      2) Nutrients
      3) Wastes
      4) Gases
      5) Regulatory substances (hormones, etc.)

B. Serum (Fig. 17-18)

1. The liquid of the blood without the clotting factors

VI. Blood Clotting (Coagulation) (Fig. 17-19, 17-20)

A. Mechanism of blood clotting (Fig. 17-21)

1. Extrinsic clotting pathway
   a. Starts with damaged tissue and ends with production of an enzyme—prothrombinase (prothrombin activator)

2. Intrinsic clotting pathway
   a. Starts with damaged endothelial cells contacting platelets and ends with production of an enzyme—prothrombinase (prothrombin activator)

3. Common clotting pathway
   a. Prothrombin activator converts prothrombin to thrombin
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b. Thrombin is an enzyme that converts fibrinogen to fibrin for the clot

4. Components (Fig. 17-21; Table 17-3)
   a. Clotting factors listed in Table 17-3

B. Conditions that oppose clotting in intact vessels
   1. Smooth endothelium
   2. Presence of antithrombins (e.g., heparin)

C. Conditions that hasten clotting
   1. Rough places on endothelium
   2. Abnormally slow blood flow

D. Clot dissolution (fibrinolysis) (Fig. 17-22)
   1. Naturally occurring plasminogen can be activated to form plasmin, which dissolves clots.
   2. Bacteria produce clot-dissolving chemicals to enhance their invasion; these include streptokinase and t-PA, both of which have medical applications

VII. The Big Picture: Blood and the Whole Body (p. 549)
   A. Plasma links tissues of the body by transporting materials throughout the body to maintain homeostasis
   B. Red blood cells transport oxygen and carbon dioxide
   C. White blood cells are important in the whole body's defense mechanisms
   D. Functions of blood depend on respiratory, endocrine, and urinary systems
   E. Blood must flow continuously to maintain stability

VIII. Mechanisms of Disease: Blood Disorders
   A. Red blood cell disorders
      1. Anemia = loss of total oxygen-carrying capacity by the RBCs due to either a decrease of hemoglobin or a decrease in RBCs
         a. Aplastic anemia
         b. Pernicious anemia
         c. Folate deficiency anemia
         d. Acute blood-loss anemia
         e. Anemia of chronic disease
         f. Iron deficiency anemia
         g. Hemolytic anemia
            1) Sickle cell anemia
            2) Thalassemia
      2. Polycythemia = excess of RBCs
   B. White blood cell disorders
      1. Leukopenia: under 5,000 WBCs/mm³

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a. Acquired immune deficiency syndrome (AIDS)

2. Leukocytosis: abnormally high WBC count—over 10,000 WBCs/mm$^3$
   a. Leukemia

C. Clotting disorders
   1. Excessive clotting
      a. Thrombus and thrombosis
      b. Embolus and embolism
   2. Failure to clot
      a. Hemophilia
      b. Thrombocytopenia