

17: blood



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17: Blood Objectives Overview: Blood Composition and Functions 1. Describe the composition and physical characteristics of whole blood. Explain why it is classified as a connective tissue. 2. List eight functions of blood. Blood Plasma 3. Discuss the composition and functions of plasma. Formed Elements 4. Describe the structure, function, and production of erythrocytes. 5. Describe the chemical makeup of hemoglobin. 6. Give examples of disorders caused by abnormalities of erythrocytes. Explain what goes wrong in each disorder. 7. List the classes, structural characteristics, and functions of leukocytes. 8. Describe how leukocytes are produced. 9. Give examples of leukocyte disorders, and explain what goes wrong in each disorder. 10. Describe the structure and function of platelets. Hemostasis 11. Describe the processes of hemostasis. List factors that limit clot formation and prevent undesirable clotting. 12. Give examples of hemostatic disorders. Indicate the cause of each condition. Transfusion and Blood Replacement 13. Describe the ABO and Rh blood groups. Explain the basis of transfusion reactions. 14. Describe fluids used to replace blood volume and the circumstances for their use. Diagnostic Blood Tests 15. Explain the diagnostic importance of blood testing. Developmental Aspects of Blood 16. Describe changes in the sites of blood production and in the type of hemoglobin produced after birth. 17. Name some blood disorders that become more common with age. Chapter Outline I. Overview: Blood Composition and Functions (pp. 635—636; Fig. 17. 1) A. Components (p. 635; Fig. 17. 1) 1. Blood is a specialized connective tissue consisting of living cells, called formed elements, suspended in a nonliving fluid matrix, blood plasma. 2. Blood that has been centrifuged separates into three layers: erythrocytes, the buffy coat, and plasma. 3. The blood hematocrit represents the percentage of erythrocytes in whole blood.

B. Physical Characteristics and Volume (p. 635) 1. Blood is a slightly basic (pH = 7.35–7.45) fluid that has a higher density and viscosity than water, due to the presence of formed elements. 2. Normal blood volume in males is 5–6 liters, and 4–5 liters for females. C. Functions (pp. 635–636) 1. Blood is the medium for delivery of oxygen and nutrients, removal of metabolic wastes to elimination sites, and distribution of hormones. 2. Blood aids in regulating body temperature, body fluid pH, and fluid volume within fluid compartments. 3. Blood protects against excessive blood loss through the clotting mechanism, and from infection through the immune system. II. Blood Plasma (p. 636; Table 17.1) A. Blood plasma consists of mostly water (90%), and solutes including nutrients, gases, hormones, wastes, products of cell activity, ions, and proteins (p. 636; Table 17.1). B. Plasma proteins account for 8% of plasma solutes, mostly albumin, which function as carriers (p. 636). III. Formed Elements (pp. 637–649; Figs. 17.2–17.12; Table 17.2) A. Erythrocytes (pp. 637–643; Figs. 17.2–17.8) 1. Erythrocytes, or red blood cells, are small cells that are biconcave in shape. They lack nuclei and most organelles, and contain mostly hemoglobin. a. Hemoglobin is an oxygen-binding pigment that is responsible for the transport of most of the oxygen in the blood. b. Hemoglobin is made up of the protein globin bound to the red heme pigment. 2. Production of Erythrocytes a. Hematopoiesis, or blood cell formation, occurs in the red bone marrow. b. Erythropoiesis, the formation of erythrocytes, begins when a myeloid stem cell is transformed to a proerythroblast, which develops into mature erythrocytes. c. Erythrocyte production is controlled by the hormone erythropoietin. d. Dietary requirements for erythrocyte formation include iron, vitamin B12, and folic acid, as well as proteins, lipids, and carbohydrates. e. Blood cells have a

short life span due to the lack of nuclei and organelles; destruction of dead or dying blood cells is accomplished by macrophages. 3. Erythrocyte Disorders a. Anemias are characterized by a deficiency in RBCs. b. Polycythemia is characterized by an abnormal excess of RBCs. B. Leukocytes (pp. 643—648; Figs. 17. 9—17. 11; Table 17. 2) 1. Leukocytes, or white blood cells, are the only formed elements that are complete cells and make up less than 1% of total blood volume. 2. Leukocytes are critical to our defense against disease. 3. Granulocytes are a main group of leukocytes characterized as large cells with lobed nuclei and visibly staining granules; all are phagocytic. a. Neutrophils are the most numerous type of leukocyte. They are chemically attracted to sites of inflammation and are active phagocytes. b. Eosinophils are relatively uncommon and attack parasitic worms. c. Basophils are the least numerous leukocyte and release histamine to promote inflammation. 4. Agranulocytes are a main group of lymphocytes that lack visibly staining granules. a. T lymphocytes directly attack virus-infected and tumor cells; B lymphocytes produce antibody cells. b. Monocytes become macrophages and activate T lymphocytes. 5. Production and Life Span of Leukocytes a. Leukopoiesis, the formation of white blood cells, is regulated by the production of interleukins and colony-stimulating factors (CSF). b. Leukopoiesis involves differentiation of hemocytoblasts along two pathways: lymphoid and myeloid stem cells. 6. Leukocyte Disorders a. Leukopenia is an abnormally low white blood cell count. b. Leukemias are clones of a single white blood cell that remain unspecialized and divide out of control. c. Infectious mononucleosis is a disease caused by the Epstein-Barr virus. C. Platelets (pp. 648—649; Fig. 17. 12) 1. Platelets are not complete cells, but fragments of large cells called megakaryocytes. 2.

Platelets are critical to the clotting process, forming the temporary seal when a blood vessel breaks. 3. Formation of platelets involves repeated mitoses of megakaryocytes without cytokinesis. IV. Hemostasis (pp. 649—654; Figs. 17. 13—17. 14; Table 17. 3) A. A break in a blood vessel stimulates hemostasis, a fast, localized response to reduce blood loss through clotting (p. 649). B. Vascular spasms are the immediate vasoconstriction response to blood vessel injury (p. 649). C. Platelet Plug Formation (pp. 649—650; Fig. 17. 13) 1. When endothelium is damaged, platelets become sticky and spiky, adhering to each other and the damaged vessel wall. 2. Once attached, other platelets are attracted to the site of injury, activating a positive feedback loop for clot formation. D. Coagulation, or blood clotting, is a multistep process in which blood is transformed from a liquid to a gel (pp. 650—652; Figs. 17. 13—17. 14; Table 17. 3). 1. Factors that promote clotting are called clotting factors, or procoagulants; those that inhibit clot formation are called anticoagulants. 2. The clotting process involves three phases: formation of prothrombin activator, conversion of prothrombin to thrombin, and the formation of fibrin mesh from fibrinogen in the plasma. a. The intrinsic pathway of clotting is so named because all factors necessary are present within the blood. It is a slower clotting pathway, and may be triggered by negatively charged surfaces, such as activated platelets, collagen, or glass. b. The extrinsic pathway is triggered through an endothelium-derived protein factor, called tissue factor (TF) or factor III, and can occur very rapidly. E. Clot Retraction and Repair (p. 652) 1. Clot retraction is a process in which the contractile proteins within platelets contract and pull on neighboring fibrin strands, squeezing plasma from the clot and pulling damaged tissue edges together. 2. Repair is stimulated by

platelet-derived growth factor (PDGF). F. Fibrinolysis removes unneeded clots through the action of the fibrin-digesting enzyme plasmin (p. 652). G. Factors Limiting Clot Growth or Formation (pp. 652—653) 1. Rapidly moving blood disseminates clotting factors before they can initiate a clotting cascade. 2. Thrombin that is not bound to fibrin is inactivated by antithrombin III and protein C, as well as heparin. H. Disorders of Hemostasis (pp. 653—654) 1. Thromboembolytic disorders result from conditions that cause undesirable clotting, such as roughening of vessel endothelium, slow-flowing blood, or blood stasis. 2. Disseminated intravascular coagulation is a situation leading to widespread clotting throughout intact vessels, and may occur as a complication of pregnancy, septicemia, or incompatible blood transfusions. 3. Bleeding disorders arise from abnormalities that prevent normal clot formation, such as a deficiency in circulating platelets, lack of synthesis of procoagulants, or hemophilia. V. Transfusion and Blood Replacement (pp. 654—657; Fig. 17. 15; Table 17. 4) A. Transfusion of whole blood is routine when blood loss is substantial, or when treating thrombocytopenia (pp. 654—656; Fig. 17. 15; Table 17. 4). 1. Humans have different blood types based on specific antigens on RBC membranes. 2. ABO blood groups are based on the presence or absence of two types of agglutinogens. 3. Preformed antibodies (agglutinins) are present in blood plasma and do not match the individual's blood. 4. The Rh factor is a group of RBC antigens that are either present in Rh+ blood, or absent in Rh— blood. 5. A transfusion reaction occurs if the infused donor blood type is attacked by the recipient's blood plasma agglutinins, resulting in agglutination and hemolysis of the donor cells. B. Plasma and blood volume expanders are given in cases of extremely low blood volume (pp. 656—657). VI. Diagnostic Blood Tests (p. 657) A.

Changes in some of the visual properties of blood can signal diseases such as anemia, heart disease, and diabetes (p. 657). B. Differential white blood cell counts are used to detect differences in relative amounts of specific blood cell types (p. 657). C. Prothrombin time, which measures the amount of prothrombin in the blood, and platelet counts evaluate the status of the hemostasis system (p. 657). D. SMAC, SMA12—60, and complete blood count (CBC) give comprehensive values of the condition of the blood (p. 657). VII. Developmental Aspects of Blood (p. 657) A. Prior to birth, blood cell formation occurs within the fetal yolk sac, liver, and spleen, but by the seventh month, red bone marrow is the primary site of hematopoiesis (p. 657). B. Fetal blood cells form hemoglobin-F, which has a higher affinity for oxygen than adult hemoglobin, hemoglobin-A (p. 657). Cross References From Chapters 1-15 Additional information on topics covered in Chapter 17 can be found in the chapters listed below. 1. Chapter 3: Diffusion; osmosis 2. Chapter 4: Tissue repair 3. Chapter 6: Hematopoietic tissue Laboratory Correlations 1. Marieb, E. N., and S. J. Mitchell. Human Anatomy & Physiology Laboratory Manual: Cat and Fetal Pig Versions. Ninth Edition Updates. Benjamin Cummings, 2009. Exercise 29: Blood PhysioEx™ 8. 0 Exercise 29B: Blood Analysis: Computer Simulation 2. Marieb, E. N., and S. J. Mitchell. Human Anatomy & Physiology Laboratory Manual: Main Version. Eighth Edition Update. Benjamin Cummings, 2009. Exercise 29: Blood PhysioEx™ 8. 0 Exercise 29B: Blood Analysis: Computer Simulation Online Resources for Students myA&P™ [www.myaandp.com](http://www.myaandp.com) The following shows the organization of the Chapter Guide page in myA&P™. The Chapter Guide organizes all the chapter-specific online media resources for Chapter 17 in one convenient location, with e-book links to each section of the textbook.

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Students can also access A&P Flix animations, MP3 Tutor Sessions, Interactive Physiology® 10-System Suite, Practice Anatomy Lab™ 2. 0, PhysioEx™ 8. 0, and much more. Objectives Section 17. 1 Overview: Blood Composition and Functions (pp. 635—636) Section 17. 2 Blood Plasma (p. 636) Memory Game: Blood Cells Section 17. 3 Formed Elements (pp. 637—649) MP3 Tutor Session: Hemoglobin: Function and Impact Interactive Physiology® 10-System Suite: Respiratory System: Gas Transport Memory Game: Identifying the Formed Elements of Blood Case Study: Iron-Deficiency Anemia Case Study: Sickle-Cell Anemia Section 17. 4 Hemostasis (pp. 649—654) Section 17. 5 Transfusion and Blood Replacement (pp. 654—657) Section 17. 6 Diagnostic Blood Tests (p. 657) Section 17. 7 Developmental Aspects of Blood (p. 657) Chapter Summary Crossword Puzzle 17. 1 Crossword Puzzle 17. 2 Crossword Puzzle 17. 3 Web Links Chapter Quizzes Art Labeling Quiz Matching Quiz Multiple-Choice Quiz True-False Quiz Chapter Practice Test Study Tools Histology Atlas myeBook Flashcards Glossary Answers to End-of-Chapter Questions Multiple-Choice and Matching Question answers appear in Appendix G of the main text. Short Answer Essay Questions 11. a. -The formed elements are living blood cells. The major categories of formed elements are erythrocytes, leukocytes, and platelets. b. The least numerous of the formed elements are the leukocytes. c. The buffy coat in a hematocrit tube comprises the white blood cells and platelets. (p. 635) 12. Hemoglobin is made up of the protein globin bound to the pigment heme. Each molecule contains four polypeptide chains (globins) and four heme groups, each bearing an atom of iron in its center. Its function is to bind oxygen to each iron atom. When oxygen is loaded (bound to hemoglobin), the hemoglobin becomes bright red. When oxygen is unloaded

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from the iron, the hemoglobin becomes dark red. (p. 638) 13. With a high hematocrit, you would expect the hemoglobin determination to be high, since the hematocrit is the percent of blood made up of RBCs. (p. 635) 14. In addition to carbohydrates for energy and amino acids needed for protein synthesis, the nutrients needed for erythropoiesis are iron and certain B vitamins. (p. 640) 15. a. -In the process of erythropoiesis, a hemocytoblast is transformed into a proerythroblast, which gives rise to early, then late erythroblasts, normoblasts, and reticulocytes. b. The immature cell type released to the circulation is the reticulocyte. c. The reticulocyte differs from a mature erythrocyte in that it still contains some rough ER. (p. 639) 16. The physiological attributes that contribute to the function of white blood cells in the body include the ability to move by amoeboid action, exhibition of positive chemotaxis enabling them to pinpoint areas of tissue damage, diapedesis (moving through capillary walls), and the ability to participate in phagocytosis. (p. 643) 17. a. With a severe infection, the WBC count would be closest to 15, 000 WBC/mm<sup>3</sup> of blood. b. This condition is called leukocytosis. (p. 643) 18. a. Platelets appear as small discoid fragments of large, multinucleated cells called megakaryocytes. They are essential for the clotting process and work by clumping together to form a temporary plug to prevent blood loss. b. Platelets should not be called " cells" because they are only fragments of cells. (p. 648) 19. a. Literally, hemostasis is " blood standing still" because it refers to clotted blood. It encompasses the steps that prevent blood loss from blood vessels. (p. 649) b. The three major steps of coagulation include the formation of prothrombin activator by a cascade of activated procoagulants, the use of prothrombin activator enzymatically to release the active enzyme thrombin from prothrombin, and the use of

thrombin to cause fibrinogen to form fibrin strands. (pp. 649—652) c. The intrinsic pathway depends on substances present in (intrinsic to) blood. It has many more steps and intermediates, and is slower. The extrinsic mechanism bypasses the early steps of the intrinsic mechanism and is triggered by tissue factor (thromboplastin) released by injured cells in the vessel wall or in surrounding tissues. (pp. 650—651) d. Calcium is essential to virtually all stages of coagulation. (p. 651) 20. a. Fibrinolysis is the disposal of clots when healing has occurred. b. The importance of this process is that without it, blood vessels would gradually become occluded by clots that are no longer necessary. (p. 652) 21. a. Clot overgrowth is usually prevented by rapid removal of coagulation factors and inhibition of activated clotting factors. (pp. 652—653) b. Two conditions that may lead to unnecessary (and undesirable) clot formation are roughening of the vessel wall endothelium and blood stasis. (p. 653) 22. Bleeding disorders occur when the liver cannot synthesize its usual supply of procoagulants. (p. 653) 23. a. A transfusion reaction involves agglutination of foreign RBCs, leading to clogging of small blood vessels, and lysis of the donated RBCs. It occurs when mismatched blood is transfused. b. Possible consequences include disruption of oxygen-carrying capacity, fever, chills, nausea, vomiting, general toxicity, and renal failure. (p. 656) 24. Among other things, poor nutrition can cause iron-deficiency anemia due to inadequate intake of iron-containing foods or to pernicious anemia due to deficiency of vitamin B12. (p. 642) 25. The most common blood-related problems for the aged include chronic types of leukemias, anemias, and thromboembolytic disease. (p. 657) Critical Thinking and Clinical Application Questions 1. Hemopoiesis is a process involving fairly rapid cell production. Because chemotherapeutics

simply target cells exhibiting rapid turnover (rather than other specific properties of cancer cells), hemopoiesis is a target of chemotherapeutic drugs and must be carefully monitored. (pp. 638—639) 2. a. The woman would probably be given a whole blood transfusion. It is essential that she maintain sufficient O<sub>2</sub>-carrying capacity to serve fetal needs and blood volume to maintain circulation. b. The blood tests that would be performed include tests for ABO and Rh group antigen and cross matching. (pp. 654—655) 3. a. Polycythemia accounts for his higher erythrocyte count because of the need to produce more RBCs to increase his O<sub>2</sub> binding and transport ability in the high-altitude (thinner air) environment of the Alps. Enhanced production of RBCs was prompted by an increased production of erythropoietin. b. His RBC count will not stay higher than normal because the excess production of RBCs will depress erythropoietin production by the kidneys when adequate levels of O<sub>2</sub> are being transported in the blood. (p. 643) 4. Janie's leukocytes are immature or abnormal and are incapable of defending her body in the usual way. (p. 648) 5. Red bone marrow is the site of hemopoiesis, and if it is destroyed by benzene, hemocytoblasts will not be produced, which will reduce the production of megakaryocytes (the progenitor cells of platelets, which are involved in clotting). (p. 638) 6. Tyler is turning out a high rate of reticulocytes (immature red blood cells), which accounts for his high hematocrit. (p. 639) 7. An analysis of the clotting process described in the text should reveal that the two blood proteins are thrombin and fibrinogen. (p. 650) 8. An elevated RBC count could be related to smoking, due to the frequent hypoxia that results from inhalation of oxygen-poor cigarette smoke. (p. 643) 9. Aspirin is a mild anticoagulant, which could cause excessive bleeding during or after surgery. (p. 653)