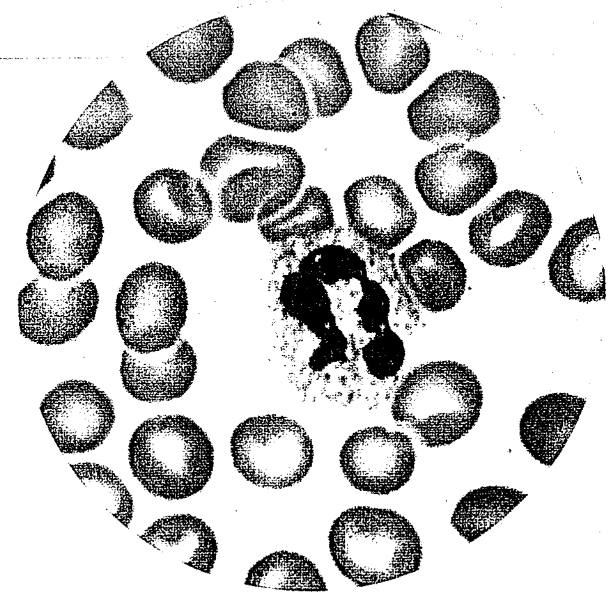
10

Blood



Outline

Objectives

AFTER YOU HAVE COMPLETED THIS CHAPTER, YOU SHOULD BE ABLE TO:

1. Describe the primary functions of blood.
2. Describe the characteristics of blood plasma.
3. List the formed elements of blood and identify the most important function of each.
4. Discuss anemia in terms of red blood cell numbers and hemoglobin content.
5. Explain the steps involved in blood clotting.
6. Describe ABO and Rh blood typing.
7. Define the following medical terms associated with blood: *hematocrit, leukocytosis, leukopenia, polycythemia, sickle cell, phagocytosis, acidosis, thrombosis, erythroblastosis fetalis, serum, fibrinogen, Rh factor, anemia.*

The next few chapters deal with **transportation** and **protection,** two of the body's most important functions. Have you ever thought of what would happen if the transportation ceased in your city or town? Or what would happen if the police, firefighters, and armed services stopped doing their jobs? Food would become scarce, garbage would pile up, and no one would protect you or your property. Stretch your imagination just a little, and you can imagine many disastrous results. Similarly, lack of transportation and protection for the cells—the "individuals" of the body—threatens the homeostasis of the body. The systems that provide these vital services for the body are the **circulatory system** and **lymphatic system.** In this chapter, we will discuss the primary transportation fluid: blood. Blood not only performs vital pickup and delivery services, but it also provides much of the protection necessary to withstand foreign "invaders." Blood vessels and the heart are discussed in Chapter 11. The lymphatic system is discussed in Chapter 12.

BLOOD COMPOSITION

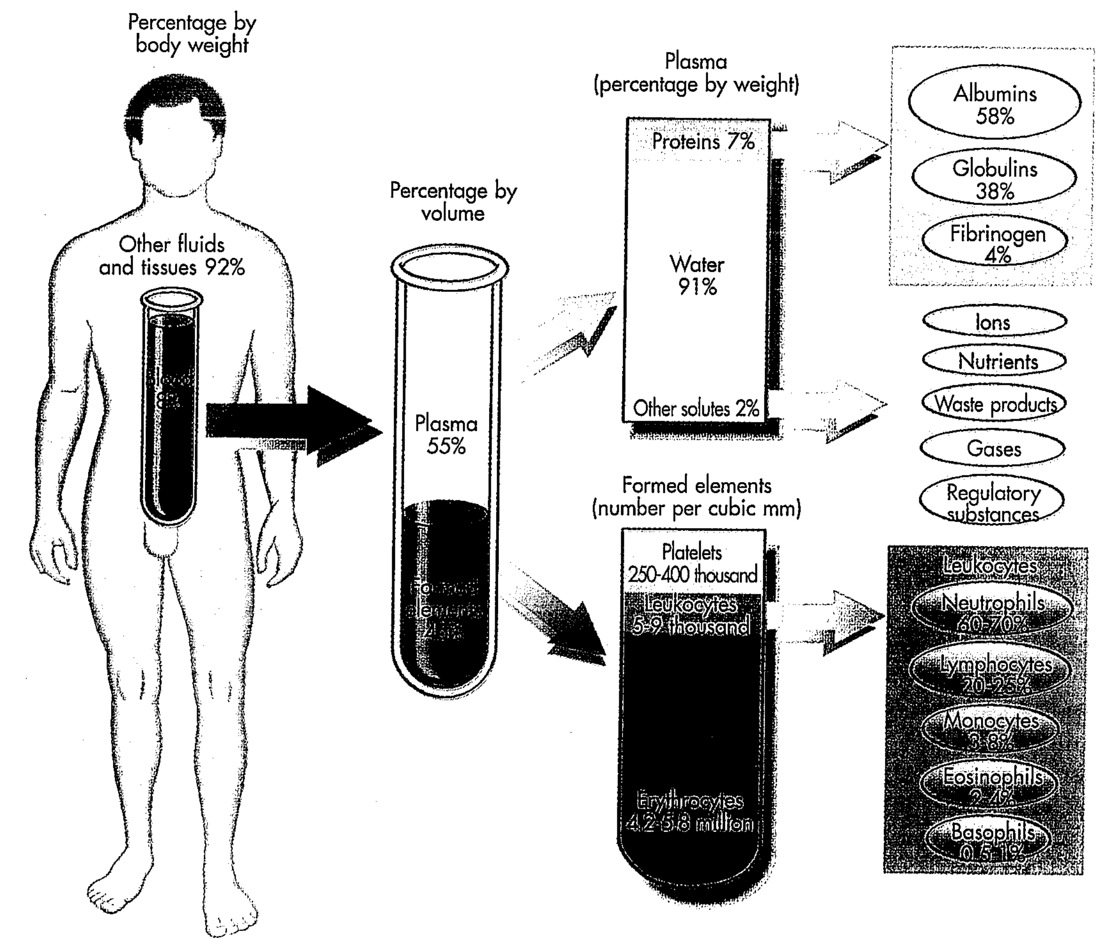
Blood is a fluid tissue that has many kinds of chemicals dissolved in it and millions upon millions of cells floating in it (Figure 10-1). The liquid (extracellular) part is called **plasma.** Suspended in the plasma are many different types of cells and cell fragments, which make up the **formed elements** of blood.

Blood Plasma

Blood plasma is the liquid part of the blood, or blood minus its formed elements. It consists of water with many substances dissolved in it. All of the chemicals needed by cells to stay alive—food, oxygen, and salts, for example—have to be brought to them by the blood. Food and salts are dissolved in plasma; so, too, is a small amount of oxygen. (Most of the oxygen in the blood is carried

FIGURE 10-1

Components of blood. Approximate values for the components of blood in a normal adult. Values will vary with age, sex, and nutritional status.



in the red blood cells as oxyhemoglobin.) Wastes that cells must get rid of are dissolved in plasma and transported to the excretory organs. The hormones and other regulatory chemicals that help control cells' activities are also dissolved in plasma. As Figure 10-1 shows, the most abundant type of solute in the plasma is a group of **plasma proteins.** These proteins include *albumins,* which help thicken the blood; *globulins,* which include the antibodies that help protect us from infections; and *fibrinogen,* which is necessary for blood clotting.

Blood **serum** is plasma minus its clotting factors such as fibrinogen. Serum is obtained from whole blood by allowing it to clot in the bottom of a tube and then pouring off the liquid serum. Serum still contains antibodies, so it can be used to treat patients that have a need for specific antibodies.

Many people seem curious about how much blood they have. The amount depends on how big they are and whether they are male or female. A big person has more blood than a small person, and a man has more blood than a woman. But as a general rule, most adults probably have between 4 and 6 liters of blood. It normally accounts for about 7% to 9% of the total body weight.

The volume of the plasma part of blood is usually a little more than half the volume of whole blood. Examples of normal volumes are plasma: 2.6 L; blood cells: 2.4 L; total blood: 5 L.

Formed Elements

There are three main types and several subtypes of formed elements:

1. Red blood cells (RBCs) or **erythrocytes** (e-RITH-ro-sites)
2. White blood cells (WBCs) or **leukocytes** (LOO-ko-sites)
   a. Granular leukocytes (have granules in their cytoplasm)
      (1) Neutrophils
      (2) Eosinophils
      (3) Basophils
   b. Nongranular leukocytes (do not have granules in their cytoplasm)
      (1) Lymphocytes
      (2) Monocytes
3. Platelets or **thrombocytes** (THROM-bo-sites)

Figure 10-1 shows the breakdown of numbers and percentages of the formed elements. Table 10-1 lists the functions of these different kinds of blood cells and shows what each looks like under the microscope.

It is difficult to believe how many blood cells and cell fragments there are in the body. For instance, 5,000,000 RBCs, 7500 WBCs, and 300,000 platelets in 1 cubic millimeter (mm^3) of blood (approximately 1 drop) would be considered normal RBC, WBC, and platelet counts. Because RBCs, WBCs, and platelets are continually being destroyed, the body must continually make new ones to take their place at a really staggering rate; a few million RBCs are manufactured *each second!*

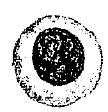
Two kinds of connective tissue—**myeloid tissue** and **lymphatic tissue**—make blood cells for the body. Recall that formation of new blood cells is called *hemopoiesis.* Myeloid tissue is better known as *red bone marrow.* In the adult, it is chiefly in the sternum, ribs, and hipbones. A few other bones such as the vertebrae, clavicles, and cranial bones also contain small amounts of this valuable substance. Red bone marrow forms all types of blood cells except some lymphocytes and monocytes. Most of these others are formed by lymphatic tissue, which is located chiefly in the lymph nodes, thymus, and spleen.

As blood cells mature, they move into the circulatory vessels. Erythrocytes circulate up to 4 months before they break apart and their components are removed from the bloodstream by the liver. Granular leukocytes often have a lifespan of only a few days, but nongranular leukocytes may live for more than 6 months.

Red Blood Cells

As you can see in Figure 10-2, RBCs have an unusual shape. The cell is "caved in" on both sides so that each one has a thin center and thicker edges. Notice also that mature RBCs have no nucleus. Figure 10-2 shows RBCs photographed with a scanning electron microscope. With this instrument, extremely small objects can be enlarged far more than is possible with a standard light microscope, and, as you can see in the illustration, objects appear more three-dimensional. Because of

TABLE 10-1
Classes of Blood Cells

BODY CELL		FUNCTION	BODY CELL		FUNCTION
Erythrocyte		Oxygen and carbon dioxide transport	B-lymphocyte		Antibody production (precursor of plasma cells)
Neutrophil		Immune defense (phagocytosis)	T-lymphocyte		Cellular immune response
Eosinophil		Defense against parasites	Monocyte		Immune defenses (phagocytosis)
Basophil		Inflammatory response	Platelet		Blood clotting

the large numbers of RBCs and their unique shape, their total surface area is enormous. It provides an area larger than a football field for the exchange of oxygen and carbon dioxide between the blood and the body's cells.

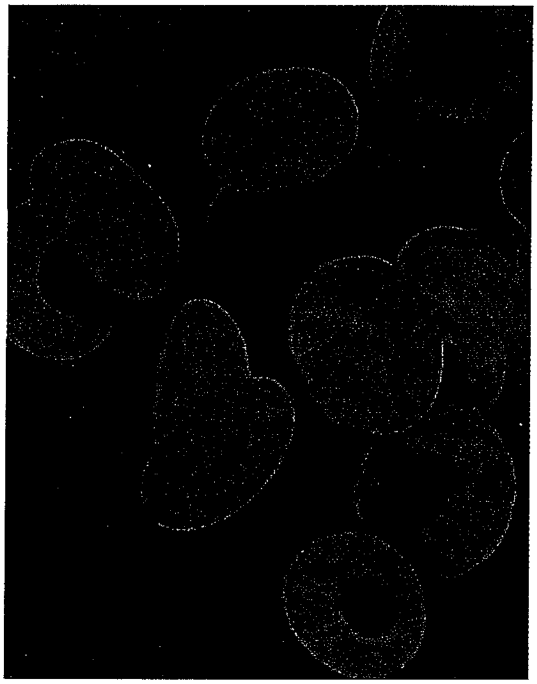
RBCs perform several important functions. One essential function is to help transport carbon dioxide. Carbon dioxide (CO_2) is a harmful waste produced by the energy-producing processes of all living cells. It must be carried away from cells and to the lungs for disposal into the external environment. RBCs also transport oxygen from the lungs to other cells in the body. A red pigment called **hemoglobin** (hee-mo-glo-bin) in RBCs unites with oxygen to form **oxyhemoglobin** (ok-see-hee-mo-glo-bin). This combined oxygen-hemoglobin complex makes possible the efficient transport of large quantities of oxygen to body cells. Hemoglobin can also carry a small proportion of the CO_2 carried by the blood.

The term **anemia** (ah-NEE-me-ah) is used to describe a number of different disease conditions caused by an inability of the blood to carry sufficient oxygen to the body cells. Anemias can result from inadequate numbers of RBCs or a deficiency of hemoglobin. Thus anemia can occur if the hemoglobin in RBCs is inadequate, even if adequate numbers of RBCs are present. Anemias caused by an actual decrease in the number of RBCs can occur if blood is lost by hemorrhage, as with accidents or bleeding ulcers, or if the blood-forming tissues cannot maintain normal numbers of blood cells. Such failures occur because of cancer, radiation (x-ray) damage, and certain types of infections. The term **pernicious** (per-NISH-us) **anemia** is used to describe a deficiency of RBCs caused by the lack of vitamin B_{12}. If bone marrow produces an *excess* of RBCs, the result is a condition called **polycythemia** (pol-ee-sye-THEE-me-ah). The blood in individuals suffering from this condition may contain so many RBCs that it may become too thick to flow properly.

Iron is a critical component of the hemoglobin molecule. Without adequate iron in the diet, the

FIGURE 10-2

RBCs. Color-enhanced scanning electron micrograph shows the detailed structure of normal RBCs.



CLINICAL APPLICATION

Sickle Cell Anemia

Sickle cell anemia is a severe and sometimes fatal hereditary disease caused by an abnormal type of hemoglobin. A person who inherits only one defective gene develops a form of the disease called *sickle cell trait.* In this condition, RBCs contain a small amount of a type of hemoglobin that is less soluble than normal. It forms solid crystals when the blood oxygen level is low, causing distortion of the RBC. If two defective genes are inherited (one from each parent), more of the defective hemoglobin is produced, and the distortion of red blood cells becomes severe. In the United States, nearly 1 in every 500 African-American and 1 in every 1000 Hispanic newborns are affected each year.

Stroke is one of the most devastating problems associated with sickle cell anemia in children. Unfortunately, once a stroke occurs, recurrence is common. Recent studies have shown that frequent blood transfusions in addition to standard care can dramatically reduce the risk of stroke in many children suffering from sickle cell anemia.

The illustration shows the characteristic shape of many RBCs in sickle cell anemia.

body cannot manufacture enough hemoglobin. The result is **iron deficiency anemia,** a worldwide medical problem. If hemoglobin falls below the normal level, as it does in this type of anemia, it starts an unhealthy chain reaction: less hemoglobin, less oxygen transported to cells, slower breakdown and use of nutrients by cells, less energy produced by cells, decreased cellular functions. If you understand this relationship between hemoglobin and energy, you can correctly guess that an anemic person's chief complaint will probably be that he or she feels "so tired all the time."

A common laboratory test called the **hematocrit** can tell a physician a great deal about the volume of RBCs in a blood sample. If whole blood is placed in a special hematocrit tube and then "spun down" in a centrifuge, the heavier formed elements will quickly settle to the bottom of the tube. During the hematocrit procedure, RBCs are forced to the bottom of the tube first. The WBCs and platelets then settle out in a layer called the **buffy coat.** In Figure 10-3 the buffy coat can be seen between the packed RBCs on the bottom of the hematocrit tube and the liquid layer of plasma above. Normally about 45% of the blood volume consists of RBCs. For a patient with anemia, the percentage of RBCs drops, and for a

FIGURE 10-3

Hematocrit tubes showing normal blood, anemia, and polycythemia. Note the buffy coat located between the packed RBCs and the plasma. **A,** A normal percentage of RBCs. **B,** Anemia (a low percentage of RBCs). **C,** Polycythemia (a high percentage of RBCs).

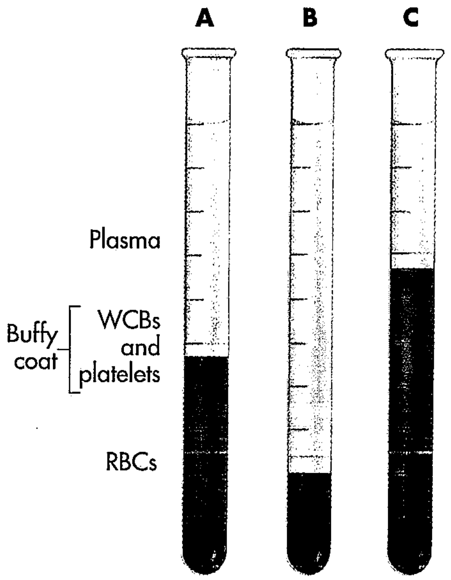
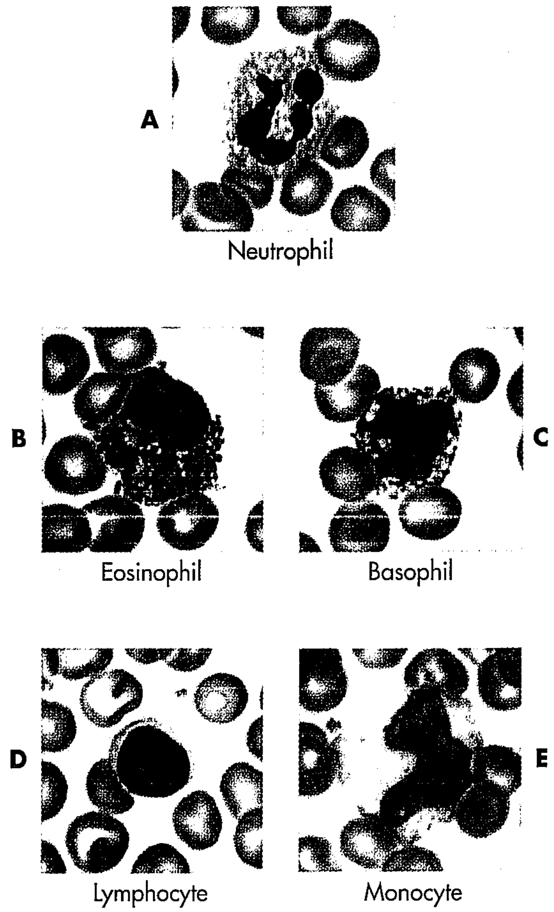


FIGURE 10-4

Leukocytes in human blood smears. Each light micrograph shows a different type of stained WBC surrounded by several smaller RBCs.



patient with polycythemia, it increases dramatically (see Figure 10-3).

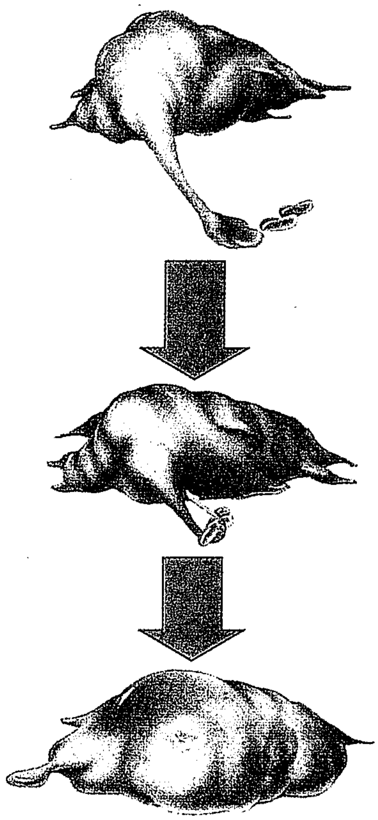
White Blood Cells

WBCs have a function that is just as vital as that of RBCs. They defend the body from microorganisms that have succeeded in invading the tissues or bloodstream. For example, **neutrophils** (NOO-tro-fils) (Figure 10-4, *A*) and **monocytes** (MON-o-sites) (Figure 10-4, *E*) engulf microbes. They actually take them into their own cell bodies and digest them in the process of **phagocytosis** (see p. 261), and the cells that carry on this process are called **phagocytes** (FAG-o-sites) (Figure 10-5). The neutrophils are the most numerous of the phagocytes.

WBCs of the type called **lymphocytes** (LIM-fo-sites) (Figure 10-4, *D*) also help protect us against infections, but they do it by a process different from phagocytosis. Lymphocytes function in the immune mechanism, the complex process that makes us immune to infectious diseases. The immune mechanism starts to operate, for example, when microbes invade the body. In some way, their presence stimulates lymphocytes to start multiplying and become active immune cells. Lymphocytes called *B-lymphocytes* begin to actively produce specific antibodies that inhibit the microbes. Other lymphocytes, called *T-lymphocytes,* may also become involved, directly attacking the microbes or aiding in the function of B-lymphocytes. Details of the immune system are discussed in Chapter 12.

FIGURE 10-5

Phagocytosis of bacteria by a white blood cell. Note how an extension of cytoplasm envelops the bacteria, which are drawn through the cell membrane and into the cytoplasm.



Eosinophils (ee-o-SIN-o-fils) (Figure 10-4, *B*) are granulocytic WBCs that help protect the body from parasites and the numerous irritants that cause allergies. They are also capable of phagocytosis. **Basophils** (BAY-so-fils) (Figure 10-4, *C*) also function in allergic reactions. These leukocytes, which are less abundant than other types, also secrete a number of important substances. For example, they secrete the potent chemical **heparin,** which helps prevent the clotting of blood as it flows through the blood vessels of the body.

The term **leukopenia** (loo-ko-PEE-nee-ah) refers to an abnormally low WBC count (less than 5000 WBCs/mm^3 of blood). A number of disease conditions may affect the immune system and decrease the amount of circulating WBCs. **Acquired immunodeficiency syndrome** or **AIDS,** which will be discussed in Chapter 12, is one example of a disease characterized by marked leukopenia. **Leukocytosis** (loo-ko-SYE-toe-sis) refers to an abnormally high WBC count (more than 10,000 WBCs/mm^3 of blood). It is a much more common problem than leukopenia and almost always accompanies infections. There is also a malignant disease, **leukemia** (loo-KEE-mee-ah), in which the number of WBCs increases tremendously. The buffy coat is thicker and more noticeable in the hematocrit of blood from patients with leukemia because of the elevated WBC counts. You may have heard of this disease as "blood cancer." As in all cancers, the extra cells do not function properly.

Platelets and Blood Clotting

Platelets, the third main type of formed element, play an essential part in blood clotting. Your life might someday be saved just because your blood can clot. A clot plugs up torn or cut vessels and stops bleeding that otherwise might prove fatal.

The story of how blood clots is the story of a chain of rapid-fire reactions. The first step in the chain is some kind of an injury to a blood vessel that makes a rough spot in its lining. (Normally the lining of blood vessels is extremely smooth.) Almost immediately, damaged tissue cells in the injured vessel wall release certain clotting factors into the plasma. These factors rapidly react with other factors already present in the plasma to form **prothrombin activator** (pro-THROM-bin AK-tiv-ayt-or). At the same time this is happening, platelets become "sticky" at the point of injury and soon accumulate near the opening in the broken blood vessel, forming a soft, temporary *platelet plug.* As the platelets accumulate, they release additional clotting factors, forming even more prothrombin activator. If the normal amount of blood calcium is present, prothrombin activator triggers the next step of clotting by converting **prothrombin** (a protein in normal blood) to **thrombin** (THROM-bin). In the last step, thrombin reacts with **fibrinogen** (fi-BRIN-o-jen) (a normal plasma protein) to change it to a fibrous gel called **fibrin.**

CLINICAL APPLICATION

Surgical Glue

A new product developed to stop bleeding and seal wounds in surgery was approved for sale in the United States in 1999. The product, called *Tisseel,* consists of purified fibrinogen and thrombin which, when mixed, form an effective and immediate glue-like seal at the point of hemorrhage.

Under the microscope, fibrin looks like a tangle of fine threads with RBCs caught in the tangle. Figure 10-6 illustrates the steps in the blood-clotting mechanism.

The clotting mechanism contains clues for ways to stop bleeding by speeding up blood clotting. For example, you might simply apply gauze to a bleeding surface. Its slight roughness would cause more platelets to stick together and release more clotting factors. These additional factors would then make the blood clot more quickly.

Physicians sometimes prescribe vitamin K before surgery to make sure that the patient's blood will clot fast enough to prevent hemorrhage. Vitamin K stimulates liver cells to increase the synthesis of prothrombin. More prothrombin in blood allows faster production of thrombin during clotting and thus faster clot formation.

Unfortunately, clots sometimes form in unbroken blood vessels of the heart, brain, lungs, or some other organ—a dreaded thing because clots may produce sudden death by shutting off the blood supply to a vital organ. When a clot stays in the place where it formed, it is called a **thrombus** (THROM-bus) and the condition is spoken of as **thrombosis** (throm-BO-sus). If part of the clot dislodges and circulates through the bloodstream, the dislodged part is then called an **embolus** (EM-bo-lus), and the condition is called an **embolism** (EM-bo-lizm). A number of drugs are now available to help dissolve clots. *Streptokinase* and *recombinant tissue plasminogen activator (t-PA)* are drugs frequently used in a variety of conditions, including treatment of clot-induced strokes, heart attacks, and other thrombus- and embolus-induced medical emergencies. Suppose that your doctor told you that you had a clot in one of your coronary arteries. Which diagnosis would he make—coronary thrombosis or coronary embolism—if he thought that the clot had formed originally in the coronary artery as a result of the accumulation of fatty material in the vessel wall? Physicians now have effective drugs that they can use to help prevent thrombosis and embolism.

CLINICAL APPLICATION

Anticoagulant Therapy

The anticoagulant Coumadin (warfarin sodium) acts by inhibiting the synthesis of prothrombin and other vitamin K–dependent clotting factors. By doing so, Coumadin decreases the ability of blood to clot and is effective in preventing repeat thromboses following a heart attack or the formation of clots after surgical replacement of heart valves. Heparin can also be used to prevent excessive blood clotting. Heparin inhibits the conversion of prothrombin to thrombin, thus preventing formation of a thrombus.

A laboratory test called the prothrombin time is used to regulate dosage of anticoagulant drugs. In this test thromboplastin and calcium are added simultaneously to a tube of the patient's plasma and a tube containing a normal control solution, and the time required for clot formation in both tubes is determined. A patient prothrombin time in excess of the standard control value (11 to 12.5 seconds) indicates the level of anticoagulant effect caused by the administered drug. This information allows the physician to adjust the dose required to maintain an appropriate level of anticoagulant effect.

BLOOD TYPES

ABO system

Blood types are identified by certain "self-antigens" located in the plasma membrane of the RBCs (Figure 10-7). An **antigen** (AN-ti-gen) is a substance that can activate the immune system to

FIGURE 10-6

Blood clotting. A, The extremely complex clotting mechanism can be distilled into three basic steps: **1,** release of clotting factors from both injured tissue cells and sticky platelets at the injury site; **2,** formation of thrombin; and **3,** formation of fibrin and trapping of red blood cells to form a clot. **B,** Red and white blood cells entrapped in a fibrin (yellow) mesh during clot formation. (WBCs are blue).

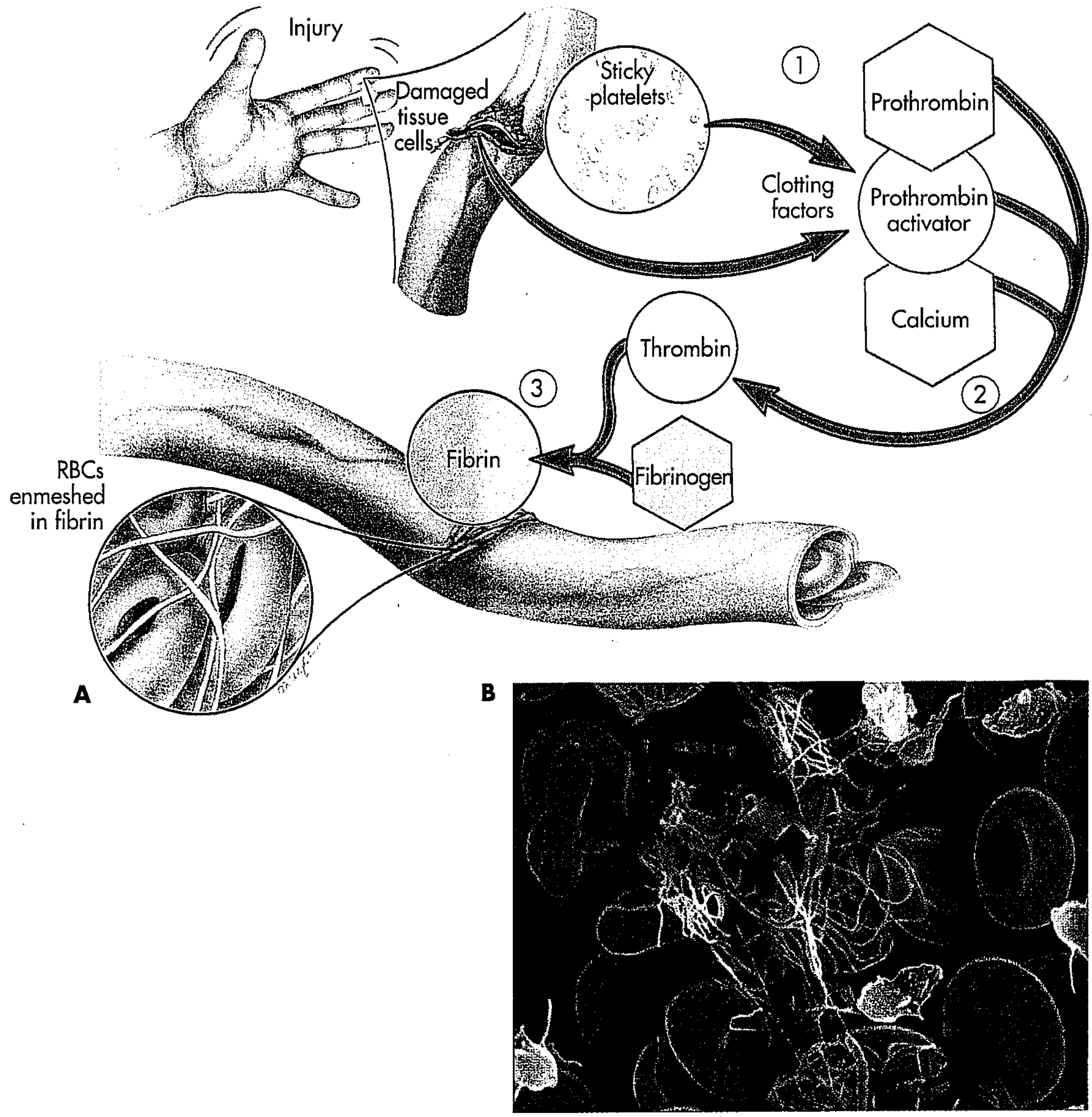
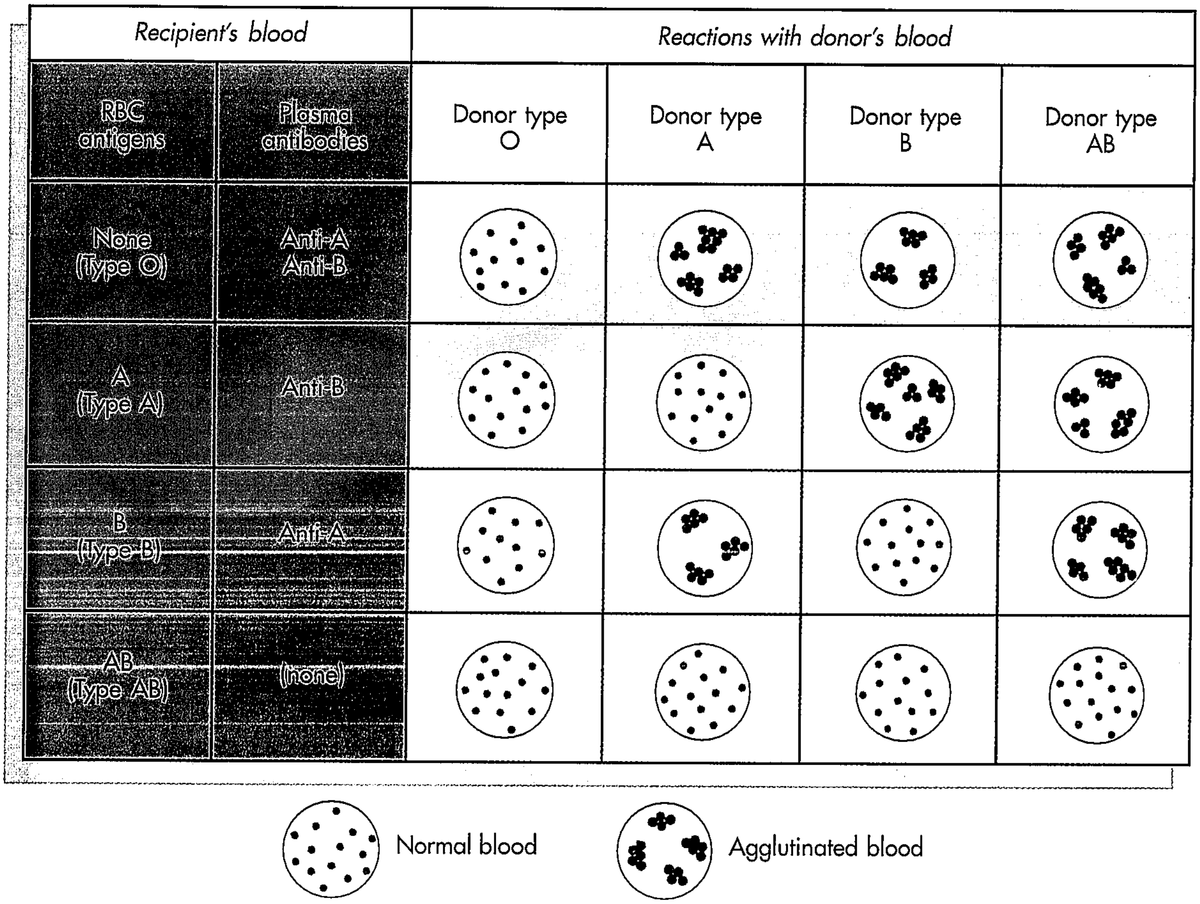


FIGURE 10-7

Results of different combinations of donor and recipient blood. The left columns show the recipient's blood characteristics and the top row shows the donor's blood type.



make certain responses, including the production of antibodies. Almost all substances that act as antigens and stimulate the immune system are foreign proteins called "non-self" antigens. That is, they are not the body's own natural self-antigens, which are found on the cell membranes of the body cells. Instead, they are generally proteins that have entered the body from the outside by infection, transfusion, or some other method.

The word *antibody* can be defined in terms of what causes its formation or in terms of how it functions. Defined the first way, an **antibody** (an-ti-bod-ee) is a substance made by the body in response to stimulation by an antigen. Defined according to its functions, an antibody is a substance that reacts with the antigen that stimulated its formation. Many antibodies react with their antigens to clump or **agglutinate** (ah-GLOO-tin-ate) them. In other words, they cause their antigens to stick together in little clusters.

Every person's blood is one of the following blood types in the ABO system of typing:

1. Type A
2. Type B
3. Type AB
4. Type O

Suppose that you have type A blood (as do about 41% of Americans). The letter *A* stands for a certain type of "self-antigen" (a protein) in the plasma membrane of your RBCs since birth. Because you were born with type A antigen, your body does not form antibodies to react with it. In other words, your blood plasma contains no anti-A antibodies. It does, however, contain anti-B antibodies. For some unknown reason, these antibodies are present naturally in type A blood plasma. The body did not form them in response to the presence of the B antigen. In summary, in type A blood the RBCs contain type A antigen and the plasma contains anti-B antibodies.

Similarly, in type B blood, the RBCs contain type B self-antigen, and the plasma contains anti-A antibodies. In type AB blood, as its name indicates, the RBCs contain both type A and type B self-antigens, and the plasma contains neither anti-A nor anti-B antibodies. The opposite is true of type O blood; its RBCs contain neither type A nor type B antigens, and its plasma contains both anti-A and anti-B antibodies.

Harmful effects or even death can result from a blood transfusion if the donor's RBCs become agglutinated by antibodies in the recipient's plasma. If a donor's RBCs do not contain any A or B antigen, they of course cannot be clumped by anti-A or anti-B antibodies. For this reason the type of blood that contains neither A nor B antigens—namely, type O blood—can be used in an emergency as donor blood without the danger of anti-A or anti-B antibodies clumping its RBCs. Type O blood has therefore been called **universal donor** blood. Similarly, blood type AB has been called **universal recipient** blood because it contains neither anti-A nor anti-B antibodies in its plasma. Therefore it does not clump any donor's RBCs containing A or B antigens. In a normal clinical setting, however, all blood intended for transfusion is matched carefully to the blood of the recipient for a variety of factors.

Figure 10-7 shows the results of different combinations of donor and recipient blood.

Rh System

You may be familiar with the term **Rh-positive** blood. It means that the RBCs of this type of blood contain an antigen called the Rh factor. This is the case for about 85% of the white and 88% of the African-American population in the United States. If, for example, a person has type AB, Rh-positive blood, his red blood cells contain type A antigen, type B antigen, and the Rh factor antigen. The term *Rh* is used because this important blood cell antigen was first discovered in the blood of Rhesus monkeys.

In **Rh-negative** blood the RBCs do not contain the Rh factor. Plasma never naturally contains anti-Rh antibodies. But if Rh-positive blood cells are introduced into an Rh-negative person's body, anti-Rh antibodies soon appear in the blood plasma. In this fact lies the danger for a baby born to an Rh-negative mother and an Rh-positive father. If the baby inherits the Rh-positive trait from his father, the Rh factor on his RBCs may stimulate the mother's body to form anti-Rh antibodies. Then, if she later carries another Rh-positive fetus, he may develop a disease called **erythroblastosis** (e-rith-ro-blas-TOE-sis) **fetalis** (fe-TAL-is), caused by the mother's Rh antibodies reacting with the baby's Rh-positive cells (Figure 10-8).

All Rh-negative mothers who carry an Rh-positive baby should be treated with a protein marketed as RhoGAM. RhoGAM stops the mother's body from forming anti-Rh antibodies and thus prevents the possibility of harm to the next Rh-positive baby.

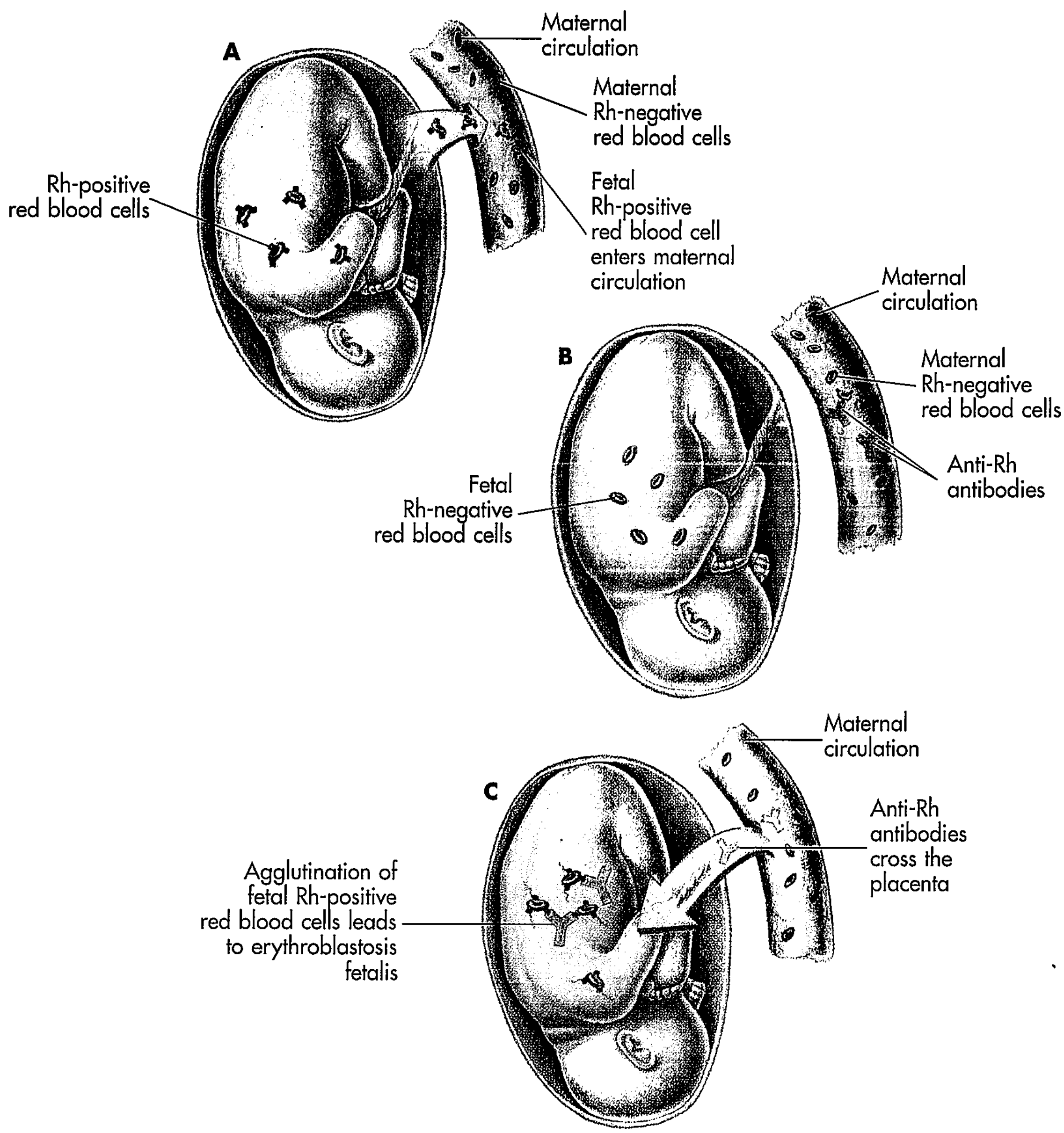
HEALTH & WELL-BEING

Blood Doping

A number of athletes have reportedly improved their performance by a practice called **blood doping.** A few weeks before an important event, an athlete has some blood drawn. The RBCs are separated and frozen. Just before competition, the RBCs are thawed and injected into the athlete. The increased hematocrit that results slightly improves the oxygen-carrying capacity of the blood, which theoretically improves performance. This method is judged to be an unfair and unwise practice in athletics.

FIGURE 10-8

Erythroblastosis fetalis. A, Rh-positive blood cells enter the mother's bloodstream during delivery of an Rh-positive baby. If not treated, the mother's body will produce anti-Rh antibodies. **B,** A later pregnancy involving an Rh-negative baby is normal because there are no Rh antigens in the baby's blood. **C,** A later pregnancy involving an Rh-positive baby may result in erythroblastosis fetalis. Anti-Rh antibodies enter the baby's blood supply and cause agglutination of RBCs with the Rh antigen.



RESEARCH, ISSUES, & TRENDS

Artificial Blood

One of the primary benefits of blood transfusion is an increase in oxygen-carrying capacity caused by increases in hemoglobin levels. However, blood is a complex liquid tissue, and transfusion always carries with it certain risks. For years medical researchers have worked to develop "artificial blood" or a "blood substitute" that could duplicate one or more blood functions without subjecting a recipient to transfusion reactions, infections, or other health dangers.

A new "artificial blood" product currently in the final stages of development is called **PolyHeme.** It is produced from chemically treated hemoglobin obtained from outdated human blood. The manufacturing process used to produce PolyHeme results in an oxygen-carrying blood substitute that can be transfused into any blood-type recipient without "typing" and is free of blood-borne viruses such as HIV and hepatitis C. Another "second-generation" artificial blood product is also under development. If efforts are successful, it will be produced using recombinant hemoglobin technology. By using genetic engineering techniques, production of this type of product would not require the use of existing human blood or blood products. When available, artificial blood substitutes will be viewed as exciting and welcome developments in transfusion medicine.

Outline Summary

BLOOD COMPOSITION (Table 10-1)

A Blood plasma
  1 Definition—blood minus its cells
  2 Composition—water containing many dissolved substances (for example, foods, salts, and hormones)
  3 Amount of blood—varies with size and sex; 4 to 6 L about average; about 7% to 9% of body weight

B Formed elements
  1 Kinds
    a RBCs (erythrocytes)
    b WBCs (leukocytes)
      (1) Granular leukocytes—neutrophils, eosinophils, and basophils
      (2) Nongranular leukocytes—lymphocytes and monocytes
    c Platelets or thrombocytes
  2 Numbers
    a RBCs—41/2 to 5 million per mm^3 of blood
    b WBCs—5000 to 10,000 per mm^3 of blood
    c Platelets—300,000 per mm^3 of blood
  3 Formation—red bone marrow (myeloid tissue) forms all blood cells except some lymphocytes and monocytes, which are formed by lymphatic tissue in the lymph nodes, thymus, and spleen

C RBCs
  1 Structure—disk-shaped, without nuclei
  2 Functions—transport oxygen and carbon dioxide
  3 Anemia—inability of blood to carry adequate oxygen to tissues; caused, for example, by:
    a Inadequate RBC numbers
    b Deficiency of hemoglobin
    c Pernicious anemia—deficiency of vitamin B_{12}
  4 Hematocrit—medical test in which a centrifuge is used to separate whole blood into formed elements and liquid fraction (Figure 10-3)
    a Buffy coat is WBC and platelet fraction
    b Normal RBC level is about 45%
    c Polycythemia—abnormally high RBC count

D WBCs
  1 General function—defense
  2 Neutrophils and monocytes carry out phagocytosis
  3 Lymphocytes produce antibodies (B-lymphocytes) or directly attack foreign cells (T-lymphocytes)
  4 Eosinophils protect against parasitic irritants that cause allergies
  5 Basophils produce heparin, which inhibits clotting
  6 Clinical conditions related to blood:
    a Leukopenia—abnormally low WBC count
    b Leukocytosis—abnormally high WBC count
    c Leukemia—cancer: elevated WBC count; cells do not function properly

E Platelets and blood clotting (Figure 10-6)
  1 Platelets play an essential role in blood clotting
  2 Blot clot formation
    a Clotting factors released at the injury site produce prothrombin activator
    b Prothrombin activator and calcium convert prothrombin to thrombin
    c Thrombin triggers formation of fibrin, which traps RBC to form a clot

BLOOD TYPES

A ABO system (Figure 10-7)
  1 Type A blood—type A self-antigens in RBCs; anti-B type antibodies in plasma
  2 Type B blood—type B self-antigens in RBCs; anti-A type antibodies in plasma
  3 Type AB blood—type A and type B self-antigens in RBCs; no anti-A or anti-B antibodies in plasma
  4 Type O blood—no type A or type B self-antigens in RBCs; both anti-A and anti-B antibodies in plasma

B Rh system
  1 Rh-positive blood—Rh factor antigen present in RBCs
  2 Rh-negative blood—no Rh factor present in RBCs; no anti-Rh antibodies present natu-

Outline Summary—cont'd

rally in plasma; anti-Rh antibodies, however, appear in the plasma of Rh-negative persons if Rh-positive RBCs have been introduced into their bodies

3 Erythroblastosis fetalis—may occur when Rh-negative mother carries a second Rh-positive fetus; caused by mother's Rh antibodies reacting with baby's Rh-positive cells

New Words

anemia	erythrocyte	leukopenia	polycythemia
antibodies	fibrin	lymphocyte	prothrombin
antigens	fibrinogen	monocyte	prothrombin activator
basophil	hematocrit	neutrophil	serum
buffy coat	hemoglobin	oxyhemoglobin	thrombin
embolism	heparin	pernicious anemia	thrombocyte
embolus	leukemia	phagocyte	thrombosis
eosinophil	leukocyte	plasma	thrombus
erythroblastosis fetalis	leukocytosis	plasma protein	

Review Questions

1. Name several substances found in blood plasma.
2. Explain the function of albumins, globulins and fibrinogen.
3. What is the difference between serum and plasma?
4. What two types of connective tissue form blood cells? Where are they found and what do each of them form?
5. Describe the structure of a red blood cell. What advantage does the unique shape of the red blood have?
6. What is anemia? Give two possible causes of anemia.
7. What is the buffy coat?
8. Explain the function of neutrophils and monocytes.
9. Explain the function of lymphocytes.
10. Explain the function of eosinophils and basophils.
11. Explain fully the process of blood clot formation.
12. Differentiate between a thrombus and an embolus.
13. Explain how type A blood differs from type B blood.
14. Explain the cause of erythroblastosis fetalis.

Critical Thinking

15. Explain how heparin inhibits blood clot formation.
16. Differentiate between the process of blood clot formation and the process of blood agglutination.
17. Why is the first Rh-positive baby born to an Rh-negative mother usually unaffected?

Chapter Test

1. The liquid part of the blood is called ________.
2. Three important plasma proteins are ________, ________, and ________.
3. Blood plasma without the clotting factors is called ________.
4. The three types of formed elements in the blood are ________, ________, and ________.
5. The two types of connective tissue that make blood cells are ________ and ________.
6. The red pigment in red blood cells that carries oxygen is called ________.
7. The term ________ is used to describe a number of disease conditions caused by the inability of red blood cells to carry a sufficient amount of oxygen.
8. If the body produces an excess of red blood cells, the condition is called ________.
9. These white blood cells are the most numerous of the phagocytes: ________.
10. These white blood cells produce antibodies to fight microbes: ________.
11. Prothrombin activator and the mineral ________ in the blood convert prothrombin to thrombin in blood clot formation.
12. Thrombin converts the inactive plasma protein ________ into a fibrous gel called ________.
13. Vitamin ________ stimulates the liver to increase the synthesis of prothrombin.
14. A ________ is an unneeded blood clot that stays in the place where it was formed.
15. If part of a blood clot is dislodged and circulates through the bloodstream, it is called an ________.
16. ________ is a foreign substance that can cause the body to produce an antibody.
17. A person with type AB blood has ________ antigens on the blood cell and ________ antibodies in the plasma.
18. A person with type B blood has ________ antigens on the blood cell and ________ antibodies in the plasma.
19. Type ________ blood is considered the universal donor.
20. Type ________ blood is considered the universal recipient.
21. A condition called ________ can develop if an Rh-negative mother produces antibodies against an Rh-positive fetus.

Study Tips

Blood consists of a liquid portion, the plasma, and formed elements: the red blood cells, white blood cells, and platelets. The function of the blood is to carry substances from one part of the body to another. Many transported materials are dissolved in the plasma, so the composition of the plasma varies based on what is going on in the body. Because of its function, the blood plays an important role in a number of other systems such as the respiratory, digestive, urinary, and immune systems. The material in this chapter will show up again in later chapters. Flash cards will help in learning the names and functions of the blood cells. The process of blood clot formation is important and it is necessary that you get the sequence of events correct. The prefix *pro-* and the suffix *-ogen* indicate an inactive substance. When you see a term with either of these word parts, look for what activates the substance. In studying the ABO blood typing system, the things you will need to remember are what antigens are on the red blood cell and

Study Tips—cont'd

what antibodies are in the plasma. The antigens give the blood type its name; type A blood has A self-antigens. The antibodies are the opposite of the type. Type A blood has anti-B antibodies. Type O has no self-antigens and both antibodies, and type AB has both self-antigens and no antibodies.

In your study group, go over the flash cards with the function of the blood cells. Discuss the process of blood clot formation. Go through the antigens and antibodies for the various blood types. Go over the questions at the end of the chapter and discuss possible test questions.

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The Circulatory System