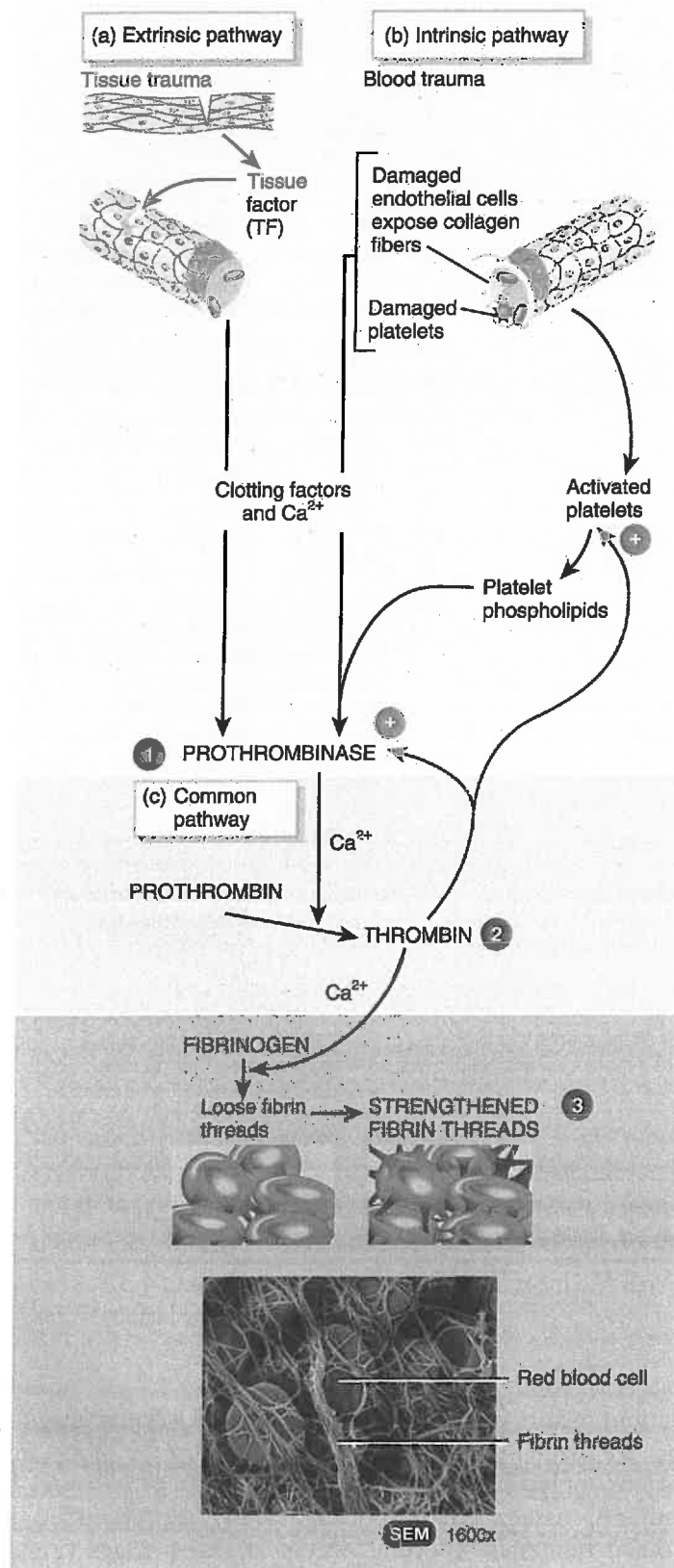


Figure 14.5 Blood clotting.

During blood clotting, the clotting factors activate each other, resulting in a cascade of reactions that includes positive feedback cycles.



- 1 **Prothrombinase** is formed.
- 2 Prothrombinase converts **prothrombin** (a plasma protein formed by the liver with the help of vitamin K) into the enzyme **thrombin**.
- 3 Thrombin converts soluble **fibrinogen** (another plasma protein formed by the liver) into insoluble fibrin. Fibrin forms the threads of the clot. (Cigarette smoke contains substances that interfere with fibrin formation.)

Prothrombinase can be formed in two ways, by either the extrinsic or the intrinsic pathway of blood clotting (Figure 14.5). The **extrinsic pathway** of blood clotting occurs rapidly, within seconds. It is so-named because damaged tissue cells release a tissue protein called **tissue factor (TF)** into the blood from *outside* (extrinsic to) blood vessels (Figure 14.5a). Following several additional reactions that require calcium ions ( $Ca^{2+}$ ) and several clotting factors, tissue factor is eventually converted into prothrombinase. This completes the extrinsic pathway.

The **intrinsic pathway** of blood clotting (Figure 14.5b) is more complex than the extrinsic pathway, and it occurs more slowly, usually requiring several minutes. The intrinsic pathway is so-named because its activators are either in direct contact with blood or contained *within* (intrinsic to) the blood. If endothelial cells lining the blood vessels become roughened or damaged, blood can come in contact with collagen fibers in the adjacent connective tissue. Such contact activates clotting factors. In addition, trauma to endothelial cells activates platelets, causing them to release phospholipids that can also activate certain clotting factors. After several additional reactions that require  $Ca^{2+}$  and several clotting factors, prothrombinase is formed. Once formed, thrombin activates more platelets, resulting in the release of more platelet phospholipids, an example of a positive feedback cycle.

Clot formation occurs locally; it does not extend beyond the wound site into the general circulation. One reason for this is that fibrin has the ability to absorb and inactivate up to nearly 90% of the thrombin formed from prothrombin. This helps stop the spread of thrombin into the blood and thus inhibits clotting except at the wound.

### Clot Retraction and Blood Vessel Repair

Once a clot is formed, it plugs the ruptured area of the blood vessel and thus stops blood loss. **Clot retraction** is the consolidation or tightening of the fibrin clot. The fibrin threads attached to the damaged surfaces of the blood vessel gradually contract as platelets pull on them. As the clot retracts, it pulls the edges of the damaged vessel closer together, decreasing the risk of further damage. Permanent repair of the blood vessel can then take place. In time, fibroblasts form connective tissue in the ruptured area, and new endothelial cells repair the vessel lining.

? What is the outcome of stage 1 of clotting?

## Hemostatic Control Mechanisms

Many times a day little clots start to form, often at a site of minor roughness inside a blood vessel. Usually, small, inappropriate clots dissolve in a process called **fibrinolysis** (fi'-bri-NOL-i-sis). When a clot is formed, an inactive plasma enzyme called **plasminogen** is incorporated into the clot. Both body tissues and blood contain substances that can activate plasminogen to **plasmin**, an active plasma enzyme. Once plasmin is formed, it can dissolve the clot by digesting fibrin threads. Plasmin also dissolves clots at sites of damage once the damage is repaired.

Patients who are at increased risk of forming blood clots may receive an **anticoagulant drug**, a substance that delays, suppresses, or prevents blood clotting. Examples are heparin or warfarin. *Heparin*, an anticoagulant that is produced by mast cells and basophils, inhibits the conversion of prothrombin to thrombin, thereby preventing blood clot formation. Heparin extracted from animal tissues is often used to prevent clotting during hemodialysis and after open heart surgery. *Coumadin*® (*warfarin sodium*) acts as an antagonist to vitamin K and thus blocks synthesis of four clotting factors. To prevent clotting in donated blood, blood banks and laboratories often add a substance that removes  $\text{Ca}^{2+}$ , for example, CPD (citrate phosphate dextrose).

## Clotting in Blood Vessels

Despite fibrinolysis and the action of anticoagulants, blood clots sometimes form within blood vessels. The endothelial surfaces of a blood vessel may be roughened as a result of **atherosclerosis** (accumulation of fatty substances on arterial walls), trauma, or infection. These conditions also make the platelets that are attracted to the rough spots more sticky. Clots may also form in blood vessels when blood flows too slowly, allowing clotting factors to accumulate in high enough concentrations to initiate a clot.

Clotting in an unbroken blood vessel is called **thrombosis** (*thromb*- = clot; *-osis* = a condition of). The clot itself, called a **thrombus**, may dissolve spontaneously. If it remains intact, however, the thrombus may become dislodged and be swept away in the blood. A blood clot, bubble of air, fat from broken bones, or a piece of debris transported by the bloodstream is called an **embolus** (*em*- = in; *-bolus* = a mass; plural is *emboli*). Because emboli often form in veins, where blood flow is slower, the most common site for the embolus to become lodged is in the lungs, a condition called **pulmonary embolism**. Massive emboli in the lungs may result in right ventricular failure and death in a few minutes or hours. An embolus that breaks away from an arterial wall may lodge in a smaller-diameter artery downstream. If it blocks blood flow

to the brain, kidney, or heart, the embolus can cause a stroke, kidney failure, or heart attack, respectively.

In patients with heart and blood vessel disease, the events of hemostasis may occur even without external injury to a blood vessel. At low doses, **aspirin** inhibits vasoconstriction and platelet aggregation. It also reduces the chance of thrombus formation. Due to these effects, aspirin reduces the risk of transient ischemic attacks (TIA), strokes, myocardial infarction, and blockage of peripheral arteries.

**Thrombolytic agents** are chemical substances that are injected into the body to dissolve blood clots that have already formed to restore circulation. They either directly or indirectly activate plasminogen. The first thrombolytic agent, approved in 1982 for dissolving clots in the coronary arteries of the heart, was **streptokinase**, which is produced by streptococcal bacteria. A genetically engineered version of human **tissue plasminogen activator (tPA)** is now used to treat both heart attacks and brain attacks (strokes) that are caused by blood clots.

### ■ CHECKPOINT

7. What is hemostasis?
8. How do vascular spasm and platelet plug formation occur?
9. What is fibrinolysis? Why does blood rarely remain clotted inside blood vessels?

## BLOOD GROUPS AND BLOOD TYPES

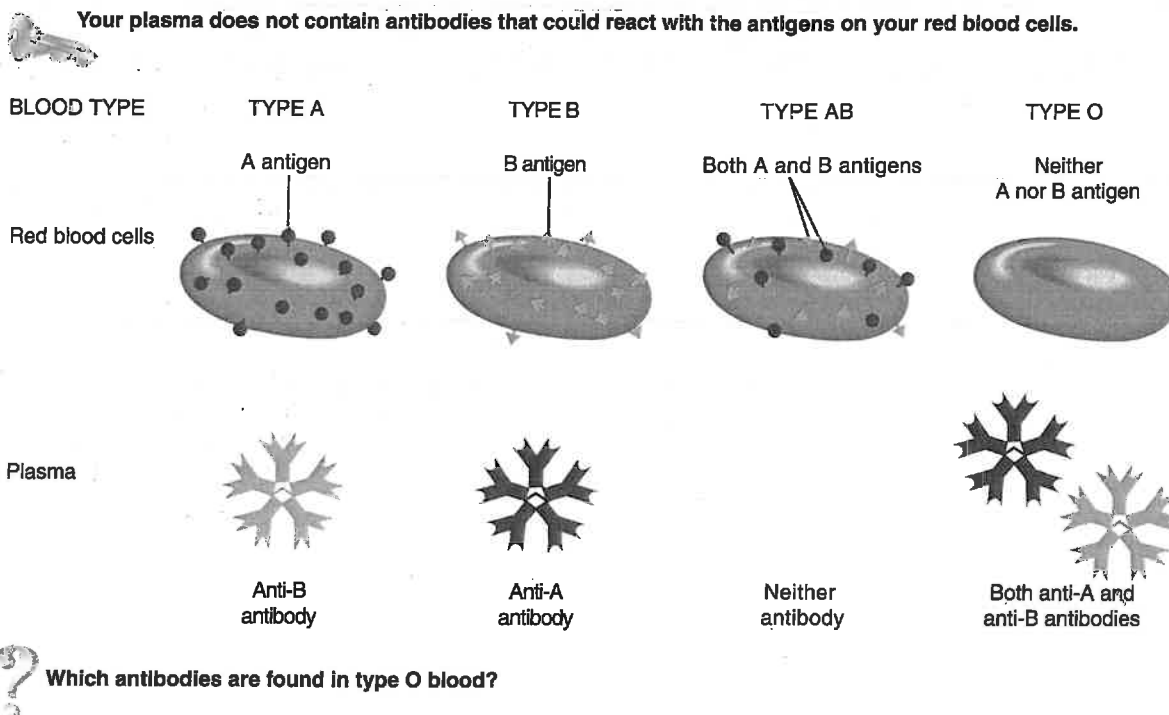
**OBJECTIVE • Describe the ABO and Rh blood groups.**

The surfaces of red blood cells contain a genetically determined assortment of **antigens** composed of glycolipids and glycoproteins called **agglutinogens** (ag'-loo-TIN-ō-jenz). Based on the presence or absence of various antigens, blood is categorized into different **blood groups**. Within a given blood group there may be two or more different **blood types**. There are at least 24 blood groups and more than 100 antigens that can be detected on the surface of red blood cells. Here we discuss two major blood groups: ABO and Rh.

### ABO Blood Group

The **ABO blood group** is based on two antigens called **A** and **B** (Figure 14.6). People whose RBCs display only antigen A have type A blood. Those who have only antigen B are type B. Individuals who have both A and B antigens are type AB, and those who have neither antigen A nor B are type O. In about 80% of the population, soluble antigens of the ABO type appear in saliva and other body fluids, in which case blood type can be identified from a sample of saliva. The incidence of ABO blood types varies among different population groups, as indicated in Table 14.3.

Figure 14.6 Antigens and antibodies involved in the ABO blood grouping system.



In addition to antigens on RBCs, blood plasma usually contains **antibodies** or **agglutinins** (a-GLOO-ti-nins) that react with the A or B antigens if the two are mixed. These are the **anti-A antibody**, which reacts with antigen A, and the **anti-B antibody**, which reacts with antigen B. The antibodies present in each of the four ABO blood types are also shown in Figure 14.6. You do not have antibodies that react with your own antigens, but you do have antibodies for any antigens that your RBCs lack. For example, if you have type A blood, it means that you have A antigens on the surfaces of your RBCs, but anti-B antibodies in your blood plasma. If you had anti-A antibodies in your blood plasma, they would attack your RBCs.

## Rh Blood Group

The **Rh blood group** is so named because the Rh antigen was first found in the blood of the rhesus monkey. People whose

RBCs have the Rh antigen are designated Rh<sup>+</sup> (Rh positive); those who lack the Rh antigen are designated Rh<sup>-</sup> (Rh negative). The percentages of Rh<sup>+</sup> and Rh<sup>-</sup> individuals in various populations are shown in Table 14.3. Under normal circumstances, plasma does not contain anti-Rh antibodies. If an Rh<sup>-</sup> person receives an Rh<sup>+</sup> blood transfusion, however, the immune system starts to make anti-Rh antibodies that do remain in the blood.

## Transfusions

Despite the differences in RBC antigens, blood is the most easily shared of human tissues, saving many thousands of lives every year through transfusions. A **transfusion** (trans-FŪ-zhun) is the transfer of whole blood or blood components (red blood cells only or plasma only) into the bloodstream. Most often a transfusion is given to alleviate anemia or when blood volume is low, for example, after a severe hemorrhage.

In an incompatible blood transfusion, antibodies in the recipient's plasma bind to the antigens on the donated RBCs. When these antigen-antibody complexes form, they cause hemolysis and release hemoglobin into the plasma. Consider what happens if a person with type A blood receives a transfusion of type B blood. In this situation, two things can happen. First, the anti-B antibodies in the recipient's plasma can bind to the B antigens on the donor's RBCs, causing hemolysis. Second, the anti-A antibodies in the donor's plasma can bind to the A antigens on the recipient's RBCs. The second reaction is usually not serious because the donor's anti-A

Table 14.3 Blood Types in the United States

Population Group	Blood Type (percentage)				
	O	A	B	AB	Rh <sup>+</sup>
European American	45	40	11	4	85
African American	49	27	20	4	95
Korean	32	28	30	10	100
Japanese	31	38	21	10	100
Chinese	42	27	25	6	100
Native American	79	16	4	1	100

## Lifestyle and Blood Circulation— Let It Flow

**M**any people fear cholesterol, an evil substance that silently accumulates within artery walls, year after year, until it eventually kills its victim by shutting off blood flow to an important organ such as the heart or brain. But cholesterol is not the only villain in this atherosclerosis melodrama. Cholesterol contributes to the formation of arterial plaques, but the antagonist delivering the final blow is often a blood clot that forms in a blood vessel and subsequently blocks a narrowed artery, cutting off circulation to the tissues downstream. Fortunately, many of the things you can do to keep your arteries healthy also reduce your risk of blood clots.

### Quit Smoking

If you need yet another reason to quit smoking, here it is: Smoking increases blood fibrinogen levels. Increased fibrinogen levels are associated with increased clotting risk. High fibrinogen levels increase platelet aggregation and fibrin deposition, contributing to both clotting and plaque deposition.

### Exercise Regularly

Regular physical activity increases plasma volume. An increase in plasma volume means that the blood is more dilute, or "thinner," with a lower percentage of red blood cells and less fibrinogen, and consequently a reduced risk of blood clotting. Several studies have shown that vigorous exercise also reduces platelet stickiness and enhances fibrinolytic activity. These effects may help to explain why active people are at lower risk for heart disease and stroke. A sedentary lifestyle, by contrast, leads to increased clotting risk: Blood thickens as plasma volume decreases. Sedentary people have stickier platelets, which together with higher levels of fibrinogen are more likely to form blood clots.

### Cope Effectively with Stress

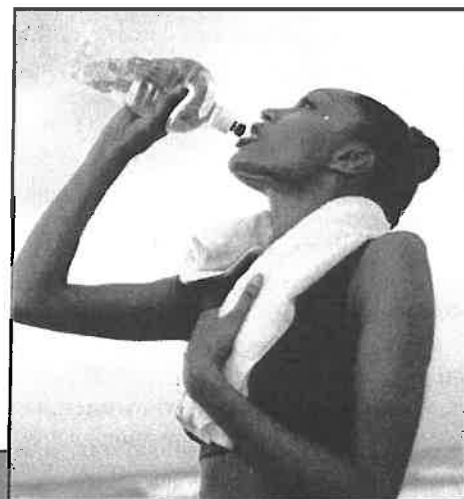
Prolonged mental stress impairs fibrinolysis by decreasing the activity of tissue plasminogen activator (tPA), which helps break down fibrinogen.

### Eat a Heart-healthy Diet

People with high blood cholesterol levels exhibit disturbances in coagulation,

fibrinolysis, and platelet behavior. Lowering blood lipid levels by diet or drug therapy seems to reverse these disturbances and may be one way that a heart-healthy lifestyle reduces heart disease risk. An interesting study from Denmark found that volunteers who stuck to a low-fat, high-fiber diet showed increased fibrinolytic activity and thus a reduced risk of blood clot formation.

A moderate alcohol intake (one to two drinks per day) has been associated with a reduced heart disease risk. This risk reduction may be due in part to the increase in tPA level observed in moderate drinkers.



### ► THINK IT OVER . . .

- Why are people at risk for clot formation told to avoid sitting for extended periods of time, such as on long airplane flights or car rides?

antibodies become so diluted in the recipient's plasma that they do not cause any significant hemolysis of the recipient's RBCs.

People with type AB blood do not have any anti-A or anti-B antibodies in their plasma. They are sometimes called "universal recipients" because theoretically they can receive blood from donors of all four ABO blood types. People with type O blood have neither A nor B antigens on their RBCs and are sometimes called "universal donors." Theoretically, because there are no antigens on their RBCs for antibodies to attack, they can donate blood to all four ABO blood types. Type O persons requiring blood may receive only type O blood, as they have antibodies to both A and B antigens in their plasma. In practice, use of the terms *universal recipient* and *universal donor* is misleading and dangerous. Blood

contains antigens and antibodies other than those associated with the ABO system, and they can cause transfusion problems. Thus, blood should always be carefully matched before transfusion.

### ■ CHECKPOINT

10. What is the basis for distinguishing the various blood groups?
11. What precautions must be taken before giving a blood transfusion?

. . .

We will next direct our attention to the heart, the second major component of the cardiovascular system.



## COMMON DISORDERS

### Anemia

**Anemia** is a condition in which the oxygen-carrying capacity of blood is reduced. Many types of anemia exist; all are characterized by reduced numbers of RBCs or a decreased amount of hemoglobin in the blood. The person feels fatigued and is intolerant of cold, both of which are related to lack of oxygen needed for ATP and heat production. Also, the skin appears pale, due to the low content of red-colored hemoglobin circulating in skin blood vessels. Among the most important types of anemia are the following:

- **Iron-deficiency anemia**, the most prevalent kind of anemia, is caused by inadequate absorption of iron, excessive loss of iron, or insufficient intake of iron. Women are at greater risk for iron-deficiency anemia due to monthly menstrual blood loss.
- **Pernicious anemia** is caused by insufficient hemopoiesis resulting from an inability of the stomach to produce intrinsic factor (needed for absorption of dietary vitamin B<sub>12</sub>).
- **Hemorrhagic anemia** is due to an excessive loss of RBCs through bleeding resulting from large wounds, stomach ulcers, or especially heavy menstruation.
- In **hemolytic anemia**, RBC plasma membranes rupture prematurely. The condition may result from inherited defects or from outside agents such as parasites, toxins, or antibodies from incompatible transfused blood.
- **Thalassemia** (thal'-a-SĒ-mē-a) is a group of hereditary hemolytic anemias in which there is an abnormality in one or more of the four polypeptide chains of the hemoglobin molecule. Thalassemia occurs primarily in populations from countries bordering the Mediterranean Sea.
- **Aplastic anemia** results from destruction of the red bone marrow caused by toxins, gamma radiation, and certain medications that inhibit enzymes needed for hemopoiesis.

### Sickle Cell Disease

The RBCs of a person with **sickle cell disease (SCD)** contain Hb-S, an abnormal kind of hemoglobin. When Hb-S gives up oxygen to the interstitial fluid, it forms long, stiff, rodlike structures that bend the erythrocyte into a sickle shape. The sickled cells rupture easily. Even though the loss of RBCs stimulates erythropoiesis, it cannot keep pace with hemolysis; hemolytic anemia is the result. Prolonged oxygen reduction may eventually cause extensive tissue damage.

### Hemophilia

**Hemophilia** (hē-mō-FIL-ē-a; -*philia* = loving) is an inherited deficiency of clotting in which bleeding may occur spontaneously or

after only minor trauma. Different types of hemophilia are due to deficiencies of different blood clotting factors and exhibit varying degrees of severity. Hemophilia is characterized by spontaneous or traumatic subcutaneous and intramuscular hemorrhaging, nosebleeds, blood in the urine, and hemorrhages in joints that produce pain and tissue damage. Treatment involves transfusions of fresh plasma or concentrates of the deficient clotting factor to relieve the tendency to bleed.

### Hemolytic Disease of the Newborn

**Hemolytic disease of the newborn (HDN)** is a problem that results from Rh incompatibility between a mother and her fetus. Normally, no direct contact occurs between maternal and fetal blood while a woman is pregnant. However, if a small amount of Rh<sup>+</sup> blood leaks from the fetus through the placenta into the bloodstream of an Rh<sup>-</sup> mother, her body starts to make anti-Rh antibodies. Because the greatest possibility of fetal blood transfer occurs at delivery, the first-born baby typically is not affected. If the mother becomes pregnant again, however, her anti-Rh antibodies, made after delivery of the first baby, can cross the placenta and enter the bloodstream of the fetus. If the fetus is Rh<sup>-</sup>, there is no problem, because Rh<sup>-</sup> blood does not have the Rh antigen. If, however, the fetus is Rh<sup>+</sup>, life-threatening **hemolysis** (rupture of RBCs) is likely to occur in the fetal blood. By contrast, ABO incompatibility between a mother and her fetus rarely causes problems because the anti-A and anti-B antibodies do not cross the placenta.

HDN is prevented by giving all Rh<sup>-</sup> women an injection of anti-Rh antibodies called anti-Rh gamma globulin (RhoGAM) soon after every delivery, miscarriage, or abortion. These antibodies destroy any Rh antigens that are present so the mother doesn't produce her own antibodies to them. In the case of an Rh<sup>+</sup> mother, there are no complications, because she cannot make anti-Rh antibodies.

### Leukemia

The term **leukemia** (loo-KĒ-mē-a; *leuko-* = white) refers to a group of red bone marrow cancers in which abnormal white blood cells multiply uncontrollably. The accumulation of the cancerous white blood cells in red bone marrow interferes with the production of red blood cells, white blood cells, and platelets. As a result, the oxygen-carrying capacity of the blood is reduced, an individual is more susceptible to infection, and blood clotting is abnormal. In most leukemias, the cancerous white blood cells spread to the lymph nodes, liver, and spleen, causing them to enlarge. All leukemias produce the usual symptoms of anemia (fatigue, intolerance to cold, and pale skin). In addition, weight loss, fever, night sweats, excessive bleeding, and recurrent infections may also occur.

## MEDICAL TERMINOLOGY AND CONDITIONS

**Autologous preoperative transfusion** (aw-TOL-o-gus trans-FŪ-zhun; *auto-* = self) Donating one's own blood in preparation for surgery; can be done up to six weeks before elective surgery. Also called *predonation*.

**Blood bank** A facility that collects and stores a supply of blood for future use by the donor or others. Because blood banks have now assumed additional and diverse functions (immunohematology reference work, continuing medical education, bone and tissue storage, and clinical consultation), they are more appropriately referred to as *centers of transfusion medicine*.

**Cyanosis** (sī-a-NŌ-sis; *cyano-* = blue) Slightly bluish/dark-purple skin discoloration, most easily seen in the nail beds and mucous membranes, due to an increased quantity of reduced hemoglobin (hemoglobin not combined with oxygen) in systemic blood.

**Hemochromatosis** (hē'-mō-krō'-ma-TŌ-sis; *chroma* = color) Disorder of iron metabolism characterized by excess deposits of iron in tissues (especially the liver, heart, pituitary gland, gonads, and pancreas) that result in discoloration (bronzing) of

the skin, cirrhosis, diabetes mellitus, and bone and joint abnormalities.

**Jaundice** (*jaund-* = yellow) An abnormal yellowish discoloration of the sclerae of the eyes, skin, and mucous membranes due to excess bilirubin (yellow-orange pigment) in the blood that is produced when the heme pigment in aged red blood cells is broken down.

**Phlebotomist** (fle-BOT-ō-mist; *phlebo-* = vein; *-tom* = cut) A technician who specializes in withdrawing blood.

**Polycythemia** (pol'-ē-sī-THĒ-mē-a) An abnormal increase in the number of red blood cells in which hematocrit is above 55%, the upper limit of normal.

**Septicemia** (sep'-ti-SĒ-mē-a; *septic-* = decay; *-emia* = condition of blood) An accumulation of toxins or disease-causing bacteria in the blood. Also called *blood poisoning*.

**Thrombocytopenia** (throm'-bō-sī'-tō-PĒ-nē-a; *-penia* = poverty) Very low platelet count that results in a tendency to bleed from capillaries.

## STUDY OUTLINE

### Functions of Blood (p. 346)

1. Blood transports oxygen, carbon dioxide, nutrients, wastes, and hormones.
2. It helps to regulate pH, body temperature, and water content of cells.
3. It prevents blood loss through clotting and combats microbes and toxins through the action of certain phagocytic white blood cells or specialized plasma proteins.

### Components of Whole Blood (p. 346)

1. Physical characteristics of whole blood include a viscosity greater than that of water, a temperature of 38°C (100.4°F), and a pH range between 7.35 and 7.45.
2. Blood constitutes about 8% of body weight in an adult.
3. Blood consists of 55% plasma and 45% formed elements.
4. The formed elements in blood include red blood cells (erythrocytes), white blood cells (leukocytes), and platelets. Hematocrit is the percentage of red blood cells in whole blood.
5. Plasma contains 91.5% water, 7% proteins, and 1.5% solutes other than proteins.
6. Principal solutes include proteins (albumins, globulins, fibrinogen), nutrients, hormones, respiratory gases, electrolytes, and waste products.
7. Hemopoiesis, the formation of blood cells from pluripotent stem cells, occurs in red bone marrow.
8. Red blood cells (RBCs) are biconcave discs without nuclei that contain hemoglobin.
9. The function of the hemoglobin in red blood cells is to transport oxygen.

10. Red blood cells live about 120 days. A healthy male has about 5.4 million RBCs/ $\mu$ L of blood and a healthy female has about 4.8 million RBCs/ $\mu$ L.
11. After phagocytosis of aged red blood cells by macrophages, hemoglobin is recycled.
12. RBC formation, called erythropoiesis, occurs in adult red bone marrow. It is stimulated by hypoxia, which stimulates release of erythropoietin by the kidneys.
13. A reticulocyte count is a diagnostic test that indicates the rate of erythropoiesis.
14. White blood cells (WBCs) are nucleated cells. The two principal types are granular leukocytes (neutrophils, eosinophils, basophils) and agranular leukocytes (lymphocytes and monocytes).
15. The general function of WBCs is to combat inflammation and infection. Neutrophils and macrophages (which develop from monocytes) do so through phagocytosis.
16. Eosinophils combat inflammation in allergic reactions, phagocytize antigen-antibody complexes, and combat parasitic worms; basophils liberate heparin, histamine, and serotonin in allergic reactions that intensify the inflammatory response.
17. B cells (lymphocytes) are effective against bacteria and other toxins. T cells (lymphocytes) are effective against viruses, fungi, and cancer cells. Natural killer cells attack microbes and tumor cells.
18. White blood cells usually live for only a few hours or a few days. Normal blood contains 5000 to 10,000 WBCs/ $\mu$ L.
19. Platelets are disc-shaped cell fragments without nuclei.
20. Platelets are formed from megakaryocytes and take part in hemostasis by forming a platelet plug.
21. Normal blood contains 150,000 to 400,000 platelets/ $\mu$ L.

**Hemostasis (p. 354)**

1. Hemostasis, the stoppage of bleeding, involves vascular spasm, platelet plug formation, and blood clotting.
2. In vascular spasm, the smooth muscle of a blood vessel wall contracts.
3. Platelet plug formation is the aggregation of platelets to stop bleeding.
4. A clot is a network of insoluble protein fibers (fibrin) in which formed elements of blood are trapped. The chemicals involved in clotting are known as clotting factors.
5. Blood clotting involves a series of reactions that may be divided into three stages: formation of prothrombinase by either the extrinsic or intrinsic pathway, conversion of prothrombin into thrombin, and conversion of soluble fibrinogen into insoluble fibrin.

6. Normal coagulation involves clot retraction (tightening of the clot) and fibrinolysis (dissolution of the clot).
7. Anticoagulants (for example, heparin) prevent clotting.
8. Clotting in an unbroken blood vessel is called thrombosis. A thrombus that moves from its site of origin is called an embolus.

**Blood Groups and Blood Types (p. 357)**

1. In the ABO system, the antigens on RBCs, called A and B, determine blood type. Plasma contains antibodies termed anti-A and anti-B antibodies.
2. In the Rh system, individuals whose erythrocytes have Rh antigens are classified as Rh<sup>+</sup>. Those who lack the antigen are Rh<sup>-</sup>.

 **SELF-QUIZ**

1. A hematocrit is
  - a. used to measure the quantity of the five types of white blood cells
  - b. essential for determining a person's blood type
  - c. the percentage of red blood cells in whole blood
  - d. also known as a platelet count
  - e. involved in blood clotting
2. Match the following:
 

<ol style="list-style-type: none"> <li>— a. involved in certain immune responses</li> <li>— b. develop into mature red blood cells</li> <li>— c. required for vitamin B<sub>12</sub> absorption</li> <li>— d. most abundant plasma protein</li> <li>— e. blood after formed elements are removed</li> <li>— f. plasma without clotting proteins</li> <li>— g. needed for blood clotting</li> </ol>	<ol style="list-style-type: none"> <li>A. albumin</li> <li>B. fibrinogen</li> <li>C. intrinsic factor</li> <li>D. immunoglobulins</li> <li>E. plasma</li> <li>F. serum</li> <li>G. reticulocytes</li> </ol>
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3. In adults, erythropoiesis takes place in
  - a. the liver
  - b. yellow bone marrow
  - c. red bone marrow
  - d. lymphatic tissue
  - e. the kidneys
4. Which of the following pigments contributes to the yellow color in urine?
  - a. hemoglobin
  - b. stercobilin
  - c. biliverdin
  - d. urobilin
  - e. bilirubin
5. Which of the following statements is NOT true about red blood cells?
  - a. The production of red blood cells is known as erythropoiesis.
  - b. Red blood cells originate from pluripotent stem cells.
  - c. Hypoxia increases the production of red blood cells.
  - d. The liver takes part in the destruction and recycling of red blood cell components.
  - e. Red blood cells have a lobed nucleus and granular cytoplasm.
6. A primary function of red blood cells is to
  - a. maintain blood volume
  - b. help blood clot
  - c. provide immunity against some diseases
  - d. clean up debris following infection
  - e. deliver oxygen to the cells of the body
7. If a differential white blood cell count indicated higher than normal numbers of basophils, what may be occurring in the body?
  - a. chronic infection
  - b. allergic reaction
  - c. leukopenia
  - d. initial response to invading bacteria
  - e. hemostasis
8. In a person with blood type A, the antibodies that would normally be present in the plasma is (are)
  - a. anti-A antibody
  - b. anti-B antibody
  - c. both anti-A and anti-B antibodies
  - d. neither anti-A nor anti-B
  - e. anti-O antibodies
9. Hemolytic disease of the newborn (HDN) may occur in the fetus of a second pregnancy if
  - a. the mother is Rh<sup>+</sup> and the baby is Rh<sup>-</sup>
  - b. the mother is Rh<sup>+</sup> and the baby is Rh<sup>+</sup>
  - c. the mother is Rh<sup>-</sup> and the baby is Rh<sup>-</sup>
  - d. the mother is Rh<sup>-</sup> and the baby is Rh<sup>+</sup>
  - e. the father is Rh<sup>-</sup> and the mother is Rh<sup>+</sup>
10. Place the following steps of hemostasis in the correct order.
  1. clot retraction
  2. prothrombinase formed
  3. fibrinolysis by plasmin
  4. vascular spasm
  5. conversion of prothrombin into thrombin
  6. platelet plug formation
  7. conversion of fibrinogen into fibrin
  - a. 4, 6, 2, 5, 7, 1, 3
  - b. 5, 4, 7, 6, 2, 3, 1
  - c. 2, 5, 6, 7, 1, 4, 3
  - d. 4, 6, 5, 2, 7, 1, 3
  - e. 4, 2, 6, 5, 3, 7, 1

11. Which of the following is NOT a normal component of blood plasma?  
a. albumins    b. fibrinogen    c. hemoglobin  
d. immunoglobulins    e. water
12. How does aspirin prevent thrombosis?  
a. It inhibits platelet aggregation.  
b. It interferes with  $\text{Ca}^{2+}$  absorption.  
c. It inhibits the conversion of prothrombin to thrombin.  
d. It acts as an enzyme to dissolve the thrombus.  
e. It prevents the accumulation of fatty substances on blood vessel walls.
13. Match the following:  

_____ a. become wandering macrophages	A. neutrophils
_____ b. produce antibodies	B. eosinophils
_____ c. are involved in allergic reactions	C. basophils
_____ d. first to respond to bacterial invasion	D. lymphocytes
_____ e. destroy antigen-antibody complexes; combat inflammation	E. monocytes
14. Hemostasis is  
a. maintenance of a steady state in the body  
b. an abnormal increase in leukocytes  
c. a hereditary condition in which spontaneous hemorrhaging occurs  
d. an anticoagulant produced by some leukocytes  
e. a series of events that stop bleeding
15. Which of the following are mismatched?  
a. white blood cell count below 5000 cells/ $\mu\text{L}$ , leukopenia  
b. red blood cell count of 250,000 cells/ $\mu\text{L}$ , normal adult male  
c. white blood cell count above 10,000 cells/ $\mu\text{L}$ , leukocytosis  
d. platelet count of 300,000 cells/ $\mu\text{L}$ , normal adult  
e. pH 7.4, normal blood
16. An individual with type A blood has \_\_\_\_\_ in the plasma membranes of red blood cells.  
a. antigen A    b. antigen B    c. major histocompatibility antigen A  
d. antigen A and antigen Rh  
e. antigen B and antigen Rh
17. Mrs. Smith arrives at a health clinic with her ill daughter Beth. It is suspected that Beth has recently developed a bacterial infection. It is likely that Beth's leukocyte count will be \_\_\_\_\_ cells/ $\mu\text{L}$  of blood, a condition known as \_\_\_\_\_. A differential white blood cell count shows an abnormally high percentage of \_\_\_\_\_.  
a. 20,000, leukopenia, neutrophils  
b. 5000, leukocytosis, monocytes  
c. 7000, leukocytosis, basophils  
d. 2000, leukopenia, platelets  
e. 20,000, leukocytosis, neutrophils
18. Clot retraction  
a. draws torn edges of the damaged vessel closer together  
b. dissolves clots    c. is also known as the intrinsic pathway  
d. involves the formation of fibrin from fibrinogen  
e. helps prevent the formation of an embolus
19. Persons with blood type AB are sometimes referred to as universal recipients because their blood  
a. lacks A and B antigens    b. lacks anti-A and anti-B antibodies  
c. possesses type O antigens and anti-O antibodies  
d. has natural immunity to disease  
e. contains A and B antigens
20. A thrombus that is being transported by the bloodstream is called  
a. a plasma protein    b. a platelet    c. an embolus  
d. a wandering macrophage    e. a reticulocyte

### CRITICAL THINKING APPLICATIONS

1. Biliary atresia is a condition in which the ducts that transport bile out of the liver do not function properly. The whites of the eyes in a baby with this condition have a yellow color. What is the name of the yellow color and what is its cause?
2. A woman with blood type  $\text{Rh}^+$  is married to a man with blood type  $\text{Rh}^-$  and is pregnant with their second child. What is the chance the baby will have hemolytic disease of the newborn (HDN)?
3. The school nurse sighed, "I just can't get used to the blue nail polish the kids are wearing. I keep thinking there's a medical problem." What type of problem might result in blue fingernails?
4. Very small numbers of pluripotent stem cells occur normally in blood. If these cells could be isolated and grown in sufficient numbers, what medically useful products could they produce?

### ANSWERS TO FIGURE QUESTIONS

- 14.1 Red blood cells are the most numerous formed element in blood.
- 14.2 Blood makes up 8% of body weight.
- 14.3 Stercobilin is responsible for the brown color of feces.
- 14.4 Hypoxia means cellular oxygen deficiency.
- 14.5 Prothrombinase is formed during stage 1 of clotting.
- 14.6 Type O blood has anti-A and anti-B antibodies.