37–2 Blood and the Lymphatic System

Just as a plumbing system carries water through a series of pipes to different parts of a house, the circulatory system carries blood through a series of blood vessels to different parts of the body. Blood is a type of connective tissue containing both dissolved substances and specialized cells. Blood collects oxygen from the lungs, nutrients from the digestive tract, and waste products from tissues. Blood helps to regulate factors in the body’s internal environment, such as body temperature. In addition, components in blood help to fight infections. Blood can even form clots to repair damaged blood vessels.

Blood Plasma

The human body contains 4 to 6 liters of blood, which is about 8 percent of the total mass of the body. As Figure 37–7 shows, about 45 percent of the volume of blood consists of cells, which are suspended in the other 55 percent—a straw-colored fluid called plasma. Plasma is about 90 percent water and 10 percent dissolved gases, salts, nutrients, enzymes, hormones, waste products, and proteins called plasma proteins. Plasma proteins, which perform a variety of functions, are divided into three groups: albumins, globulins, and fibrinogen. Albumins and globulins transport substances such as fatty acids, hormones, and vitamins. Albumins also help to regulate osmotic pressure and blood volume. Some globulins fight viral and bacterial infections. Fibrinogen is the protein responsible for the ability of blood to clot.

Guide for Reading

Key Concepts
- What is the function of each type of blood cell?
- What is the function of the lymphatic system?

Vocabulary
- plasma
- hemoglobin
- lymphocyte
- platelet
- lymph

Reading Strategy: Asking Questions Before you read, rewrite the headings in the sections as how, why, or what questions about blood and the lymphatic system. As you read, write brief answers to the heading questions.

Figure 37–7 Blood consists of plasma, blood cells, nutrients, hormones, waste products, and plasma proteins. Interpreting Graphics When a whole blood sample is placed in a centrifuge, as shown below, what is the result?

Blood Plasma

Use Community Resources

Have students contact their local chapter of the American Red Cross to learn about blood banks and blood drives in their community. Suggest that they try to find out who can and cannot donate blood, how donations are made, and what happens to the donated blood. Urge students to share what they learn with the class.

SECTION RESOURCES

Print:
- Teaching Resources, Lesson Plan 37–2,
  Adapted Section Summary 37–2, Adapted
  Worksheets 37–2, Section Summary 37–2,
  Worksheets 37–2, Section Review 37–2
- Reading and Study Workbook A,
  Section 37–2
- Adapted Reading and Study Workbook B,
  Section 37–2
- investigations in Forensics, Investigation 10

Technology:
- iText, Section 37–2
- Transparencies Plus, Section 37–2

Answer to . . .

Figure 37–7 The cellular portion and the plasma portion of blood separate.
Blood Cells

Build Science Skills

Calculating Help students appreciate the relative proportions of red and white blood cells. Point out that a milliliter of blood contains about 5 million red blood cells (about 5.2 million in males and about 4.7 million in females) and that red blood cells outnumber white blood cells about 1000 to 1.

Ask: How many white blood cells are there in a milliliter of blood? (About 7000) If a milliliter of blood was found to have 20,000 white blood cells, what might explain this increase? (An infection)

Use Community Resources

Arrange for interested students to visit a clinic or hospital laboratory where they can observe blood counts being performed. If possible, have a lab technician or supervisor explain why blood counts are performed and what can be learned from them. Other topics the technician or supervisor might address include the importance of accuracy in blood counts and the safety precautions that must be taken when handling blood samples. Have students report to the class on what they learn.

Blood Cells

The cellular portion of blood consists of red blood cells, white blood cells, and platelets. Red blood cells transport oxygen, white blood cells perform a variety of protective functions, and platelets help in the clotting process. Platelets are actually fragments of cells derived from larger cells in bone marrow.

Red Blood Cells

The most numerous cells in the blood are the red blood cells, or erythrocytes (eh-RITH-roh-syts). Red blood cells transport oxygen. They get their color from hemoglobin. Hemoglobin is the iron-containing protein that binds to oxygen in the lungs and transports it to tissues throughout the body where the oxygen is released.

Red blood cells, like those shown in Figure 37–8, are shaped like disks that are thinner in the center than along the edges. These cells are produced from cells in red bone marrow. As these cells gradually become filled with hemoglobin, their nuclei and other organelles are forced out. Thus, mature red blood cells do not have nuclei. Red blood cells circulate for an average of 120 days before they are worn out from squeezing through narrow capillaries. Old red blood cells are destroyed in the liver and spleen.

White Blood Cells

White blood cells, or leukocytes (LOO-ko-syts), do not contain hemoglobin. They are much less common than red cells, which outnumber them almost 1000 to 1. Both white and red blood cells are produced from the same population of blood-forming stem cells found in the bone marrow. Unlike red blood cells, however, white blood cells contain nuclei. They may live for days, months, or even years.

White blood cells are the “army” of the circulatory system—they guard against infection, fight parasites, and attack bacteria. There are many types of white blood cells, and they perform a wide variety of important functions. Some protect the body by acting as phagocytes, or “eating cells,” that engulf and digest bacteria and other disease-causing microorganisms. Some white blood cells react to foreign substances by releasing chemicals known as histamines. These chemicals increase blood flow into the affected area, producing redness and swelling that are often associated with allergies. Other white blood cells, known as lymphocytes, are involved in the immune response. B lymphocytes produce antibodies. Antibodies are essential to fighting infection and help to produce immunity to many diseases. T lymphocytes help fight tumors and viruses. You will learn more about lymphocytes in Chapter 40.

White blood cells are not confined to the circulatory system. Many white blood cells are able to slip out of capillary walls, travel through the lymphatic system, and attack invading organisms in the tissues of the body. In many ways, white blood cells are the first lines of defense when the body is invaded by disease-causing organisms.
Demonstration

Use a microprojector to display prepared slides of red blood cells, white blood cells, and platelets. Have students make a sketch of each structure. Then, call on students to describe the size, shape, and general appearance of each structure.

Use Visuals

Figure 37–9 Check students’ comprehension of the figure by having them identify each of the following in the drawings: red blood cells (red), platelets (pink), and fibrin filaments (blue). Then, ask: What is the main role of platelets in blood clotting? (The production of clotting factors such as thromboplastin) What role do calcium and vitamin K play in blood clotting? (They help convert prothrombin to thrombin.)

Circulatory and Respiratory Systems

Like an army with units in reserve, the body is able to increase the number of white blood cells dramatically when a “battle” is underway. A sudden increase in the white blood cell count is one of the ways in which physicians can tell that the body is fighting a serious infection.

Platelets and Blood Clotting

Blood is essential to life. An injury can cause the body to lose this essential fluid. Fortunately, blood has an internal mechanism to slow bleeding and begin healing. A minor cut or scrape may bleed for a few seconds or minutes, but then it stops. Clean it up with soap and water, cover it with a bandage, and it begins to heal. Have you ever wondered why the bleeding stops?

The answer is that blood has the ability to form a clot. Figure 37–9 summarizes the process.

Blood clotting is made possible by plasma proteins and cell fragments called platelets. There are certain large cells in bone marrow that can break into thousands of small pieces. Each fragment of cytoplasm is enclosed in a piece of cell membrane and released into the bloodstream as a platelet.

When platelets come into contact with the edges of a broken blood vessel, their surfaces become very sticky, and a cluster of platelets develops around the wound. These platelets then release proteins called clotting factors. The clotting factors start a series of chemical reactions that are quite complicated. In one reaction, a clotting factor called thromboplastin (thrahm-boh-PLAS-tin) converts prothrombin, which is found in blood plasma, into thrombin. Thrombin is an enzyme that helps convert the soluble plasma protein fibrinogen into a sticky mesh of fibrin filaments. These filaments stop the bleeding by producing a clot. Figure 37–10 shows the tangle of microscopic fibers in an actual blood clot.

FACTS AND FIGURES

Red blood cell shapes
Normal red blood cells are disk-shaped, but some people have red blood cells with abnormal shapes, such as spherical, oval, or sickle shapes. People with spherical red blood cells have an inherited disorder called spherocytosis. Because of their shape, the red cells become trapped and destroyed by the spleen, leading to anemia. Treatment may include removal of the spleen, which corrects the anemia but not the abnormal shape of the red cells. People with oval red blood cells have the inherited disorder elliptocytosis. This sometimes causes mild anemia but usually requires no treatment. People with sickle-shaped red blood cells have sickle cell disease, another inherited disorder and the most serious of the three disorders. Sickle cell disease can cause severe anemia, organ damage, deformities, and even death.

Answers to . . .

Platelets are cell fragments that form a cluster around a wound and release clotting factors.

Figure 37–10 It is similar in forming a mesh barrier that prevents blood from leaving a damaged vessel (or that keeps insects out).
The Lymphatic System

The Lymphatic System

Blood Clotting Problems
If the wound is small, within a few minutes the mesh of platelets and fibrin seals the wound, and bleeding stops. Most of the time, this clotting reaction works so well that we take it for granted. However, if one of the clotting factors is missing or defective, the clotting process does not work well. Hemophilia is a genetic disorder that results from a defective protein in the clotting pathway. People with hemophilia cannot produce blood clots that are firm enough to stop even minor bleeding. They must take great care to avoid injury. Fortunately, hemophilia can be treated by injecting extracts containing the missing clotting factor.

The Lymphatic System
As blood circulates, some fluid leaks from the blood into the surrounding tissues. This isn’t an altogether bad thing. A steady flow of fluid helps to maintain an efficient movement of nutrients and salts from the blood into the tissues. However, more than 3 liters of fluid leak from the circulatory system into surrounding tissues every day! If this leakage continued unchecked, the body would begin to swell with fluid—not a very pleasant prospect.

Fortunately, the interrelationship between two body systems does not allow this to happen. A network of vessels, nodes, and organs called the lymphatic system collects the fluid that is lost by the blood and returns it back to the circulatory system. The fluid is known as lymph (LIMP).

Blood Transfusions
Although the first successful transfusions of human blood were carried out in the 1820s, many recipients had severe reactions to the transfused blood, and several died. Today we know why. We inherit one of four blood types—A, B, AB, or O—which are determined by antigens on our blood cells. Antigens are substances that trigger an immune response. People with blood type A have A antigens on their cells, those with type B have B antigens, those with AB blood have both A and B, and those with type O have neither A nor B antigens.

When blood types match, the transfusion is successful. However, transfusions are successful in some cases even when the blood types of the donor and the recipient do not match. Use the table to answer the questions that follow.

<table>
<thead>
<tr>
<th>Blood Type of Donor</th>
<th>Blood Type of Recipient</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>✓</td>
</tr>
<tr>
<td>B</td>
<td>X ✓</td>
</tr>
<tr>
<td>AB</td>
<td>X ✓</td>
</tr>
<tr>
<td>O</td>
<td>✓ ✓</td>
</tr>
</tbody>
</table>

X = Unsuccessful transfusion ✓ = Successful transfusion

1. Drawing Conclusions Which blood type is sometimes referred to as the “universal donor”? Which is known as the “universal recipient”?
2. Drawing Conclusions In a transfusion involving the A and O blood types, does it make a difference which blood type belongs to the recipient and which to the donor?
3. Applying Concepts Write a brief explanation for the results in the chart using information about phenotypes and genotypes in blood group genes. (Hint: Review Section 14–1 if needed.)
Lymph collects in lymphatic capillaries and slowly flows into larger and larger lymph vessels. Like large veins, lymph vessels contain valves that prevent lymph from flowing backward. Ducts collect the lymph and return it to the circulatory system through two openings in the superior vena cava. The openings are under the left and right clavicle bones just below the shoulders. Figure 37–11 shows the lymphatic system. Along the length of the lymph vessels are small bean-shaped enlargements called lymph nodes. Lymph nodes act as filters, trapping bacteria and other microorganisms that cause disease. When large numbers of microorganisms are trapped in the lymph nodes, the nodes become enlarged. If you have ever had “swollen glands,” you actually had swollen lymph nodes.

Lymph vessels do not merely return excess fluid to the circulation. They also play a very important role in nutrient absorption. Lymph vessels lie near the cells that line the intestines, where they absorb fats and fat-soluble vitamins from the digestive tract and carry them to the blood. Lymph moves through the lymphatic system under osmotic pressure from the blood and is pushed along by the contractions of nearby skeletal muscles. It is important that there is a steady flow of lymph. Edema, a swelling of the tissues due to the accumulation of excess fluid, can occur when lymph vessels are blocked due to injury or disease. In addition to the lymph vessels and lymph nodes, the thymus and spleen also have important roles in the lymphatic system. The thymus is located beneath the sternum. Certain lymphocytes called T cells mature in the thymus before they can function in the immune system. T cells are the cells that recognize foreign “invaders” in the body. The spleen helps to cleanse the blood and removes damaged blood cells from the circulatory system. The spleen also harbors phagocytes that engulf and destroy bacteria and other microorganisms.

**37–2 Section Assessment**

1. **Key Concept** List the main function of red blood cells, white blood cells, and platelets.
2. **Key Concept** Describe the role of the lymphatic system.
3. What types of materials are dissolved in plasma?
4. Explain how blood clots.

**Thinking Visually**

**Thinking Visually**

**Constructing a Concept Map**

Construct a concept map that shows the components of blood. Include information about the functions of the different components. (Be sure to include the different types of white blood cells.)

**Critical Thinking** Inferring

Sometimes lymph nodes must be surgically removed. Although more lymph vessels eventually grow, what result would you expect to see immediately after surgery?

**Interactive Textbook**

If your class subscribes to the iText, use it to review the Key Concepts in Section 37–2.