


# Circulation

## chapter preview

### sections

- 1** The Circulatory System  
*Lab* The Heart as a Pump
  - 2** Blood
  - 3** The Lymphatic System  
*Lab* Blood Type Reactions
-  **Virtual Lab** What factors affect the likelihood of hypertension?

## What does a highway have to do with circulation?

Think of this interchange as a simplified way to visualize how your blood travels through your body. Your complex circulatory system also plays an important role in protecting you from disease.

**Science Journal** Infer how the circulatory system provides your body with the nutrients it needs to stay healthy?



# Start-Up Activities



## Comparing Circulatory and Road Systems

If you look at an aerial view of a road system, as shown in the photograph, you see roads leading in many directions. These roads provide a way to carry people and goods from one place to another. Your circulatory system is like a road system. Just as roads are used to transport goods to homes and factories, your blood vessels transport substances throughout your body.

1. Look at a map of your city, county, or state.
2. Identify roads that are interstates, as well as state and county routes, using the map key.
3. Plan a route to a destination that your teacher describes. Then plan a different return trip.
4. Draw a diagram in your Science Journal showing your routes to and from the destination.
5. **Think Critically** If the destination represents your heart, what do the routes represent? Draw a comparison between a blocked road on your map and a clogged artery in your body.

## FOLDABLES™ Study Organizer

**Circulation** Your body is supplied with nutrients by blood circulating through your blood vessels. Make the following Foldable to help you organize information about circulation.

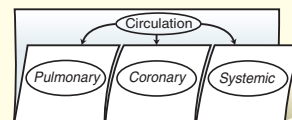
- STEP 1** **Fold** a sheet of paper in half lengthwise. Make the back edge about 5 cm longer than the front edge.



- STEP 2** **Turn** the paper so the fold is on the bottom. Then, **fold** it into thirds.



- STEP 3** **Unfold and cut** only the top layer along both folds to make three tabs. **Label** the top of the page *Circulation*, and label the three tabs *Pulmonary*, *Coronary*, and *Systemic*.



**Read and Write** As you read the chapter, write about each section under its tab.



Preview this chapter's content and activities at [bookd.msscience.com](http://bookd.msscience.com)

# The Circulatory System

## as you read

### What You'll Learn

- **Compare and contrast** arteries, veins, and capillaries.
- **Explain** how blood moves through the heart.
- **Identify** the functions of the pulmonary and systemic circulation systems.

### Why It's Important

Your body's cells depend on the blood vessels to bring nutrients and remove wastes.

### Review Vocabulary

**heart:** organ that circulates blood through your body continuously

### New Vocabulary

- atrium
- ventricle
- coronary circulation
- pulmonary circulation
- systemic circulation
- artery
- vein
- capillary

## How Materials Move Through the Body

It's time to get ready for school, but your younger sister is taking a long time in the shower. "Don't use up all the water," you shout. Water is carried throughout your house in pipes that are part of the plumbing system. The plumbing system supplies water for all your needs and carries away wastes. Just as you expect water to flow when you turn on the faucet, your body needs a continuous supply of oxygen and nutrients and a way to remove wastes. In a similar way materials are moved throughout

your body by your cardiovascular (kar dee oh VAS kyuh lur) system. It includes your heart, kilometers of blood vessels, and blood.

Blood vessels carry blood to every part of your body, as shown in **Figure 1**. Blood moves oxygen and nutrients to cells and carries carbon dioxide and other wastes away from the cells. Sometimes blood carries substances made in one part of the body to another part of the body where these substances are needed. Movement of materials into and out of your cells occurs by diffusion (dih FYEW zhun) and active transport. Diffusion occurs when a material moves from an area where there is more of it to an area where there is less of it. Active transport is the opposite of diffusion. Active transport requires an input of energy from the cell, but diffusion does not.



**Figure 1** The blood is pumped by the heart to all the cells of the body and then back to the heart through a network of blood vessels.

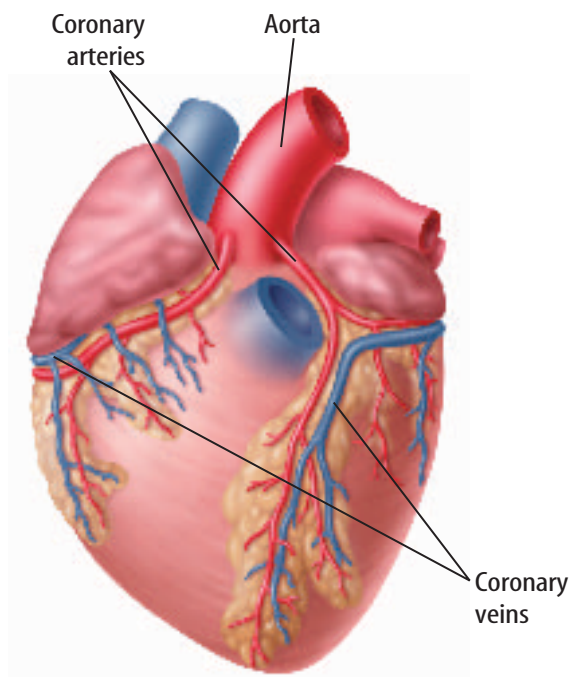


## The Heart

Your heart is an organ made of cardiac muscle tissue. It is located behind your breastbone, called the sternum, and between your lungs. Your heart has four compartments called chambers. The two upper chambers are called the right and left **atria** (AY tree umz). The two lower chambers are called the right and left **ventricles** (VEN trih kulz). During one heartbeat, both atria contract at the same time. Then, both ventricles contract at the same time. A one-way valve separates each atrium from the ventricle below it. The blood flows only in one direction from an atrium to a ventricle, then from a ventricle into a blood vessel. A wall prevents blood from flowing between the two atria or the two ventricles. This wall keeps blood rich in oxygen separate from blood low in oxygen. If oxygen-rich blood and oxygen-poor blood were to mix, your body's cells would not get all the oxygen they need.

Scientists have divided the circulatory system into three sections—coronary circulation, pulmonary (PUL muh ner ee) circulation, and systemic circulation. The beating of your heart controls blood flow through each section.

**Coronary Circulation** Your heart has its own blood vessels that supply it with nutrients and oxygen and remove wastes. **Coronary** (KOR uh ner ee) **circulation**, as shown in **Figure 2**, is the flow of blood to and from the tissues of the heart. When the coronary circulation is blocked, oxygen and nutrients cannot reach all the cells of the heart. This can result in a heart attack.



**Figure 2** Like the rest of the body, the heart receives the oxygen and nutrients that it needs from the blood. The blood also carries away wastes from the heart's cells. On the diagram, you can see the coronary arteries, which nourish the heart.

## Mini LAB

### Inferring How Hard the Heart Works

#### Procedure

1. Make a fist and observe its size, which is approximately the size of your heart.
2. Place your fist in a **bowl of water**. Then clench and unclench your fist to cause water to squirt out between your thumb and forefinger.
3. Continue the squeezing action for 3 min. Determine the number of squeezes per minute.

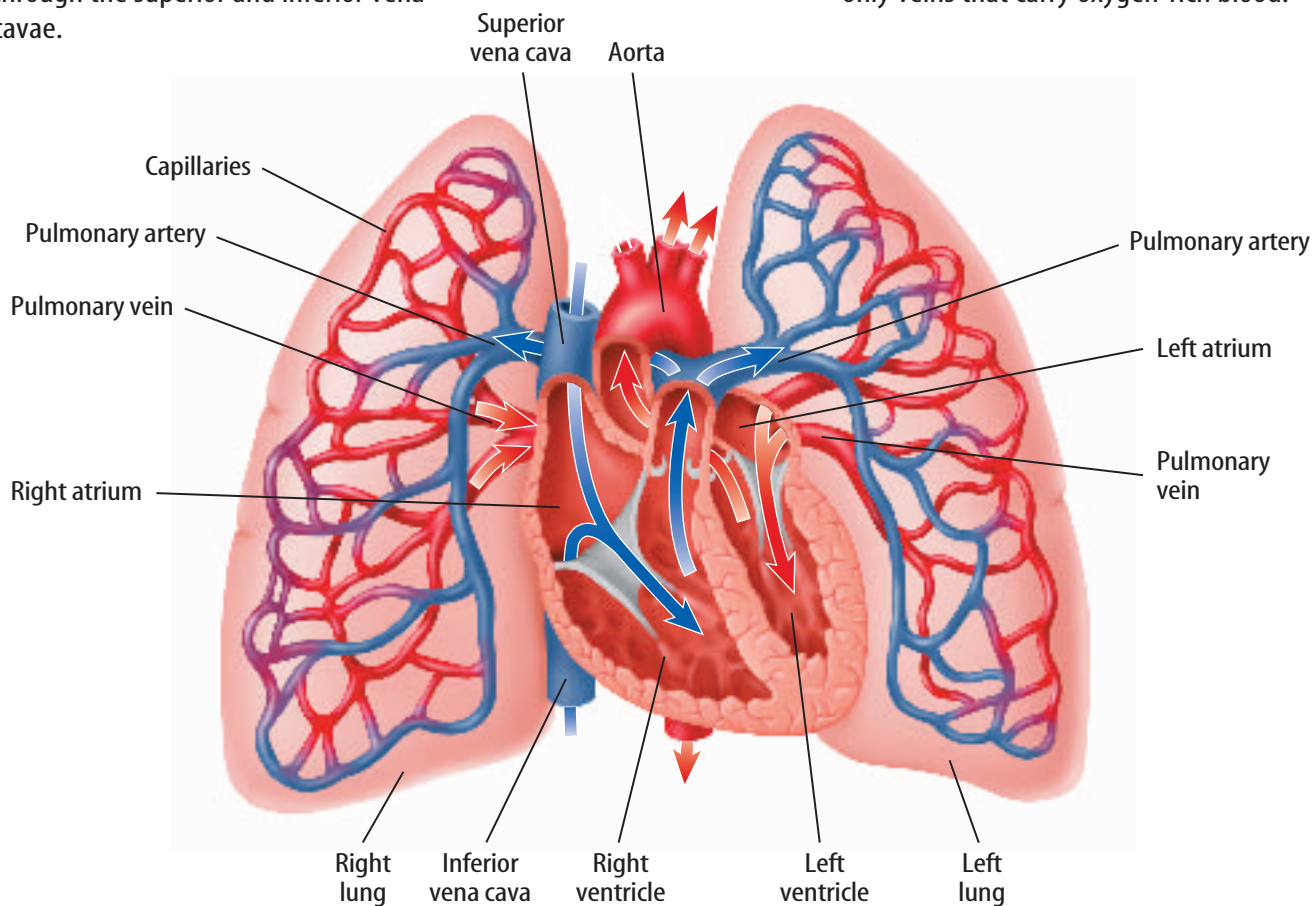
#### Analysis

1. State how many times you squeezed your fist in 1 min. A resting heart beats approximately 70 times per minute.
2. What can you do when the muscles of your hand and arm get tired? Explain why cardiac muscle does not get tired.



Blood, high in carbon dioxide and low in oxygen, returns from the body to the heart. It enters the right atrium through the superior and inferior vena cavae.

Oxygen-rich blood travels from the lungs through the pulmonary veins and into the left atrium. The pulmonary veins are the only veins that carry oxygen-rich blood.



The right atrium contracts, forcing the blood into the right ventricle. When the right ventricle contracts, the blood leaves the heart and goes through the pulmonary arteries to the lungs. The pulmonary arteries are the only arteries that carry blood that is high in carbon dioxide.

The left atrium contracts and forces the blood into the left ventricle. The left ventricle contracts, forcing the blood out of the heart and into the aorta.

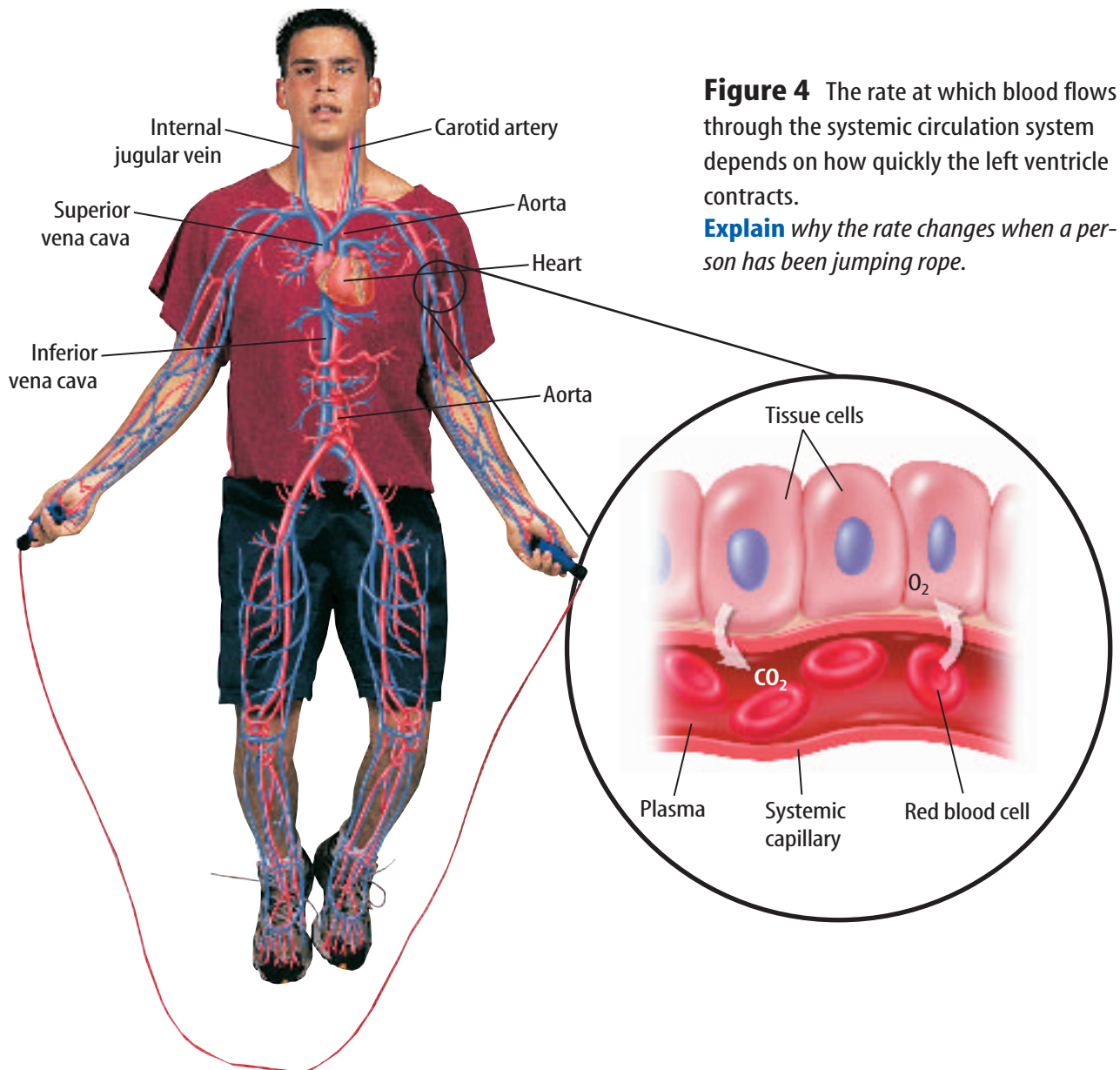
**Figure 3** Pulmonary circulation moves blood between the heart and lungs.

**Pulmonary Circulation** The flow of blood through the heart to the lungs and back to the heart is **pulmonary circulation**. Use **Figure 3** to trace the path blood takes through this part of the circulatory system. The blood returning from the body through the right side of the heart and to the lungs contains cellular wastes. The wastes include molecules of carbon dioxide and other substances. In the lungs, gaseous wastes diffuse out of the blood, and oxygen diffuses into the blood. Then the blood returns to the left side of the heart. In the final step of pulmonary circulation, the oxygen-rich blood is pumped from the left ventricle into the aorta (ay OR tuh), the largest artery in your body. Next, the oxygen-rich blood flows to all parts of your body.

**Systemic Circulation** Oxygen-rich blood moves to all of your organs and body tissues, except the heart and lungs, by **systemic circulation**, and oxygen-poor blood returns to the heart. Systemic circulation is the largest of the three sections of your circulatory system. **Figure 4** shows the major arteries (AR tuh reez) and veins (VAYNZ) of the systemic circulation system. Oxygen-rich blood flows from your heart in the arteries of this system. Then nutrients and oxygen are delivered by blood to your body cells and exchanged for carbon dioxide and wastes. Finally, the blood returns to your heart in the veins of the systemic circulation system.

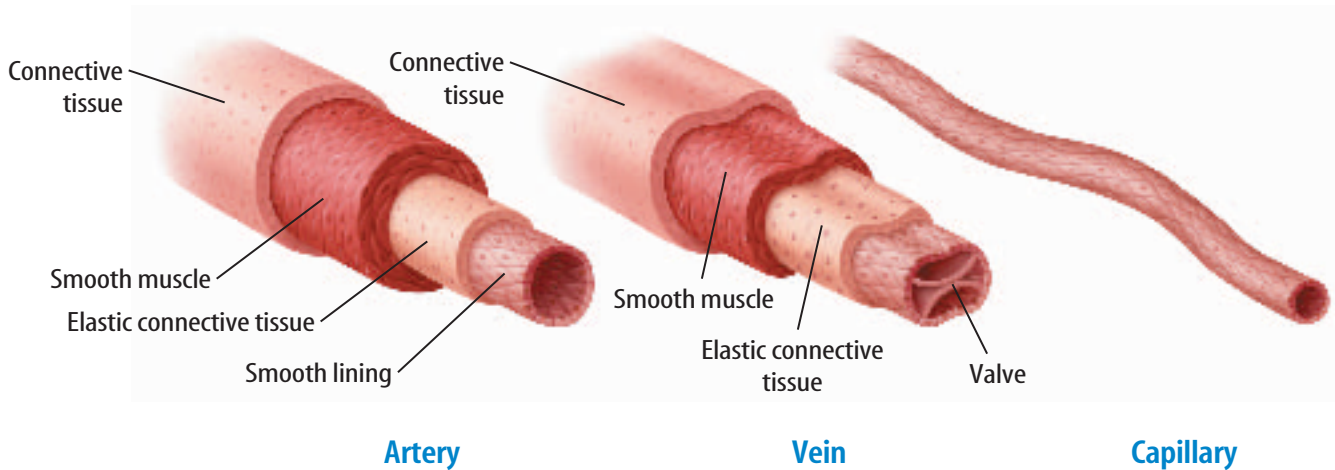
**Reading Check**

*What are the functions of the systemic circulation system in your body?*



**Figure 4** The rate at which blood flows through the systemic circulation system depends on how quickly the left ventricle contracts.

**Explain** why the rate changes when a person has been jumping rope.



**Figure 5** The structures of arteries, veins, and capillaries are different. Valves in veins prevent blood from flowing backward. Capillaries are much smaller. Capillary walls are only one cell thick.

## Blood Vessels

In the middle 1600s, scientists proved that blood moves in one direction in a blood vessel, like traffic on a one-way street. They discovered that blood moves by the pumping of the heart and flows from arteries to veins. But, they couldn't explain how blood gets from arteries to veins. Using a new invention of that time, the microscope, scientists discovered capillaries (KAP uh ler eez), the connection between arteries and veins.

**Arteries** As blood is pumped out of the heart, it travels through arteries, capillaries, and then veins. **Arteries** are blood vessels that carry blood away from the heart. Arteries, shown in **Figure 5**, have thick, elastic walls made of connective tissue and smooth muscle tissue. Each ventricle of the heart is connected to an artery. The right ventricle is connected to the pulmonary artery, and the left ventricle is attached to the aorta. Every time your heart contracts, blood is moved from your heart into arteries.

**Veins** The blood vessels that carry blood back to the heart are called **veins**, as shown in **Figure 5**. Veins have one-way valves that keep blood moving toward the heart. If blood flows backward, the pressure of the blood against the valves causes them to close. The flow of blood in veins also is helped by your skeletal muscles. When skeletal muscles contract, the veins in these muscles are squeezed and help blood move toward the heart. Two major veins return blood from your body to your heart. The superior vena cava returns blood from your head and neck. Blood from your abdomen and lower body returns through the inferior vena cava.



*What are the similarities and differences between arteries and veins?*



**Capillaries** Arteries and veins are connected by microscopic blood vessels called **capillaries**, as shown in **Figure 5**. The walls of capillaries are only one cell thick. You can see capillaries when you have a bloodshot eye. They are the tiny red lines you see in the white area of your eye. Nutrients and oxygen diffuse into body cells through the thin capillary walls. Waste materials and carbon dioxide diffuse from body cells into the capillaries.

## Blood Pressure



If you fill a balloon with water and then push on it, the pressure moves through the water in all directions, as shown in **Figure 6**. Your circulatory system is like the water balloon. When your heart pumps blood through the circulatory system, the pressure of the push moves through the blood. The force of the blood on the walls of the blood vessels is called blood pressure. This pressure is highest in arteries and lowest in veins. When you take your pulse, you can feel the waves of pressure. This rise and fall of pressure occurs with each heartbeat. Normal resting pulse rates are 60 to 100 heartbeats per minute for adults, and 80 to 100 beats per minute for children.

**Measuring Blood Pressure** Blood pressure is measured in large arteries and is expressed by two numbers, such as 120 over 80. The first number is a measure of the pressure caused when the ventricles contract and blood is pushed out of the heart. This is called the systolic (sihs TAH lihk) pressure. Then, blood pressure drops as the ventricles relax. The second number is a measure of the diastolic (di uh STAH lihk) pressure that occurs as the ventricles fill with blood just before they contract again.

**Controlling Blood Pressure** Your body tries to keep blood pressure normal. Special nerve cells in the walls of some arteries sense changes in blood pressure. When pressure is higher or lower than normal, messages are sent to your brain by these nerve cells. Then messages are sent by your brain to raise or lower blood pressure—by speeding up or slowing the heart rate for example. This helps keep blood pressure constant within your arteries. When blood pressure is constant, enough blood reaches all organs and tissues in your body and delivers needed nutrients to every cell.



**Blood Pressure** Some molecules of nutrients are forced through capillary walls by the force of blood pressure. What is the cause of the pressure? Discuss your answer with a classmate. Then write your answer in your Science Journal.

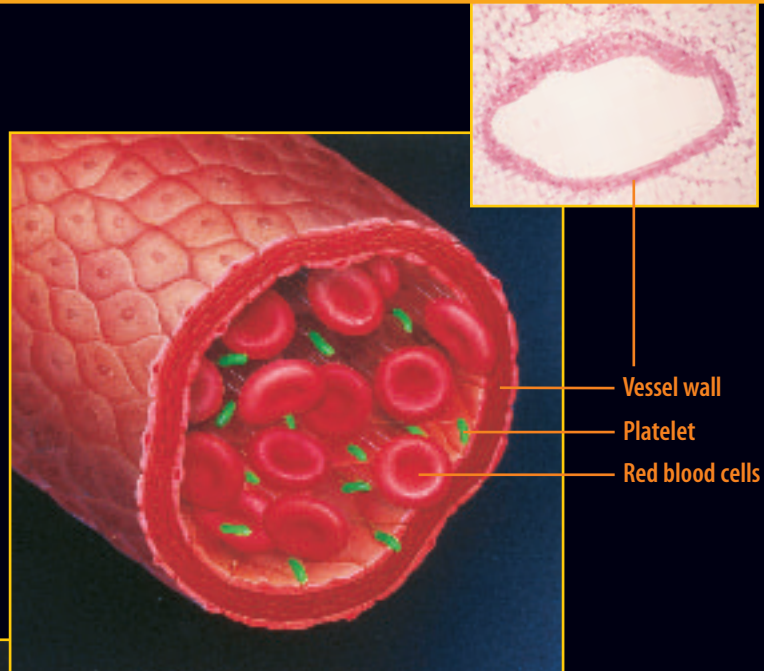
**Figure 6** When pressure is exerted on a fluid in a closed container, the pressure is transmitted through the liquid in all directions. Your circulatory system is like a closed container.



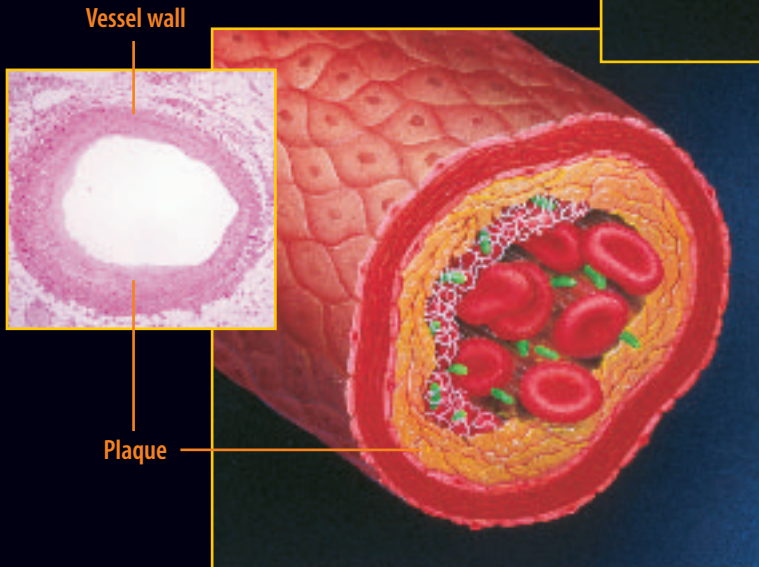


**Figure 7**

**H**ealthy blood vessels have smooth, unobstructed interiors like the one at the right. Atherosclerosis is a disease in which fatty substances build up in the walls of arteries, such as the coronary arteries that supply the heart muscle with oxygen-rich blood. As illustrated below, these fatty deposits can gradually restrict—and ultimately block—the life-giving river of blood that flows through an artery.

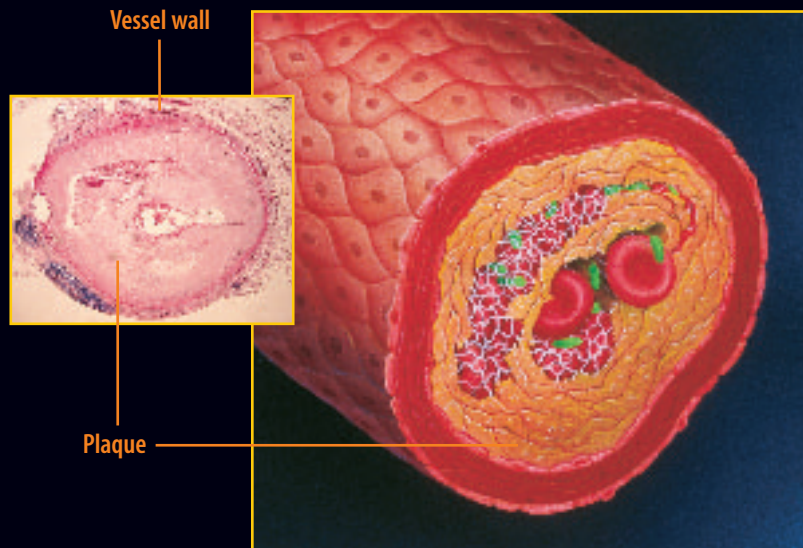


▲ **HEALTHY ARTERY** The illustration and photo above show a normal functioning artery.



◀ **PARTIALLY CLOGGED ARTERY** The illustration and inset photo at left show fatty deposits, called plaques, that have formed along the artery's inner wall. As the diagram illustrates, plaques narrow the pathway through the artery, restricting and slowing blood flow. As blood supply to the heart muscle cells dwindles, they become starved for oxygen and nutrients.

▶ **NEARLY BLOCKED ARTERY** In the illustration and photo at right, fatty deposits have continued to build. The pathway through the coronary artery has gradually narrowed until blood flow is very slow and nearly blocked. Under these conditions, the heart muscle cells supplied by the artery are greatly weakened. If blood flow stops entirely, a heart attack will result.



## Cardiovascular Disease

Any disease that affects the cardiovascular system—the heart, blood vessels, and blood—can seriously affect the health of your entire body. People often think of cancer and automobile accidents as the leading causes of death in the United States. However, heart disease is the leading cause of death, when you factor in all age groups.

**Atherosclerosis** One leading cause of heart disease is called atherosclerosis (ah thuh roh skluh ROH sus). In this condition, shown in **Figure 7**, fatty deposits build up on arterial walls. Eating foods high in cholesterol and saturated fats can cause these deposits to form. Atherosclerosis can occur in any artery in the body, but deposits in coronary arteries are especially serious. If a coronary artery is blocked, a heart attack can occur. Open heart surgery may then be needed to correct the problem.

**Hypertension** Another condition of the cardiovascular system is called hypertension (HI pur TEN chun), or high blood pressure. **Figure 8** shows the instruments used to measure blood pressure. When blood pressure is higher than normal most of the time, extra strain is placed on the heart. The heart must work harder to keep blood flowing. One cause of hypertension is atherosclerosis. A clogged artery can increase pressure within the vessel. The walls become stiff and hard, like a metal pipe. The artery walls no longer contract and dilate easily because they have lost their elasticity.

**Heart Failure** Heart failure results when the heart cannot pump blood efficiently. It might be caused when heart muscle tissue is weakened by disease or when heart valves do not work properly. When the heart does not pump blood properly, fluids collect in the arms, legs, and lungs. People with heart failure usually are short of breath and tired.

 **Reading Check** *What is heart failure?*

**Figure 8** Blood pressure is measured in large arteries using a blood pressure cuff and stethoscope.



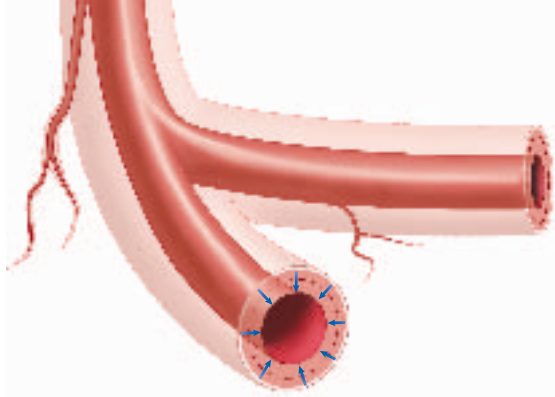
Science  online

### Topic: Cardiovascular Disease

Visit [bookd.msscience.com](http://bookd.msscience.com) for Web links to recent news or magazine articles about cardiovascular disease.

**Activity** In your Science Journal, list five steps you can take to lead a healthy life style.





**Figure 9** Nicotine, present in tobacco, contracts blood vessels and causes the body to release hormones that raise blood pressure.

**Name** *another substance that raises blood pressure.*

**Preventing Cardiovascular Disease** Having a healthy lifestyle is important for the health of your cardiovascular system. The choices you make to maintain good health may reduce your risk of future serious illness. Regular checkups, a healthful diet, and exercise are part of a heart-healthy lifestyle.

Many diseases, including cardiovascular disease, can be prevented by following a good diet. Choose foods that are low in salt, sugar, cholesterol, and saturated fats. Being overweight is associated with heart disease and high blood pressure. Large amounts of body fat force the heart to pump faster.

Learning to relax and having a regular program of exercise can help prevent tension and relieve stress. Exercise also strengthens the heart and lungs, helps in controlling cholesterol, tones muscles, and helps lower blood pressure.

Another way to prevent cardiovascular disease is to not smoke. Smoking causes blood vessels to contract, as shown in **Figure 9**, and makes the heart beat faster and harder. Smoking also increases carbon monoxide levels in the blood. Not smoking helps prevent heart disease and a number of respiratory system problems, too.

## section 1 review

### Summary

#### Cardiovascular System

- Coronary circulation is the flow of blood to and from the tissues of the heart.
- Pulmonary circulation is the flow of blood through the heart, to the lungs, and back to the heart.
- Oxygen-rich blood is moved to all tissues and organs of the body, except the heart and lungs, by systemic circulation.

#### Blood Vessels

- Arteries carry blood away from the heart.
- Veins carry blood back to the heart.
- Arteries and veins are connected by capillaries.

#### Blood Pressure

- The force of the blood on the walls of the blood vessels is called blood pressure.

#### Cardiovascular Disease

- Atherosclerosis occurs when fatty deposits build up on arterial walls.
- High blood pressure is called hypertension.

### Self Check

1. **Compare and contrast** the structure of the three types of blood vessels.
2. **Explain** the pathway of blood through the heart.
3. **Contrast** pulmonary and systemic circulation. Identify which vessels carry oxygen-rich blood.
4. **Explain** how exercise can help prevent heart disease.
5. **Think Critically** What waste product builds up in blood and cells when the heart is unable to pump blood efficiently?

### Applying Skills

6. **Concept Map** Make an events-chain concept map to show pulmonary circulation beginning at the right atrium and ending at the aorta.
7. **Use a Database** Research diseases of the circulatory system. Make a database showing what part of the circulatory system is affected by each disease. Categories should include the organs and vessels of the circulatory system.

# LAB

## The Heart as a Pump

The heart is a pumping organ. Blood is forced through the arteries as heart muscles contract and then relax. This creates a series of waves in blood as it flows through the arteries. These waves are called the pulse. Try this lab to learn how physical activity affects your pulse.

### Real-World Question

What does the pulse rate tell you about the work of the heart?

#### Goals

- **Observe** pulse rate.
- **Compare** pulse rate at rest to rate after jogging.

#### Materials

watch or clock with a second hand

\*stopwatch

\*Alternate materials

Pulse Rate		
Pulse Rate	Partner's	Yours
At rest	Do not write in this book.	
After jogging		

### Procedure

1. Make a table like the one shown. Use it to record your data.
2. Sit down to take your pulse. Your partner will serve as the recorder.
3. Find your pulse by placing your middle and index fingers over the radial artery in your wrist as shown in the photo.  
**WARNING:** Do not press too hard.
4. **Count** each beat of the radial pulse silently for 15 s. Multiply the number of beats by four to find your pulse rate per minute. Have your partner record the number in the data table.
5. Now jog in place for 1 min and take your pulse again. Count the beats for 15 s.
6. **Calculate** this new pulse rate and have your partner record it in the data table.
7. Reverse roles with your partner and repeat steps 2 through 6.
8. **Collect** and record the new data.

### Conclude and Apply

1. **Describe** why the pulse rate changes.
2. **Infer** what causes the pulse rate to change.
3. **Explain** why the heart is a pumping organ.

### Communicating Your Data

Record the class average for pulse rate at rest and after jogging. Compare the class averages to your data. For more help, refer to the **Science Skill Handbook**.



# Blood

## as you read

### What You'll Learn

- **Identify** the parts and functions of blood.
- **Explain** why blood types are checked before a transfusion.
- **Give examples** of diseases of blood.

### Why It's Important

Blood plays a part in every major activity of your body.

### Review Vocabulary

**blood vessels:** Structures that include arteries, veins, and capillaries, which transport blood

### New Vocabulary

- plasma
- hemoglobin
- platelet

**Figure 10** The blood in this graduated cylinder has separated into its parts. Each part plays a key role in body functions.

## Functions of Blood

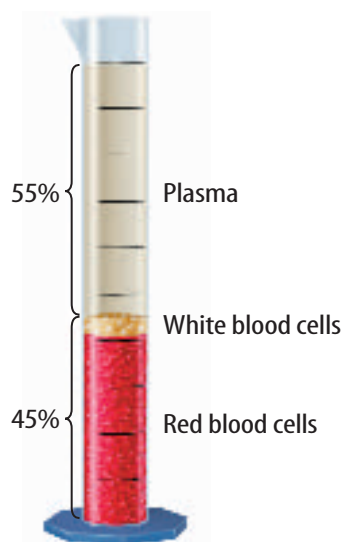
You take a last, deep, calming breath before plunging into a dark, vessel-like tube. The water transports you down the slide much like the way blood carries substances to all parts of your body. Blood has four important functions.

1. Blood carries oxygen from your lungs to all your body cells. Carbon dioxide diffuses from your body cells into your blood. Your blood carries carbon dioxide to your lungs to be exhaled.
2. Blood carries waste products from your cells to your kidneys to be removed.
3. Blood transports nutrients and other substances to your body cells.
4. Cells and molecules in blood fight infections and help heal wounds.

Anything that disrupts or changes these functions affects all the tissues of your body. Can you understand why blood is sometimes called the tissue of life?

## Parts of Blood

As shown in **Figure 10**, blood is a tissue made of plasma (PLAZ muh), platelets (PLAYT luts), and red and white blood cells. Blood makes up about eight percent of your body's total mass. If you weigh 45 kg, you have about 3.6 kg of blood moving through your body. The amount of blood in an adult would fill five 1-L bottles.



**Plasma** The liquid part of blood is mostly water and is called **plasma**. It makes up more than half the volume of blood. Nutrients, minerals, and oxygen are dissolved in plasma and carried to cells. Wastes from cells are also carried in plasma.

**Blood Cells** A cubic millimeter of blood has about five million red blood cells. These disk-shaped blood cells, shown in **Figure 11**, are different from other cells in your body because they have no nuclei. They contain **hemoglobin** (HEE muh gloh bun), which is a molecule that carries oxygen and carbon dioxide, and made of an iron compound that gives blood its red color. Hemoglobin carries oxygen from your lungs to your body cells. Then it carries some of the carbon dioxide from your body cells back to your lungs. The rest of the carbon dioxide is carried in the cytoplasm of red blood cells and in plasma. Red blood cells have a life span of about 120 days. They are made at a rate of 2 million to 3 million per second in the center of long bones like the femur in your thigh. Red blood cells wear out and are destroyed at about the same rate.

In contrast to red blood cells, a cubic millimeter of blood has about 5,000 to 10,000 white blood cells. White blood cells fight bacteria, viruses, and other invaders of your body. Your body reacts to invaders by increasing the number of white blood cells. These cells leave the blood through capillary walls and go into the tissues that have been invaded. Here, they destroy bacteria and viruses and absorb dead cells. The life span of white blood cells varies from a few days to many months.

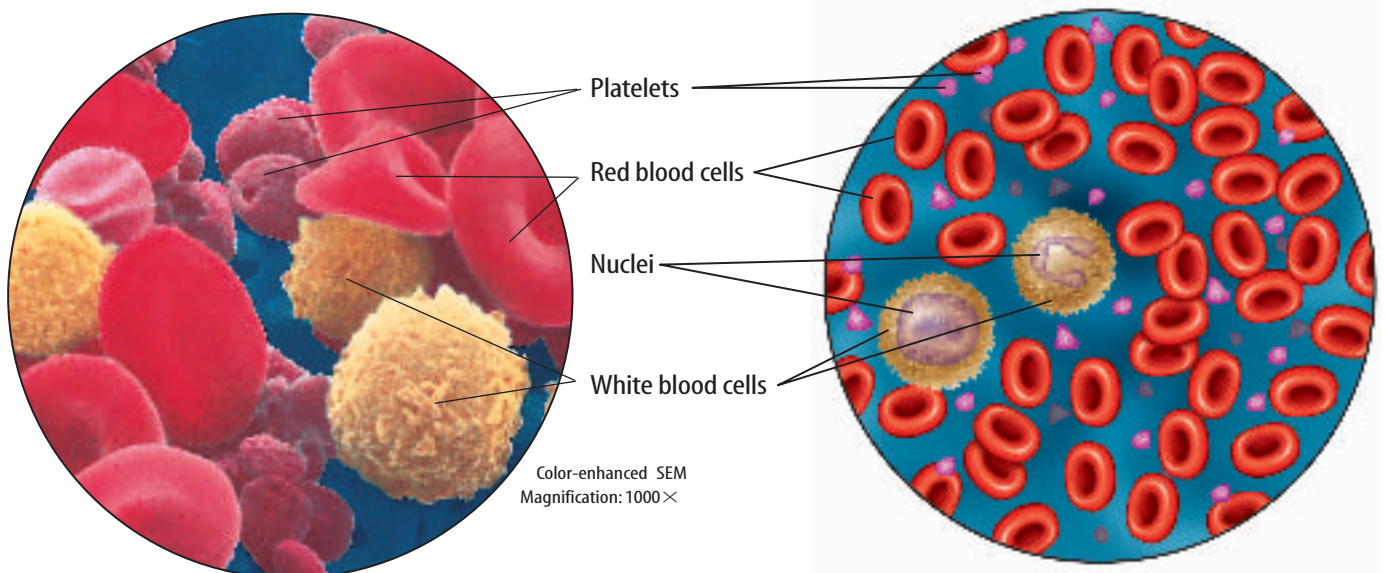
Circulating with the red and white blood cells are platelets. **Platelets** are irregularly shaped cell fragments that help clot blood. A cubic millimeter of blood can contain as many as 400,000 platelets. Platelets have a life span of five to nine days.

**Scienceonline**

**Topic: White Blood Cells**  
 Visit [bookd.msscience.com](http://bookd.msscience.com) for Web links to information about types of human white blood cells and their functions.

**Activity** Write a brief summary describing how white blood cells destroy bacteria and viruses in your Science Journal.

**Figure 11** Red blood cells supply your body with oxygen, and white blood cells and platelets have protective roles.

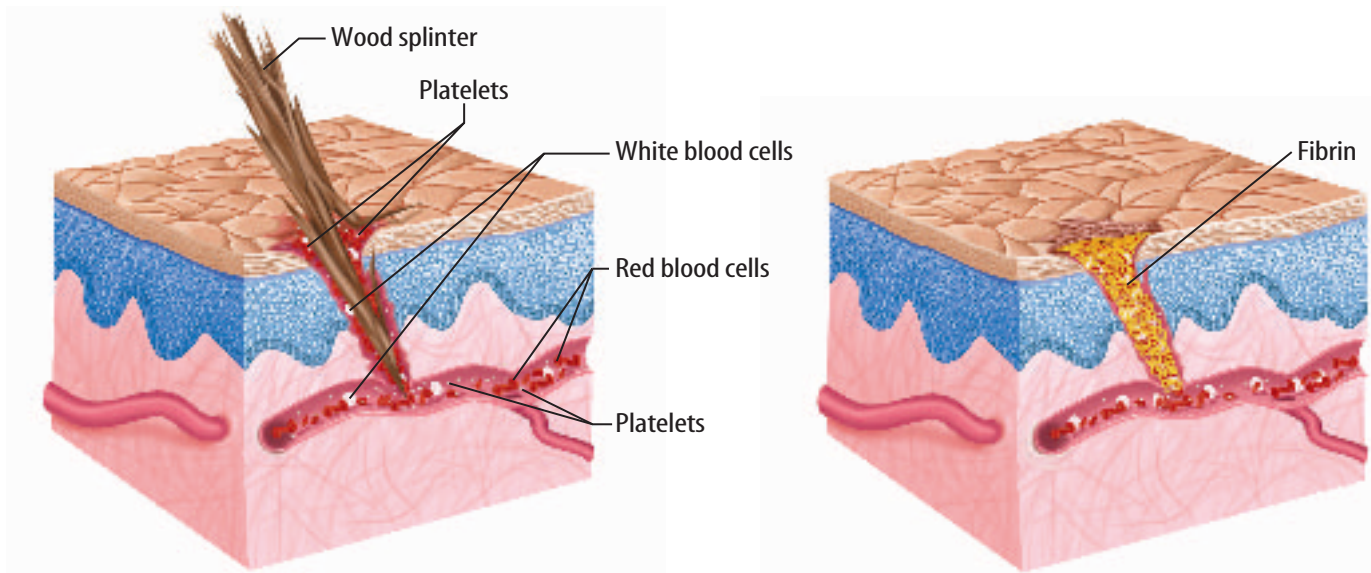


Platelets help stop bleeding. Platelets not only plug holes in small vessels, they also release chemicals that help form filaments of fibrin.

Several types, sizes, and shapes of white blood cells exist. These cells destroy bacteria, viruses, and foreign substances.



**Figure 12** When the skin is damaged, a sticky blood clot seals the leaking blood vessel. Eventually, a scab forms to protect the wound from further damage and allow it to heal.



## Mini LAB

### Modeling Scab Formation

#### Procedure

1. Place a 5-cm × 5-cm square of **gauze** on a piece of **aluminum foil**.
2. Place several drops of a **liquid bandage solution** onto the gauze and let it dry. Keep the liquid bandage away from eyes and mouth.
3. Use a **dropper** to place one drop of **water** onto the area of the liquid bandage. Place another drop of water in another area of the gauze.

#### Analysis








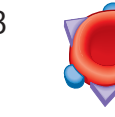

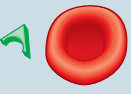


1. Compare the drops of water in both areas.
2. Describe how the treated area of the gauze is like a scab.

## Blood Clotting

You're running with your dog in a park, when all of a sudden you trip and fall down. Your knee starts to bleed, but the bleeding stops quickly. Already the wounded area has begun to heal. Bleeding stops because platelets and clotting factors in your blood make a blood clot that plugs the wounded blood vessels. A blood clot also acts somewhat like a bandage. When you cut yourself, platelets stick to the wound and release chemicals. Then substances called clotting factors carry out a series of chemical reactions. These reactions cause threadlike fibers called fibrin (FI brun) to form a sticky net, as shown in **Figure 12**. This net traps escaping blood cells and plasma and forms a clot. The clot helps stop more blood from escaping. After the clot is in place and becomes hard, skin cells begin the repair process under the scab. Eventually, the scab is lifted off. Bacteria that might get into the wound during the healing process are destroyed by white blood cells.

 **Reading Check** *What blood components help form blood clots?*

Most people will not bleed to death from a minor wound, such as a cut or scrape. However, some people have a genetic condition called hemophilia (hee muh FIH lee uh). Their plasma lacks one of the clotting factors that begins the clotting process. A minor injury can be a life threatening problem for a person with hemophilia.

Table 1 Blood Types		
Blood Type	Antigen	Antibody
A 	A 	Anti-B 
B 	B 	Anti-A 
AB 	A, B 	None 
O 	None 	Anti-A and Anti-B 

## Blood Types

Blood clots stop blood loss quickly in a minor wound, but a person with a serious wound might lose a lot of blood and need a blood transfusion. During a blood transfusion, a person receives donated blood or parts of blood. The medical provider must be sure that the right type of blood is given. If the wrong type is given, the red blood cells will clump together. Then, clots form in the blood vessels and the person could die.

**The ABO Identification System** People can inherit one of four types of blood: A, B, AB, or O, as shown in **Table 1**. Types A, B, and AB have chemical identification tags called antigens (AN tih junz) on their red blood cells. Type O red blood cells have no antigens.

Each blood type also has specific antibodies in its plasma. Antibodies are proteins that destroy or neutralize substances that do not belong in or are not part of your body. Because of these antibodies, certain blood types cannot be mixed. This limits blood transfusion possibilities as shown in **Table 2**. If type A blood is mixed with type B blood, the type A antibodies determine that type B blood does not belong there. The type A antibodies cause the type B red blood cells to clump. In the same way, type B antibodies cause type A blood to clump. Type AB blood has no antibodies, so people with this blood type can receive blood from A, B, AB, and O types. Type O blood has both A and B antibodies.



**Reading Check**

*Why are people with type O blood called universal donors?*

**Table 2**  
**Blood Transfusion Options**

Type	Can Receive	Can Donate To
A	O, A	A, AB
B	O, B	B, AB
AB	all	AB
O	O	all





### INTEGRATE History

**Blood Transfusions** The first blood transfusions took place in the 1600s and were from animal to animal, and then from animal to human. In 1818, James Blundell, a British obstetrician, performed the first successful transfusion of human blood to a patient for the treatment of hemorrhage.

**The Rh Factor** Another chemical identification tag in blood is the Rh factor. The Rh factor also is inherited. If the Rh factor is on red blood cells, the person has Rh-positive (Rh+) blood. If it is not present, the person's blood is called Rh-negative (Rh-). If an Rh- person receives a blood transfusion from an Rh+ person, he or she will produce antibodies against the Rh factor. These antibodies can cause Rh+ cells to clump. Clots then form in the blood vessels and the person could die.

When an Rh- mother is pregnant with an Rh+ baby, the mother might make antibodies to the child's Rh factor. Close to the time of birth, Rh antibodies from the mother can pass from her blood into the baby's blood. These antibodies can destroy the baby's red blood cells. If this happens, the baby must receive a blood transfusion before or right after birth. At 28 weeks of pregnancy and immediately after the birth, an Rh- mother can receive an injection that blocks the production of antibodies to the Rh+ factor. These injections prevent this life-threatening situation. To prevent deadly results, blood groups and Rh factor are checked before transfusions and during pregnancies.



### Reading Check

*Why is it important to check Rh factor?*

## Applying Science

### Will there be enough blood donors?

Successful human blood transfusions began during World War II. This practice is much safer today due to extensive testing of the donated blood prior to transfusion. Health care professionals have determined that each blood type can receive certain other blood types as illustrated in **Table 2**.

#### Identifying the Problem

The table on the right lists the average distribution of blood types in the United States. The data are recorded as percents, or a sample of 100 people. By examining these data and the data in **Table 2**, can you determine safe donors for each blood type? Recall that people with Rh- blood cannot receive a transfusion from an Rh+ donor.

Blood Type Distribution		
	Rh+ (%)	Rh- (%)
O	37	7
A	36	6
B	9	1
AB	3	1

#### Solving the Problem

1. If a Type B, Rh+ person needs a blood transfusion, how many possible donors are there?
2. Frequently, the supply of donated blood runs low. Which blood type and Rh factor would be most affected in such a shortage? Explain your answer.

## Diseases of Blood

Because blood circulates to all parts of your body and performs so many important functions, any disease of the blood is a cause for concern. One common disease of the blood is anemia (uh NEE mee uh). In this disease of red blood cells, body tissues can't get enough oxygen and are unable to carry on their usual activities. Anemia has many causes. Sometimes, anemia is caused by the loss of large amounts of blood. A diet lacking iron or certain vitamins also might cause anemia. In addition, anemia can be the result of another disease or a side effect of treatment for a disease. Still other types of anemia are inherited problems related to the structure of the red blood cells. Cells from one such type of anemia, sickle-cell anemia, are shown in **Figure 13**.

Leukemia (lew KEE mee uh) is a disease in which one or more types of white blood cells are made in excessive numbers. These cells are immature and do not fight infections well. They fill the bone marrow and crowd out the normal cells. Then not enough red blood cells, normal white blood cells, and platelets can be made. Types of leukemia affect children or adults. Medicines, blood transfusions, and bone marrow transplants are used to treat this disease. If the treatments are not successful, the person eventually will die from related complications.



Color-enhanced TEM Magnification: 7400×

**Figure 13** Persons with sickle-cell anemia have misshapened red blood cells. The sickle-shaped cells clog the capillaries of a person with this disease. Oxygen cannot reach tissues served by the capillaries, and wastes cannot be removed. **Describe** how this damages the affected tissues.

### section 2 review

#### Summary

##### Parts of Blood

- Plasma is made mostly of water, with nutrients, minerals, and oxygen dissolved in it.
- Red blood cells contain hemoglobin, which carries oxygen and carbon dioxide.
- White blood cells control infections and viruses.
- Blood clotting factors and platelets help blood to clot.

##### Blood Types

- People can inherit one of four types of blood and an Rh factor.
- Type A, B, and AB blood all have antigens. Type O blood has no antigens.

##### Diseases of Blood

- Anemia is a disease of red blood cells.
- Leukemia is a disease that produces immature white blood cells that don't fight infections.

#### Self Check

1. **List** the four functions of blood in the body.
2. **Infer** why blood type and Rh factor are checked before a transfusion.
3. **Interpret Data** Look at the data in **Table 2** about blood group interactions. To which group(s) can blood type AB donate blood, and which blood type(s) can AB receive blood from?
4. **Think Critically** Think about the main job of your red blood cells. If red blood cells couldn't deliver oxygen to your cells, what would be the condition of your body tissues?

#### Applying Math

5. **Use Percentages** Find the total number of red blood cells, white blood cells, and platelets in  $1 \text{ mm}^3$  of blood. Calculate what percentage of the total each type is.



# The Lymphatic System

## as you read

### What You'll Learn

- **Describe** functions of the lymphatic system.
- **Identify** where lymph comes from.
- **Explain** how lymph organs help fight infections.

### Why It's Important

The lymphatic system helps protect you from infections and diseases.

### Review Vocabulary

**smooth muscles:** muscles found in your internal organs and digestive track

### New Vocabulary

- lymph
- lymphatic system
- lymphocyte
- lymph node

## Functions of the Lymphatic System

You're thirsty so you turn on the water faucet and fill a glass with water. The excess water runs down the drain. In a similar way, your body's excess tissue fluid is removed by the lymphatic (lihm FA tihk) system. The nutrient, water, and oxygen molecules in blood diffuse through capillary walls to nearby cells. Water and other substances become part of the tissue fluid that is found between cells. This fluid is collected and returned to the blood by the lymphatic system.

After tissue fluid diffuses into the lymphatic capillaries it is called **lymph** (LIHMF). Your **lymphatic system**, as shown in **Figure 14**, carries lymph through a network of lymph capillaries and larger lymph vessels. Then, the lymph drains into large veins near the heart. No heartlike structure pumps the lymph through the lymphatic system. The movement of lymph depends on the contraction of smooth muscles in lymph vessels and skeletal muscles. Lymphatic vessels, like veins, have valves that keep lymph from flowing backward. If the lymphatic system is not working properly, severe swelling occurs because the tissue fluid cannot get back to the blood.

In addition to water and dissolved substances, lymph also contains **lymphocytes** (LIHM fuh sites), a type of white blood cell. Lymphocytes help your body defend itself against disease-causing organisms.



### Reading Check

*What are the differences and similarities between lymph and blood?*

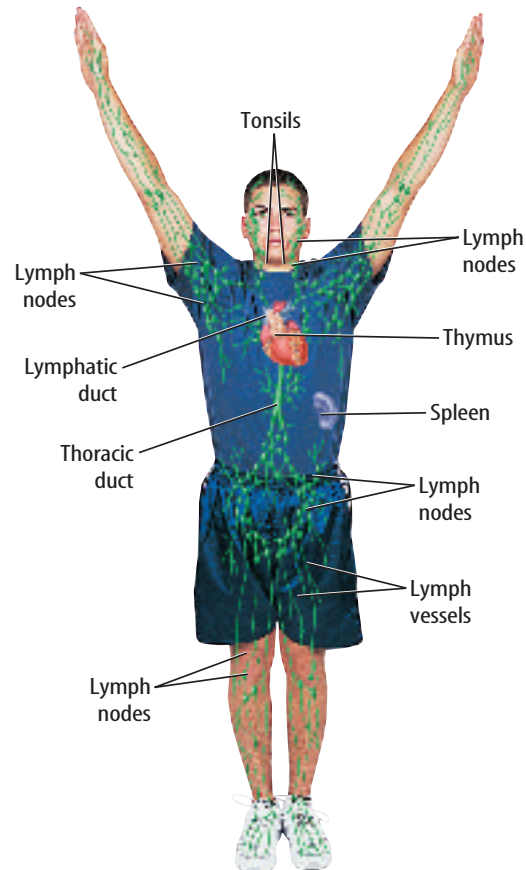
## Lymphatic Organs

Before lymph enters the blood, it passes through lymph nodes, which are bean-shaped organs of varying sizes found throughout the body. **Lymph nodes** filter out microorganisms and foreign materials that have been taken up by lymphocytes. When your body fights an infection, lymphocytes fill the lymph nodes. The lymph nodes become warm, reddened, and tender to the touch. After the invaders are destroyed, the redness, warmth, and tenderness in the lymph nodes goes away.

Besides lymph nodes, the tonsils, the thymus, and the spleen are important lymphatic organs. Tonsils are in the back of your throat and protect you from harmful microorganisms that enter through your mouth and nose. Your thymus is a soft mass of tissue located behind the sternum. It makes lymphocytes that travel to other lymph organs. The spleen is the largest lymphatic organ. It is located behind the upper-left part of the stomach and filters the blood by removing worn out and damaged red blood cells. Cells in the spleen take up and destroy bacteria and other substances that invade your body.

## A Disease of the Lymphatic System

HIV is a deadly virus. When HIV enters a person's body, it attacks and destroys lymphocytes called helper T cells that help make antibodies to fight infections. This affects a person's immunity to some diseases. Usually, the person dies from these diseases, not from the HIV infection.



**Figure 14** The lymphatic system is connected by a network of vessels.

**Describe** how muscles help move lymph.

### section 3 review

#### Summary

##### Functions of the Lymphatic System

- Fluid is collected and returned from the body tissues to the blood by the lymphatic system.
- After fluid from tissues diffuses into the lymphatic capillaries it is called lymph.
- Lymphocytes are a type of white blood cell that helps your body defend itself against disease.

##### Lymphatic Organs

- Lymph nodes filter out microorganisms and foreign materials taken up by lymphocytes.
- The tonsils, thymus, and spleen also protect your body from harmful microorganisms that enter through your mouth and nose.

##### A Disease of the Lymphatic System

- HIV destroys helper T cells that help make antibodies to fight infections.

#### Self Check

1. **Describe** where lymph comes from and how it gets into the lymphatic capillaries.
2. **Explain** how lymphatic organs fight infection.
3. **Sequence** the events that occur when HIV enters the body.
4. **Think Critically** When the amount of fluid in the spaces between cells increases, so does the pressure in these spaces. What do you infer will happen?

#### Applying Skills

5. **Concept Map** The circulatory system and the lymphatic system work together in several ways. Make a concept map comparing the two systems.
6. **Communicate** An infectious microorganism enters your body. In your Science Journal, describe how the lymphatic system protects the body against the microorganism.



# Blood Type Reactions

## Goals

- **Design** an experiment that simulates the reactions between different blood types.
- **Identify** which blood types can donate to which other blood types.

## Possible Materials

simulated blood (10 mL low-fat milk and 10 mL water plus red food coloring)  
 lemon juice as antigen A (for blood types B and O)  
 water as antigen A (for blood types A and AB)  
 droppers  
 small paper cups  
 marking pen  
 10-mL graduated cylinder

## Safety Precautions



**WARNING:** Do not taste, eat, or drink any materials used in the lab.

## Real-World Question

Human blood can be classified into four main blood types—A, B, AB, and O. These types are determined by the presence or absence of antigens on the red blood cells. After blood is collected into a transfusion bag, it is tested to determine the blood type. The type is labeled clearly on the bag. Blood is refrigerated to keep it fresh and available for transfusion. What happens when two different blood types are mixed?



## Form a Hypothesis

Based on your reading and observations, state a hypothesis about how different blood types will react to each other.



## ▶ Test Your Hypothesis

### Make a Plan

1. As a group, agree upon the hypothesis and decide how you will test it. Identify the results that will confirm the hypothesis.
2. **List** the steps you must take and the materials you will need to test your hypothesis. Be specific. Describe exactly what you will do in each step.
3. **Prepare** a data table like the one at the right in your Science Journal to record your observations.
4. Reread the entire experiment to make sure all steps are in logical order.
5. **Identify** constants and variables. Blood type O will be the control.

Blood Type Reactions	
Blood Type	Clumping (Yes or No)
A	Do not write in this book.
B	
AB	
O	

### Follow Your Plan

1. While doing the experiment, record your observations and complete the data table in your Science Journal.

## ▶ Analyze Your Data

1. **Compare** the reactions of each blood type (A, B, AB, and O) when antigen A was added to the blood.
2. **Observe** where clumping took place.
3. **Compare** your results with those of other groups.
4. What was the control factor in this experiment?
5. What were your variables?

## ▶ Conclude and Apply

1. Did the results support your hypothesis? Explain.
2. **Predict** what might happen to a person if other antigens are not matched properly.
3. What would happen in an investigation with antigen B added to each blood type?

### Communicating Your Data

**Write** a brief report on how blood is tested to determine blood type. **Describe** why this is important to know before receiving a blood transfusion. **For more help, refer to the Science Skill Handbook.**

# Have a Heart



Dr. Daniel Hale Williams was a pioneer in open-heart surgery.

## People didn't always know where blood came from or how it moved through the body

“Ouch!” You prick your finger, and when blood starts to flow out of the cut, you put on a bandage. But if you were a scientist living long ago, you might have also asked yourself some questions: How did your blood get to the tip of your finger? And why and how does it flow through (and sometimes out of!) your body?

As early as the 1500s, a Spanish scientist named Miguel Serveto (mee GEL • ser VE toh) asked that question. His studies led him to the theory that blood circulated throughout the human body, but he didn't know how or why.

About 100 years later, William Harvey, an English doctor, explored Serveto's idea. Harvey studied animals to develop a theory about how the heart and the circulatory system work.

Harvey hypothesized, from his observations of animals, that blood was pumped from the heart throughout the body, and that it returned to the heart and recirculated. He published his ideas in 1628 in his famous book, *On the Motion*

*of the Heart and Blood in Animals*. His theories were correct, but many of Harvey's patients left him. His patients thought his ideas were ridiculous. His theories were correct, and over time, Harvey's book became the basis for all modern research on heart and blood vessels.

## Medical Pioneer

More than two centuries later, another pioneer stepped forward and used Harvey's ideas to change the science frontier again. His name was Dr. Daniel Hale Williams. In 1893, Williams used what he knew about heart and blood circulation to become a new medical pioneer. He performed the first open-heart surgery by removing a knife from the heart of a stabbing victim. He stitched the wound to the fluid-filled sac surrounding the heart, and the patient lived several more years. In 1970, the U.S. recognized Williams by issuing a stamp in his honor.

**Report** Identify a pioneer in science or medicine who has changed our lives for the better. Find out how this person started in the field, and how they came to make an important discovery. Give a presentation to the class.

Science  **online**

For more information, visit  
[bookd.msscience.com/time](http://bookd.msscience.com/time)



Reviewing Main Ideas

**Section 1 The Circulatory System**

1. Arteries carry blood away from the heart. Capillaries allow the exchange of nutrients, oxygen, and wastes in cells. Veins return blood to the heart.
2. Carbon-dioxide-rich blood enters the right atrium, moves to the right ventricle, and then goes to the lungs through the pulmonary artery. Oxygen-rich blood returns to the left atrium, moves to the left ventricle, and then leaves through the aorta.
3. Pulmonary circulation is the path of blood between the heart and lungs. Circulation through the rest of the body is called systemic circulation. Coronary circulation is the flow of blood to tissues of the heart.

2. Red blood cells carry oxygen and carbon dioxide, platelets form clots, and white blood cells fight infection.
3. A, B, AB, and O blood types are determined by the presence or absence of antigens on red blood cells.
4. Anemia is a disease of red blood cells, in which not enough oxygen is carried to the body's cells.
5. Leukemia is a disease where one or more types of white blood cells are present in excessive numbers. These cells are immature and do not fight infection well.

**Section 2 Blood**

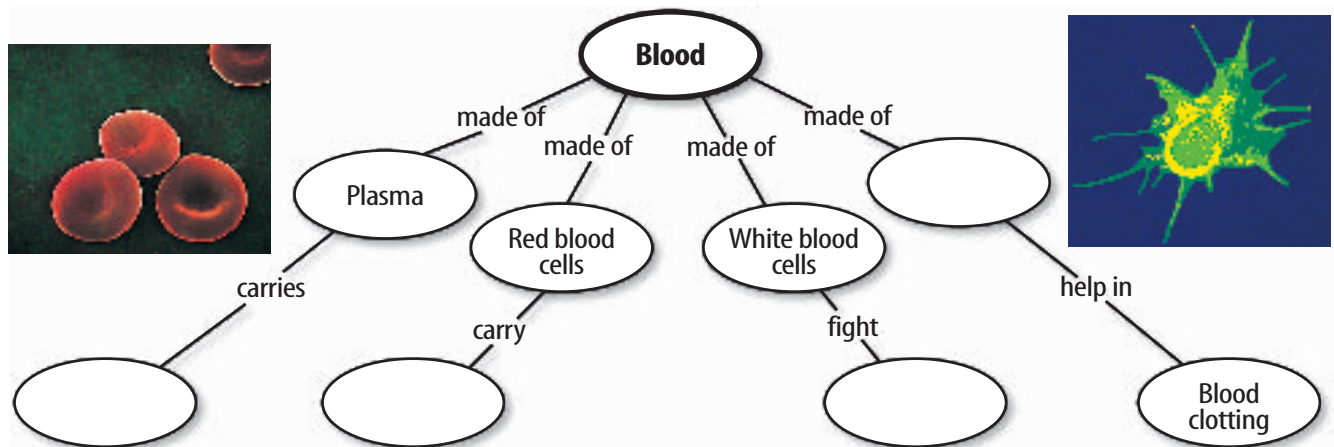
1. Plasma carries nutrients, blood cells, and other substances.

**Section 3 The Lymphatic System**

1. Lymph structures filter blood, produce white blood cells that destroy bacteria and viruses, and destroy worn out blood cells.
2. HIV attacks helper T cells, which are a type of lymphocyte. The person is unable to fight infections well.

Visualizing Main Ideas

Copy and complete this concept map on the functions of the parts of the blood.



## Using Vocabulary

artery p.68	lymphocyte p.80
atrium p.65	plasma p.74
capillary p.69	platelet p.75
coronary circulation p.65	pulmonary circulation p.66
hemoglobin p.75	systemic circulation p.67
lymph p.80	vein p.68
lymph node p.80	ventricle p.65
lymphatic system p.80	

Fill in the blanks with the correct vocabulary word(s).

- The \_\_\_\_\_ carries blood to the heart.
- The \_\_\_\_\_ transports tissue fluid through a network of vessels.
- \_\_\_\_\_ is the chemical in red blood cells.
- \_\_\_\_\_ are cell fragments.
- The smallest blood vessels are called the \_\_\_\_\_.
- The flow of blood to and from the lungs is called \_\_\_\_\_.
- \_\_\_\_\_ helps protect your body against infections.
- The largest section of the circulatory system is the \_\_\_\_\_.
- \_\_\_\_\_ are blood vessels that carry blood away from the heart.
- The two lower chambers of the heart are called the right and left \_\_\_\_\_.

## Checking Concepts

Choose the word or phrase that best answers the question.

- Where does the exchange of food, oxygen, and wastes occur?
 

A) arteries	C) veins
B) capillaries	D) lymph vessels

- What is circulation to all body organs called?
 

A) coronary	C) systemic
B) pulmonary	D) organic
- Where is blood under greatest pressure?
 

A) arteries	C) veins
B) capillaries	D) lymph vessels
- Which cells fight off infection?
 

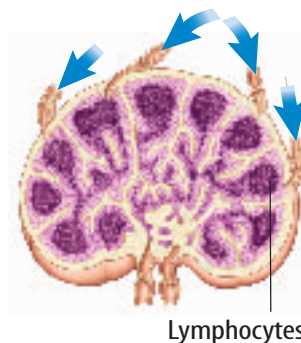
A) red blood	C) white blood
B) bone	D) nerve
- Of the following, which carries oxygen in blood?
 

A) red blood cells	C) white blood cells
B) platelets	D) lymph
- What is required to clot blood?
 

A) plasma	C) platelets
B) oxygen	D) carbon dioxide
- What kind of antigen does type O blood have?
 

A) A	C) A and B
B) B	D) no antigen

Use the figure below to answer question 18.



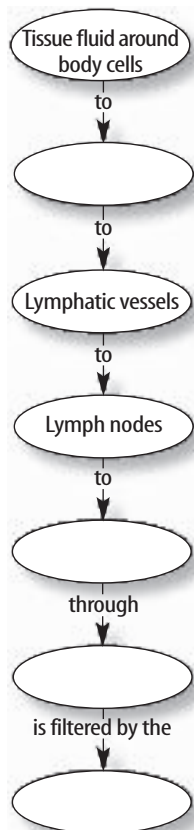
- What is the bean-shaped organ above that filters out microorganisms and foreign materials taken up by lymphocytes?
 

A) kidney	C) lung
B) lymph	D) lymph node
- What is the largest filtering lymph organ?
 

A) spleen	C) tonsil
B) thymus	D) node

**Thinking Critically**

- 20. **Identify** the following as having oxygen-rich or carbon dioxide-filled blood: *aorta, coronary arteries, coronary veins, inferior vena cava, left atrium, left ventricle, right atrium, right ventricle, and superior vena cava.*
- 21. **Compare and contrast** the three types of blood vessels.
- 22. **Compare and contrast** the life spans of the red blood cells, white blood cells, and platelets.
- 23. **Describe** the sequence of blood clotting from the wound to forming a scab.
- 24. **Compare and contrast** the functions of arteries, veins, and capillaries.
- 25. **Concept Map** Copy and complete the events-chain concept map showing how lymph moves in your body.



- 26. **Explain** how the lymphatic system works with the cardiovascular system.
- 27. **Infer** why cancer of the blood cells or lymph nodes is hard to control.
- 28. **Explain** why a pulse is usually taken at the neck or wrist, when arteries are distributed throughout the body.

**Performance Activities**

- 29. **Poster** Prepare a poster illustrating heart transplants. Include an explanation of why the patient is given drugs that suppress the immune system and describe the patient's life after the operation.
- 30. **Scientific Illustrations** Prepare a drawing of the human heart and label its parts.

**Applying Math**

Use the table below to answer question 31.

Gender and Heart Rate	
Sex	Pulse/Minute
Male 1	72
Male 2	64
Male 3	65
Female 1	67
Female 2	84
Female 3	74

- 31. **Heart Rates** Using the table above, find the average heart rate of the three males and the three females. Compare the two averages.
- 32. **Blood Mass** Calculate how many kilograms of blood is moving through your body, if blood makes up about eight percent of your body's total mass and you weigh 38 kg.



**Part 1 Multiple Choice**

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

- Which of the following is a function of blood?
  - A. carry saliva to the mouth
  - B. excrete salts from the body
  - C. transport nutrients and other substances to cells
  - D. remove lymph from around cells

Use the table below to answer questions 2 and 3.

Results from Ashley's Activities			
Activity	Pulse Rate (beats/min)	Body Temperature	Degree of Sweating
1	80	98.6°F	None
2	90	98.8°F	Minimal
3	100	98.9°F	Little
4	120	99.1°F	Moderate
5	150	99.5°F	Considerable

- Which of the following activities caused Ashley's pulse to be less than 100 beats per minute?
  - A. Activity 2
  - B. Activity 3
  - C. Activity 4
  - D. Activity 5
- A reasonable hypothesis based on these data, is that during Activity 2, Ashley was probably
  - A. sprinting
  - B. marching
  - C. sitting down
  - D. walking slowly
- Which of the following activities contributes to cardiovascular disease?
  - A. smoking
  - B. jogging
  - C. sleeping
  - D. balanced diet
- Where does blood low in oxygen enter first?
  - A. right atrium
  - B. left atrium
  - C. left ventricle
  - D. right ventricle

- Which of the following is an artery?
  - A. left ventricle
  - B. aorta
  - C. superior vena cava
  - D. inferior vena cava
- Which of the following is NOT a part of the lymphatic system?
  - A. lymph nodes
  - B. valves
  - C. heartlike structure
  - D. lymph capillaries

Use the table below to answer questions 8 and 9.

Blood Cell Counts (per 1 mm <sup>3</sup> )			
Patient	Red Blood Cells	White Blood Cells	Platelets
Normal	3.58–4.99 million	3,400–9,600	162,000–380,000
Mrs. Stein	3 million	8,000	400,000
Mr. Chavez	5 million	7,500	50,000

- What problem might Mrs. Stein have?
  - A. low oxygen levels in tissues
  - B. inability to fight disease
  - C. poor blood clotting
  - D. irregular heart beat
- If Mr. Chavez cut himself, what might happen?
  - A. minimal bleeding
  - B. prolonged bleeding
  - C. infection
  - D. quick healing
- Which lymphatic organ protects your body from harmful microorganisms that enter through your mouth?
  - A. spleen
  - B. thymus
  - C. node
  - D. tonsils

**Test-Taking Tip**

**Don't Stray** During the test, keep your eyes on your own paper. If you need to rest them, close them or look up at the ceiling.

## Part 2 Short Response/Grid In

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

11. If red blood cells are made at the rate of 2 million per second in the center of long bones, how many red blood cells are made in one hour?
12. If a cubic milliliter of blood has 10,000 white blood cells and 400,000 platelets, how many times more platelets than white blood cells are present in a cubic milliliter of blood?
13. What would happen if type A blood was given to a person with type O blood?

Use the illustration below to answer questions 14 and 15.

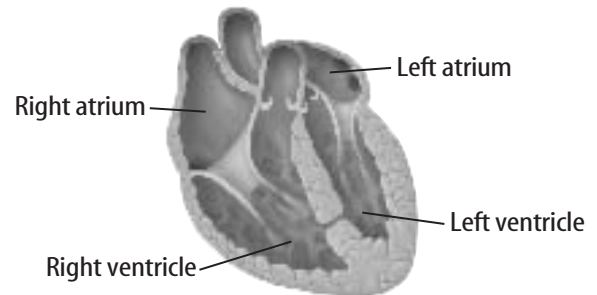


14. What might happen if there was a blood clot blocking vessel “A”?
15. What might happen if there was a blood clot blocking vessel “B”?
16. Why don't capillaries have thick, elastic walls?
17. Why would a cut be dangerous for a person with hemophilia?
18. Why would a person with leukemia have low numbers of red blood cells, normal white blood cells, and platelets in the blood?

## Part 3 Open Ended

Record your answers on a sheet of paper.

Use the illustration below to answer questions 19 and 20.



19. What is wrong with this heart? How do you know?
20. The left ventricle pumps blood under higher pressure than the right ventricle does. In which direction would you predict blood would flow through the hole in the heart? Compare the circulation in this heart with that of a normal heart.
21. What are some ways to prevent cardiovascular disease?
22. Compare and contrast diffusion and active transport.
23. Describe the role of the brain in blood pressure homeostasis. Why is this important?
24. Thrombocytopenia is a condition in which the number of platelets in the blood is decreased. Hemophilia is a genetic condition where blood plasma lacks one of the clotting factors. Compare how a small cut would affect a person with thrombocytopenia and someone with hemophilia.