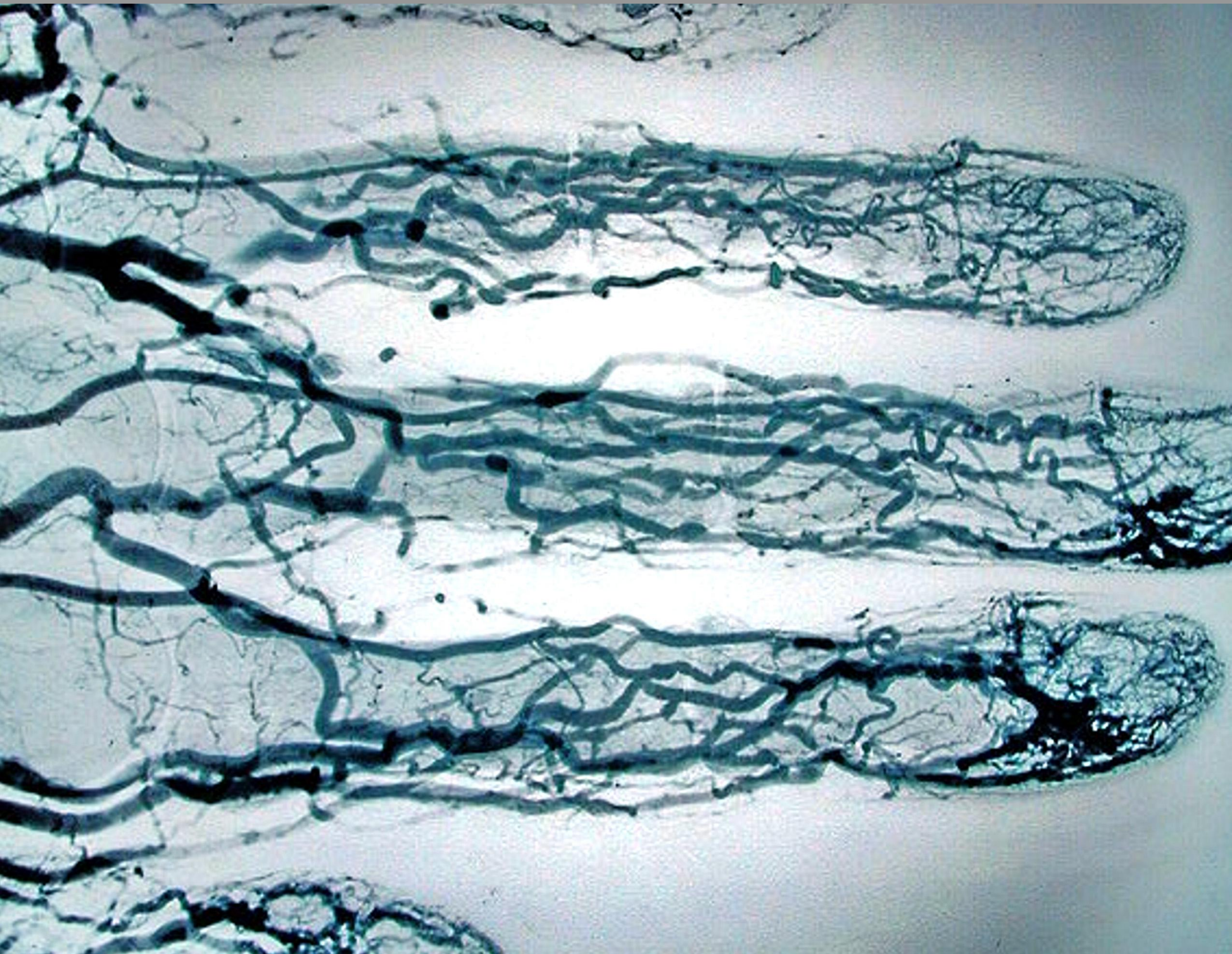
Human Biology - Circulation



Human Biology - Circulation

The Program in Human Biology,
Stanford University, (HumBio)

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CHAPTER 1 Introduction to Circulation - Student Edition (Human Biology)

CHAPTER OUTLINE

1.1 Human Biology

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1.2 Introduction to Circulation

Contents

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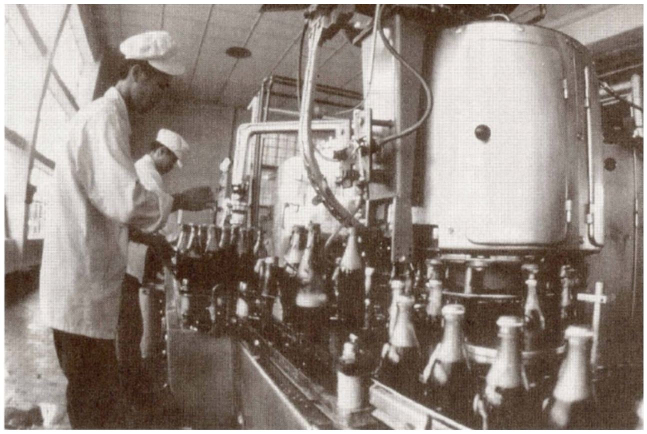
CHAPTER 2 Circulation - Student Edition (Human Biology)

CHAPTER OUTLINE

2.1 Circulation



Why is blood important to life?

This unit explores all the parts of your circulatory system. The unit begins with a look at blood and the heart. You will then learn about the different kinds of blood vessels and how your body controls blood flow. The unit concludes with a discussion of how to keep your heart and blood vessels strong and healthy.

A City of Cells

Think of your body as a city of cells. Each cell is like a house. A house needs fuel, energy, water, and raw materials. A house must also have a sewer system and garbage pickup to get rid of wastes. Your body must take in needed materials and get rid of waste materials just like a house does.

Journal Writing

What makes a delivery system efficient? Imagine you are in charge of a package delivery service. What things might make your job harder? What things might make your job easier? What would be the most important parts of a successful delivery company? Write a paragraph to explain your ideas, and include any lists, diagrams, or drawings that help your explanation.

Pipelines, electrical cables, phone lines, and automobiles transport materials to and from buildings, apartments, and houses in a city. In your body, cells are served by **blood** in the **circulatory** (SUHR-kuelah-tor-ee) **system.** Blood flows through a series of tubes in your body called **vessels** (VES-uhls). The blood brings food, water, and oxygen to each cell "house." The blood also removes wastes produced by your cells, including carbon dioxide gas, through a series of vessels. The carbon dioxide is carried to your lungs where you breathe it out. At the center of your network of blood vessels is your **heart**-the power pump of your circulatory system.

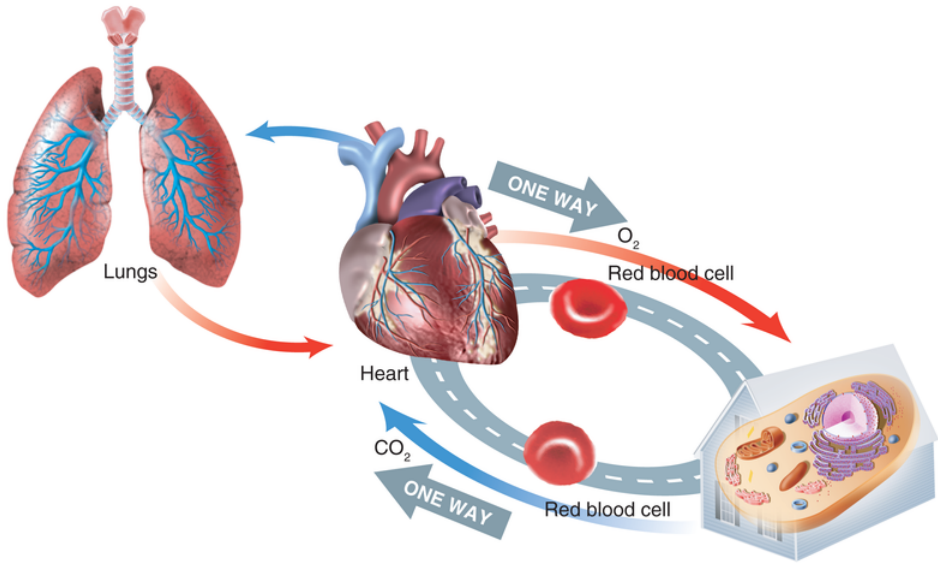
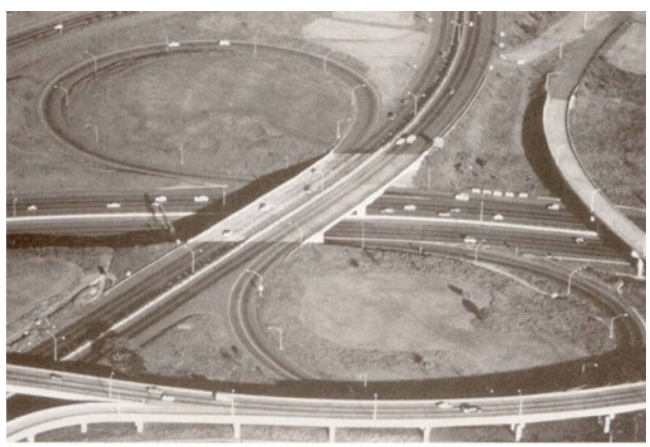


Figure 1.1 Your circulatory system is like the streets of a city, with lots of traffic flowing through the streets to and from different destinations.

Your heart pumps blood through a network of blood vessels. The network and your heart together are called a "circulatory" system. It's called a circulatory system because the blood circulates around and around. You also know that your blood carries oxygen to all of the cells in your body. The blood gets the oxygen from your lungs, which is a part of your breathing machine called the **respiratory system.** What you might not know is that your heart is really two pumps in one. It pumps the blood through two connected circuits. One circuit goes to the lungs, and one circuit goes to the rest of the body. So a map of the circulatory system is really more like a figure eight than a circle. You can demonstrate the map of the circulatory system by making the model in *Activity 1-1: Pathway of Blood through Your Body.*



Activity 1-1: Pathway of Blood through Your Body

Introduction

In this activity you will learn about all the parts of your circulatory system and what they do. Let's start by building a model that can serve as your guide to the parts of the circulatory system and how they fit together.

Materials

- Paper cups (4)

- Straw
- Glue
- Paper towels
- Colored pencils, pens, or paint (blue and red)
- Tape
- Balloon (white)
- Colored thread (blue and red)
- Colored yarn (blue and red, 2 pieces 20 cm each)
- Lima beans (3 or 4)
- Scissors
- Ruler
- Activity Report

Procedure

First, you are going to build a model heart. The heart is two pumps side by side. Each pump has two chambers. In both pumps, blood enters the upper chamber and leaves the lower chamber. So you will have four blood vessels attached to your heart model. Now follow **Steps 1** to **6** as you build your model heart.

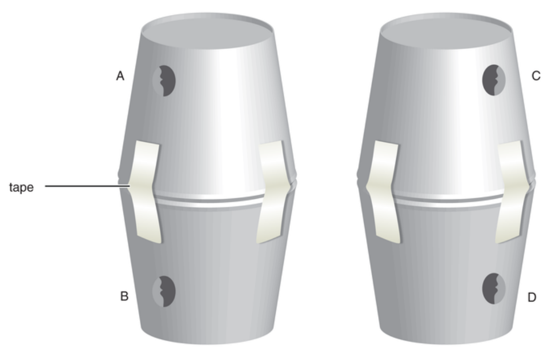


Figure 1.2 Use a pencil to carefully make a hole in each cup. You will place straws in the holes in the heart model. The straws will represent blood vessels.

Step 1 Place the open ends of two paper cups together. Secure the cups together with tape. Do the same thing with the other two cups.

Step 2 Stand the two sets of cups side by side. Each cup represents a heart chamber.

Step 3 Carefully poke a hole in the side of each cup as shown in **Figure 1.2** above,

Step 4 Cut a straw into four equal pieces. Color or paint two of the pieces blue and the other two pieces red, (You'll find out what the colors mean later.)

Step 5 Insert and glue one of the blue straws into opening B. Insert and glue a red straw into opening C.

Step 6 Stick a piece of blue yarn into the open end of the blue straw attached to the cups. Stick a piece of red yarn into the open end of the red straw attached to the cups. The straws and yarn represent blood vessels corning to and leaving the heart

Now you have two halves of what will be your model of the heart. The straws and yarn represent the system of blood vessels through which the heart pumps blood. Remember that this model resembles a figure eight rather than a simple circle. Half of the figure eight is the lung circuit where blood picks up oxygen. The other half of the figure eight is the body circuit where blood gives oxygen to all the cells of the body. Now you know the significance of the blue and red colors. Blue represents vessels carrying blood after it gives oxygen to cells. Red represents vessels carrying blood with a full load of oxygen. You can use this information in completing the following steps to finish your model.

Step 7 Inflate a white balloon to about 10 centimeters (4 inches) in diameter and tie it off. The balloon represents the lungs.

Step 8 Glue blue and red threads on the surface of the inflated balloon, or use pens to draw blue and red lines. The threads (or colored lines) represent the tiniest blood vessels where the blood picks up oxygen from the air in the lungs.

Step 9 Glue the free ends of the blue yarn to the surface of the balloon that has the tiny blue vessels. Glue the free ends of the red yarn to the surface of the balloon that has the tiny red vessels. You have completed the part of the model that represents the pump that moves blood to your lungs and back to the heart. This part of your completed model should look like the one in **Figure 1.3**.

Step 10 Now finish your two-pump model of the heart by making a model of the pump that moves the blood to your body cells. Insert and glue the other red straw into opening D. Insert and glue the other blue straw into opening A.

Step 11 Stick a piece of red yarn into the open end of the second red straw. Stick a piece of blue yarn into the open end of the second blue straw.

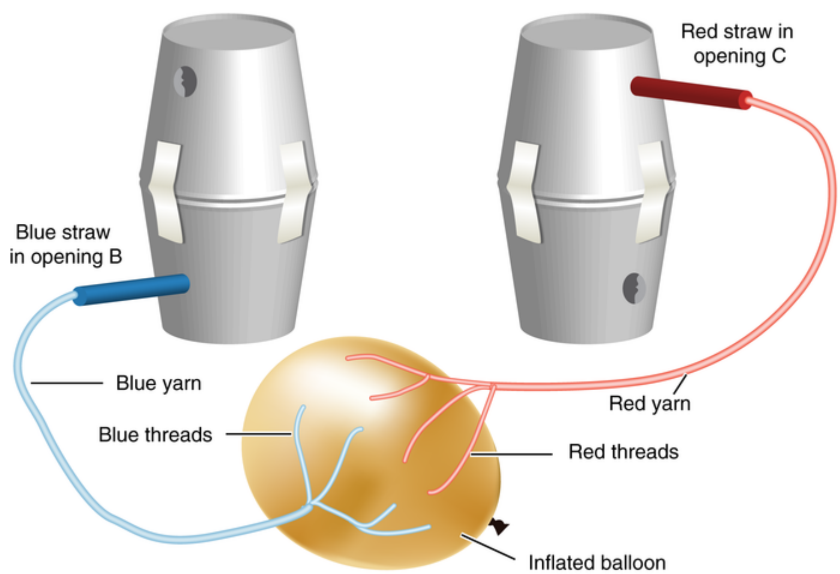


Figure 1.3 This is how the two halves of your model heart should look.

Step 12 Obtain three or four lima beans to represent body cells. Cut about 10 to 12 pieces of thread, each about 3 centimeters long. Half of the pieces should be red. The other half should be blue. Glue one end of several red and blue threads on the surface of each bean.

Step 13 Attach the free end of the red threads to the red yarn. Attach the free ends of the blue threads to the blue yarn. Your completed model should look like the one in **Figure 1.4**.

Step 14 Be sure you can explain to someone the path that a drop of blood would take in flowing through your model. Draw a picture of your model on your Activity Report. Then write an explanation of how the blood would flow through your model.

Step 15 Write your name and the date on your completed model.

Step 16 Check with your teacher for cleanup instructions and to find out where to store your model.

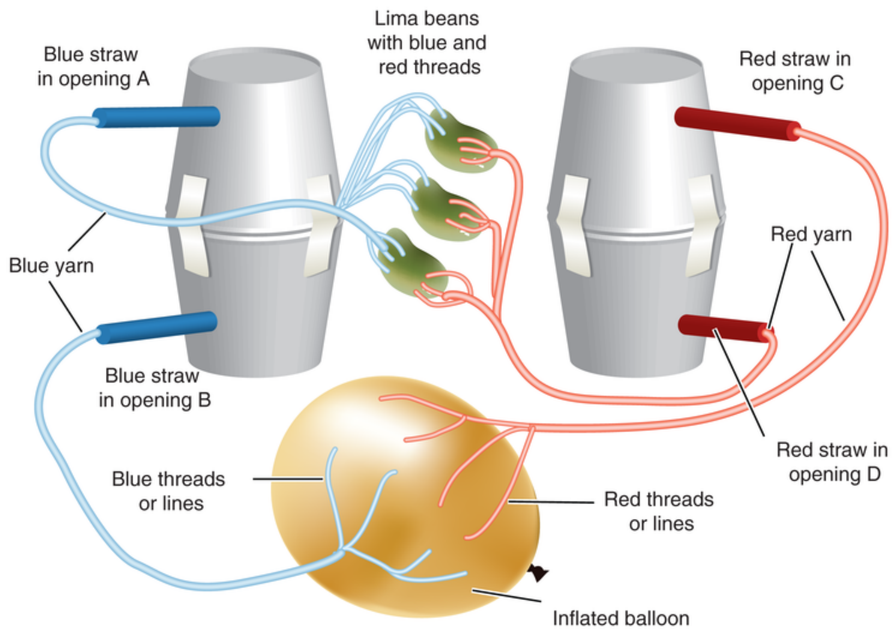


Figure 1.4 Blood carries oxygen from the lungs to the heart and from the heart to the cells. Blood carries carbon dioxide from the cells to the heart and from the heart to the lungs. This is a two-pump, figure eight model of the heart.

Blood

Blood is the fluid that circulates through your body. Blood is a liquid, but it functions like an organ in your body. An **organ** is a part of a living organism that has a specific function, such as the heart or brain. Blood serves many functions or has many jobs.

- Blood transports oxygen, food nutrients, wastes, and heat.
- Blood transports chemical messages called hormones throughout your body.
- Blood has special cells that protect you against infection.
- Blood has a clotting system to keep you from bleeding to death.

By doing all of these jobs, blood helps the body maintain homeostasis (hoh-mee-oh-STAY-sis). It helps keep conditions in your body in balance and functioning normally.

> **Did You Know?** Plants such as tall trees don't have hearts to pump fluids. But gases, water, and nutrients also move through plants. Water evaporates through tiny holes in a plant's leaves. As the water evaporates, more water is pulled upward from the roots toward the top of the plant. The water flows through special elongated cells that join end to end to form vessels.

You have about five liters of blood in your body. Your blood contains red blood cells, white blood cells, and platelets. Blood is also made up of a straw-colored fluid called **plasma** (PLAS-muh). Plasma is about 90 percent water. Plasma also contains salts, nutrients, wastes, proteins, and other substances including **hormones** (HOHR-mohns). Hormones are chemicals that stimulate cells to respond in certain ways. Blood carries all these substances along with oxygen and carbon dioxide to and from your body cells.

Did You Know? Blood is heavier and stickier than water. Your blood makes up approximately 8 percent of your total body weight. Calculate how much the blood in your body weighs. Then calculate how many liters of blood will weigh that much. Assume blood weighs the same as water, or 1 milliliter = 1 gram .

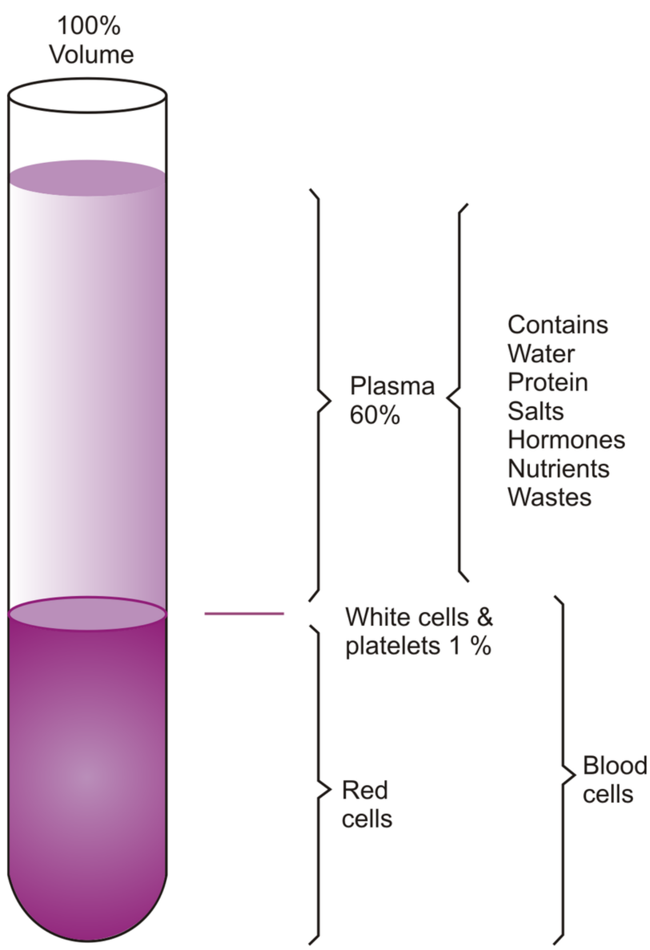


Figure 1.5 When a test tube of blood is spun around in a centrifuge, the heavier blood cells settle to the bottom. The lighter plasma rises to the top.

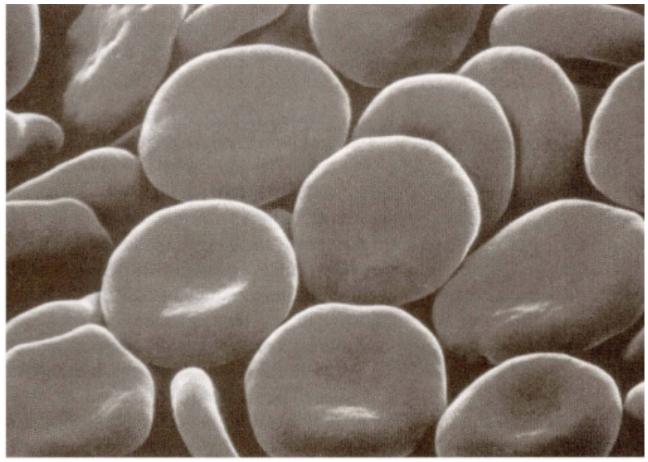


Figure 1.6 Here are some red blood cells seen with a high-powered microscope. The shape of a red blood cell maximizes its surface area. Its surface area determines how rapidly it can exchange O_2 and CO_2 .

Red Blood Cells

Red blood cells are doughnut-shaped cells with a flat, filled center. One milliliter (ml) of blood may contain 5 million red blood cells. Two thousand red blood cells lined up next to each other would cross the middle of a dime.

> **Did You Know?** A lobster's blood is blue rather than red. It has no iron-containing hemoglobin to carry oxygen around its body. Instead, it has a blue pigment called hemocyanin (hee-moh-SY-ah-nihn), which contains copper instead of iron.

Red blood cells contain **hemoglobin** (HEE-muh-glow-bihn), which is a reddish protein that carries oxygen. The red color comes from iron, which is a mineral that is part of hemoglobin. Blood appears bright red in color when oxygen is attached to the iron in hemoglobin. Blood appears dark red when no oxygen is attached to the iron in hemoglobin.

A mature red blood cell has no **nucleus** (NOO-klee-us). The nucleus is the information and control center found in most other cells. Without a nucleus, the red blood cell has room to carry lots of hemoglobin. The flexible, flattened shape of a red blood cell lets it bend and squeeze through narrow capillaries that are the tiny blood vessels that supply your body's cells.

Figure 1.7 If you could place 2,000 red blood cells side by side, they would fit across the middle of a dime. There are about 25 trillion red blood cells floating in the bloodstream of a human adult. That is the number 25 followed by 12 zeros!

Red blood cells are made in the **bone marrow.** Bone marrow is the spongy material inside bones. In the marrow each immature red blood cell has a nucleus. The nucleus tells the red blood cell to make hemoglobin. The red blood cell loses its nucleus when it leaves the bone marrow to begin flowing through the vessels of the circulatory system. The new red blood cell is now like a bag of hemoglobin. A red blood cell circulates in the blood for about 120 days.

After 120 days the parts of a red blood cell, including the iron in its hemoglobin, are recycled. They are reused by the bone marrow to make new red blood cells.

> **Did You Know?** If blood did not carry away wastes, the body would poison itself with its own waste products.

Each red blood cell contains 200 to 300 million molecules of hemoglobin. Hemoglobin is a complex protein containing iron. Iron allows hemoglobin to bind to oxygen. The binding process makes it possible for the red blood cells to carry oxygen from the lungs to the cells of the body. When the blood reaches the tiny blood vessels called capillaries, oxygen is released from the hemoglobin. The oxygen passes through the thin capillary walls to reach the body cells. At the same time, carbon dioxide from body cells passes back through the capillary walls. The carbon dioxide enters the blood and is carried back to the lungs. Hemoglobin transports about 23 percent of the carbon dioxide back to the lungs. The rest of the carbon dioxide travels back to the lungs in the plasma.

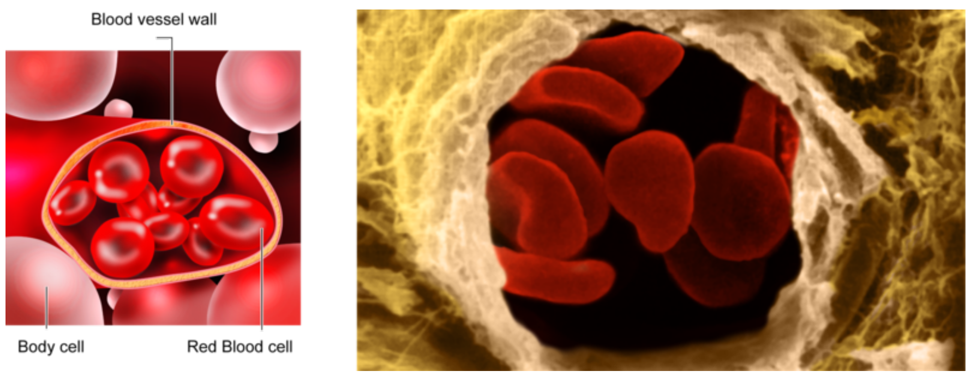


Figure 1.8 If you use a powerful microscope to look at a cross-section of a blood vessel, you might see red blood cells inside. The photograph (right) shows across-section of a blood vessel. Red blood cells are inside.

Apply Your KNOWLEDGE

> **Explain why a person living on a mountain at high altitude has a greater number of red blood cells than a person living at sea level.**

> **What Do You Think?**
> Some athletes use a procedure called "blood doping." Weeks before an important event they have some of their blood withdrawn and placed in cold storage. Their bodies make new red blood cells to replace the ones that were taken away. The athletes have their stored blood transfused back into their bodies just before the event. This increases the number of red blood cells in their blood and the amount of oxygen they are able to take up from each breath. Why do you think an athlete might do this? Do you think blood doping should be an illegal procedure? Why or why not?

> **Did You Know?**
> - The body produces 200 billion red blood cells daily.
> - White blood cells live two weeks.
> - Red blood cells live four months.
> - When watching TV, it takes 35 seconds for blood to make a complete trip through the body. When exercising, it only takes 10 seconds.

Diseases in Red Blood Cells

Sometimes things go wrong with red blood cells. For example, they can make abnormal hemoglobin. People whose blood cells make abnormal hemoglobin usually have a faulty hemoglobin gene. A **gene** is a part of the cell that contains information about making a protein such as hemoglobin. Genes are inherited or passed on from parent to child. One kind of faulty gene produces a type of hemoglobin that tends to form crystals. The sharp crystals make the red blood cells sickle-shaped and fragile. The fragile cells break easily, leaving the person without enough healthy red blood cells. This problem causes a disease known as **sickle-cell anemia** (uh-NEE-mee-uh).

Anemia is the name for a condition in which a person doesn't have enough red blood cells or enough hemoglobin. A person with anemia tires easily. An anemic person may have other symptoms, such as dizziness, a headache, and drowsiness, too. These symptoms occur because there is too little hemoglobin to carry enough oxygen for the body's needs. Medical doctors can check for anemia with a blood test that measures the volume of red blood cells in the blood. The blood test is called the hematocrit (hee-MAT-oh-crit). If a person's hematocrit is too low he or she can take iron supplements to help the bone marrow produce more red blood cells. A normal hematocrit is about 40 . That means that when 100 ml of blood is centrifuged, the packed cell volume at the bottom of the tube is 40 ml and the plasma on top is 60 ml , as you saw in **Figure 1.5**.

White Blood Cells

White blood cells are produced in the bone marrow, spleen, tonsils, and **lymph nodes.** You will investigate the lymphatic system and lymph nodes a little later. Now it's important to understand that lymph nodes are only one place white blood cells are produced. A white blood cell has a nucleus and is bigger dun a red blood cell. Another difference is that there are many fewer white blood cells than red blood cells in the blood. There is only one white blood cell for every 700 red blood cells in your bloodstream.

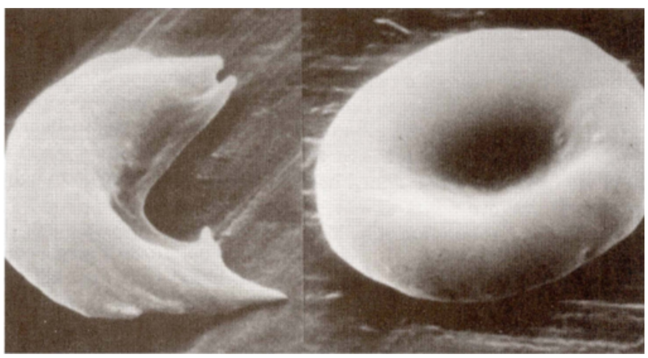


Figure 1.9 The red blood cell at the left is a sickle cell. The red blood cell on the right is a healthy cell.

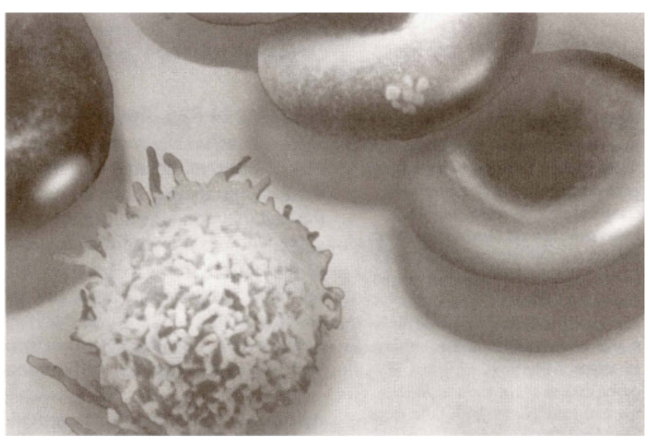


Figure 1.10 A high-powered microscope shows a white blood cell (bottom left). The cells, above right and above left, are red blood cells.

White blood cells work hard to keep you healthy. They spend most of their time circulating with the blood around the body in search of unwanted intruders in the body. Unlike red blood cells, white blood cells can move on their own. They can travel easily to parts of the body where they are needed to fight infection. White blood cells can travel against the current of blood. They can even leave the blood vessel system to attack infections in other parts of the body. The white blood cells attack unwanted organisms, such as bacteria, and unwanted materials, such as a splinter, in different parts of your body.

White blood cells fight off infection in several ways. One way they fight infection is called **phagocytosis** (fay-go-sy-TOH-sis), A **phagocyte** (fAY-go-site) is a type of white blood cell that can change its shape and wrap around unwanted or foreign substances. Phagocytosis occurs when a phagocyte "eats up" solid substances such as a virus or bacterial cell. White blood cells also fight infection by releasing germ-fighting proteins called **antibodies**. Antibodies in your blood can act as either permanent or temporary germ fighters.

Some white cells can "remember" how to fight off infections that they have fought before. So if germs enter your body a second or third time, the white blood cells may kill the germ even before you feel any symptoms. This ability to fight repeat infections is called immunity (ih-MYOON-ih-tee). Vaccinations are an example of this process at work. Vaccinations prevent you from getting certain diseases. A vaccination is an injection of weak or dead virus particles or bacterial cells.

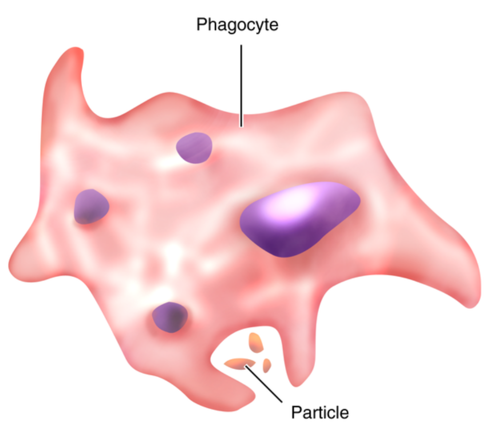


Figure 1.11 The cell membrane of a phagocyte can surround a particle and pull it into the cell. This process is called phagocytosis.

Figure 1.12 This lymph node is swollen due to trapped microorganisms.

The weakened virus or bacteria cause your body to produce antibodies against them. But the virus or bacteria are so weak that they don't give you the symptoms of the illness. The antibodies produced from a vaccination are permanent antibodies. That means they stay in your body to fight off the same intruder if it returns. Some viruses, such as colds and flu, change so quickly that it is impossible to produce one vaccination that stimulates production of effective antibodies.

Most white blood cells live for a few days unless they are fighting an infection. But white blood cells that are attacking infection might live only a few hours. When you are sick, your body makes more white blood cells to battle the infection. White blood cells can increase from $5,000$ to $25,000$ per cubic millimeter of blood during an infection.

Have you ever gone to the doctor with painful, swollen glands? If you have an infection in your throat, the lymph nodes in your neck may become swollen and tender. Lymph nodes are usually the size and shape of a small bean and can hardly be noticed underneath the skin. White blood cells in the lymph nodes attack foreign particles like bacteria and viruses. When the white blood cells in the lymph nodes attack the intruding bacteria or virus the nodes swell and become tender or even painful. That's how you know where attacks on bacteria or viruses are probably taking place. Common lymph nodes that swell are in the groin and in the scalp behind the ears or at the hairline. The disease called mumps is an example of swollen lymph nodes.

Apply Your KNOWLEDGE

In what other ways does your body keep germs and dirt out?
What other protectors does your body have?

Diseases in White Blood Cells

Sometimes white blood cells show an abnormal increase in number. This increase of white blood cells is called **leukemia** (loo-KEE-mee-uh), a form of cancer. In any cancer cell division is out of control. So a leukemia patient has too many white blood cells. The white blood cells that are produced in a leukemia patient also may not function normally. When the white blood cells are not able to work normally, the patient's body can't fight infection. **Mononucleosis** (mah-noh-noo-clee-OH-sis) is another disease of the white blood cells. A virus causes mononucleosis. The mononucleosis virus causes an increase in abnormal white blood cells. The disease also affects the liver and can cause a sore throat and swollen tonsils. Have you ever heard mononucleosis called "the kissing disease?" The virus that causes the disease can live in the throat and mouth of people who have had the disease without any symptoms. The virus is very contagious. A contagious disease is a disease that can be transferred from person to person by contact such as kissing. Mononucleosis is common among young people. The treatment is plenty of rest and a healthy diet.

Apply Your KNOWLEDGE

What can doctors tell about your health from a blood test?

What Do You Think?

Donations of blood and body organs are needed to save the lives of injured or sick people. Blood can be stored for only a few weeks. So new blood is constantly needed. Organs of healthy people who die prematurely could save the lives of others. At the present time not enough donations of blood and body organs are made to meet the need. How do you think the medical profession could educate people about the importance of donations of blood and organs?

Blood Types

Sometimes when someone has lost blood either through an accident or an operation, he or she needs a blood transfusion. A blood transfusion is a process in which blood that has been donated is transferred into the body of someone in need of blood. But blood transfusions are successful only when blood types are compatible. Certain proteins in the cell membranes affect the compatibility. These proteins in the blood cell membranes give people different blood types. The proteins involved in blood typing are called protein A and protein B . Individuals with protein A have blood type A . Those with protein B have blood type B . People with both proteins A and B have blood type AB . People who lack proteins A and B have type O blood.

TABLE 2.1:

Protein	Blood Type
A	A
B	B
$A+B$	AB
Neither A nor B	O

Did You Know? Blood transfusion is the transfer of blood from one person to another. The Inca people of Peru tried some early blood transfusions hundreds of years ago. Sometimes the transfusions worked, and sometimes they didn't. No one knew why until 1901. An Austrian doctor discovered that certain proteins in the cell membranes of blood cells give people different blood types.

What happens if you give a transfusion of type B blood to someone whose own blood is type A ? That person's immune system sees the B protein as a foreign material and attacks the transfused cells as though they were intruders. This transfusion reaction can be very serious, even fatal. In case of emergencies, you should know your blood type and carry it with you on a medical information card.

Blood Platelets

Everyday you do something that ruptures small blood vessels and causes bleeding. Sometimes you can see the bleeding. But sometimes the bleeding is inside your body and you can't see it. Although blood has to be fluid to move through your body, there must be a way to plug the leaks and keep you from losing too much blood from your circulatory system.

Did You Know? Minor cuts may scare you. But they really don't amount to much and usually stop by themselves. Putting pressure on a cut for ten minutes allows blood to clot. Usually, this is all you need to do. Your body does the rest. Remember to keep the healing cut clean and keep it covered with a bandage or gauze.

Bleeding from a major blood vessel can be life threatening. A person only has about 4 or 5 liters of blood. So it is very important to control the bleeding and get medical help. To stop the bleeding from a large wound, grasp the sides of the wound, firmly squeeze them together, and apply pressure. Cover the wound with a pad, dressing, or piece of cloth. Get someone else to call for help while you apply pressure.

Plugging blood leaks is a job for **blood platelets** in the blood. Blood platelets are smaller than red blood cells. Your blood has more platelets than white blood cells. But it has fewer platelets than red blood cells. You learned that white blood cells are produced in the bone marrow. Certain cells in the bone marrow also make platelets. But platelets are not cells. Platelets are little fragments of cells that contain chemicals needed to clot the blood. Platelets are named that because they look like little oval plates. They stay in the bloodstream about one week-unless they are put to use.

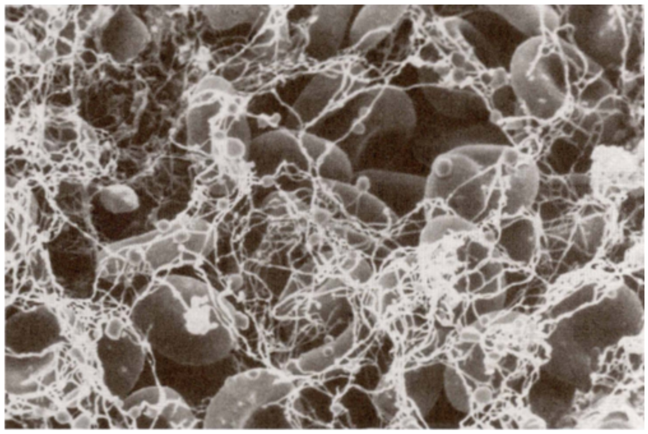


Figure 1.13 Platelets gather at the site of bleeding to form a mesh-like plug.

Blood clotting stops bleeding when a blood vessel breaks. Remember that blood starts to leak out when a small vessel breaks. The vessel constricts, or gets narrower, as the blood starts to leak out. Constricting slows the flow of blood leaking out of the vessel. The platelets come into contact with the damaged part of the vessel. As they contact the vessel, the platelets change. They become sticky and start to stick together. More platelets stick and eventually they form a plug. The platelets also release chemicals that start a series of events to finish the process of blood clotting. The clotting process involves a protein called **fibrinogen** (fy-BRIN-oh-jin), Fibrinogen is a protein circulating in the blood. Fibrinogen changes into protein fibers, called fibrin, at the clot. The protein fibers form a mesh, or net, that traps blood cells and stops the bleeding. Have you ever noticed a scab on your skin after an injury? That scab was the mesh formed from fibrin. A scab forms a barrier against germs and provides the base for new tissue to begin growing.

Hemophilia: A Blood Clotting Disease

Some people have a disease called **hemophilia** (hee-moh-FEEL-ee-uh). The blood in people who have hemophilia takes longer than normal to clot. People with the disease are called hemophiliacs. Their bodies cannot make certain blood proteins called clotting factors. As a result, they tend to bleed internally after a fall or accident. Hemophiliacs receive transfusions of blood plasma with concentrated clotting factors to get the needed clotting factors they are unable to make. Genetic engineers are looking for cures since faulty genes that are inherited cause hemophilia. Clotting factors are now being made in laboratories by genetic engineering techniques. Artificial clotting factors will make life much easier and safer for hemophiliacs.

Apply Your KNOWLEDGE

What is a bruise? Why does it change color?

Activity 1-2: Composition of Blood

Introduction

What do you know about blood? What makes up your blood? How does your blood help your body to maintain homeostasis? In this activity you make a model that represents your blood. This model helps demonstrate the composition of blood and how it functions in your body.

Materials

- 2 beakers, 1000 ml (milliliter) or clear plastic containers
- 3 containers, one of which is at least 500 ml (milliliter) in capacity
- Red beans, dried
- White beans, dried, about twice the size of the red beans
- Split peas, dried, about half the size of the red beans
- Salt
- Yellow food coloring
- Raw egg
- Water
- Small pieces of paper towel
- 2 graduated cylinders, 25 or 50 ml (milliliter)and 500 ml
- Activity Report

Procedure A: Modeling the Solid Portion of Blood

Step 1 Using graduated cylinders measure the following amounts of dried beans or peas. Then, place the correct amount of each material into a separate container:

A. The red beans represent red blood cells. Measure 425 ml of red beans. Label a container "Red Blood Cells." Place the 425 ml of red beans into the container marked "Red Blood Cells."

B. The split peas represent platelets. Label a second container "Platelets." Measure 22 ml of split peas and place them into the container labeled "Platelets."

C. The white beans represent white blood cells. Label a third container "White Blood Cells." Measure 3 ml of white beans and place them into the container labeled "White Blood Cells."

Step 2 Answer Questions 1 and 2 on the Activity Report.

Step 3 Label a $1000 - $ ml beaker "Solid Components of the Blood." Place all of the beans and the peas into the $1000 - $ ml container labeled "Solid Components of the Blood."

Procedure B: Modeling the Liquid Portion of Blood

Step 1 Using graduated cylinders measure the following amounts of solids and liquids. Then, place the correct amount of each solid or liquid into the correctly marked container.

A. Measure 550 ml of water to represent the water in plasma. Then, place the $550 - $ ml of water into a second clean $1,000 - $ ml container. Do not use the $1,000 - $ ml container labeled "Solid Components of Blood."

B. Label a paper cup "Proteins and Fats." Place a raw egg into the paper cup. The egg white represents the proteins and the yolk represents the fats in plasma.

C. Label a second paper cup "Minerals, Nutrients, and Wastes." Salt represents minerals and nutrients. Add a pinch of salt to the paper cup labeled "Minerals, Nutrients, and Wastes."

D. Yellow food coloring represents wastes. Add one drop of yellow food coloring to the salt to represent the wastes in plasma.

Step 2 Answer Question 3 on the Activity Report.

Step 3 Now beat the egg well, so the yolk (fat) and egg white (protein) are mixed. Add the beaten egg to the $1000 - $ ml container of water. Then add the salt and yellow food coloring to the $1000 - $ ml container of water and beaten egg. All of these materials mixed together represent the liquid portion of blood. Label this container "Blood

Plasma." DO NOT MIX THE CONTENTS OF THE TWO, 1,000 – ml CONTAINERS REPRESENTING THE SOLID AND THE LIQUID COMPONENTS OF BLOOD TOGETHER. THAT WOULD MAKE A MESS!

Step 4 Complete Questions 4-6 on the Activity Report.

Step 5 Follow cleanup directions given by your teacher.

Procedure C: What can you learn from your model?

Step 1 To perform all of its functions, the composition of the blood must remain within certain narrow ranges. This is a state of homeostasis. Your model represents normal values for the various components of the blood. Describe on your Activity Report how your model simulates blood.

Step 2 Describe what you could do with your model to simulate each of the following conditions. Then after each description explain how a person would function if his or her blood changed that way.

- Following massive blood loss a person's body can replace plasma volume quicker than the body can produce new red blood cells. The resulting condition is called anemia.
- Leukemia is a cancer of the white blood cells. Cancer is a state of uncontrolled cell division.
- Most plasma proteins are made in the liver. Alcoholism can destroy the ability of the liver to make these proteins.
- A disease that destroys your kidneys makes it impossible for waste products to be removed from your plasma.
- Platelets are necessary for the blood clotting process to function effectively. Blood takes longer to clot in hemophiliacs.
- If you eat a very fatty meal, lots of fat enters your blood via your lymphatic vessels.

Mini-Activity

Blood Impressions What is your impression of how blood looks and works? Paint or draw a picture of blood. Show all of the parts that make up blood. Make sure people will be able to learn something about the parts of blood and their functions from your picture.

Maintaining Homeostasis

Remember that **homeostasis** is the maintenance of a constant internal environment in your body so that all of your cells can function effectively. So how do all the parts of the blood help the body maintain homeostasis? Each part of the blood helps respond to the many different changes that take place both inside and outside of your body. The blood helps your body work efficiently by decreasing or increasing the exchange of food nutrients, wastes, and gases. The body can make more white cells to fight infection. The body also makes enough platelets to keep you from bleeding to death. You aren't aware of most of the things your blood does for you because it all works automatically without having to think about it. However, you can help your blood do its job better by avoiding the risk factors you will investigate in Section 7 of this unit.

To do its job, your blood needs to be able to move through your body. Your blood could not do this without the power of the heart behind it. In the next section, you will find out more about the heart and how it works.

Apply Your KNOWLEDGE

- **How can your circulatory system help you regulate your body temperature?**
- **An accident victim in the emergency room needs a blood transfusion. Her blood type is A. Which blood type(s) are compatible with hers?**

Mini-Activity

Artificial Blood What is artificial blood? Why are scientists having such a hard time making it? Do research on the Internet or in the library on artificial blood. Locate articles about artificial blood. Share them with your class. What do you think might be some benefits of artificial blood?

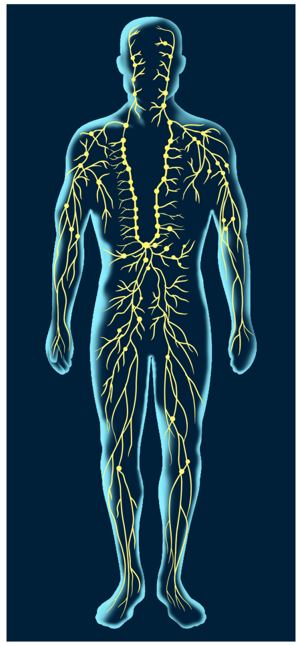


Figure 1.14 Your lymphatic system naturally recycles and cleanses fluid from body tissues.

Lymphatic System

Although your blood circulates in a closed system of blood vessels, some fluid leaks out. Most of these leaks occur around the tiniest blood vessels where the exchange of food nutrients and gases takes place. Have you ever been stung by a bee? The area around the sting usually becomes hot, red, and swollen. The bee venom stimulates an increased blood flow to the area making it hot and red. The bee venom also causes the tiny blood vessels to become more leaky. When the fluid leaks out from the vessels into the spaces between the cells, the area swells with fluid. This kind of swelling caused by the accumulation of fluids in spaces outside of blood vessels and between cells is called **edema** (eh-DEE-muh).

Where does fluid go that leaks out of the blood vessels? Extra fluid travels back to the heart through another network of vessels called the **lymphatic system.** Your lymph nodes are part of the lymphatic system. Lymph nodes play important roles in defending your body against infection. You will learn more about them when you study the immune system. Lymphatic vessels carry no blood. The lymphatic vessels carry a thin, watery fluid called **lymph.** Lymph is made up of water, salts, food nutrients, waste products, white blood cells, proteins, and other chemicals. After you eat a meal that contains fats, your lymph turns milky white. The lymph is carrying the digested fats from your intestines to your blood. When your body is not absorbing fats from your intestines, the lymph is a pale yellowish fluid.

Lymph vessels go wherever blood vessels go. The lymph vessels pick up the fluids that leak out of blood vessels and fill the spaces between your body cells. The lymphatic system recycles this extra fluid back into your circulatory system. Small lymphatic vessels empty into bigger ones that eventually merge into a single large vessel. That large vessel is called the **thoracic duct.** The thoracic duct empties into a vein at the base of your neck returning fluids to the circulatory system.

There are some important differences between the lymphatic system and the blood circulatory system. Remember that the circulatory system is a closed circuit. The lymphatic system is not a closed circuit. Also, remember that the heart pumps the blood through the circulatory system. The heart does not pump the lymph through vessels. Instead, your muscles help to move the lymph through the lymph vessels. As the muscles contract and relax, they squeeze the lymph vessels. When the muscles squeeze the vessels the vessels move the lymph that is inside them.

Journal Writing

Your school circulates information. Your body circulates blood. Compare and contrast the methods of delivery between your school and your body. What kinds of information circulate? How is information best absorbed? What methods are the more efficient? Which are the most effective? How do students contribute to the flow of information? Is a school like your body-does the system travel in only one direction? Make a chart of different ways of circulating different kinds of information. In writing, compare your school's information circulation system to your circulatory system.

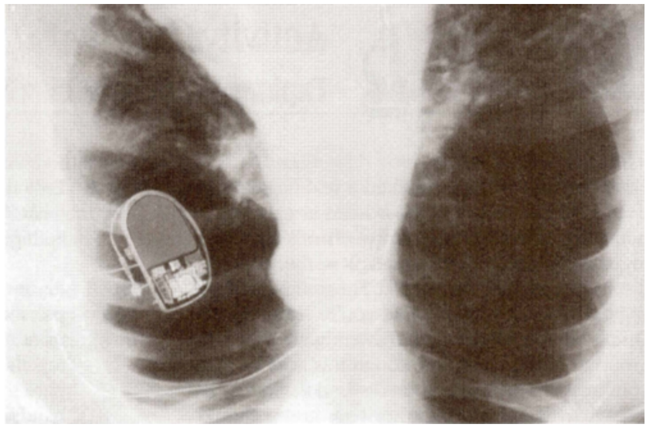
Review Questions

1. What are five differences between red blood cells and white blood cells?
2. How do red blood cells carry oxygen? What happens if red blood cells aren't the right shape or there aren't enough of them?
3. What is in plasma? What do the things in plasma do?
4. If the doctor discovers your platelet count is low, what might you have to be careful of? Why?
5. Describe two functions of the lymphatic system.

CHAPTER 3 The Heart - Student Edition (Human Biology)

Chapter Outline

3.1 The Heart



How does the heart pump blood?

People have had many different ideas about what the heart does. More than 3000 years ago, the ancient Egyptians believed the heart held a person's thoughts and feelings. But many centuries later, in the year 200 , a Greek doctor named Galen proposed that the heart worked like an oven to warm blood. He also thought that blood flowed in the body like tides. Finally, he suggested that it was the liver, not the heart that controlled the circulatory system. Of course, you know all of those ideas are incorrect. But his incorrect ideas actually lasted almost 1500 years! Then, in 1628 , an English doctor named William Harvey showed that the heart pumped blood around the body. But what's interesting is that the same idea was described in an ancient Chinese text more than 4000 years earlier. In this section you will investigate how the heart functions and learn some more about why your heart is such an important part of your body.

The Heart

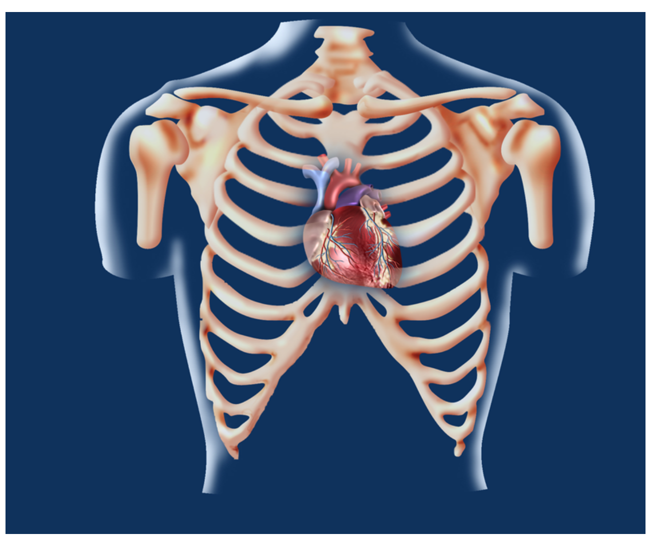


Figure 2.1 Your heart is located in the middle of your chest just above your stomach. It is about 12 centimeters long, 9 centimeters wide, and 6 centimeters

Your heart is the pump for your circulatory system. It is about the size of your two fists. Your heart is located in your chest behind your breastbone (sternum) and it tilts towards the left. It weighs about 300 grams , which is a little less than a can of soda. Your body pumps about 15 times its own weight in blood each minute, even while you're resting. This work goes on every minute of every day of every month of every year of your life.

Activity 2-1: Exploring the Heart

Introduction

Have you ever seen or touched a real heart? What does the heart look like? Your heart is a double pump about the size of your two hands clenched together. In this activity you explore me parts of me heart and how they work. There are questions to help you mink about what you're learning. Discuss the questions and answers with your group to help you work through this activity. Write your answers and important discussion points on your Activity Report. Together your group should choose one person to be me recorder.

Materials

- Animal heart (sheep, cow, or pig)
- Tweezers
- Scalpel
- Scissors
- Probes
- Apron or smock
- Plastic or latex disposable gloves
- Dissection pan
- Paper towels
- Plastic bag
- Activity Reports 1, 2, and 3

Procedure

Step 1 Put on plastic gloves to work with the heart. Why do you mink this precaution is important?

Step 2 Place the heart specimen in me dissection pan and place me pan with the heart in front of you. Clench your two hands together to represent your heart. Compare me sizes by putting your clenched hands near the animal heart. How does the size of your clenched hands compare with the size of me heart specimen?

Step 3 Touch me heart. Describe how the heart muscle feels when you touch it.

Step 4 Observe me vessels that carry blood to and from me heart. There are two kinds of vessels. The **arteries** are the vessels that carry blood away from me heart. The **veins** are vessels mat carry blood to me heart. How can you tell me difference between arteries and veins?

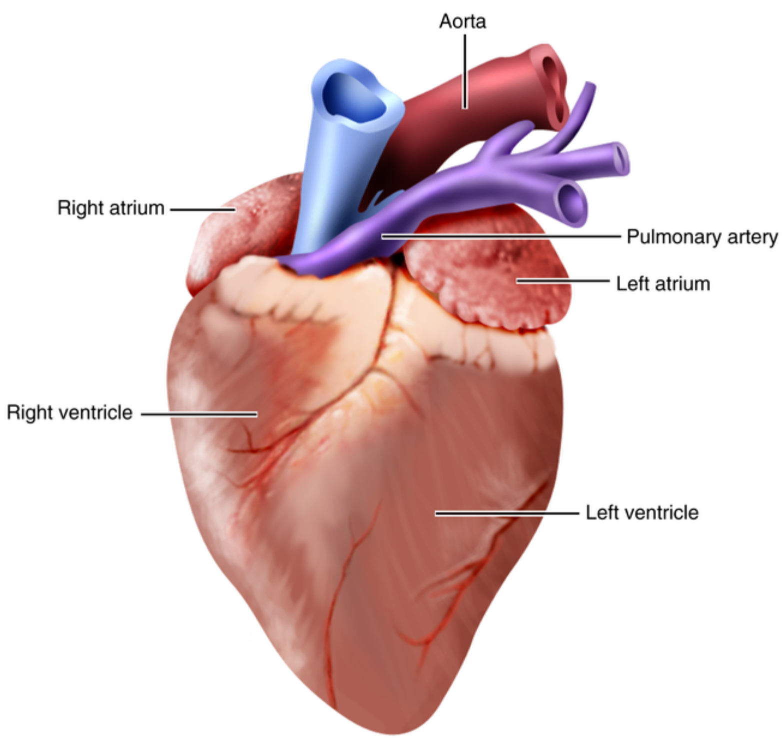


Figure 2.2 The surface of a sheep heart.

Step 5 A membrane sac that covers the heart has been removed. This sac is called the **pericardium** (payr-ih-KAR-dee-um). Pericardium means "around the heart."

Step 6 With your teacher's help, put your heart specimen in its correct anatomical position with the front of the heart facing you.

The Right Side of the Heart

Step 7 Find a wavy-edged flap that has an opening on the top. This flap is the chamber of the heart called the atrium (AY-treeuhm). There is a right atrium and a left atrium. The vessels entering the right atrium are the **superior vena cava** and the **inferior vena cava**. These veins bring oxygen-poor blood back to the heart from the rest of the body. Each atrium is a receiving chamber for the heart. Each atrium receives blood. Find the right atrium. Describe the atrium so the recorder can write the description on the Activity Report.

Step 8 Use your finger to find the opening into the right atrium. Push down into the right atrium with your finger. If your finger goes completely into the heart, then you have reached the right ventricle (VE -trih-kuhl). Take your finger out of the heart. Then push a straw back into where your finger was. If you push the straw all the way down, it will be in both the right atrium and the right ventricle.

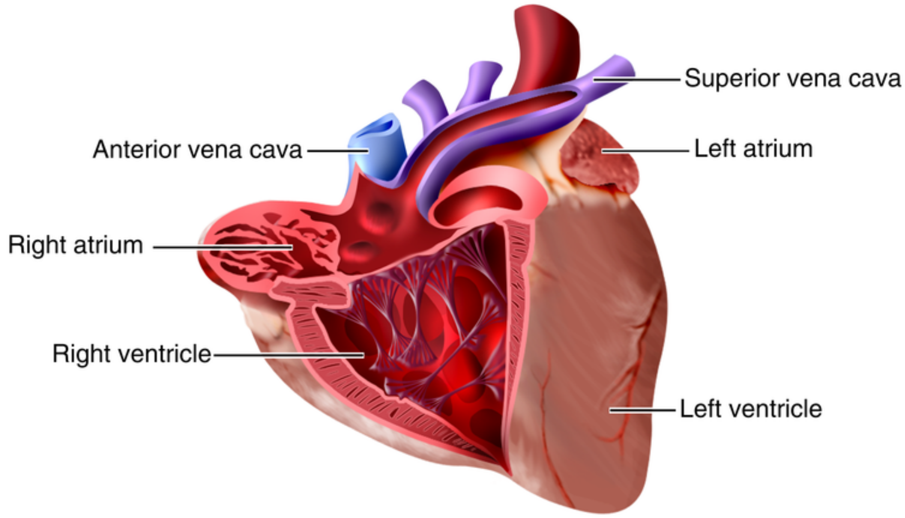


Figure 2.3 The right atrium and right ventricle of a sheep heart.

Step 9 Push on the straw until you can see it stretching the wall of the heart. Stick the point of the scissors through the heart wall to meet the tip of the straw. Cut all the way up to the top following the straw. Now you can observe the inside of the heart. Find the inside of the atrium and the ventricle. What can you observe and describe inside the heart? Write your responses on your Activity Report.

Step 10 Look between the right atrium and the right ventricle. You should be able to see thin, transparent membranes. Those membranes form the **tricuspid** (try-KUHspihd) **valve**. The tricuspid valve stays open when the right ventricle fills with blood. Describe the valve on your Activity Report. So the blood entering the right ventricle through the right atrium passes through the tricuspid valve. Then the blood leaves the right ventricle through the **pulmonary** (PUHL-muhn-ayr-ee) **artery**. When the heart pumps the blood out of the ventricle, the tricuspid valve closes making a "lub" sound. And the **pulmonary** (or semi-lunar) **valve** opens to let the blood into the pulmonary artery. The pulmonary valve is between the right ventricle and the pulmonary artery.

Step 11 Look at the open side of the heart. Poke the second finger of your right hand into the back of the lower chamber. After your finger comes out on top, put a straw in the opening. The straw marks the pulmonary artery, which carries oxygen-poor blood to the lungs. Remember that the blood gives off carbon dioxide and picks up oxygen in the lungs, and that arteries carry blood away from the heart. But the pulmonary artery is different from all the other arteries. The pulmonary artery is the only artery in the body that carries blood low in oxygen. All other arteries carry blood rich in oxygen to all parts of the body. Why do you think the blood in the pulmonary artery is low in oxygen?

The Left Side of the Heart

Step 12 Find the opening on the top of the left side of the heart. The opening leads to the left atrium. Put a straw through the opening. Push it all the way down. After the blood leaves the lungs it returns to the heart through the **pulmonary vein.** Remember that all veins carry blood to the heart. Pulmonary veins are the only veins in the body that carry oxygen-rich instead of oxygen-poor blood. All of the other veins carry oxygen-poor blood back from the body to the heart. The pulmonary veins bring oxygen-rich blood back from the lungs into the left atrium.

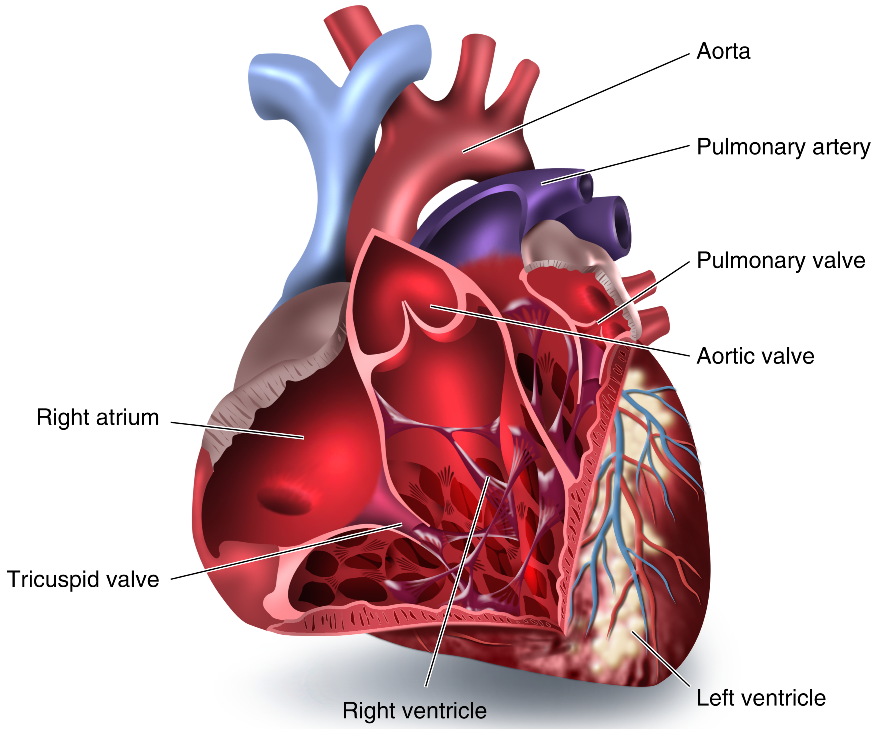


Figure 2.4 This is an interior view of the right atrium and the right ventricle showing the tricuspid. pulmonary, and aortic valves.

Step 13 Poke your scissors through the point where you think the end of the straw would be. Cut until you see the end of the straw. The end of the straw should be in the left ventricle. The straw has passed through the **mitral** or **bicuspid valve.** You just cut through the wall of the left ventricle. How is the wall of the left ventricle different from the wall of the right ventricle?

Step 14 Find the opening from the lower left ventricle near the middle of the heart that leads to the outside. This opening leads to a large artery called the **aorta** (ay-OHR-tuh). Put a straw in the aorta. Which kind of blood, oxygen-rich or oxygen-poor, do you think flows through the aorta?

Step 15 Cut down the aorta toward the heart and observe the valve. This is the aortic semi-lunar valve or **aortic valve**. Describe what the aortic valve looks like on your Activity Report.

Step 16 Look for the two **coronary arteries** in the walls of the ventricles. Locate two tiny holes just above the aortic valve. This is were the coronary arteries leave the aorta to transport food and oxygen to the heart.

Step 17 What other observations can you make as you examine the heart? Describe any new observations on your Activity Report. Make sure you discuss and answer all of the questions on the Activity Report.

Step 18 Follow directions from your teacher to complete your dissection and clean up.

> **Did You Know?** When you were a fetus the heart was one of the first organs to develop. After only four weeks of development your tiny heart began to form in the shape of a tube. This tube became an atrium and a ventricle in a two-chambered heart. A two-chambered heart is similar to the kind of heart a fish has. Later, as you continued developing, your heart developed a third chamber. A three-chambered heart is similar to a frog's heart. Then long before you were born, the fourth chamber developed. That tiny heart was a miniature, fully functioning heart.

How Do You Know You're Alive? Your vital signs provide health care workers with a good idea of what's going on inside your body at a given moment. Your vital signs include your temperature, heart rate, breathing rate, and blood pressure. You can measure some of these vital signs yourself. You can take your temperature with a thermometer. Also, you can feel your pulse on your wrist. Look at the drawing in **Figure 2.5**.

When you feel your pulse, the blood in your arteries is flowing beneath your fingers and pushing on them. The up-and-down movement of your pulse tells you there are two parts to your heart's pumping cycle. The pulse that pushes up against your fingers is the squirting phase of the heart cycle. The squirting phase is when your heart squeezes blood into your arteries under high pressure. This squirting phase is called **systole** (SIS-toe-Iee). Systole is a Greek word that means *contracting*. That correctly describes the contracting of the heart muscle when it squeezes and squirts out the blood.

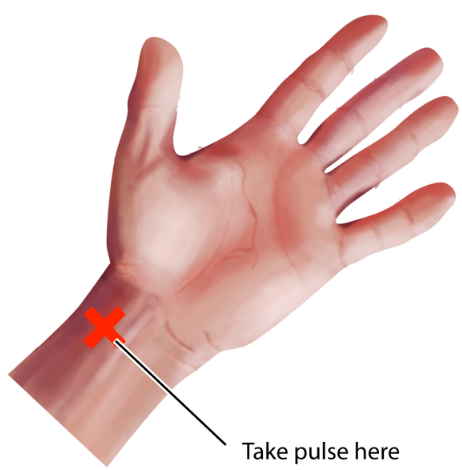


Figure 2.5 You can feel your pulse on your wrist, near the base of your thumb. Calculate your heart rate by counting the number of beats per minute. A normal resting heart rate for an adult is 60 to 100 beats per minute.

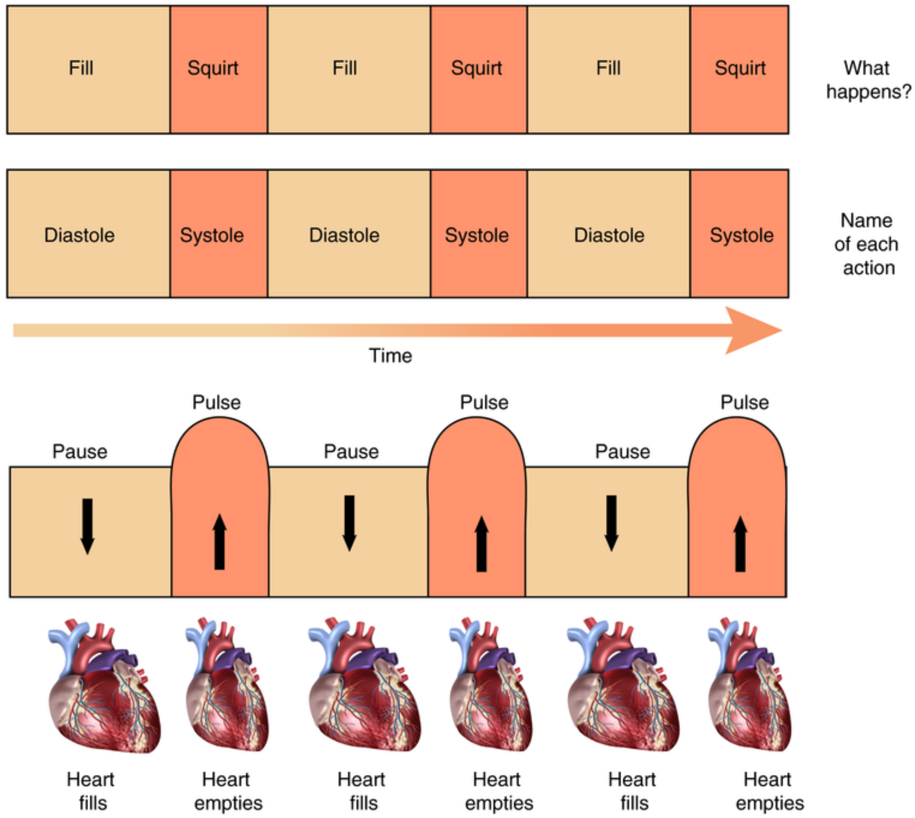


Figure 2.6 Your heartbeat is the rhythm of the heart muscle relaxing and contracting. When the heart muscle relaxes, the heart fills with blood. When the heart muscle contracts, it sends blood flowing out of the heart and to the lungs or body.

Mini-Activity

Is Pumping Hard Work? How hard does your heart work? Put a tennis ball in your hand and squeeze it until it dents. That's how hard your heart muscles squeeze each time to send blood around your body. Do you think that's not too hard? Well, try to do it 70 times in a minute. Your heart pumps about 70 times per minute all day every day of your life. Your heart works even harder when you exercise.

Mini-Activity

Heartbeats Determine your own heart rate by taking your pulse. Look at **Figure 2.5** again. Place your fingers lightly on your wrist at the same place shown in the drawing. Find your pulse. Count the number of beats in one minute. Then use your heart rate to calculate the following:

- How many times does your heart beat in a day? In a week? In a year?
- How many times might your heart beat in your lifetime? Assume you will live to age 80 .

- Do you think your estimates are high or low? Why?

Did You Know? A fretful newborn baby will often calm down and sleep if a ticking clock is placed nearby. Perhaps the ticking mimics the sound of its mother's heartbeat from its time in the womb.

When the pulse you feel with your fingers falls away, your heart is not squirting blood. That is when the heart is filling with blood. This filling phase of the heart cycle is called **diastole** (dy-AS-toe-lee). Diastole is also a Greek word that means expand. Expanding describes how the heart muscle relaxes so the heart can fill with blood. Your heart fills and squirts all your life. The sequence of fill (diastole) then squirt (systole) repeats over and over throughout your entire life. This sequence is called the cardiac (heart) cycle because it repeats over and over.

Mini-Activity

Word Origins Use a dictionary to find the word origins of the following terms.

a. atrium
b. ventricle
c. pulmonary
d. coronary
e. cardiac

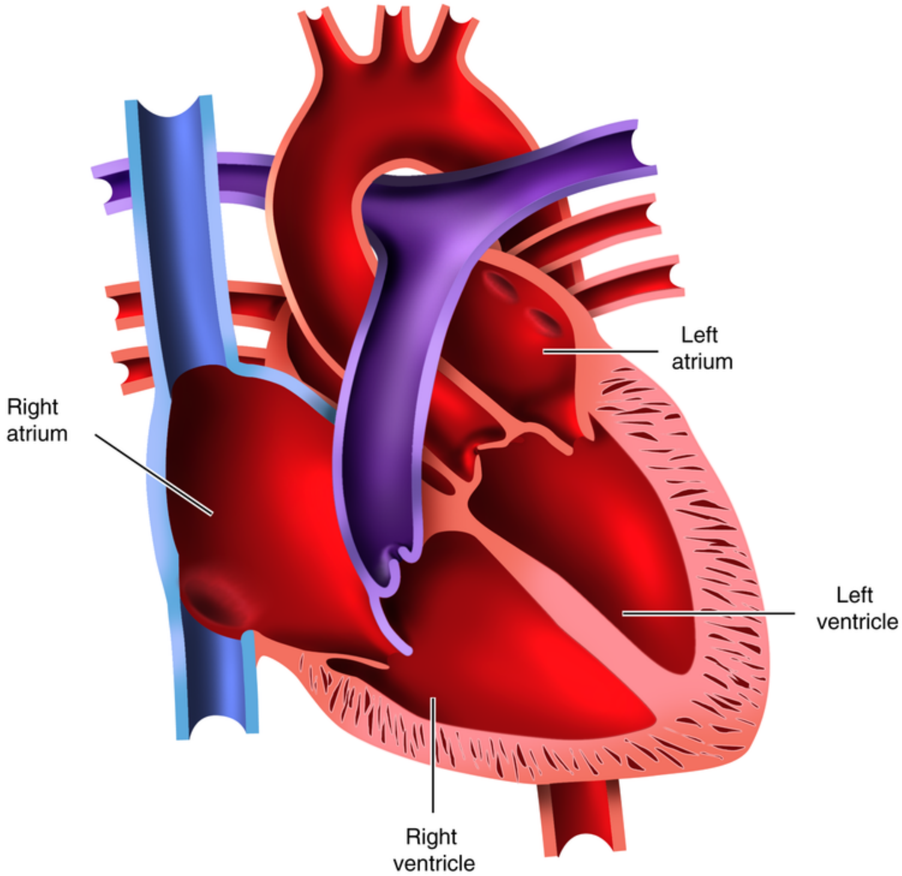


Figure 2.7 A four-chambered heart.

Apply Your KNOWLEDGE

Your friend tells you that she has a "heart murmur." What do you think this means?

A Closer look at the Heart

Let's take a closer look at how the heart works. The heart's job is to pump blood throughout the body. The blood delivers oxygen and nutrients to cells. The blood also picks up waste materials like carbon dioxide gas. You couldn't live without this constant circulation of gases and nutrients.

Remember the model you built in the beginning of this unit. Your heart is actually two pumps in one. The right pump moves blood from the heart to the lungs to pick up oxygen and release carbon dioxide, then back to the heart. The left pump moves blood around the body. In each pump there is an **atrium** and a **ventricle**. So a human heart has four chambers: two atria and two ventricles.

The Heart Pump

Your heart is a pressure pump. The heart squeezes the blood and creates blood pressure. Blood pressure is the force that moves blood through your body and keeps the blood moving in one direction. A good way to begin learning how the heart works is to explore how a **siphon pump** works.

Have you ever used a siphon? You may have used a siphon to empty a fish tank, as shown in **Figure 2.8**. The siphon is the tube that allows water from the fish tank to flow into the bucket. You put one end of the siphon in the tank and suck on the other end until the tube fills with water. Then you quickly put the free end of the tube in the bucket. Gravity is the force that keeps the water moving from the tank to the bucket. As long as the free end of the tube is below the water level in the tank, gravity will pull the water through the siphon. Can you explain how this works?

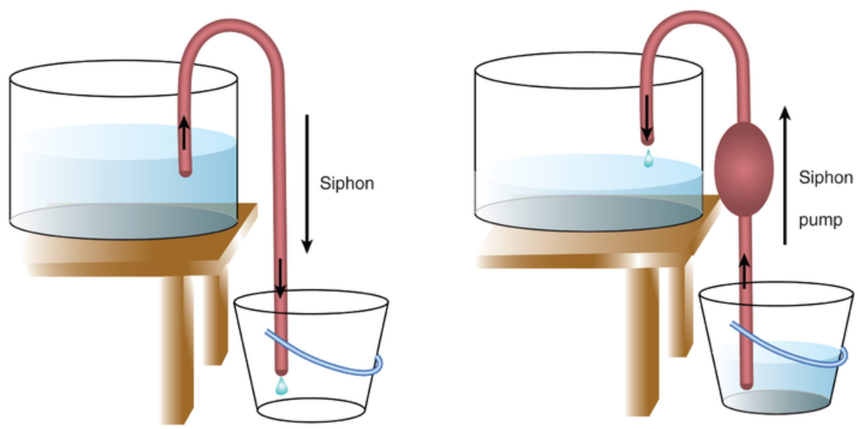


Figure 2.8 A siphon moves water downhill using gravity.

Figure 2.9 A siphon pump moves water uphill aganist the force of gravity.

How could you get the water to flow from the bucket into the tank? One way, of course, is to lift the bucket and pour the water into the tank. But, suppose that the bucket is too heavy for you. Instead, you could use a siphon pump like the one shown in **Figure 2.9**.

In a siphon pump, a squeeze puts pressure on the liquid in the bulb or chamber. The pressure of the liquid closes the inlet valve and opens the outlet valve. The closed inlet valve keeps liquid from going into the inlet hose. So all the liquid is forced out the outlet hose.

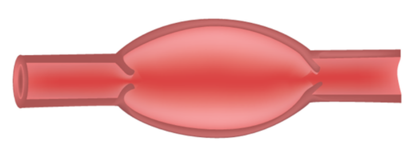


Figure 2.10 A siphon pump is a squeeze bulb with a hose on each end. One hose is an inlet hose, and the other hose is an outlet hose. There is a **valve** where each hose connects to the squeeze bulb.

The valves keep fluid moving in just one direction. Each valve works like a trapdoor that opens in one direction. Pressing against the door from the "wrong" side keeps the door closed. Pushing on the door from the "correct" side lets the door open.

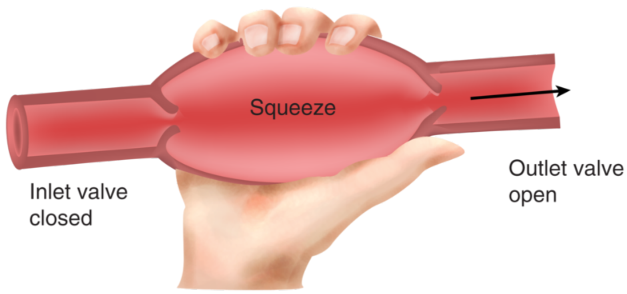


Figure 2.11 When using a siphon pump, you squeeze the bump chamber, or squeeze bulb, so it empties. Squeezing closes the inlet valve but opens the outlet valve. How is his action similar to the action in the heart?

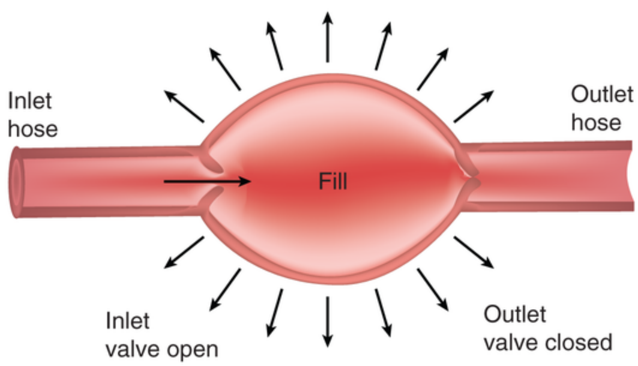


Figure 2.12 The bulb expands when the bulb of a siphon pump is not being squeezed. The outlet valve closes and the inlet valve opens. Liquid enters the bulb through the inlet hose. The expanding bulb wall lets the pump draw liquid in and get ready for the next squeeze.

Activity 2-2: Siphon Pump

Introduction

Your heart is really two pumps in one. Each pump works like a siphon pump. In this activity you explore how siphons and siphon pumps work. As you learn about siphon pumps think about how the heart is like two siphon pumps working together.

Materials

- Rubber or plastic tube (about 1 cm diameter and 1.5 m long)
- Siphon pump with inlet and outlet tubes

- 2 large containers (such as buckets or dishpans)
- Water
- Activity Report

Procedure

Part A: How Does A Siphon Work?

Step 1 Place one of the containers near the edge of a stool or table. Fill the container about three-quarters full with water. Place the other container (empty) on the floor. Completely submerge the siphon tube in the water-filled container and remove the bubbles from the tube.

Step 2 Now plug both ends of the tube with your fingers. Hold one end of the tube full of water in the top container and place the other end in the container on the floor so it will empty into the floor container.

Step 3 Raise the lower end of the tube to the level of the upper end of the tube. What happens to the rate of flow?

Step 4 Find out what determines how fast the water flows through the siphon. Experiment by moving the bottom end of the water-filled tube below the water level in the floor container. What happens when you raise the bottom end of the tube to the level of the water's surface in the top container?

Step 5 Siphon all the water from the top container into the bottom container.

Part B: How Does a Siphon Pump Work?

Step 1 Immerse the siphon pump and hose in the bottom container of water.

Step 2 Squeeze the bulb several times to remove bubbles. Continue to squeeze the bulb until water comes out.

Step 3 Plug the outlet hose with your finger and pump the bulb. Watch what happens.

Step 4 Use the siphon pump to pump water from the lower container to the higher one as shown in **Figure 2.13**.

Part C: How Is Your Heart Like a Siphon Pump?

Step 1 Imagine that the siphon pump represents the right side of your heart. If this pump is your heart, where is the blood coming from? Where is the blood going?

Step 2 Now imagine that the siphon pump represents the left side of your heart. Where is the blood coming from? Where is it going?

Step 3 The heart of a fish consists of a single pump. You, other mammals, birds, and crocodiles all have a double pump. Two siphon pumps working together represent both sides of a double pump. What advantage(s) does the double-pump arrangement have?

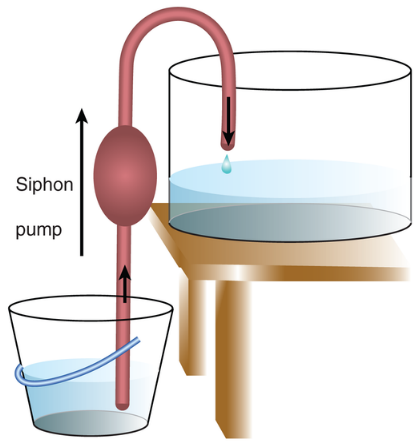


Figure 2.13 A siphon pump moves water from the lower container to the higher one.

Did You Know? A heart murmur is an extra sound the heart makes between the lub-dupp sounds. Poorly formed valves that allow some leakage between the heart's chambers cause the extra sound. Most people with heart murmurs don't have medical problems due to the leakage. But in some cases the leakage keeps the heart from working properly and medical treatment may be needed.

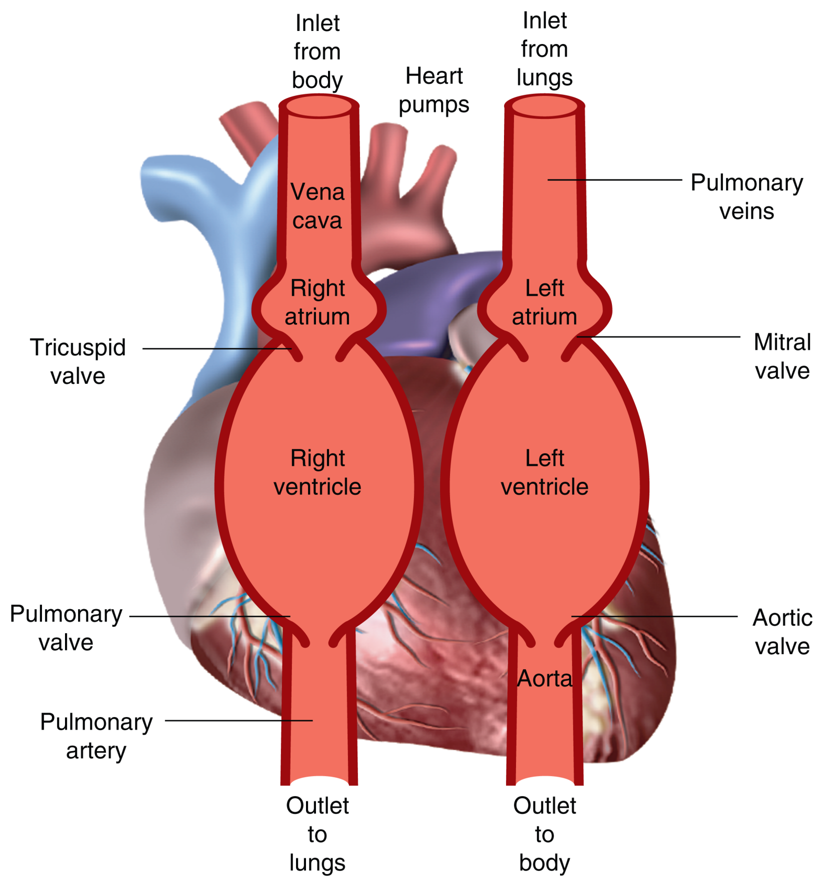


Figure 2.14 Your heart works like two siphon pumps.

Did You Know? Your heart rate slows down as you get older. At birth it was probably around 120 beats per minute. During elementary school it was probably between 80 – 100 beats per minute. By adulthood it will be about 70 beats per minute. Compare this to the heart rates of some animals.

TABLE 3.1:

Animal	Heart rate Animal (beats per minute)
Mouse	650
Iguana	150
Cat	150
Hamster (hibernating)	4

Each of the two heart pumps works like a siphon pump. **Figure 2.14** compares the pumps. In both pumps the squeeze/fill cycle moves liquid through from the inlet to the outlet tube. Notice that the inlet "tubes" of the heart are swollen just in front of the inlet valves. These swollen areas represent the atria.

The two pumps squeeze together and relax together. Both pumps beat as one heart. The right side of the heart pushes blood through your lungs and back to the left side of the heart. The left side pushes blood through the rest of your body and back to the right side of the heart.

The heart cycle is like the pump cycle-fill (diastole), squeeze (systole). During systole both heart pumps squeeze together. When they start to squeeze the inlet valves slam shut, making the first heart sound-"lub." The outlet valves are open. The ventricles squirt blood into the arteries. The inlet valves are the tricuspid valves on the right side of the heart and the mitral or bicuspid valve on the left side. The outlet valves are the pulmonary valve on the right side of the heart and the aortic valve on the left side. When the heart pumps stop squeezing, the outlet valves slam shut making the second heart sound-"dub." The two heart sounds mark the heart cycle. The "lub" sound occurs at the beginning of systole. The "dub" sound occurs at the beginning of diastole.

During diastole, both heart pumps fill together, as shown in **Figure 2.16**. The ventricles are relaxed. Blood flows from atria to ventricles in both sides of the heart. During diastole (filling) the heart works like a filling siphon pump. The inlet valves (tricuspid and mitral) are open but the outlet valves (pulmonary and aortic) are closed.

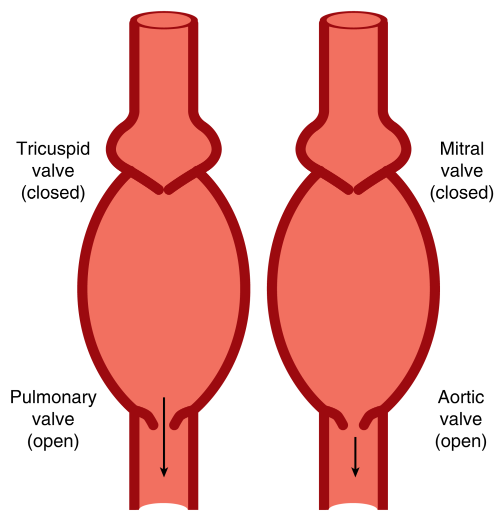


Figure 2.15 Your two heart pumps during systole.

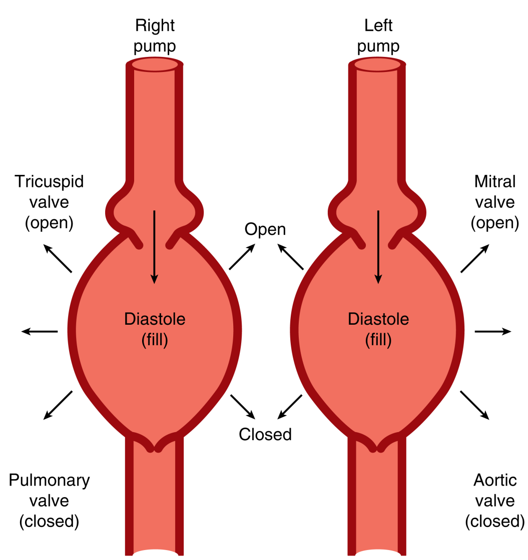


Figure 2.16 Your two heart pumps during diastole.

Mini-Activity

What's Your Cardiac Output Today?

What is your body's cardiac output for one day? You can figure it out.

- Take your pulse to determine your heart rate.
- Multiply your heart rate by atypical stroke volume, which is about 70 milliliters. This calculation gives you your cardiac output for one minute.
- Multiply your cardiac output for one minute by the number of minutes in one day. How might your cardiac output change if you start exercising?

The blood your heart puts out with each squeeze is called your **stroke volume.** Your **heart rate** is the number of times your heart beats in one minute. The amount of blood your heart pumps out in a certain period of time is called your **cardiac output.**

Let's summarize what you have learned so far about the heart. You learned about:

- the parts of the heart,
- how the two sides or pumps of the heart beat and fill together,
- that the heart cycle is systole (squeezing) and diastole(filling), and
- how your heart works like two siphon pumps connected together.

Apply Your KNOWLEDGE

- **When exercising your working muscles help return blood to the heart more quickly. Remember that the stroke volume is the amount of blood the heart pumps out with each squeeze. Does exercise increase or decrease the heart stroke volume? Explain. Remember, what goes into the heart must come out!**
- **Why do athletes often have lower resting heart rates than non-athletes? If their hearts don't beat as frequently why don't they faint from a shortage of blood in circulation?**

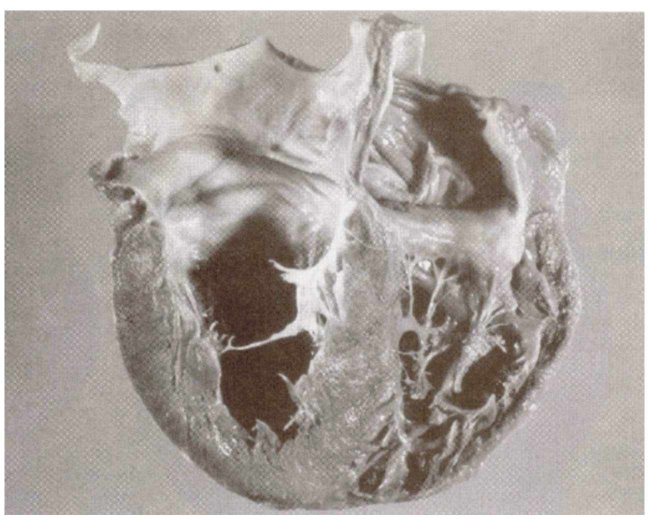


Figure 2.17 If you cut open a heart, it would look like a mass of twisted tubes and muscle tissue.

Now you've read that the heart works like two siphon pumps. But the heart you used in Activity 2-1 didn't look like two siphon pumps did it? The picture of the heart shown in **Figure 2.17** doesn't really look like a picture of two siphon pumps either. If you cut open a heart as you did in Activity 2-1 and look inside, all the compartments seem to be twisted together. It all looks pretty complicated. Actually, the heart looks complicated because the two pumps twisted together as the heart developed.

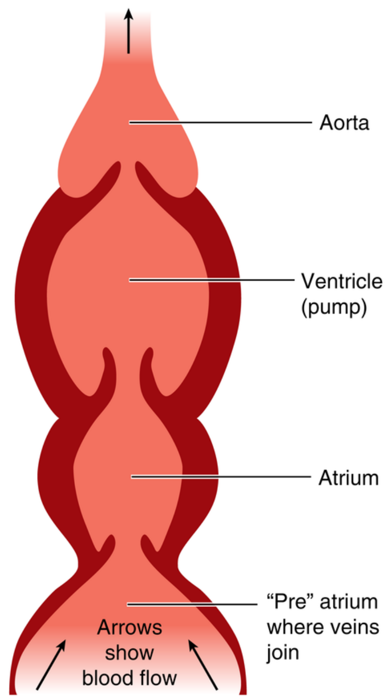


Figure 2.18 A fish heart has one pump with two chambers, an atrium and a ventricle.

To understand the structure of a heart a little better, it helps to look at a less complicated heart such as a fish's heart. So, look at **Figure 2.18**. A fish heart is similar in structure to ours. Except the fish heart has only one pump. The fish heart's single pump has two chambers. It has an atrium and a ventricle. The pump structure of the fish's heart is straight.

The bending and folding of the two pumps inside a human heart make its structure a little harder to understand. Although the pictures may be hard to follow, remember that the human heart is simply two pumps. One pump moves blood from the body to the lungs. The other pump moves blood from the lungs to the body.

To see the two pumps that make up the human heart look at **Figure 2.19**. Follow the heavy black arrows to see how the pumps are bent or folded at the ventricles. Notice that the pumps are like mirror images of each other. This way the flow of blood moves in the opposite direction.

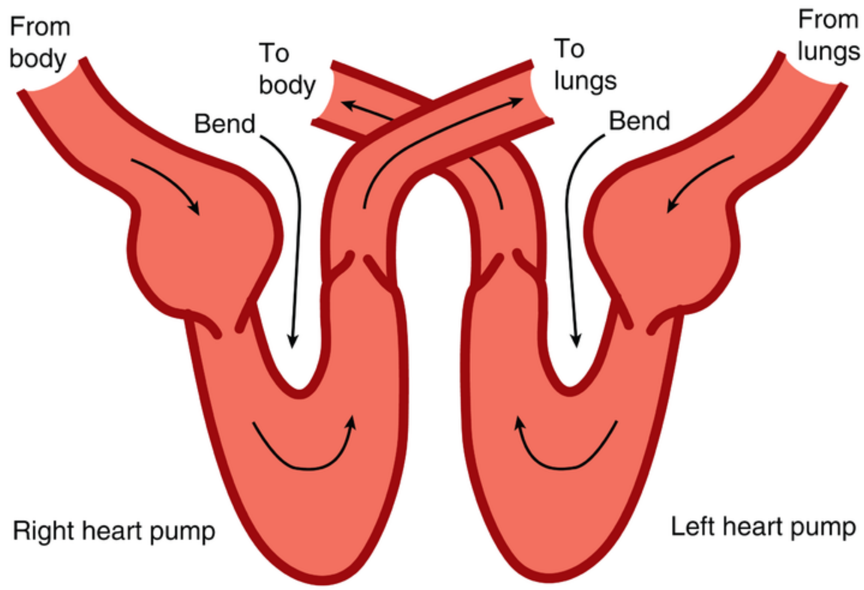


Figure 2.19 Here are the two pumps in the human heart separated. The arrows show the directions of blood flow.

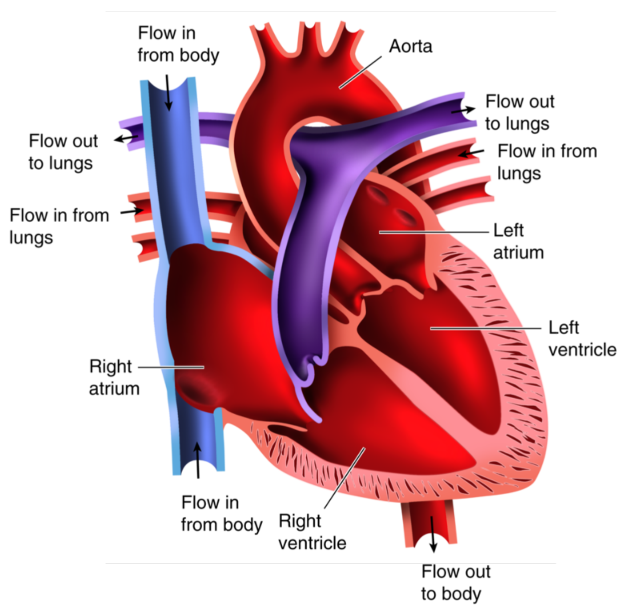


Figure 2.20 The heart's two pumps work together side by side. Can you trace the flow of blood through the heart?

> **Did You Know?** When you exercise your heart can pump 5 to 7 times as much blood as when you are at rest. What would be your cardiac output increase if during exercise your heart rate goes from 50 (resting rate) to 120 and your stroke volume goes from 70 ml to 85 m ? What percentage increase is this?

Now imagine that the two pumps moved together and attached. If that happened, they would look like the drawing of the heart in **Figure 2.20**. The left side of the heart is shown on the right side of the drawing. The right side of the heart is shown on the left side of the drawing. Now that may not make sense. So look at the drawing. Remember that this is just a drawing. In your body, the left pump sits to the left in your chest nearer to your left arm. Hold this picture up to your chest and look at it in a mirror. Study the arrows to follow the path that the blood takes.

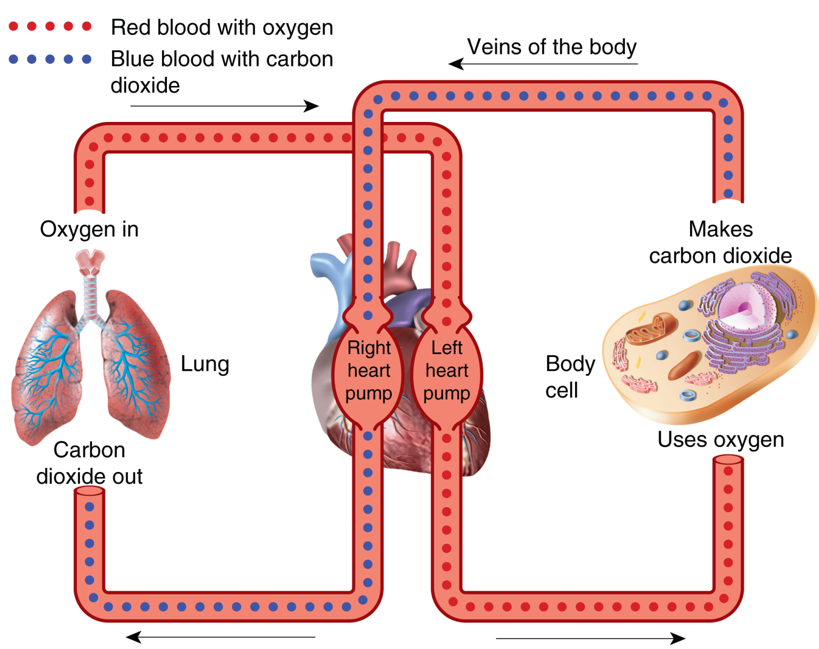


Figure 2.21 One pump brings blood from the body to the lungs to get oxygen. The other pump brings the oxygen-rich blood from the lungs and pumps it throughout the body.

Why do you have two pumps in your heart? Isn't one enough? **Figure 2.21** shows why you need two pumps. The right side of the heart brings in oxygen-poor blood from the body and sends that blood out to the lungs. There an exchange of carbon dioxide and oxygen occurs. The lungs get rid of the carbon dioxide lie cells produced and replace the oxygen the body cells will use. Then the oxygen-rich blood returns to lie left side of lie heart. The left side of the heart receives lie oxygen-rich blood from lie lungs. Then it pumps that oxygen-rich blood out to lie body. You need two pumps for the whole process to take place.One pump can't do the job alone.

Apply Your KNOWLEDGE

Why can a fish get by with only one pump in its heart when you need two?

Heartbeat

What makes your heart beat? How does your heart know when to beat and how fast to beat? In the wall of the right atrium there are specialized muscle cells. These special cells can produce an electrical signal. That electrical signal travels through the heart muscle. The rhythm of the electrical signal makes the heart beat. The specialized muscle cells in the right atrium are called lie heart's **pacemaker.** The pacemaker makes the heart beat faster or slower when it receives messages from the nervous system of from chemical "messengers" called hormones.

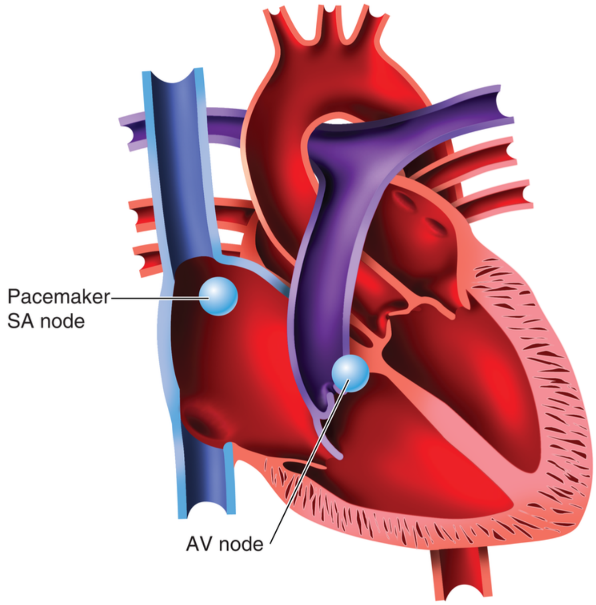


Figure 2.22 The heart's pacemaker is sometimes called the SA node. The pacemaker initiates your heartbeat, signaling your atria to contract. The signal is delayed at the AV node. The AV node then tells your ventricles to contract.

Journal Writing

Imagine you are a drop of blood in the left atrium of the heart. Describe your voyage through the heart and body and back to the heart. Include labeled diagrams to illustrate your story.

There is another group of specialized muscle cells that sits between the atria and the ventricles. This group of special cells is called the AV node. The AV node causes a slight delay in the electrical signal going to the ventricles. This delay allows the atria to contract a little before the ventricles contract. This early contraction of the atria helps to fill the ventricles to their full capacity before they squeeze the blood out again.

Review Questions

1. What is the heart cycle?
2. Describe the four steps in which blood flows through the heart. Draw a picture showing the path of blood from when it enters the right atrium until it leaves the left ventricle.
3. What do heart valves do?
4. How is a siphon pump most similar to a heart?
5. When you hear your heart beat, what exactly are you hearing?
6. What two properties of your heart can change to increase your cardiac output?

CHAPTER 4 Arteries and Arterioles - Student Edition (Human Biology)

CHAPTER OUTLINE

4.1 Arteries and Arterioles

How Does Blood Get From the Heart to All Parts of the Body?

Blood circulates around the body in a system of blood vessels. Remember that arteries take blood from the heart and veins bring blood back to the heart. In this section you will investigate how the blood moves through the arteries to get to the cells all over the body.

> **Did You Know?** The blue whale is the largest animal that has ever lived on Earth. An adult blue whale is so large that its heart is the size of a compact car. You could crawl on your hands and knees through its aorta.

Let's begin the journey blood takes from the heart through the body to the cells. The vessels that take blood from the heart to body cells are called **arteries.** Arteries bulge when they get blood from the heart during systole (squeeze). They have thick, elastic walls that help to squeeze and push the blood along its way. Arteries take blood to every organ in the body. Arteries branch from larger arteries to smaller ones called **arterioles.** Most arteries are located deep inside muscles or close to bones to protect the vessels from injury. About 15 percent of the body's blood is in the arteries at any one time.

The biggest artery is the aorta, which is the big artery that comes out of the left ventricle. Arteries that branch from the aorta supply the entire body with blood. The very first branches are the **coronary** (KOHR-uhn-ayr-ee) **arteries.** The word coronary comes from a word that means crown. The main coronary arteries circle the top of the heart like a crown. Your heart is a very hard-working muscle that needs a steady supply of oxygen and nutrients, which it gets from the coronary blood in the arteries. These coronary arteries receive up to 5 percent of the cardiac output. Have you ever heard of someone having a "coronary" or **heart attack?** A heart attack occurs when a coronary artery gets clogged and cannot deliver oxygen to the heart muscle. **Figure 3.1** is a drawing of where some of the coronary arteries are located.

Figure 3.1 shows a surface view of the heart with the left and right coronary arteries. Find the aortic valve. The left coronary artery and the right coronary artery leave the aorta just above the aortic valve. They take blood to the muscle cells making up the walls of the ventricles. This blood carries a lot of oxygen. The heart muscle cells are working all the time so the heart needs a lot of oxygen.

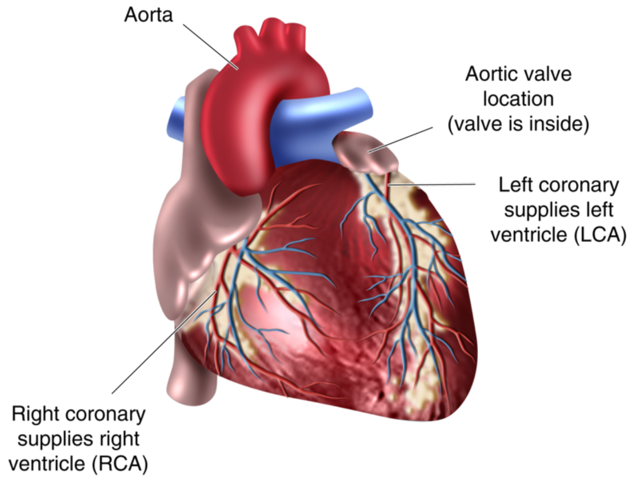


Figure 3.1 Your heart has the same needs as the rest of your body for food nutrients, gas exchange, and waste removal. To do this the heart has its own system of blood vessels including the coronary arteries.

If you turn back to **Figure 2.20**, you can remind yourself of how the aorta leaves the heart and makes a big arch as it turns to take blood to the body below the head and arms. Look again in **Figure 2.20** at the arteries that leave the right ventircle to go to the lungs. These arteries are called the **pulmonary arteries.** It takes less force to push blood through the lungs than it does to push it all around the rest of the body. So, the pulmonary arteries are not as large and thick as the aorta. The blood coming from the right ventricle to the lungs is at a lower pressure than the blood coming from the left ventricle to the rest of the body.

Blood Pressure

Apply Your KNOWLEDGE

Why does more blood go to muscles of the ventricles during diastole than during systole?

The pressure inside arteries is high. So if you cut an artery, blood spurts out. This high pressure results when the ventricles pump blood into the arteries during systole. The high pressure tends to stretch the walls of the arteries-sort of like filling a balloon with water. At the end of systole, the stretched walls of the arteries return to their normal size. As they do, they squeeze the blood inside. This pushes the blood through the arteries even during diastole while the heart fills.

Why does the pressure in arteries need to be high? Well, think about water pipes. If a truck hits a fire hydrant, the water may spurt 12 meters (40 feet) into the air. The pipe connected to the fire hydrant is called the water main. The water main is like an artery. Water in the water main is under high pressure. This high pressure forces water all over the city. In a similar way, blood passing through the aorta is under high pressure. The high pressure distributes blood to all the cells of the body.

Figure 3.2 Your blood vessel system has many branches varying in size.

Taking Your Pulse

Mini-Activity

Taking your own pulse helps you understand how your heart and arteries work. Use a clock or watch with a second hand to take your pulse.

a. Find your wrist pulse using the second and third fingers of either hand. Look at **Figure 3.3**.
b. Press lightly to feel the blood make the artery expand as a result of each heartbeat. This is your pulse.
c. Sit comfortably and remain quiet. Determine your pulse by counting the number of pulses during a 60 second period.
d. Record your results. Compare your pulse rate with those of your classmates. You also can take your pulse in the neck by finding your carotid artery just to the side of your larynx or voice box.

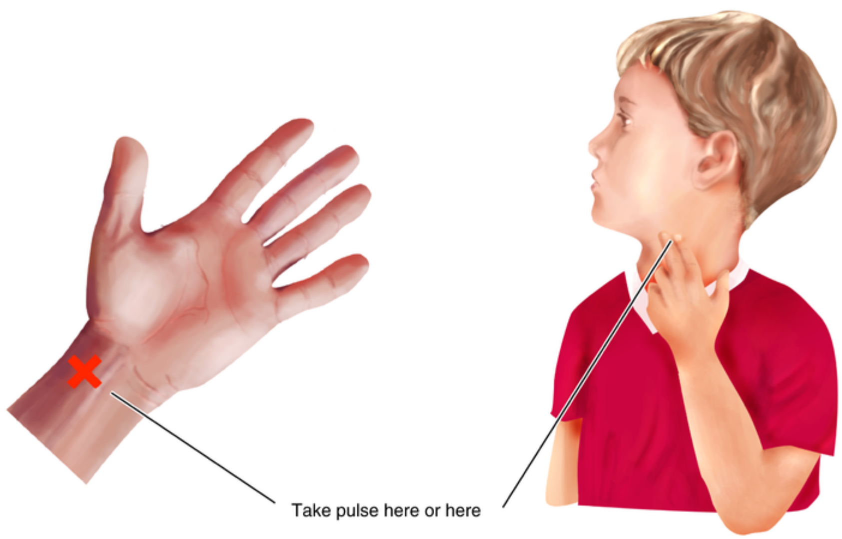


Figure 3.3 You can feel your pulse on your wrist, near the base of your thumb. Calculate your heart rate by counting the number of beats per minute.

Activity 3-1: Blocked Arteries

Introduction

What does a diet containing too much fat and cholesterol (kuh-LES-ter-ahl) do to your arteries? Too much cholesterol can cause **atherosclerosis** (ATH-uh-roh-skluhr-OH-sus). Atherosclerosis is a disease that blocks the arteries. But how do doctors know that cholesterol can cause atherosclerosis? What do blocked arteries look like? Why are they dangerous? In this activity you will learn about atherosclerosis. The activity helps you find out what causes it and how to prevent it.

Materials

- Clear rubber tubing or toilet paper rolls
- Scissors
- Water
- Paste
- Markers
- Cotton or clay
- Resources 1 and 2
- Activity Report

Procedure

Step 1 Read Resource 1. Examine the arteries shown in the photographs.

Step 2 Make a sketch of the artery under item number 1 of the Activity Report as you examine each photograph. Label each sketch.

Step 3 In your group discuss the following questions.

- Why is atherosclerosis considered a danger to health?
- What evidence suggests that a high-fat, high-cholesterol diet is linked to atherosclerosis?
- Should you be concerned about your diet at your age? Why or why not? At what age should you become concerned?
- What are two things you can do to prevent atherosclerosis?

Step 4 Design and build models of a healthy artery and an unhealthy artery. Compare and contrast the two arteries. Demonstrate how blood flow in the unhealthy artery is reduced and/or blocked.

Step 5 Discuss with your group how a coronary bypass operation is performed. Use the diagram on Resource 2. Use the scissors as a scalpel. Then use glue or staples to stitch the blood vessel into position.

Arteries

Apply Your KNOWLEDGE

Why is cutting an artery dangerous?

Arteries start out large as the aorta. But they branch again and again to reach all parts of the body. As they branch, the arteries get smaller and smaller. Arterioles are the smallest and narrowest arteries. At the ends of the smallest arteriole there is a bed of tiny vessels called capillaries. This is where materials and gases are exchanged, because the capillaries are very thin and very leaky. Every cell of the body is close to a capillary. The cell exchanges oxygen (O_2) , nutrients, and wastes such as carbon dioxide (CO_2) with the blood passing through that capillary.

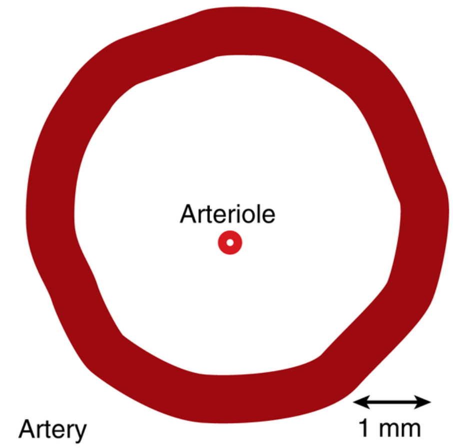


Figure 3.4 Arterioles have a much smaller diameter than arteries.

As blood flows from the aorta through smaller arteries to arterioles and finally to capillaries, its pressure is steadily falling. There are two reasons why blood pressure falls as it flows from the heart to the capillaries. The first reason may surprise you. The *total* cross-sectional area of the capillaries is greater than the cross-sectional area of the huge aorta. Think of a garden hose leading to sprinklers. When there is only one sprinkler on the hose, its pressure is high. But as more and more sprinklers are added, their pressure goes down.

The other reason blood pressure falls as it flows towards the capillaries is that the resistance to flow is greater the smaller the vessel. Think about drinking milk through a tiny straw in comparison to a bigger tube. You have to suck harder when you use the tiny straw because the resistance to flow is higher.

The smallest arterioles have rings of muscle around them. These muscles control the diameter of the arteriole and therefore how much blood flows into each capillary bed.

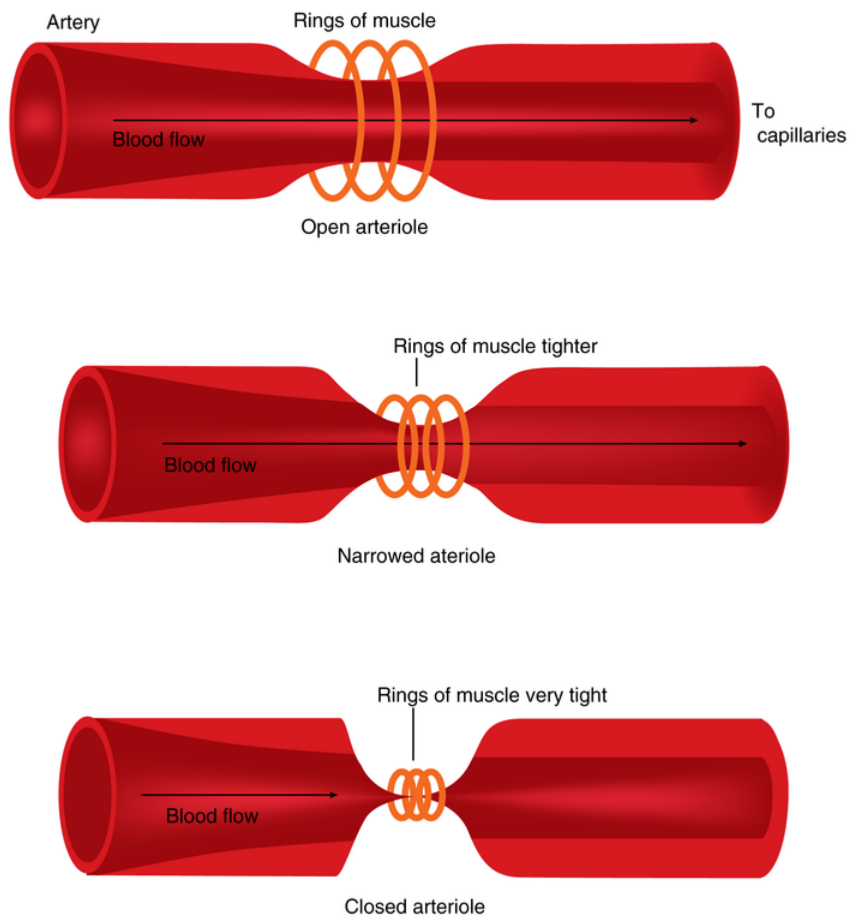


Figure 3.5a The arteriole is completely open when the rings of muscle are relaxed.

Figure 3.5b When the rings of muscle contract the arteriole becomes narrower and less blood flows through.

Figure 3.5c Sometimes the rings of muscle can squeeze so tightly that very little blood flows through. This situation can occur if more blood is needed in one part of the body than another. This is how arterioles help direct the flow of blood.

Apply Your KNOWLEDGE

- **What do you think happens to the arterioles in your leg muscles when you are running? Explain.**
- **If you are sick or frightened your face may get pale. What's happening in your body?**
- **If you are embarrassed you may blush. What's happening in this situation inside your body?**

Journal Writing

Pretend you are a drop of blood. Describe any differences in passing through a healthy artery and passing through an unhealthy, atherosclerotic artery.

Arterioles are “downstream” from arteries and “upstream” from capillaries. The position of the arterioles helps in several ways. Being between the arteries and the capillaries, the arterioles act together to keep the pressure high in arteries. And they act to control the distribution of blood to capillary beds so that blood is directed to where it is needed most. Individual arterioles control how much blood enters capillaries downstream from them. If all the arterioles in the body opened at once, pressure inside the arteries would drop too low to distribute blood to all parts of the body.

Review Questions

1. Describe three characteristics of arteries.
2. Why doesn’t blood stop flowing in your arterioles when the heart relaxes between beats?
3. Describe two characteristics of arterioles. Explain how they work.
4. What happens during a heart attack?
5. What is atherosclerosis? How can you prevent it?
6. Explain the role of blood pressure in moving blood from the heart through arteries to the cells of the body.

CHAPTER 5 Capillaries - Student Edition (Human Biology)

CHAPTER OUTLINE

5.1 Capillaries

How Do Oxygen and Nutrients Get From Blood to Cells?

Capillaries are the body's smallest blood vessels. Blood flowing in capillaries nourishes body cells with nutrients and oxygen and receives waste materials such as carbon dioxide. In this section you will find out more about capillaries-their structure, how they function, and what they do for your body.

Did You Know? Capillaries are tiny! They are only about $\frac{1}{10}$ the width of a hair. You have about 10 billion capillaries in your body.

There are capillaries in the lungs and in every organ and tissue in the body. They act as the body's exchange vessels. Gases, food nutrients, water, and wastes pass back and forth between body cells and the bloodstream across the thin walls of capillaries.

Let's follow nutrients from the digestive tract to see how the capillaries and arterioles work together. First, remember that the arterioles control the blood that enters the capillaries. Now suppose you eat a large meal. When you begin to digest your food, the arterioles that are connected to capillaries in your intestine open. Blood flows to the intestines and takes up nutrients from your food. When you begin to exercise, the arterioles to your muscles open so the blood can carry nutrients to your muscle cells. When the arterioles going to the muscles open, some arterioles to your intestine close down. Blood moves from your intestines to your muscles carrying the needed nutrients.

The walls of capillaries are made up of very thin, flat cells. The capillary walls keep large structures such as red blood cells inside the capillary. Other substances such as oxygen, carbon dioxide, glucose (sugar), and water can pass through.

Did You Know? Blood coming out of the heart travels at 40 centimeters (15 inches) per second. By the time it reaches the capillaries it travels about $\frac{1}{20}$ of a centimeter ($\frac{1}{50}$ of an inch) per second.

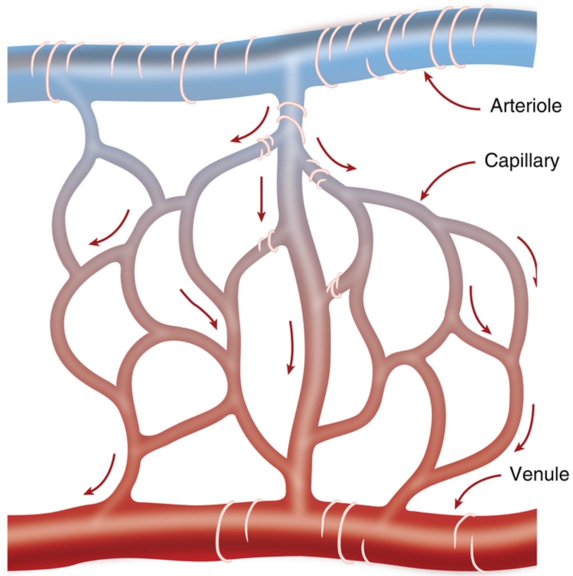


Figure 4.1 A web-like structure of capillaries, called a capillary bed, receives blood from an arteriole. The blood drains into a small vein called a **venule** (VEEN-yool.) The venule returns blood to larger veins and finally back to the heart.

Think about what happens to the water you drink. Where does it go after it gets to your stomach? Water molecules squeeze through the walls of your intestines and enter nearby capillaries. The water molecules that squeeze through the intestine wall mix with water molecules already in your blood plasma. Together the water molecules circulate in your bloodstream-pushed along by the pumping action of your heart. Eventually these water molecules pass through the walls of other capillaries and enter the spaces between body cells. In this way, water moves everywhere in your body. So the water you drink can go to your brain, your toes, your liver, and everywhere else in your body. Water moves everywhere because it passes through capillary walls.

Now let's see how blood moves from an arteriole to the capillaries that supply body tissues. Tissues are the sheets of cells that make up body organs. Every body organ has networks of capillaries that supply its tissues with blood. Look at **Figure 4.1**. This drawing illustrates how blood moves through capillaries.

Follow the flow of blood in **Figure 4.1** starting at the arteriole. Remember the high blood pressure of the arteries drops in the arterioles. The pressure drops even more when the blood leaves the arteriole and branches into the many capillaries. The blood pressure is low as the blood moves through the capillaries. Blood moves slowly from the arteriole through the twisted web of capillaries. At each turn the blood flow may slow down or even turn around and go backwards for a second before going forward again. As blood reaches the end of the capillary bed, the capillaries start joining together. The blood starts flowing a little faster when it enters a venule (little vein). Then the blood flows into larger veins and finally back to the heart.

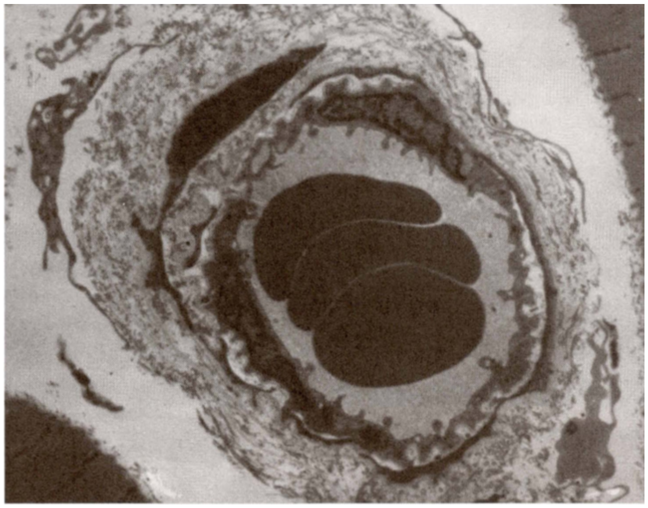


Figure 4.2 The thin walls of a capillary bed and the slow movement of blood through it allow nutrients, gases, and wastes to be exchanged between the blood and the tissues.

Did You Know? It takes 1 to 3 seconds for blood to pass through a capillary. Capillaries hold about 5 percent of the body's blood at any given time.

Did You Know? Sometimes red blood cells, which carry oxygen for delivery to the body's cells, have to go single file into the capillaries. Some capillaries are so tiny that the red blood cells have to bend and squeeze to get through.

Mini-Activity

Transport of Nutrients: Exploring Diffusion

Answer the following questions in writing.

a. What do you think would happen if you filled a small beaker with tap water and added one drop of food coloring?
b. What would happen if you filled a small beaker with tap water and added a cube of sugar?
c. How is diffusion affected by temperature?
d. What happens when someone opens a container of perfume or uses a spray bottle of room deodorizer?
e. Design your own activity to explore one of these questions. Then answer this question. How is the diffusion described here like the diffusion of nutrients and wastes in your cells?

Summary

Let's summarize what happens in capillaries. Blood moves very slowly through capillaries. As the blood moves through a capillary, nutrients, oxygen, and food leave the blood and enter the body cells. The blood also picks up wastes and carbon dioxide. The blood in capillaries works like a mail carrier. The mail carrier goes to each house on the route delivering mail and picking up letters to be mailed. The blood flows through the capillaries picking up and delivering materials as it passes each cell.

Capillaries go everywhere in the body. No cell in your body is more than two cells away from a capillary. Capillaries are exchange vessels. Gases (oxygen and carbon dioxide), nutrients, and wastes pass in both directions across capillary walls. Blood flow in capillaries is pushed by the pumping of the heart. Since water gets though cell membranes easily, the circulating blood moves water through every cell of the body.

Activity 4-1: Making a Capillary Bed Model

Introduction

You learned that capillaries have an important role in bringing nutrients and oxygen to your cells and in carrying away waste materials and carbon dioxide. Use your creativity to build a model of a capillary bed to help you learn more about the role of capillaries.

Materials

- Construction or drawing paper
- Scissors
- Glue or clear tape
- Marking pens
- Materials to represent arteries, veins, capillaries, and cells (Some examples include string, yarn, thread, rope, and dried beans.)

Procedure

Step 1 Brainstorm with your lab partners how to design your capillary bed model. Select appropriate materials to represent the following.

- capillaries carrying oxygen-rich blood and nutrients
- capillaries carrying oxygen-poor blood and wastes including carbon dioxide
- cells nourished by these capillaries
- small artery (arteriole) carrying oxygen-rich blood with nutrients to the capillaries
- small vein (venule) taking oxygen-poor blood with wastes away from the capillaries

Step 2 Construct and identify the parts of your model. Use arrows to show the direction of blood flow.

Step 3 Identify in your model where oxygen and nutrients leave the capillaries cells and where wastes and carbon dioxide leave the cells and enter the capillaries.

Step 4 Record your names and date on your model.

Red Blood cells

Journal Writing

Pretend you are a red blood cell.

Describe your journey as you pass through a capillary bed. How are you different leaving the capillary bed than when you entered the capillary bed?

How do materials move from the blood in the capillaries into your body cells? The exchange of oxygen and carbon dioxide and the exchange of nutrients and waste materials happen due to a process called **diffusion** (dih-FYOO-shun). Diffusion is the random movement of molecules from a region of higher concentration to a region of lower concentration. For example, a cell uses oxygen and produces carbon dioxide. The oxygen-rich blood from the heart has a lot of oxygen and much less carbon dioxide. The oxygen diffuses from the blood, where there is a greater concentration, to the cell, where there is a lower concentration. The carbon dioxide diffuses from the cell, where there is a greater concentration, to the blood, where there is a lower concentration. Given enough time, diffusion leads to an even distribution of molecules.

Review Questions

1. How are capillaries different from arterioles?
2. Why do you have capillaries?
3. Describe and explain the process by which substances enter and leave capillaries.

CHAPTER 6 Veins and Venules - Student Edition (Human Biology)

CHAPTER OUTLINE

6.1 Veins and Venules

How Does Blood Get Back to the Heart?

You learned about the arteries and arterioles that deliver nutrients and oxygen to the cells of your body. But the story doesn't end in the cell. When the cell uses the oxygen and nutrients, it produces wastes such as carbon dioxide. So the body has vessels called veins to carry those wastes away from the cells that produce them. In this section you investigate the vessels that carry the wastes away from the cells.

Veins and **venules** are the vessels that return blood from the capillaries back to the heart. For every major artery carrying blood to an area, there is a vein taking blood back out of that area. The blood that carries waste materials from cells flows through the veins. The veins close to the heart are the largest of the veins in your body. The walls of large veins are thicker than the walls of the smaller veins. But they are not nearly as thick as the walls of arteries that have the same diameter. The smallest veins called venules have very soft and thin walls.

The walls of veins can be thinner and less elastic than the walls of arteries, because the blood is under much less pressure in veins than in arteries. The pressure created by the squeezing of the heart pushes blood through arteries, arterioles, and capillaries. But that pressure is almost completely gone by the time the blood enters the venules. Then how does the blood get back to the heart?

Observing Veins

Find someone whose veins on the top of the hand are easy to see. Boys sometimes have more obvious veins than girls do. Ask your partner to swing and shake one hand down at his or her side for 30 seconds . What happens to the blood in these veins? Now ask the person to raise the same hand high in the air for 30 seconds . What happened to the blood? Explain your observations.

Did You Know? Varicose veins are those squiggly veins that some people have on the backs of their legs, often just below the knee. Varicose veins form when blood flows backwards and overloads the veins by stretching out the walls. Those veins lying outside muscle groups, closest to the skin, are the most likely to become varicose.

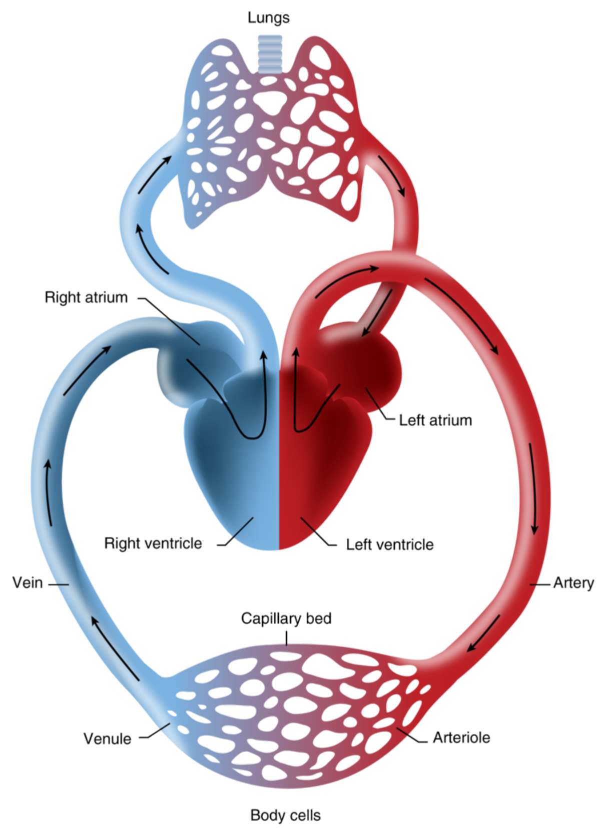


Figure 5.1 The veins form a network of vessels that return blood to the heart.

You learned that blood moves through vessels because of a pressure difference. The pressure difference that causes blood to move through vessels is like the pressure that moves water through a garden hose. It's also like the pressure difference that forces air out of a balloon. You learned that the squeezing of the blood by the heart generates the pressure that moves blood through arteries. This pressure causes the arteries to stretch. Then when the heart relaxes, the recoil of the stretched arteries keeps the blood moving. But the pressure generated by the heart is all used up pushing blood through mile of tiny arterioles and even tinier capillaries. So what pushes the blood through veins?

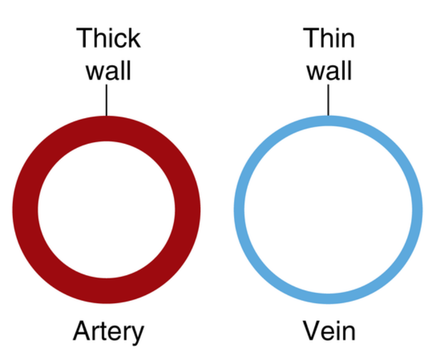


Figure 5.2 Veins have thinner, less elastic walls than arteries. The walls of veins can expand to hold more blood, or collapse when they hold little blood.

Gravity or Valves

There are two important mechanisms that return blood to the heart. One mechanism is gravity. Some blood ends up in veins above the heart, such as the blood in the head. Blood above the heart flows back to the heart just like water in a stream flows down a mountain. But gravity makes the problem of getting blood back to the heart worse when the blood ends up below the heart, such as the blood in the feet. To take care of this problem, veins have something that arteries don't. Veins have one-way valves.

Veins have flaps of tissue that work as valves allowing blood to flow in one direction only-toward the heart. But we still haven't discovered what causes the blood to flow up in the veins from below the heart. The answer is the muscles of your body working with the one-way valves. As the muscles of your body contract and relax to move your limbs they also squeeze your veins. Whenever veins are squeezed the blood in them moves. Because of the one-way valves, the blood can only keep moving toward the heart.

About 60 percent of your blood is in your veins when you are resting. Remember that the walls of the veins are thinner than the walls of the arteries. The thinner walls of veins can expand more than the thicker walls of arteries. So your veins can hold a larger volume of blood than your arteries can. Unlike arteries, veins collapse when they are empty.

Activity 5-1: The Direction of Blood Flow

Introduction

How does blood flow through your blood vessels? Does it flow back and forth or in one direction only? In this activity you recreate the procedures and experiments of William Harvey. In the 17^{th} century Dr. Harvey discovered evidence that blood flows in one direction only through blood vessels. He showed that blood moves away from the heart in arteries and then back to the heart in veins. William Harvey used a tourniquet to trap blood in the surface veins of the arm and hand. This procedure helped him explore the one-way flow of blood. You will use a much safer method to explore blood flow.

Materials

- Clock or watch
- Activity Report

Procedure

Step 1 Raise one arm and hand as shown in **Figure 5.3**. Hold it above your head for four minutes. Keep your other arm relaxed at your side.

Do you notice any tingling or throbbing in the ends of your fingers? Is there any change in the warmth of your hand? Is there any difference between the feelings in your two arms and hands? Describe the differences between them to your lab partner. Have your lab partner record these differences on your Activity Reports.

Figure 5.3 Hold one arm above your head.

Step 2 After four minutes, place your two hands in front of you. Compare the backs of your two hands and note any differences in color and visibility of blood vessels. Trace around each hand and draw in the pattern of blood vessels.

Step 3 Shake your left hand vigorously for about 30 seconds or until you can easily see the vessel pattern on the back of your hand.

Step 4 Immediately place your left hand on the table surface palm-Side up. Place the index finger of your other hand over a prominent vessel at your wrist. This vessel is a vein. Arteries are deeper. Press firmly as you move your finger about 3 cm toward the elbow. You should notice that the blood follows your finger.

Step 5 Repeat step 4 moving your finger away from the elbow. Be sure to note any differences in color and size of the vessel immediately behind the path of your finger. You should notice that the blood does not follow your finger. There are valves located in the vein that prevent the backward flow of blood.

Step 6 Now let your lab partner follow Steps 1 to 5 while you record the observations your partner experiences.

Step 7 What did you learn about the flow of blood in this activity? Complete the questions on the Activity Report. Then write a summary of what you have learned about the one-way flow of blood in your body.

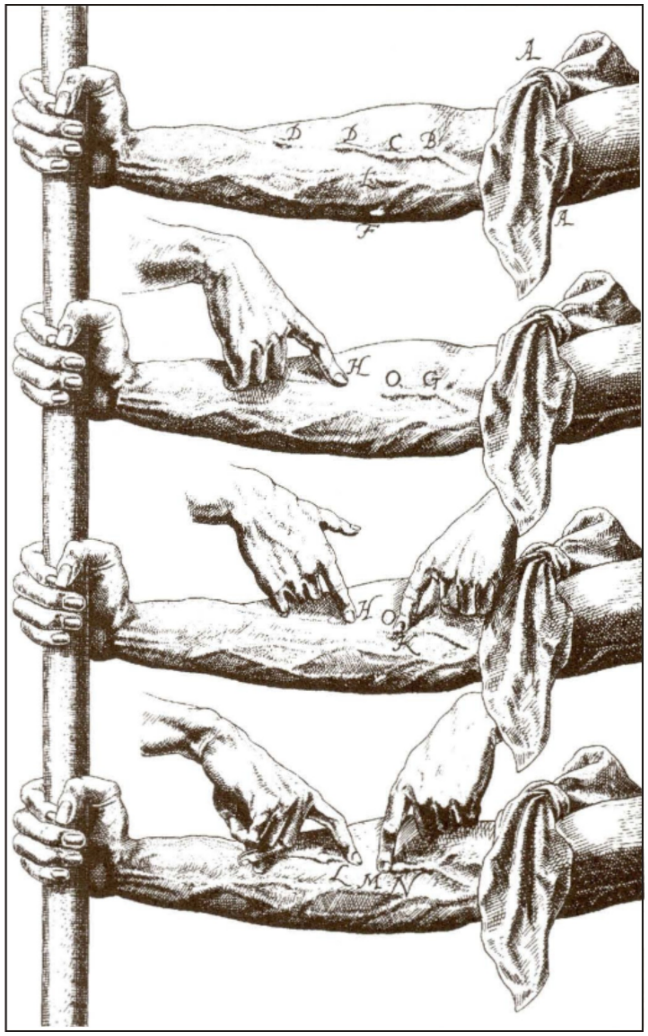


Figure 5.4 English scientist Dr. William Harvey drew these diagrams of his experiments on blood circulation. They were first published in the year 1653.

Veins and Muscle Contraction

Did You Know? Veins appear blue because a yellow pigment in the skin makes the dark red blood in the vessels look bluish.

Did You Know?

Airplane test pilots who pull their planes out from steep dives can experience increased gravity that makes blood pool in their feet. Unless they wear pressurized suits called G-suits they can pass out. A G-suit increases pressure on the legs and feet, and counteracts the effects of gravity.

Since veins are especially flexible, gravity causes the blood to pool in the feet and legs when you are standing. For this reason soldiers that have to stand at attention for long periods of time must keep their leg muscles contracting and relaxing even though they are not walking around. If they don't, the blood pools in the veins of the feet and legs. If too much blood pools in the feet and legs, the brain doesn't get enough blood and a person can pass out.

You may get a warning from your body before you faint. You can feel unsteady and become giddy or dizzy. Your vision may blur and you may start to sweat. You can feel cold or clammy and may not think straight. If this starts happening to you or someone else, remember you need to increase blood flow to the brain. There's a very good way to increase the blood flow to the brain. Lie flat and prop the feet up so they are higher than the head. This position lets blood from the legs move up to the heart thanks to gravity. However, that is not the only action you should take in a fainting situation. After a person who has fainted or is feeling faint is lying down safely, you or someone should get help right away.

Did You Know? Strenuous exercise can increase the amount of blood the heart pumps out from 5 liters (1.3 gallons) per minute to 30 liters (8 gallons) per minute.

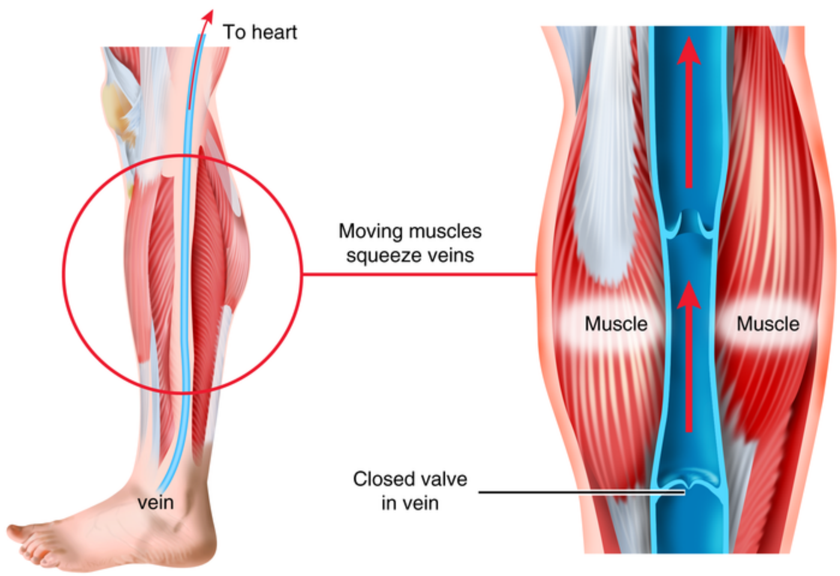


Figure 5.5 While the heart powers blood through the arteries, the veins depend on muscles contracting (squeezing) to move blood upward to the heart. Valves in the veins keep blood from flowing backwards.

The drawing in **Figure 5.5** shows that when leg muscles contract they squeeze the veins and push the blood towards the heart. The drawing also shows that veins have valves that prevent the back flow of blood. These are like the valves in the siphon pumps. They let fluid pass in one direction only. Exercise helps your circulation because when you contract your leg muscles, you empty your leg veins. The leg veins fill from the capillary beds in your feet when the muscles relax.

Apply Your KNOWLEDGE

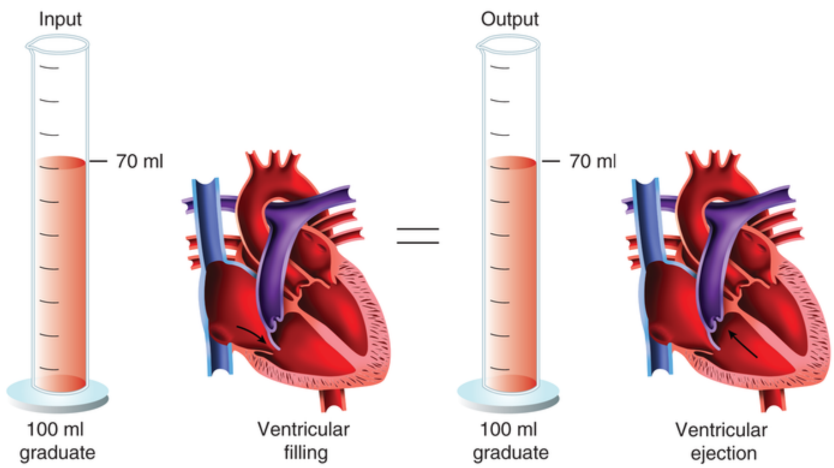
- The soldiers who guard Buckingham Palace in London, England do not move when they are on guard. They are known for their ability to stand still for very long periods of time. Some guards have fainted after only 30 minutes on duty. Why do you think this happened? What happened? How could the guards have prevented it?
- Why is it more important for leg veins to have valves than neck veins?

A Closed Circuit

You learned how the heart pumps blood to the body. Now you've learned how the blood returns from the body to the heart. All these vessels working together with each other and the heart form a closed circuit. There is usually a good balance within that closed circuit. Each minute, the amount of blood the heart pumps to the arteries equals the amount of blood returned by the veins to the heart. Here's another way to explain that. The amount of blood the right side of the heart pumps to the lungs is the same as the amount of blood the left side of the heart pumps to the body. Or the simplest way to explain it is what comes into the heart must flow out of the heart.

The amount of blood flowing through the heart changes depending on the oxygen needs of the body cells. During exercise the veins return more blood to the heart and more blood is pumped out to deliver oxygen to the cells.

> **Did You Know?** At rest your 5 liters of blood is distributed in your circulatory system as follows:
> veins and venules 60 percent
> arteries and arterioles 15 percent
> pulmonary 12 percent
> (in lung capillaries)
> heart 8 percent
> capillaries 5 percent



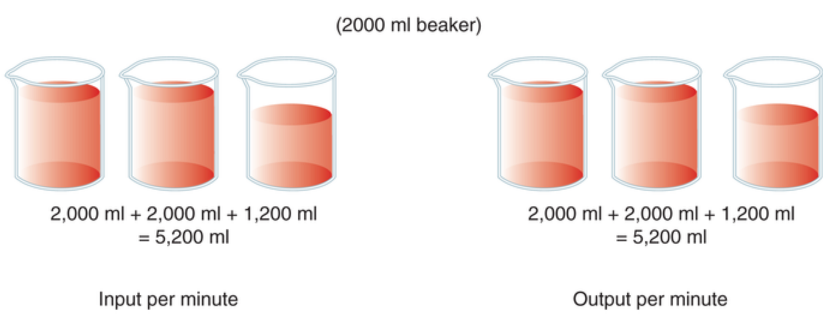


Figure 5.6a The amount of blood entering the heart per beat is the same as the amount of blood leaving the heart per beat. In this example, each ventricle pumps 70 ml (milliliters) of blood with each heartbeat.

Figure 5.6b The amount of blood pumped per minute is the cardiac output.

Mini-Activity

Percentages of Blood Compare the percentages of blood found in different parts of your circulatory system listed in the **Did You Know?** above. Make a circle graph showing the data. Remember that you have 5 liters of blood in your body. Now calculate how many liters of blood are in each part of your circulatory system while you are at rest.

Apply Your KNOWLEDGE

- At rest, your heart pumps only 20 to 25 percent of the total blood volume in your body. What is the purpose of the other 75 to 80 percent of the blood? Where is this blood?
- In which blood vessels does blood travel the most slowly? Why would the blood travel more slowly in those vessels?

Journal Writing

Pretend you are a drop of blood. What differences would you feel going to the heart through a vein than going from the heart through an artery?

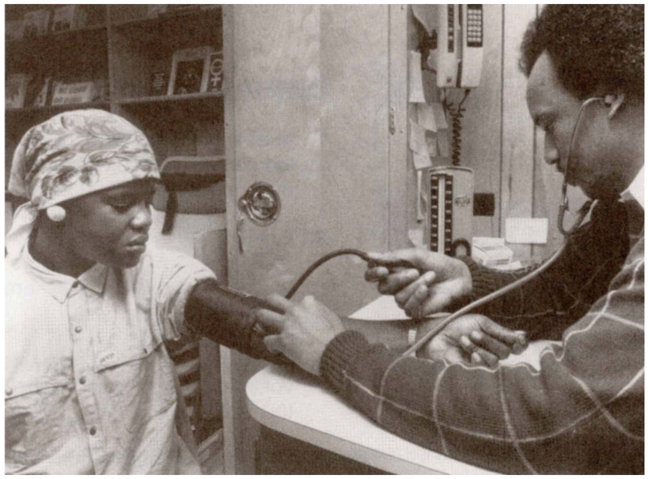
Review Questions

1. In the *Arteries and Arterioles* section you learned about arteries. In this section you learned about veins and compared the structure and function of an artery and vein. List four differences.
2. Explain how blood gets back to your heart from your feet when you are walking. What factors help the return of venous blood to the heart? What makes it more difficult to return venous blood back to the heart?
3. When you are resting, a greater percentage of your total blood volume is in your veins than when you are exercising. How is this possible?
4. How is blood output from the heart related to blood return?
5. Describe William Harvey's famous experiment. Include what he did and the conclusions he reached.

Chapter 7 Pressure, Flow, and Resistance - Student Edition (Human Biology)

Chapter Outline

7.1 Pressure, Flow, and Resistance



How is the Right Amount of Blood Directed to Each Part of the Body?

You've investigated the heart and how it pumps blood through the body. You also investigated the vessels that carry the blood to all parts of the body and back to the heart again. But how does the body make sure the right amount of blood is sent to all the different parts of the body? Have you ever had your blood pressure taken? In this section you investigate what blood pressure is and how pressure affects the flow of blood.

What is pressure? Pressure is a force exerted over an area. You feel pressure on your skin when you touch it. If you shake a can of soda and make a small hole in the can pressure squirts soda out of the hole, as shown in **Figure 6.1**.

Figure 6.1 When you shake up a can of soda, pressure builds up inside. Then if you open the can, soda comes squirting out.

In the soda can example, the size of the hole will affect how the pressure is released. If the hole is narrow and "resists" the squirt, the squirting lasts longer. If the hole in a similar can is very large, a lot more soda squirts out all at once. The big hole doesn't resist the flow as much as the small hole does.

Remember how a siphon pump works. When pressure builds up in the outlet tube, fluid squirts out. The pressure buildup in the outlet tube is called a **pressure head** or a head of pressure. In a siphon pump the head of pressure comes from the squeezing of your hand. In your heart the pressure head comes from the squeezing of the ventricle. The pressure forces water through the tubes in a siphon. In the same way, the pressure forces blood through the vessels in your body. Vessels, especially the arterioles, can create pressure heads by squeezing the vessel opening smaller. This creates a slowing of the blood flow within the vessel. The slowing of the blood flow is called **resistance.** This kind of resistance can be affected by the thickness of the blood, by the length of the vessel, and by the diameter (the width across) of the vessel.

Figure 6.2 Arterioles help regulate the pressure and flow of blood. When arterioles are relaxed, blood flows freely. This is similar to the free flow of water in a garden hose when the spray nozzle is removed, as seen on the left. The spray nozzle adds resistance and a pressure head builds up, as seen on the right.

Blood Pressure

Your blood pressure tells how hard your circulatory system is working. **Blood pressure** measures the force with which blood travels through your blood vessels. High blood pressure means your circulatory system is working too hard. Low blood pressure occurs when your circulatory system is not working as hard as normal. Low blood pressure can signal that your body tissues may not be getting enough of what they need. Blood pressure is really a measure of how much resistance the blood meets when traveling through the vessels. Let's take a closer look at resistance.

Resistance

Have you ever used a very long straw to drink your milk? Is it hard or easy? A short straw is easier to drink milk through than a long straw of the same diameter. You know your heart pumps blood through long narrow tubes called arteries. The arteries from the left side of your heart (aorta and its branches) are longer than the arteries connected to the right side (the pulmonary arteries.) So the left side of the heart has to be stronger to push blood through the longer blood vessels that reach all parts of your body.

Why is it harder to push blood through long, narrow tubes? The blood rubs against the wall along the entire length of the tube. This rubbing is called **friction.** Friction is the rubbing of any two things together. There is more friction in long tubes than in short ones when the tubes have the same inside diameters. Of course there is more friction in small diameter tubes than in ones with larger diameters.

Activity 6-1: Pressure, Flow, and Resistance Introduction

Does blood flow at the same rate through vessels of different diameters? In this activity you investigate how pressure and resistance influence the rate of flow.

Materials

- 2 large containers or beakers

- 2 equal lengths of flexible tubing of different inside diameters
- Clamp
- Metric ruler
- Plastic bottle or large metal can
- Masking tape
- Large nail
- Water
- Sink, container, or large tray to collect water
- Activity Report

Procedure

Part A

Step 1 Obtain 2 large beakers or containers. Label one beaker A. Label the other beaker B. Fill each beaker $\frac{3}{4}$ full of water. Make sure you use the same amount of water in each container.

Step 2 Obtain 2 pieces of tubing and 2 clamps.

Step 3 Fill the tubes with water. Close off one end of each tube with a clamp.

Step 4 Submerge one piece of tubing in the beaker marked A. Submerge the other piece of tubing in the beaker marked B.

Step 5 Allow the closed ends of the tubing to hang over the side of the container as shown in **Figure 6.3**.

Step 6 Organize the team tasks. Decide the following: Who will be the timer? Who will start the flow for beaker A? Who will start the flow for beaker B? Who will record the results? Who will observe the distance of the water stream from each beaker?

Step 7 Make sure the closed ends of the tube are pointing to the sink or large tray. At the timer's signal, remove the clamps. This will start the tubes flowing from beakers A and B into the sink or large tray.

Step 8 Answer the questions on the Activity Report.

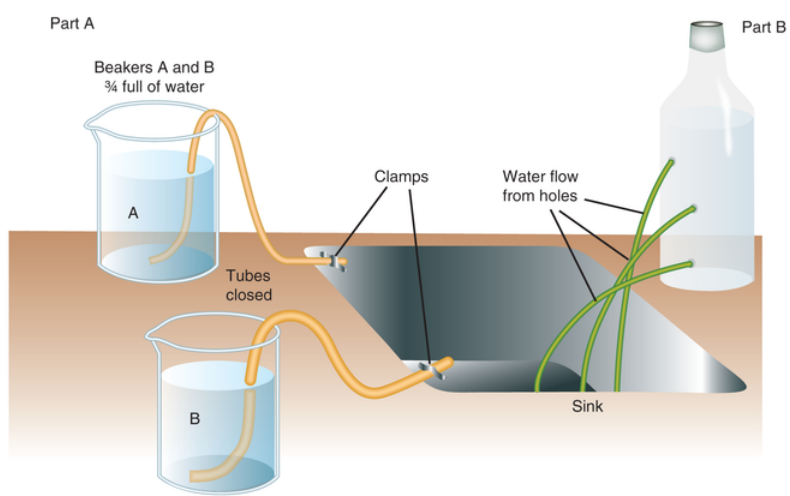


Figure 6.3 Let the closed ends of the tubing hang over the side of the container.

Part B

Step 1 Using the large nail make three holes at different heights in the side of the plastic bottle.

Step 2 Cover the holes with tape.

Step 3 Fill the bottle with water.

Step 4 Place the bottle near a sink or large tray, and pull the tape off from all three holes.

Step 5 Compare the flow from each of the holes.

Step 6 Answer the questions on the Activity Report.

Friction and Resistance

More friction makes the heart work harder to push the blood. What factors increase friction in your arteries? Think about the straw example. If the straw is longer, you have to do more work to suck the liquid up. In a similar way, the heart has to work harder to move blood through longer blood vessels. A longer vessel has more resistance than a shorter one. Is it easier to drink through a narrow straw or a straw with a larger diameter? Think about the diameter of the blood vessels. How does the diameter of vessels affect friction?

How does friction affect the function of your heart? Let's try to find out. First think about how much blood the heart pumps each minute. For example, when you exercise, your heart beats about 100 times each minute. Each heartbeat pumps 70 milliliters of blood from each ventricle. So the total volume of blood pumped per minute per ventricle is 7000 milliliters , or 7 liters .

Apply Your KNOWLEDGE

Remember that your heart is two pumps working together. Which pump is stronger? You know both pumps have to pump the same amount of blood. Why does one have to be stronger than the other?

Did You Know? During exercise, muscles get 88 percent of the blood pumped through the heart. At rest, muscles....get only 20 percent of the blood. When exercising, your stomach gets only 1 percent of blood compared to the 24 percent it needs to digest a meal.

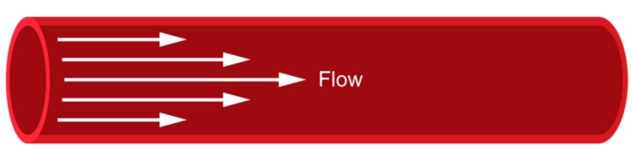


Figure 6.4 Blood flowing inside tubes is slowed by friction when the blood rubs against the vessel wall.

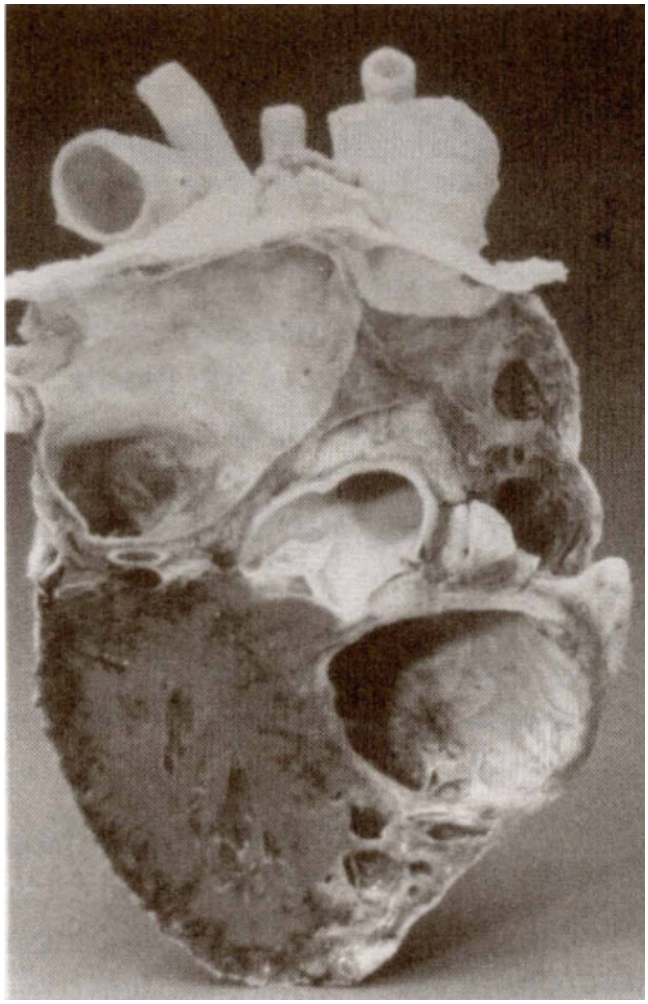


Figure 6.5 Cross-section of a human heart.

Mini-Activity

Cold Toes

When your feet, hands, ears, or nose get cold the blood vessels to those areas close down. When the tissues in those areas get very cold, they can freeze. Now what do you think frostbite is? How do you treat frostbite? What is gangrene? How is circulation involved? Do library/internet research to find out.

Look at **Figure 6.5**. Notice that the left and right sides of the heart are different from each other. Resistance makes the left side of the heart work harder than the right side. The left side of the heart pushes blood through longer blood vessels that have more resistance. The muscle of the left ventricle is thicker and stronger to do this added work. The right ventricle doesn't need to be as strong because it pumps blood to the lungs through a shorter system of blood vessels with less resistance.

The beating of the heart squirts blood under pressure into the arteries. Look at **Figure 6.6**. Blood pressure in your arteries is like the water under pressure in the outlet tube. The arterioles keep blood pressure in arteries high to keep the flow going.

The arterioles regulate the flow of blood to where it is needed. After you eat a big meal, such as Thanksgiving dinner, the arterioles of the stomach and intestines open wide. This allows the blood to flow in to absorb food nutrients. Since large muscles, such as your leg muscles, do not need as much blood, the arterioles connecting to those areas constrict. When you exercise, the reverse happens. Running too soon after Thanksgiving dinner is uncomfortable because our bodies aren't set up to run and digest food at the same time.

Measuring Blood Pressure

Have you been to the doctor and had your blood pressure taken? Your doctor wraps an inflatable cuff around your upper arm. Then the doctor pumps the cuff until it's tight, squeezing your arm. The doctor uses a stethoscope to listen to the big artery in your arm as the pressure in the cuff is released. Your arm may feel tingly as the pressure releases. Afterward, the doctor removes the cuff and writes a couple of numbers on your chart. What the doctor writes may look like this- BP$\frac{110}{70}$.

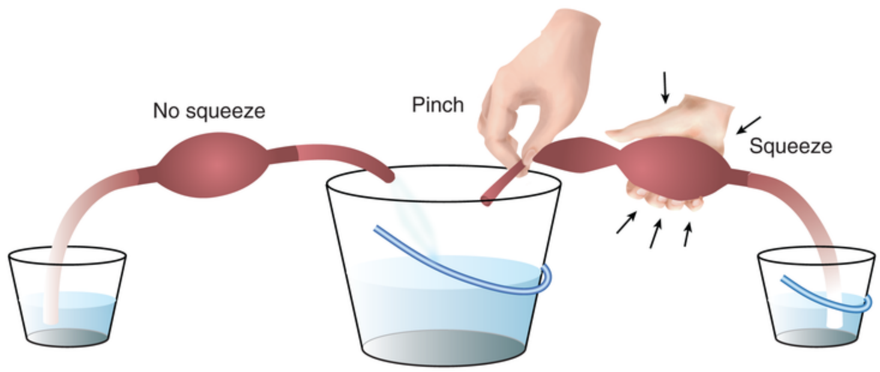


Figure 6.6 The muscles in the walls of arterioles can contract or pinch causing pressure to build up behind the pinch.

The letters BP stand for blood pressure. The number to the left or above the bar, 110 , is the systolic blood pressure. Remember that systole is when the heart is pumping blood into your arteries. So the systolic blood pressure is the pressure in your arteries when the heart is pumping. The number on the right or below the bar, 70 , is the diastolic blood pressure. Remember that diastole is when the heart is resting between beats. So the diastolic blood pressure is the pressure in your arteries when your heart is filling, not pumping.

Blood pressure is measured in units called Torr, or millimeters of mercury (mm Hg) . The tool usually used to measure blood pressure has a column of mercury in a glass tube connected to the rubber cuff. This device is called a sphygmomanometer (sfig-moh-man-AHM-ih-tur). The height of the mercury column in millimeters gives the blood pressure reading. Mechanical versions with a circular dial and electronic versions that give a digital readout are also in use.

Apply Your KNOWLEDGE

In which blood vessels is the rate of blood flow the slowest? In which blood vessels is blood pressure the lowest?

Importance of Blood Pressure

Your blood pressure measurement helps tell how well your heart and circulation are working. High blood pressure is also called **hypertension** (hi-per-TE -shun). Hypertension, or high blood pressure, is a common problem. One out of every five people in the United States either has or will get high blood pressure.

Did You Know? Blood pressure varies a lot depending on what you're doing. Compare the blood pressures in the table below.

TABLE 7.1:

	Systolic	Diastolic
Normal (resting)	120	80
Stress	140	90
Vigorous exercise	180	100

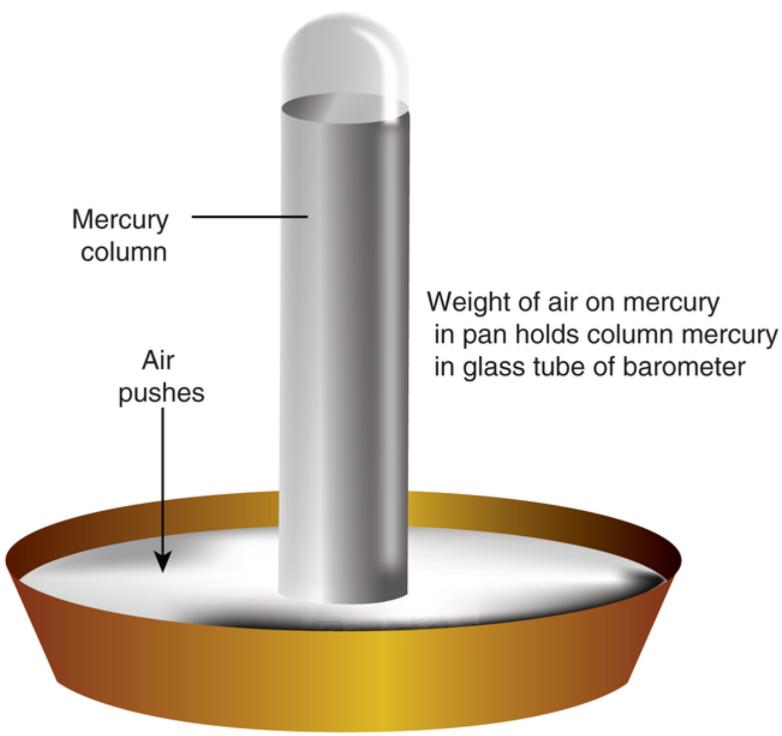


Figure 6.7 This device is called a barometer. A barometer measures the changes in air pressure. The mercury moves up or down in the tube depending on the air pressure. In a similar way blood pressure is measured in millimeters of mercury. Asphygmomanometer works a lot like a barometer.

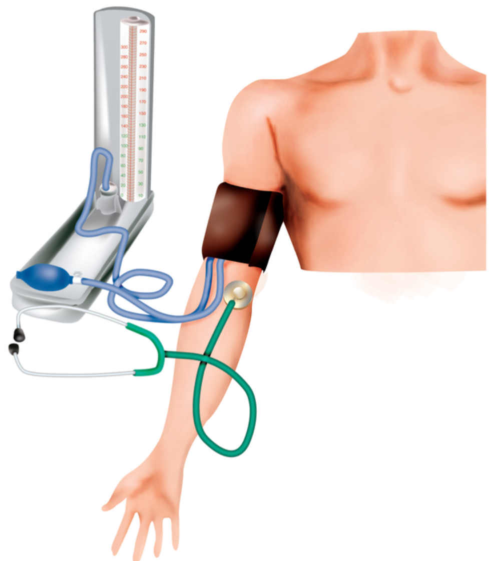


Figure 6.8 This drawing shows how the cuff and stethoscope should be positioned to read the blood pressure.

People who have high blood pressure don't always notice the symptoms. But if high blood pressure goes untreated it can cause problems with the heart, brain, and kidneys. So it is important to catch and treat me problem early. Sometimes high blood pressure is inherited in a family. people who have family members with high blood pressure should have periodic blood pressure checks.

Controlling Blood Pressure and Maintaining Homeostasis

Remember that homeostasis is the balance in all of the components of your internal environment such as temperature and blood pressure. To maintain homeostasis, your body must respond to changes both inside and outside your body 24 hours a day. How does it do this? Your body has a system of **sensors** which sense changes in your environment and in your body. The sensors send messages to the brain where **controllers** send back commands to your muscles and other organs that can respond to the change. For example, think about what happens when someone right behind you drops a pile of books. Your ears send a message to your brain. Your brain sends a message to your heart. Your heart beats faster and begins to pump more blood. If this were a real emergency, the increased blood flow to your muscles would help you escape.

Both the **nervous system** and the **endocrine system** work to control and coordinate the body's activities. Generally, the body's control systems respond to changes and make adjustments to keep everything normal. For example, in a snowstorm our control systems may start our bodies shivering from the cold. The control system also makes us feel cold and miserable. This is a way the control systems tell us to get out of the snow or put warmer clothes on.

Controllers use **negative feedback** in deciding what adjustments to make. Feedback is information about something that happened. Negative feedback tells a controller to counteract or make up for an earlier change. For example, a home thermostat uses negative feedback. Suppose you set the thermostat on the wall for $60^{\circ}F$ $(15.6^{\circ}C)$. If the room temperature drops below $60^{\circ}F$, the thermostat senses the cooler temperature and turns on the furnace. When the room reaches the set temperature again, the thermostat turns the furnace off. The difference between the thermostat's temperature setting and the room temperature acts as negative feedback. Thus, changes in the temperature information received by the thermostat causes responses that will cancel or reverse the change. That is why it is called *negative* feedback.

Activity 6-2: How a Controller Works Introduction

The controller for blood pressure is located in the medulla (muh-DOOL-uh) at the base of your brain. It regulates the heart and blood vessels to keep your blood pressure within safe limits. In this activity you investigate how a controller works by becoming the thermostat for a temperature control system. You will keep the temperature at $37°C(98.6°F)$.

Materials

- Water bath (1000 – ml beaker)
- Thermometer
- Crushed ice in container
- Hot plate or other heat source
- Paper towels
- Resources 1, 2, and 3
- Activity Report

Procedure

Step 1 There are four jobs in your group.

- Student 1 watches the thermometer and tells the others to add ice or heat in order to keep the temperature at $37°C$.
- Student 2 adds ice water to the bath if the thermometer reads greater than $37°C$.
- Student 3 turns on the hot plate if the thermometer reads less than $37°C$.
- Student 4 is the recorder and completes the temperature table.

Step 2 Use the data table on Resource Sheet 2 for recording data.

Step 3 Heat the water in the beaker to a temperature of $37°C$. Adjust the temperature with ice or the burner. When the temperature is exactly $37°C$, use this as time zero and start recording. CAUTION -hot plate is HOT!

Step 4 Maintain the water temperature at $37°C$ for 20 minutes . Add ice or heat as necessary.

Step 5 Take the temperature every 2 minutes for 20 minutes and record it in your table on Resource Sheet 2.

Step 6 Plot the data from your data table on the line graph on Resource Sheet 3.

Step 7 Ask your teacher for cleanup instructions.

Pressure Sensors

Now, let's see how a negative feedback system works in our bodies by exploring blood pressure. Blood pressure is one indicator of how hard the circulatory system has to work. If blood pressure is kept normal (about $\frac{120}{80}$ – mm Hg) blood moves through all vessels of the circulatory system at the proper rate and the body's cells thrive.

Pressure sensors in the aorta and carotid (kuh-ROT-ihd) arteries help the body maintain a safe blood pressure. If the pressure sensors sense a drop in blood pressure, they send a signal to the brain. The brain responds as if saying, "Well, seems the blood pressure in the aorta is low. If this keeps up I'll get too little blood and oxygen and pass out. So, I'd better fix it!" The brain fixes it by sending a message to the heart to beat faster and more forcefully. If the heart increases its squeezing force and the number of systoles (beats) each minute, more blood passes into the aorta. When the aorta fills with more blood, the blood pressure rises, then the brain stops getting the "low blood pressure" messages. What might happen if the brain got the message that the pressure in the aorta was too high? To answer that question, just go through the steps in the opposite way.

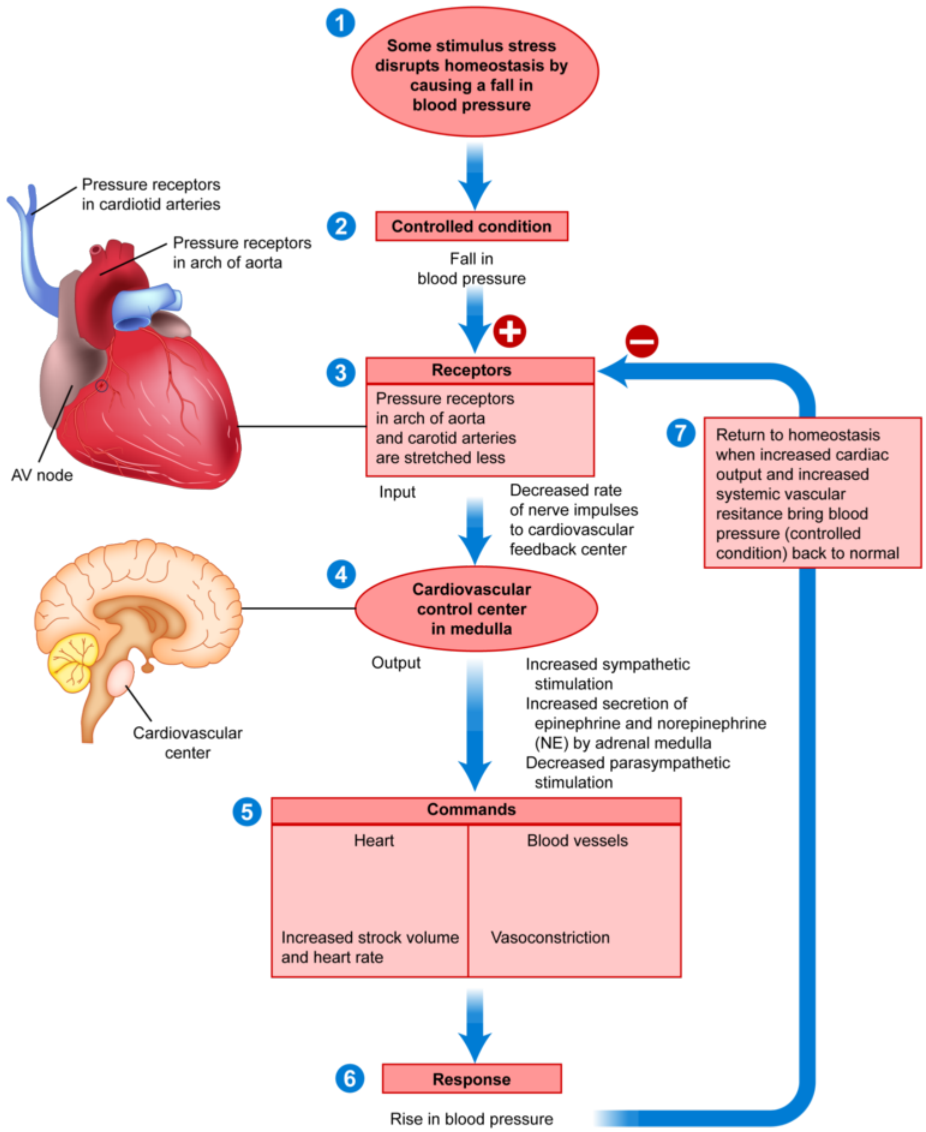


Figure 6.9 Blood pressure is maintained through a negative feedback system.

Apply Your KNOWLEDGE

Why might doctors watch diastolic pressure more carefully than systolic pressure?

Figure 6.9 shows how blood pressure is regulated. The brain receives messages about the blood pressure in the arteries. The brain sends out messages to change how fast and how strong the heart beats. This keeps the pressure at about $\frac{120}{80}$ mm Hg . Remember that the pressure must be strong enough to move enough blood from the aorta to supply all the arteries, arterioles, and capillaries. If the pressure in the arteries falls too low, the blood cannot reach everywhere it needs to go.

Apply Your KNOWLEDGE

Suppose you find a person who has cut himself and lost a lot of blood. He may be unconscious. He's pale. His heart beats fast. But his pulse is weak and hard to find. Put all these observations together to explain what you have observed.

Mini-Activity

The You in You

Lie down on a large sheet of paper and have a friend or family member use a marker to trace your body outline on the paper. Imagine what your circulatory system looks like. Then use colored markers to draw it in. Make sure to include a four-chambered heart, arteries, arterioles, capillaries, venules, veins, the lungs, and the lymph system. Include any other aspects of the circulatory system that you can think of, such as the pacemaker. Have some fun illustrating what's going on in your body as you draw.

Review Questions

1. Describe two factors that affect cardiac output.
2. Why is the muscular wall of one side of the heart thicker than the other side?
3. What is the difference between systolic and diastolic pressure?
4. How does a controller work?
5. What does the term homeostasis mean? How does it relate to blood flow?

CHAPTER 8 Cardiovascular Health - Student Edition (Human Biology)

CHAPTER OUTLINE

8.1 Cardiovascular Health

How can I keep my heart strong and my arteries clean and clear?

More people in the United States die from heart disease than from any other cause. At least 70 percent of those deaths are due to heart attacks. The remaining deaths are due to strokes, high blood pressure, and other diseases of the circulatory system. Atherosclerosis is the main cause of heart disease and the leading cause of death in the United States. Heart disease is most common in the elderly. But it is also a leading cause of death in those under age 65 .

Cardiovascular Diseases

Cardiovascular diseases affect the heart's blood vessels or blood supply. The most common cardiovascular disease is atherosclerosis. In atherosclerosis, fatty materials called plaque form on the interior of the artery walls. The buildup of plaque changes the walls of the arteries. The arteries become rigid and less springy. The plaque narrows the internal diameter of arteries. The narrowing of the arteries restricts the flow of blood and makes the heart work harder. Sometimes the arteries become so narrow that blood flow slows or stops.

Atherosclerosis can involve all major arteries, especially those leading to the heart, brain, kidneys, and legs. As the disease gets worse the internal diameters of the arteries get smaller and the artery walls get harder. A narrowed, harder artery cannot increase blood flow in times of increased demand, such as during exercise. A different condition is a localized weakening of the arterial wall leading to the artery bulging at that site. Such a bulge is called an **aneurysm** (ANN-yur-ism.) When an aneurysm gets very large and the walls of the vessel are very weak, it can burst. Then blood leaks out and a person can actually bleed to death inside.

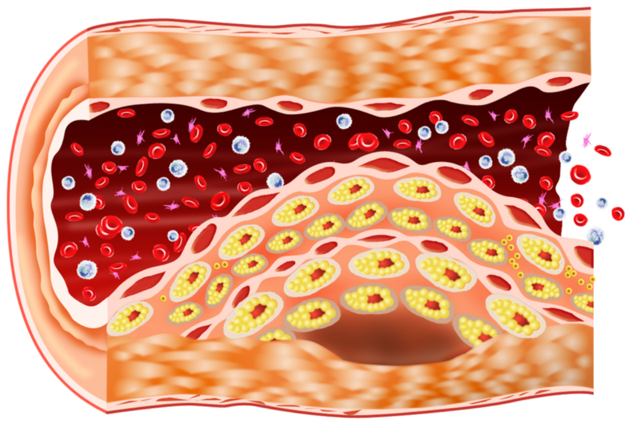


Figure 7.2 When arteries that feed the heart get narrow, the heart muscle doesn't get enough oxygen.

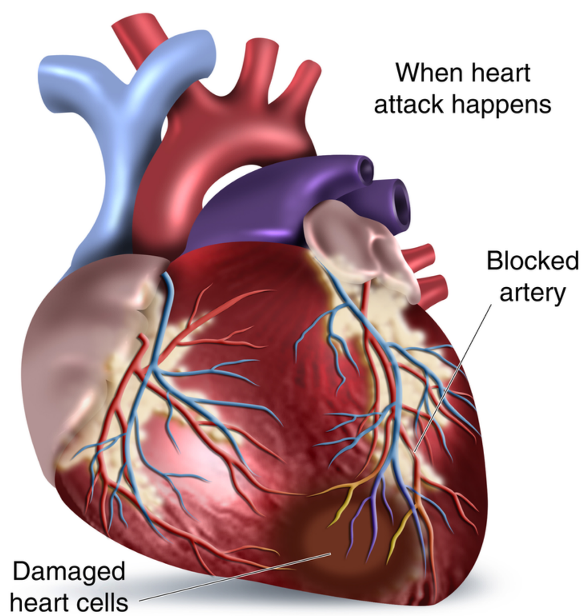


Figure 7.2 A heart attack happens when a blocked artery prevents blood flow to the heart. Heart cells may die due to lack of oxygen.

Did You Know? Every day in the United States 4100 people have heart attacks and 1500 the as a result.

Did You Know? If a person has too little oxygen in the blood or not enough blood gets to the tissues, including the brain, the person may

- increase the rate and depth of breathing,
- have a swollen red neck and face,

- have blue face, lips, nails, and fingers,
- have noisy breathing with frothing at the mouth,
- lose consciousness,
- have a seizure or uncontrolled shaking,
- die.

A **heart attack** occurs when the coronary arteries that serve the heart become clogged with plaque and/or a blood clot. When the arteries get very narrow, there is the risk of a sudden complete blockage. Where plaque forms, the artery is damaged and its inner surface becomes rough. These changes in the artery wall can trigger the blood clotting process. After a small clot forms, it can break loose and get stuck "downstream" where the artery gets narrower. The result is that blood flowing to the heart muscle is suddenly blocked, depriving heart muscle cells of oxygen. Part of the heart muscle dies.

The part of the heart the artery goes to in Figure 7.2 can no longer pump well because parts of the muscles of the left and right ventricles don't get enough blood. Without enough blood, the muscle cells get too little nutrients and oxygen. Waste products are not carried away so they build up in the muscle cells.

Someone having a heart attack may have pain in the chest, sweat, and pass out when the heart stops pumping. If the heart cannot pump, the brain gets too little blood and oxygen, which would cause the person to pass out. The first aid for cardiac arrest is CPR, or cardiopulmonary resuscitation.

Some doctors treat atherosclerosis by widening the narrowed part of the artery. One method is called angioplasty (ANN-gee-oh-plass-tee). Doctors thread a balloon-like device attached to a long, slender tube into the artery. Then they inflate the "balloon" to flatten the plaque against the artery wall. This works to open up the artery. In some cases the widened artery can narrow again and may need to be reopened more than once.

A coronary bypass operation is another way to treat atherosclerosis. In this operation doctors sew part of a healthy blood vessel in place to allow the blood to bypass the narrowed parts of the coronary arteries. Part of a leg vein is usually removed for this purpose. If a person has a "triple bypass" that means that parts of three coronary arteries are bypassed. The operation may need to be repeated if the plaque builds up again.

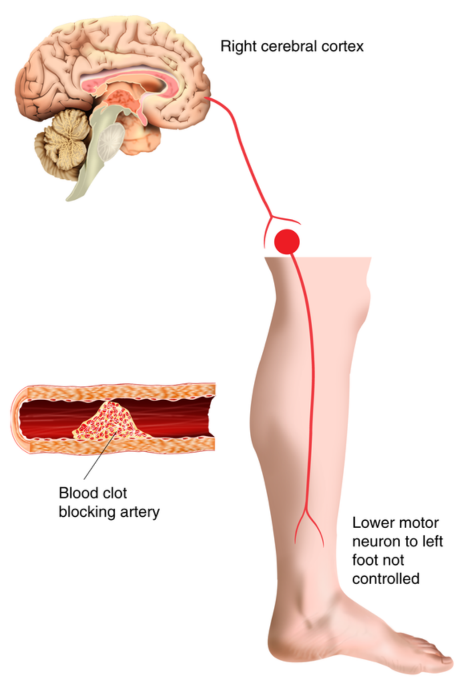


Figure 7.3 A blocked artery in the brain causes impaired function called a stroke. Damage to the brain may be

reflected in various parts of the body.

A **stroke** occurs when atherosclerosis causes narrowing in an artery that carries oxygen to the brain. Or a stroke can be caused when a piece of plaque or a blood clot breaks off and blocks an artery going to the brain. Damage to brain tissue occurs when too little oxygen-containing blood reaches one or more sections of the brain. Look at Figure 7.3. If part of the brain is damaged, such as the area controlling the left leg, the person may lose control of the leg. If the part of the brain controlling the face or part of the brain that is necessary for language is involved, the person may be unable to talk.

What Is Your Risk of Having Cardiovascular Disease?

Before we study how to lower the risk of heart disease, we need to talk about what risk is. Risk in this health context is the chance of injury or loss as a result of an activity or action. If you do something risky you run the risk of getting hurt or injured. For example, if you smoke you run the risk of getting lung cancer or heart problems. Smoking is risky. The more you smoke over longer periods of time, the more likely it is you will have health problems from smoking.

What Do You Think?
Do you think teenagers take more risks than other age groups? Why or why not?

Did You Know? More than twice as many smokers as nonsmokers die from cardiovascular disease. The earlier someone starts smoking, the more likely that person is to have heart problems later in life. Smokers who quit after a heart attack are much more likely to survive than those who keep smoking are. In general, people who don't smoke have a greater chance of a longer, healthier life.

What are risk factors for cardiovascular disease? Risk factors are conditions or habits that make getting cardiovascular disease more likely. People with cardiovascular disease often have a history of smoking. Other risks include eating habits. People who eat too much fatty food, are overweight, and exercise too little are at risk for getting cardiovascular disease. Other people may have high blood pressure and a history of heart disease in their families. Some people may cope poorly with stress. All of these are risk factors. Let's look at each one separately.

Risk Factors for Cardiovascular Disease Smoking

Cigarette smoke contains nicotine and other chemicals that damage the interior wall of the arteries. These chemicals also damage the lungs and other parts of the respiratory system. Cigarette smoke raises carbon monoxide levels in the blood. Blood with high carbon monoxide levels can't carry as much oxygen as usual, so the cells get less oxygen than they need. Smoking also narrows arterioles and raises the smoker's blood pressure. The narrowed arterioles limit the blood going into the capillaries. This also reduces the amount of oxygen going to smoker's cells. Smoking damages the inner lining of the blood vessels and makes the heart pump harder. And it's not just the smoker who is negatively affected. People near the smoker can be affected in the same way.

Apply Your KNOWLEDGE

What can happen if cells don't receive enough oxygen?

Did You Know? Cholesterol is a waxy, whitish substance found in animal cells. It's true that the body needs some cholesterol to make other substances, but the body can make its own cholesterol. The liver can produce all the cholesterol the body needs. We do not have to eat any cholesterol at all. One third of the young people in the United States may be getting too much cholesterol in their diets.

Fat in the blood

There is evidence that eating a diet high in fats and cholesterol can contribute to blocking and hardening of the arteries. Fat buildup in the arteries tends to be slow, but it can start as early as age 10 . There are no symptoms to warn you about this process until it is already well advanced. One way you can help protect yourself is to choose foods that are low in fats and cholesterol. The American Heart Association recommends that less than 30 percent of your total calories should come from fat.

High blood pressure

When a person has high blood pressure, it means that their blood pressure has been greater than normal over a period of time. Normal blood pressure for adults ranges from $\frac{100}{70}$ mm Hg to $\frac{130}{90}$ mm Hg . Most people have blood pressures that are close to $\frac{120}{80}$ mm Hg . The normal blood pressure range for teens is from $\frac{92}{57}$ mm Hg to $\frac{134}{87}$ mm Hg . You can see in the table in Figure 7.5 that "normal" is a range and not an exact value.

> **Did You Know?** The kidneys are the organs that keep your blood clean. Kidneys receive 20 percent of the blood flowing from the heart. It takes about 50 minutes to cleanse all your blood. The kidneys work to maintain homeostasis in your blood-keeping the right balance of water, salt, and other chemicals. Doctors have figured out away to help people with kidney problems. People with kidney problems can go to a hospital and be hooked up to a machine that works as an artificial kidney. The artificial kidney is called a dialysis machine.

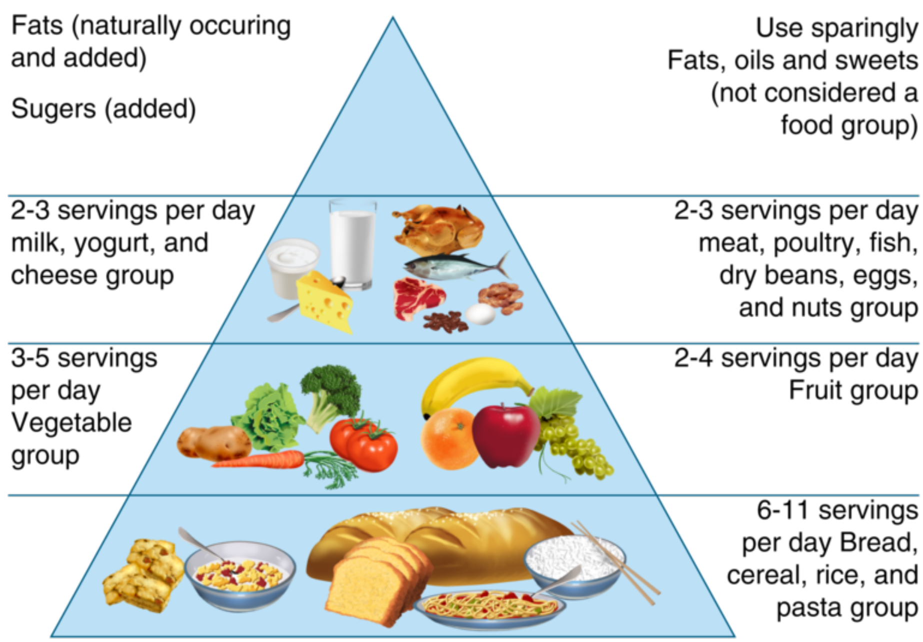


Figure 7.4 This food pyramid shows the recommended proportions of different types of foods in a healthy diet.

TABLE 8.1:

Age (years)	Sex	Systolic Diastolic	Blood Pressure Blood Pressure
6	M	78 – 115	48 – 78
6	F	78 – 113	48 – 79
12	M	95 – 135	58 – 88
12	F	94 – 133	59 – 85
14	M	98 – 143	60 – 90
14	F	97 – 139	61 – 90
16	M	103 – 148	60 – 95
16	F	100 – 143	62 – 92

Figure 7.5 This chart shows a range of blood pressure for 6– to 16 -year-olds.

High blood pressure contributes to cardiovascular disease. It increases the risk of a stroke or a heart attack by putting too much stress on the system. The high pressure can weaken the walls of the arteries and cause aneurysms. High blood pressure is a silent killer, because there are few symptoms that warn you about the problem. You don't know if you have high blood pressure unless your blood pressure is checked regularly.

The exact cause of most high blood pressure is not known. Blood pressure is largely controlled by genes inherited from your parents. It also is affected by choices you make about diet and exercise. Some people with high blood pressure are born with the disease, have it all their lives, and need medication to keep their blood pressure normal. Other people can develop high blood pressure due to unhealthy life styles. Changes in lifestyle can prevent high blood pressure or reduce blood pressure that is already high. Lowered blood pressure can decrease the chance of a heart attack or stroke.

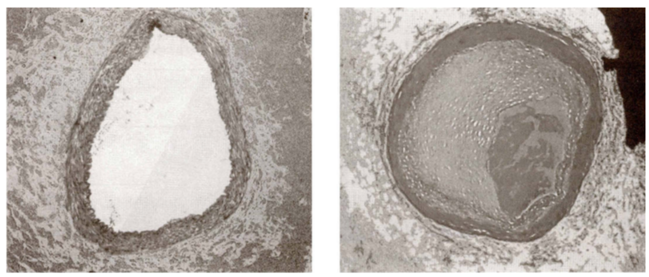


Figure 7.6 Fat helps to cause plaque formation in the arteries that supply your heart. The plaque can partially block the arteries and cause high blood pressure. If the plaque totally blocks a coronary artery, the result is a heart attack. The photograph on the right shows a totally blocked artery.

Did You Know?
Data on adults show that

- blood pressures increase with age,
- high blood pressure can be inherited,
- African-Americans are more likely to have high blood pressure than many other ethnic groups in the United States.

Some controllable factors that raise blood pressure are

- obesity (overweight),
- too much salt in the diet,
- smoking,
- stress,
- atherosclerosis,
- lack of exercise.

Did You Know? For every pound (0.45 kilograms) of excess weight, your heart has to push blood through several more miles (1.6 kilometers per mile) of blood vessels.

Obesity

Excess body weight puts stress on the cardiovascular system. The hearts of overweight people must work harder to supply nutrients and oxygen to all their cells. Obese, or overweight, people also have higher levels of fat and cholesterol in the blood. Obesity is common in children as well as adults. Middle-aged men who are overweight are about three times more likely to have a fatal heart attack than men of average weight are. Proper diet and exercise are important to avoid obesity.

Family history

Sometimes doctors joke that the best thing you can do for your health is to choose your biological parents. Of course that's impossible. But if you have a biological parent or close relative who died between ages 40 and 60 from cardiovascular disease, your chance of getting cardiovascular disease may be higher than normal.

What can you do if there is a history of heart disease in your family? The best thing you can do is live a healthy lifestyle by reducing the risk factors you do have control over. Don't smoke. Control what and how much you eat. Exercise wisely and monitor your blood pressure to keep it within a safe range. Minimize your chances for cardiovascular disease by making careful choices. It's true you can't control your family history, but you can control the choices in your life.

Mini-Activity

Your Target Heart-Rate Zone

Not everyone has the same target heart-rate zone. To find yours, try the following.

a. Subtract your age from 220 .
b. Multiply this number by 60 percent (0.60) . This is the low end of your zone.
c. Multiply the number from step 1 by 85 percent (0.85) . This is the high end of your zone.
d. Can you find the middle of your zone? Use 75 percent as an estimate of the middle.

Lack of exercise

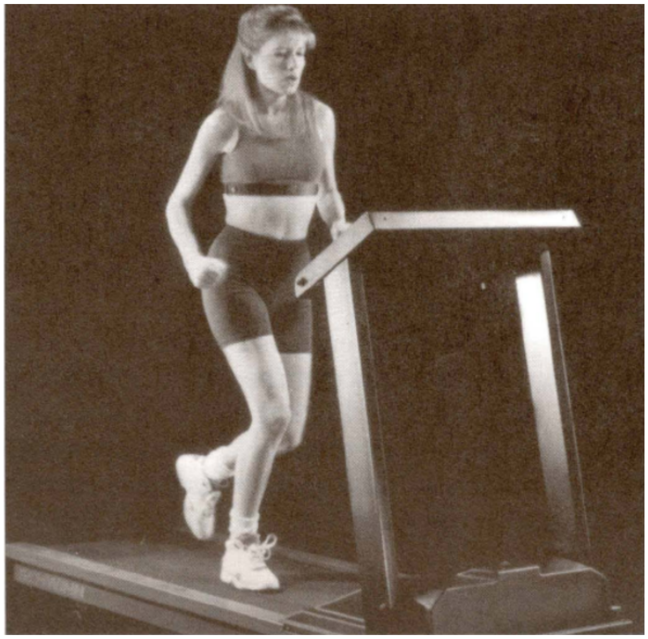
Another risk factor for cardiovascular disease is lack of exercise. Exercising the heart, lungs, and circulatory system reduces the effects of other risk factors. Exercise lowers stress and the circulating fat and cholesterol levels. Therefore, a person who exercises regularly is less likely to become obese or develop high blood pressure. Besides the health and medical benefits of exercise, staying fit can be fun. You don't have to be a super athlete to enjoy and benefit from exercise. Walking is one of the simplest and the best exercises for the heart.

Cardiovascular activities raise your heart rate up to your **target heart-rate zone.** This zone is a specific range of heartbeats per minute that's best for an individual according to age. The zone is the heartbeats per minute when you can best increase the strength and efficiency of your circulatory and respiratory systems. The best kind of exercise for your cardiovascular system is **aerobic** (ayr-OH-bik) **exercise**. Aerobic means "with oxygen." An activity that makes you breathe faster and deeper for 20 minutes or more is an aerobic activity. Your heart and lungs supply your muscles with oxygen to keep up the activity at a steady pace. Aerobic activities such as walking quickly, running, and swimming develop muscles, coordination, and heart efficiency.

The target heart rate is not the only way to measure how hard you are exercising. Since everyone is different, it is important to listen to your body. When you exercise ask yourself how hard you are working on a scale of 1 (easy) to 10 (very hard). Always start an exercise program slowly and work your way up. That way you're working at around a 6 or a 7 on your personal exercise scale.

Apply Your KNOWLEDGE

Why does aerobic exercise help you develop and maintain cardiovascular fitness?



Notice the strap around this runner's stomach area. This strap is monitoring her heart rate.

TABLE 8.2:

Activity	**Cardiovascular Workout**
Baseball	Poor
Basketball	Good/excellent
Dancing	Good
Football	Fair
Gymnastics	Fair
Hockey	Good/excellent
Racquetball	Good/excellent
Running/Jogging	Excellent
Skating	Good
Skiing (cross-country)	Excellent
Skiing (downhill)	Fair
Soccer	Excellent
Softball	Poor
Swimming	Excellent
Tennis	Fair/good
Volleyball	Fair
Walking	Good/excellent
Water-skiing	Fair

Figure 7.7 Your favorite activities may or may not help you develop cardiovascular fitness. Find your favorite activities in the table above.

The table in Figure 7.7 shows examples of aerobic activities that can help you maintain your cardiovascular health. What others can you name? The important thing is to choose an aerobic activity you like and follow these guidelines:

a. Warm up and stretch your muscles before you start.
b. Begin your activity slowly so that your heartbeat can be raised to your target heart-rate zone.
c. Keep your heart rate in this zone for at least 15 to 30 minutes.

d. Exercise at least 3 times per week.

Some teenagers believe that they will live forever and show little concern for their health. They think that health concerns are only for old people. But some of the risk factors for cardiovascular disease can start very early in life, at your age or even earlier. By choosing to begin an exercise program now, you can increase your chances for good health for the rest of your life.

Activity 7-1: Pulse Rate

Introduction

How does your pulse rate vary a a result of different activities? It's your turn to design your own investigation to answer till question. In this activity you work with a team to develop an experimental design.

Materials

- Clock or watch with a second hand
- Activity Report

Procedure

Step 1 Brainstorm with your team members an experiment that will help you explore the question, "How does your pulse rate vary as a result of different activities?" Predict how pulse rates will vary and record your predictions.

Step 2 Design the steps you'll follow in your experiment. Write up your experimental design following the style of other investigations that you've conducted in this unit.

Step 3 Identify only one variable for your experiment and incorporate it into your experimental design. Develop the tables and graphs you'll u e to record and graph data.

Step 4 List all the materials you'll need in order to conduct your experiment. Make sure all the materials you'll need to conduct each step are included in your materials' list.

Step 5 Your experimental design should include your predictions, materials, procedural steps, tables, and graphs. When you have completed your experimental design show it to your teacher. Make sure you get teacher approval of your experimental design before going any further.

Step 6 With your teacher's approval carry out your experiment and record the data.

Step 7 Summarize the results of your experiment using both a table and a graph. Include a written explanation with each.

Step 8 Share the results of your experiment with the class.

Apply Your KNOWLEDGE

How does exercise help the body maintain good health?

Stress

Your body responds to stress in several different ways. Your liver releases glucose (sugar) into your blood for "instant" energy. Your heart pumps harder and faster. The pupils in your eyes dilate. Your muscles tense. The stress response helps you deal with short-term dangers.

Some stress can be stimulating and exciting. For example, riding a roller coaster i stressful, but it can be fun too! A certain amount of stress before a musical performance may help you concentrate better and play or sing better. Many athletes who have "butterflies in their stomach" before competitions finish as winners.

So stress responses such as increased heart rate can be good for sudden, short-term situations. But they are not healthy if maintained over long periods of time. Many people suffer from the stress of constant worries and nervous tension. Continued stress can cause high blood pressure and other health problems.

Mini-Activity

Sources of Stress - What are some sources of stress for you? Make a list of things that create stress. Then think about ways of handling each kind of stress. In making your lists consider which sources of stress come from inside you and which sources of stress come from outside you. Share your completed list with the class. Then your class can create a master list of stress creators and stress relievers.

Mini-Activity

Risk Profile - Review the risk factors for cardiovascular disease. Rate yourself on each of the risk factors on a scale from 1 (low risk) to 10 (high risk). If the average of all your scores is more than 7 , you might want to consider some lifestyle changes. List some changes you could make to lower the risk of cardiovascular disease.

Stress management is an important part of cardiovascular fitness. You must decide what you can change and what you can't change. Then you need to act accordingly. Worrying about things you can't change creates even more stress. It is very important to learn how to relax in healthy ways.

Here are some tips to help you reduce and manage stress.

- Eat a healthful diet.
- Get the rest you need each day.
- Keep a stress notebook. When you feel stressed write down the time, place, and type of situation that caused the stress. You may begin to see your stressful situations as a pattern. By becoming more aware of the situations that cause your stress, perhaps you can change your habits.
- Stop and relax when you feel stressed. Take a walk or just sit by yourself. You can reduce muscle tension in the following way. First contract muscles that are tight due to stress, such as the shoulder muscles. Then suddenly release the contraction and let the muscles go limp.
- Manage your time effectively. Set priorities. Write a list of the things you need to do.
- Exercise regularly. Exercise calms you down and gives you time to be yourself, away from other pressures.
- Find out more about things that cause you stress. Know the facts, even if they are unpleasant. Trying to ignore a stressful situation can be more stressful than understanding the situation and dealing with it.
- Find out about resources available to help you deal with stress. Ask a parent, teacher, counselor, or other caring adult for suggestions.
- Seek creative solutions to your problems. Brainstorm with friends. Break down big problems into smaller parts that can be handled more easily. Make plans for resolving the problem and reward yourself for the solution.

TABLE 8.3:

Physical	Emotional	Relationships
Appetite change	Anxiety	Isolation
Headache	Frustration	Intolerance
Tension	Mood swings	Loneliness
Fatigue	Nightmares	Lashing out
Insomnia	Irritability	Distrust
Weight change	Worrying	Using people
Colds	Easily discouraged	Hiding
Pounding heart	Depression	"Clamming" up
Restlessness		
Teeth grinding		
Poor sleep		
Others		

Figure 7.8 Stress can show itself in many ways. Some symptoms of stress are listed in the table above. Have you noticed any of these symptoms in yourself or a friend lately?

Review Questions

1. Describe the most common cardiovascular disease.
2. What happens during a heart attack?
3. What is risk?
4. Describe five risk factors for cardiovascular disease and what you can do to minimize them.
5. What kind of risk taker are you? How does your willingness to take risks affect who you are? What isn't so good about being a risk taker in certain situations? What might be the consequences of any risks you are taking?

CHAPTER 9 Circulation Glossary - Student Edition (Human Biology)

CHAPTER OUTLINE

9.1 Circulation Glossary

aerobic (ayr-OH-bik) exercise an activity that makes you breathe faster and deeper and an activity that you can sustain for 20 minutes or more.

anemia a condition resulting in reduced oxygen transport by the blood that may be caused by a reduced number of red blood cells or not enough hemoglobin.

aneurysm (ANN-yur-ism) a bulge outward of a vessel when the vessel wall weakens.

antibodies germ-fighting proteins.

arterioles very small arteries.

artery a blood vessel that carries blood away from the heart.

atherosclerosis (ATH-uh-roh-skluhr-OH-sus) a build up of fatty deposits, called plaque, on the walls of arteries leading to narrowing and blockage of the arteries.

atria plural form of atrium.The fish heart has one atrium, but the human heart has two atria.

atrium the top chamber of each side of the heart.The atrium receives blood from a vessel and sends blood down to the ventricle.

blood the fluid containing cells that circulates through the heart and blood vessels transporting nutrients, gases, chemicals, and wastes through the body.

blood platelets cell fragments smaller than red blood cells that circulate with the blood and help in clotting.

blood vessel a tube through which blood flows.

bone marrow the spongy tissue inside bones. It is one of the places in the body where red blood cells are produced.

capillaries very tiny vessels at the ends of the smallest arteriole and leading to the smallest venules.

circulatory system a system that includes the blood, the heart, and the system of blood vessels that distributes blood throughout the body.

controllers mechanisms that control automatic body functions such as breathing and heart rate within certain limits.

diastole (dy-AS-toe-Iee) the relaxation period when the heart is filling with blood.

diffusion (dih-FYOO-shun) the random movement of molecules from a region of higher concentration to a region of lower concentration.

edema (eh-DEE-muh) swelling caused by the accumulation of fluids in spaces outside of blood vessels and between cells.

endocrine system a system of organs and glands that releases chemicals (hormones) into the bloodstream or directly into tissue to cause some reaction.

fibrinogen (fy-BRIN-oh-jin) a protein circulating in the blood that is meshed in forming blood clots.

gene a portion of DNA that contains the information code for a protein such as hemoglobin.

resistance the ability to hold back. In blood vessels, resistance is the slowing of blood flow through the vessels.

respiratory system the system that brings in needed oxygen and releases carbon dioxide.

sensors specialized cells that, when stimulated, send messages to the brain.

sickle-cell anemia (uh-NEE-mee-uh) a hereditary condition in which a gene produces an abnormal type of hemoglobin that results in a reduced amount of oxygen carried by red blood cells.The abnormal hemoglobin tends to form crystals inside the red blood cells that produce the sickle shape.

siphon pump a pump that uses gravity, valves, and a squeeze bulb to move fluid from one place to another.

stroke a condition in which too little oxygen gets to the brain due to a blockage or a leakage in a vessel.

stroke volume the amount of blood pumped with each squeeze of the heart.

heart the muscular pump of the circulatory system.

heart attack a condition that occurs when the coronary arteries that serve the heart become clogged with plaque and/or a blood clot.

heart rate the number of times your heart beats in one minute.

hemoglobin (HEE-muh-glow-bihn) a reddish protein that carries oxygen.

hemophilia (hee-moh-FEEL-ee-uh) a hereditary condition in which the blood in people who have the gene for hemophilia takes longer than normal to clot. People with the disease are called hemophiliacs.

homeostasis (hoh-mee-oh-STAY-sis) the condition of stability of the internal environment of the body.

hormones (HOHR-mohns) chemicals that stimulate cells to respond in certain ways.

hypertension. (hi-per-TEN-shun) high blood pressure.

leukemia (loo-KEE-mee-uh) a disease in which there are more than a normal number of white blood cells produced because cell division is out of control.

lymph nodes oval or bean-shaped structures in the lymphatic (lim-FAT-ik) system that produce lymph.

lymphatic system network of vessels that carries watery fluid called lymph.

lymph a liquid made up of water, salts, nutrients, waste products, white blood cells, proteins, and other chemicals.

mononucleosis (mah-noh-noo-clee-OH-sis) a disease of the white blood cells caused by a virus.

negative feedback a reaction to a change that will cause a reversal.

nervous system the brain, spinal cord, and a network of nerve cells that send and receive messages about the body's inside and outside environments.

nucleus (NOO-klee-us) the information and control center found in most cells.

organ a part of a living organism that has a specific function, such as the heart or brain.

pacemaker specialized muscle cells in the right atrium. The pacemaker makes the heart beat faster or slower when it receives messages from the nervous system or from chemical "messengers" called hormones.

phagocyte (fAY-go-site) a type of white blood cell that can change shape and wrap around unwanted or foreign substances.

phagocytosis (fay-go-sy-TOH-sis) the process that occurs when a phagocyte "eats up" foreign substances such as bacteria or viruses.

plasma (PLAS-muh) the liquid part of blood.

pressure head the pressure buildup in the outlet tube of a siphon pump.

red blood cells doughnut-shaped cells with a flat, filled center.

systole (SIS-toe-lee) the contracting of the heart muscle when it squeezes and squirts out the blood.

target heart-rate zone a specific range of heartbeats per minute considered best for an individual.

thoracic duct a large vessel that empties into a vein at the base of your neck returning fluids to the circulatory system.

valve a device that controls the flow of a liquid or gas

vein a blood vessel that carries blood to the heart.

ventricle the bottom chamber of each side of the heart. The ventricles receive blood from the atria and squirt it into blood vessels.

venule (VEEN-yool) a small vein that receives blood from the capillaries.

white blood cells blood cells that do not contain hemoglobin and attack unwanted organism such as bacteria, and unwanted materials such as a splinter.