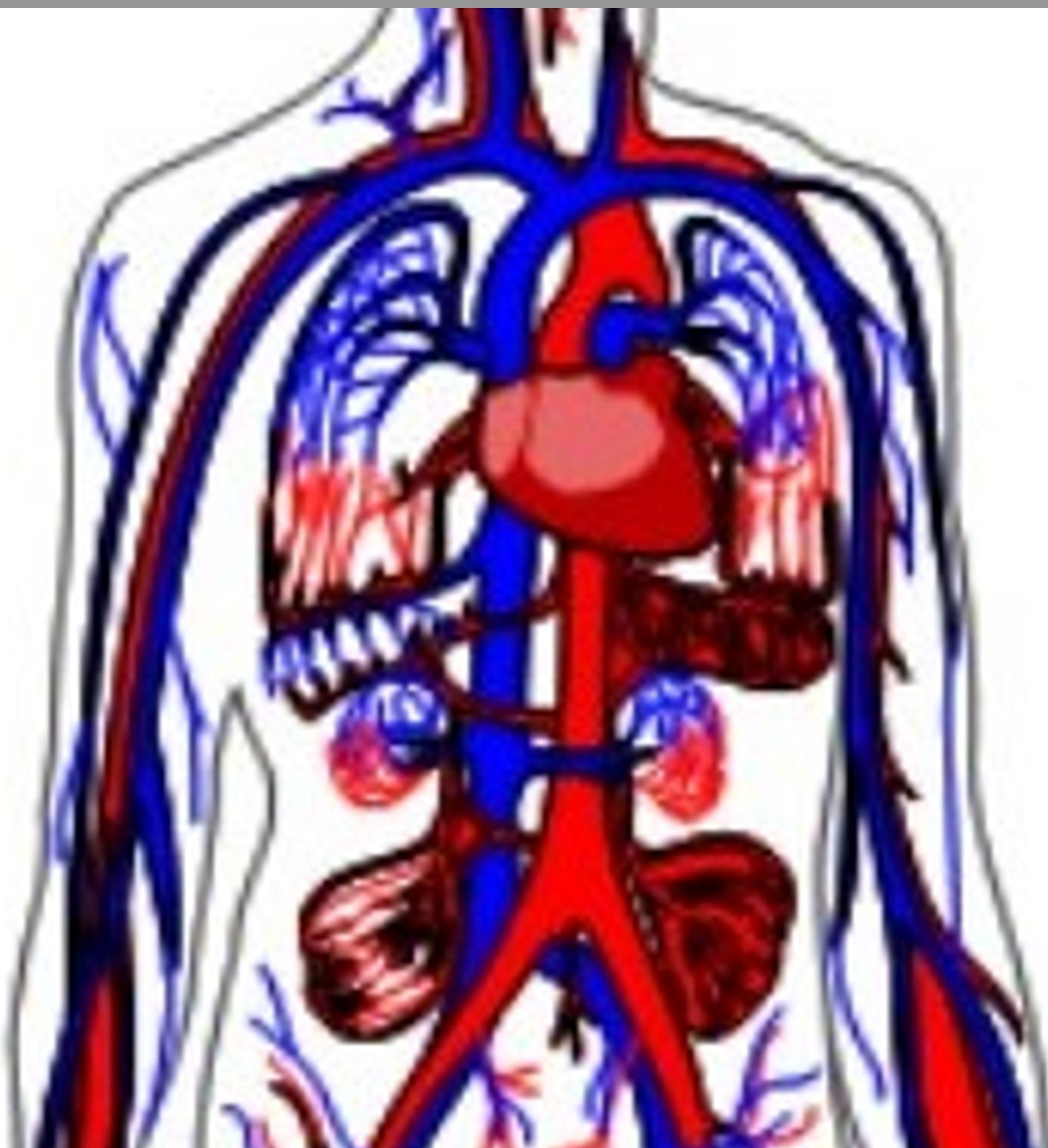
Human Physiology 110: Circulatory & Respiratory Systems



Human Physiology 110: Circulatory & Respiratory Systems

Peter MacDonald
Douglas Wilkin, Ph.D.
Jean Brainard, Ph.D.
Niamh Gray-Wilson

AUTHORS
Peter MacDonald
Douglas Wilkin, Ph.D.
Jean Brainard, Ph.D.
Niamh Gray-Wilson

To access a customizable version of this book, as well as other interactive content, visit www.ck12.org

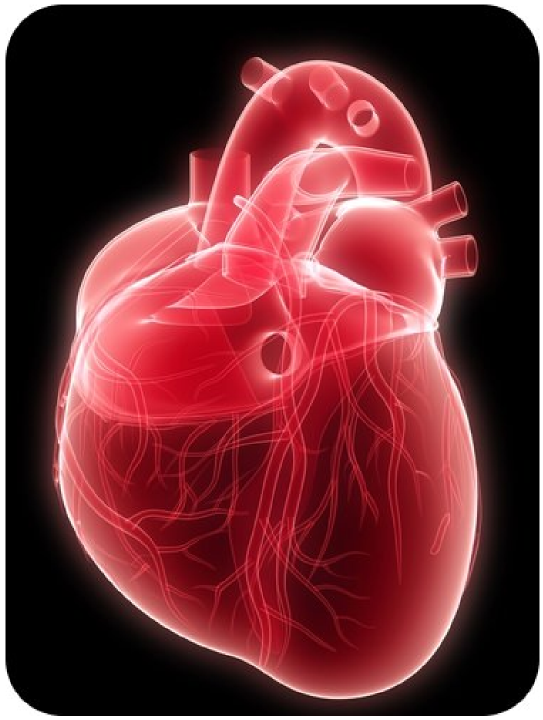
CK-12 Foundation is a non-profit organization with a mission to reduce the cost of textbook materials for the K-12 market both in the U.S. and worldwide. Using an open-source, collaborative, and web-based compilation model, CK-12 pioneers and promotes the creation and distribution of high-quality, adaptive online textbooks that can be mixed, modified and printed (i.e., the FlexBook® textbooks).

Printed: October 12, 2016

Contents

Concept 1 Heart

- Explain how the heart pumps blood throughout the body.
- Describe the main components of the circulatory system.
- Summarize blood flow through the heart.



What's the most active muscle in the body?

The human heart. An absolutely remarkable organ. Obviously, its main function is to pump blood throughout the body. And it does this extremely well. On average, this muscular organ will beat about 100,000 times in one day and about 35 million times in a year. During an average lifetime, the human heart will beat more than 2.5 billion times.

The Circulatory System

The **circulatory system** can be compared to a system of interconnected, one-way roads that range from superhighways to back alleys. Like a network of roads, the job of the circulatory system is to allow the transport of materials from one place to another. As described in **Figure** 1.1, the materials carried by the circulatory system include hormones, oxygen, cellular wastes, and nutrients from digested food. Transport of all these materials is necessary to maintain homeostasis of the body. The main components of the circulatory system are the **heart, blood vessels,** and **blood.**

The Heart

The heart is a muscular organ in the chest. It consists mainly of cardiac muscle tissue and pumps blood through blood vessels by repeated, rhythmic contractions. The heart has four chambers, as shown in **Figure** 1.2: two upper **atria** (singular, **atrium**) and two lower **ventricles**. Valves between chambers keep blood flowing through the heart in just one direction.

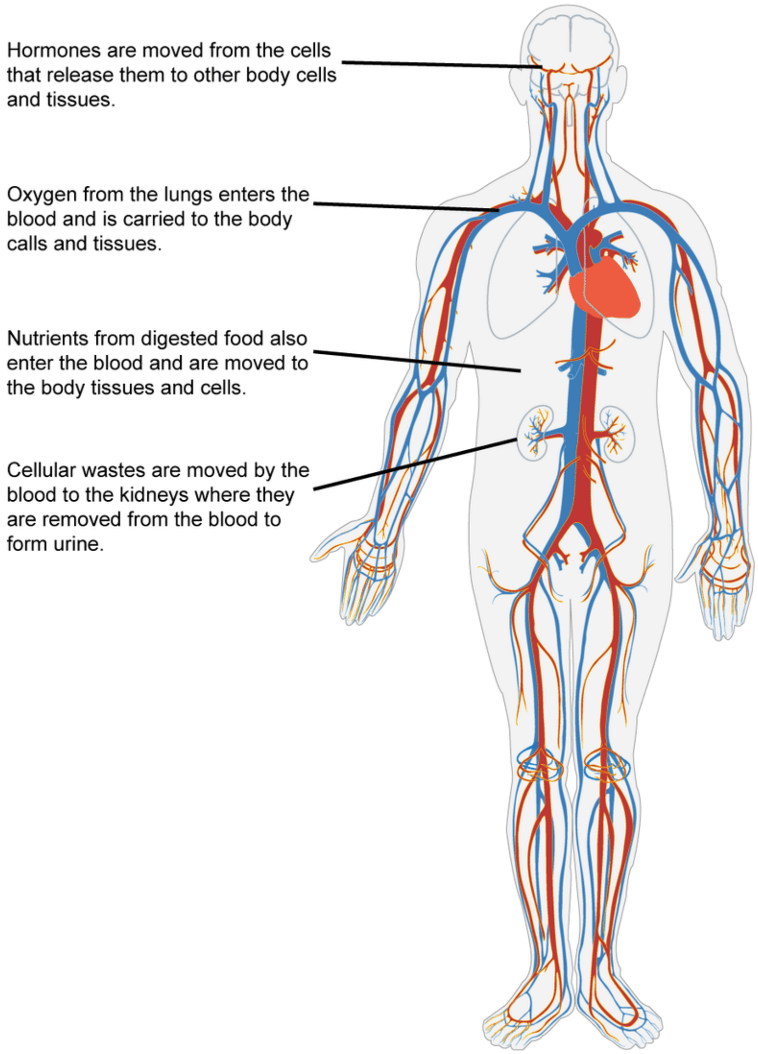


FIGURE 1.1
The function of the circulatory system is to move materials around the body.

Blood Flow Through the Heart

Blood flows through the heart in two separate loops, which are indicated by the arrows in **Figure** above. You can think of them as a "left side loop" and a "right side loop." The right side of the heart collects oxygen-poor blood from the body and pumps the blood to the lungs. In the lungs, carbon dioxide is released and oxygen obtained by the blood. The left side of the heart carries the oxygen-rich blood back from the lungs and pumps it to the rest of the body. The blood delivers oxygen to the body's cells, returning the oxygen-poor blood back to the heart.

1. Blood from the body enters the right atrium of the heart. The right atrium pumps the blood to the right ventricle, which pumps it to the lungs.
2. Blood from the lungs enters the left atrium of the heart. The left atrium pumps the blood to the left ventricle, which pumps it to the body.

Heartbeat

Unlike skeletal muscle, cardiac muscle contracts without stimulation by the nervous system. Instead, specialized cardiac muscle cells send out electrical impulses that stimulate the contractions. As a result, the atria and ventricles

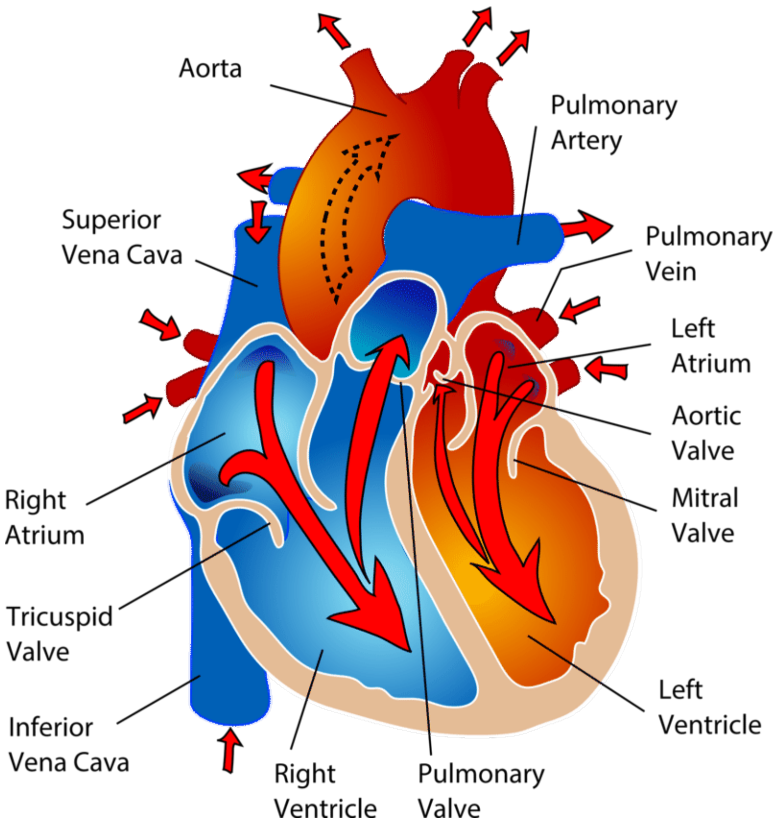


FIGURE 1.2
The chambers of the heart and the valves between them are shown here.

normally contract with just the right timing to keep blood pumping efficiently through the heart.

MEDIA
Click image to the left or use the URL below.
URL: https://www.ck12.org/flx/render/embeddedobject/50037

Summary

- The heart contracts rhythmically to pump blood to the lungs and the rest of the body.
- Specialized cardiac muscle cells trigger the contractions.

Review

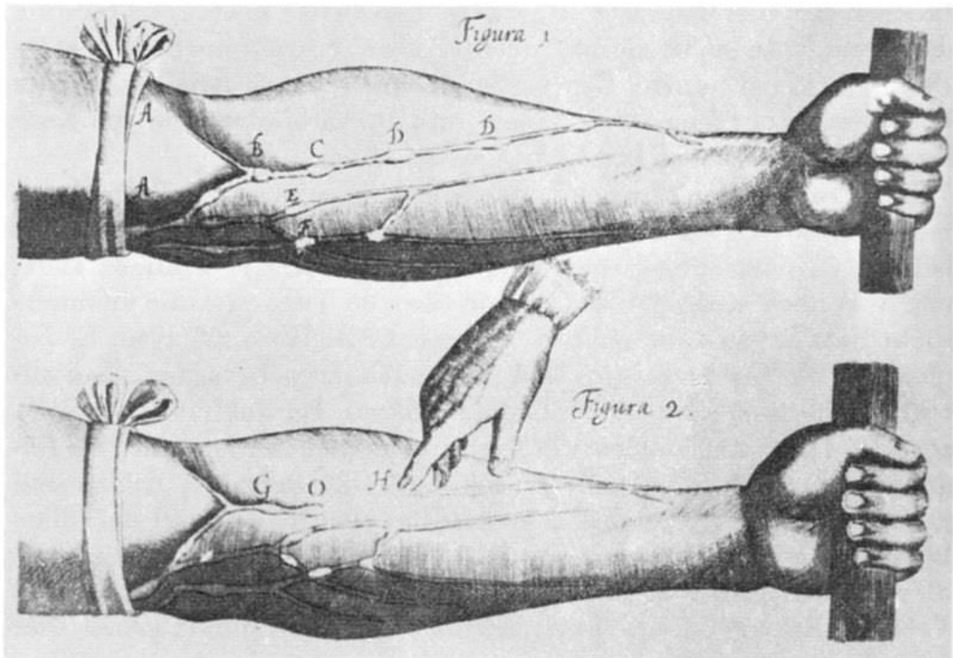
1. What are the main components of the circulatory system?
2. Describe how blood flows through the heart.
3. What controls heartbeat?

References

1. Mariana Ruiz Villarreal (LadyofHats) for CK-12 Foundation. Circulatory system relative to body . CC BY-NC 3.0
2. Mariana Ruiz Villarreal (Wikimedia: LadyofHats), modified by CK-12 Foundation. http://commons.wikimedia.org/wiki/File:Human_healthy_pumping_heart_en.svg . Public Domain

CONCEPT 2 Blood Vessels

- List and describe the three major types of blood vessels.
- Describe the roles of the aorta, superior vena cava, and inferior vena cava.
- Describe the role of the blood vessels in maintaining homeostasis.



How does blood travel around the body?

Through blood vessels, of course. This image of veins is from William Harvey's (1578-1657) *Exercitatio Anatomica de Motu Cordis et Sanguinis in Animalibus.* Harvey was the first to describe in detail the systemic circulation and properties of blood being pumped to the brain and body by the heart.

Blood Vessels

Blood vessels form a network throughout the body to transport blood to all the body cells. There are three major types of blood vessels: arteries, veins, and capillaries. All three are shown in **Figure** 2.1 and described below.

- **Arteries** are muscular blood vessels that carry blood away from the heart. They have thick walls that can withstand the pressure of blood being pumped by the heart. Arteries generally carry oxygen-rich blood. The largest artery is the **aorta**, which receives blood directly from the heart.
- **Veins** are blood vessels that carry blood toward the heart. This blood is no longer under much pressure, so many veins have valves that prevent backflow of blood. Veins generally carry deoxygenated blood. The largest vein is the **inferior vena cava**, which carries blood from the lower body to the heart. The **superior vena cava** brings blood back to the heart from the upper body.
- **Capillaries** are the smallest type of blood vessels. They connect very small arteries and veins. The exchange of gases and other substances between cells and the blood takes place across the extremely thin walls of capillaries.

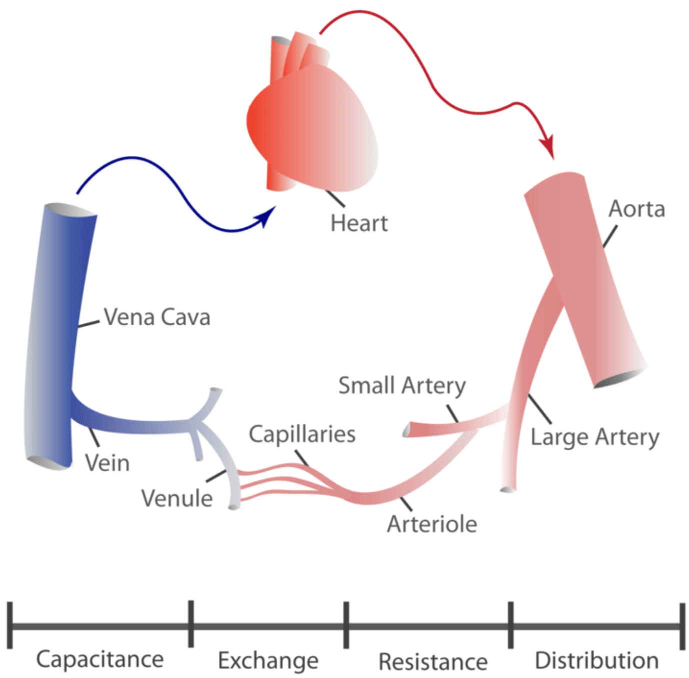


FIGURE 2.1
Blood vessels include arteries, veins, and capillaries.

Blood Vessels and Homeostasis

Blood vessels help regulate body processes by either constricting (becoming narrower) or dilating (becoming wider). These actions occur in response to signals from the autonomic nervous system or the endocrine system. **Constriction** occurs when the muscular walls of blood vessels contract. This reduces the amount of blood that can flow through the vessels (see **Figure** 2.2). **Dilation** occurs when the walls relax. This increases blood flows through the vessels.

Constriction and dilation allow the circulatory system to change the amount of blood flowing to different organs. For example, during a fight-or-flight response, dilation and constriction of blood vessels allow more blood to flow to skeletal muscles and less to flow to digestive organs. Dilation of blood vessels in the skin allows more blood to flow to the body surface so the body can lose heat. Constriction of these blood vessels has the opposite effect and helps conserve body heat.

Blood Vessels and Blood Pressure

The force exerted by circulating blood on the walls of blood vessels is called **blood pressure**. Blood pressure is highest in arteries and lowest in veins. When you have your blood pressure checked, it is the blood pressure in arteries that is measured. High blood pressure, or **hypertension**, is a serious health risk but can often be controlled with lifestyle changes or medication.

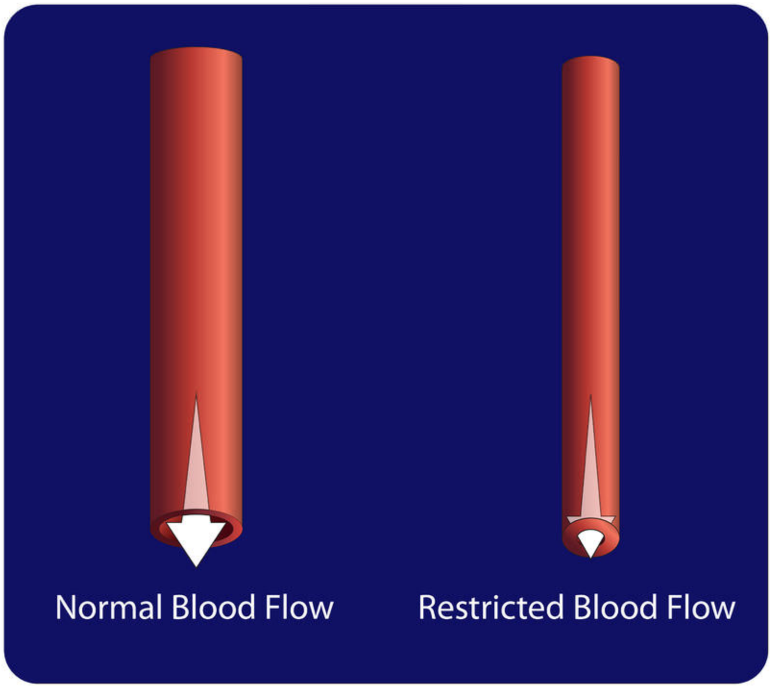
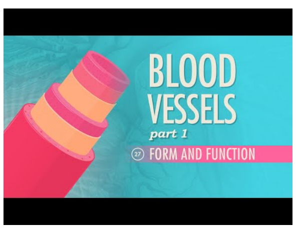


FIGURE 2.2
When a blood vessel constricts, less blood can flow through it.



MEDIA
Click image to the left or use the URL below.
URL: https://www.ck12.org/flx/render/embeddedobject/187004

MEDIA
Click image to the left or use the URL below.
URL: https://www.ck12.org/flx/render/embeddedobject/190301

Summary

- Arteries carry blood away from the heart, veins carry blood toward the heart, and capillaries connect arteries and veins.

Review

1. How do arteries differ from veins?

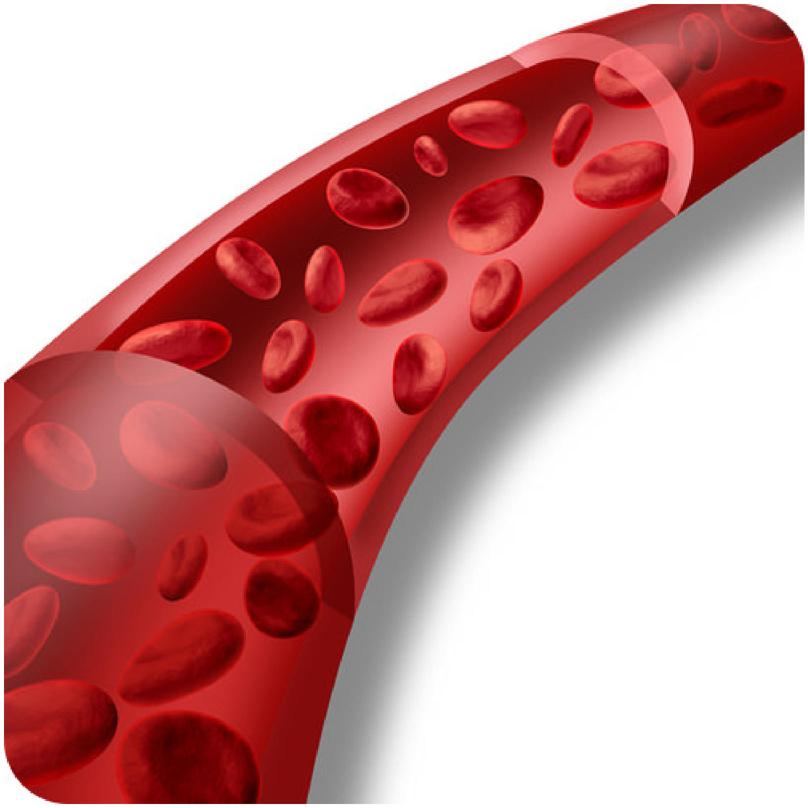
2. What is blood pressure? What is hypertension?
3. To take your pulse, you press your fingers against an artery near the surface of the body. What are you feeling and measuring when you take your pulse? Why can't you take your pulse by pressing your fingers against a vein?

References

1. Rupali Raju. Various blood vessels . CC BY-NC 3.0
2. Jodi So. Constricted blood vessels . CC BY-NC 3.0

CONCEPT 3 Blood

- Describe blood, blood components, and blood pressure.
- Summarize the composition of blood.
- Explain ABO blood type.



What exactly is blood?

All your cells need oxygen, as oxygen is the final electron acceptor during cellular respiration. How do they get this oxygen? From blood. Blood cells flow through the vessels of the human circulatory system. But what exactly is blood? It does transport oxygen, but also has other functions.

Blood

Blood is a fluid connective tissue. It circulates throughout the body through blood vessels by the pumping action of the heart. Blood in arteries carries oxygen and nutrients to all the body's cells. Blood in veins carries carbon dioxide and other wastes away from the cells to be excreted. Blood also defends the body against infection, repairs body tissues, transports hormones, and controls the body's pH.

Composition of Blood

The fluid part of blood is called **plasma**. It is a watery golden-yellow liquid that contains many dissolved substances and blood cells. Types of blood cells in plasma include red blood cells, white blood cells, and platelets (see **Figure** 3.1).

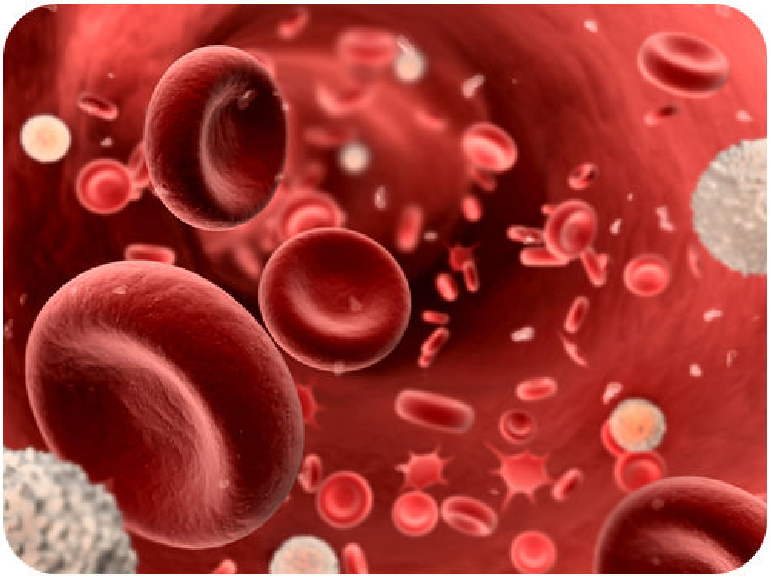


FIGURE 3.1
Cells in blood include red blood cells, white blood cells, and platelets.

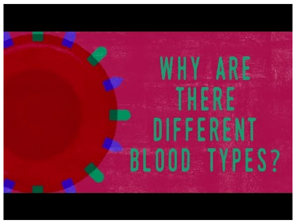
- The trillions of **red blood cells** in blood plasma carry oxygen. Red blood cells contain **hemoglobin**, a protein with iron that binds with oxygen. Red blood cells are made in the marrow of long bones, rib bones, the skull, and the vertebrae. These cells survive for about 120 days, and then they are destroyed. Mature red blood cells lack a nucleus and other organelles, allowing for more hemoglobin, and therefore more oxygen to be carried by each cell.
- **White blood cells** are generally larger than red blood cells but far fewer in number. They defend the body against foreign bacteria, viruses and other pathogens. For example, white blood cells called **phagocytes** swallow and destroy microorganisms and debris in the blood, neutrophils engulf bacteria and other parasites, and lymphocytes fight infections caused by bacteria and viruses.
- **Platelets** are cell fragments involved in blood clotting. They stick to tears in blood vessels and to each other, forming a plug at the site of injury. They also release chemicals that are needed for clotting to occur.

Blood type is a genetic characteristic associated with the presence or absence of certain molecules, called **antigens**, on the surface of red blood cells. The most commonly known blood types are the ABO and Rhesus blood types.

- **ABO blood type** is determined by two common antigens, often referred to simply as antigens A and B. A person may have blood type A (only antigen A), B (only antigen B), AB (both antigens), or O (no antigens).

- **Rhesus blood type** is determined by one common antigen. A person may either have the antigen (Rh^+) or lack the antigen (Rh^-).

Blood type is important for medical reasons. A person who needs a blood transfusion must receive blood that is the same type as his or her own. Otherwise, the transfused blood may cause a potentially life-threatening reaction in the patient's bloodstream.



MEDIA

Click image to the left or use the URL below.

URL: https://www.ck12.org/flx/render/embeddedobject/187007

MEDIA

Click image to the left or use the URL below.

URL: https://www.ck12.org/flx/render/embeddedobject/177116

Summary

- Blood is a fluid connective tissue that contains a liquid component called plasma.
- Blood also contains dissolved substances and blood cells.
- Red blood cells carry oxygen, white blood cells defend the body, and platelets help blood clot.

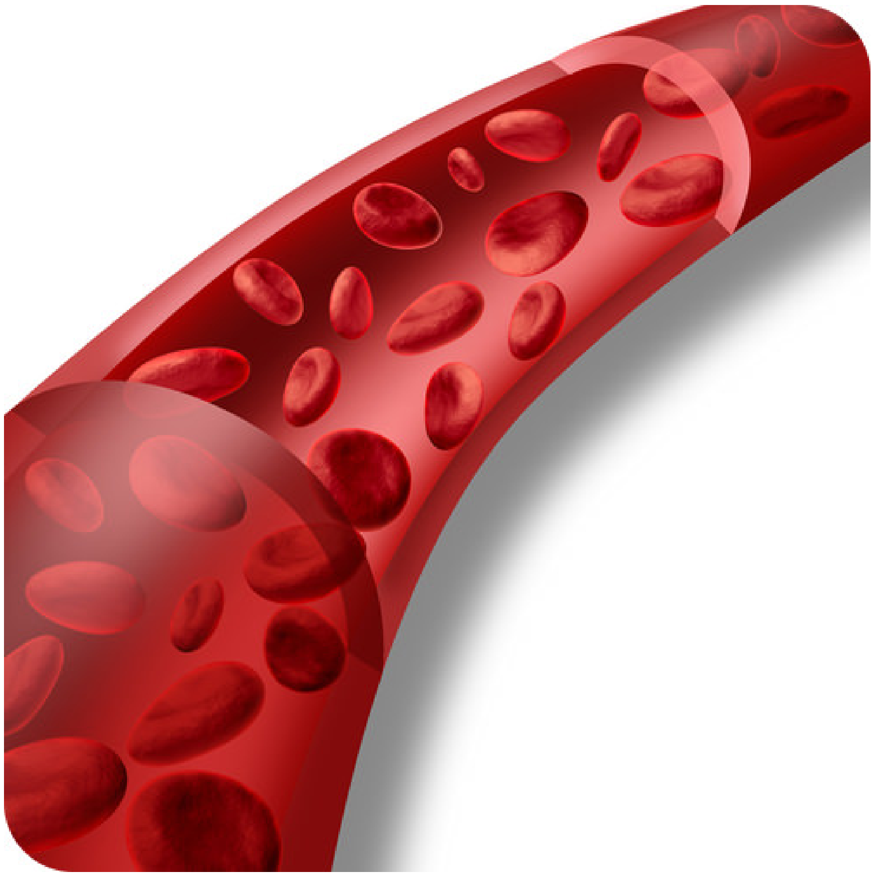
Review

1. What type of tissue is blood?
2. Identify three types of blood cells and their functions.
3. People with type O blood are called "universal donors" because they can donate blood to anyone else, regardless of their ABO blood type. Explain why.

References

1. Image copyright Sebastian Kaulitzki, 2014. Components cells of blood . Used under license from Shutterstock.com

CONCEPT 4 Composition of Blood



What exactly is blood?

All your cells need oxygen, as oxygen is the final electron acceptor during cellular respiration. How do they get this oxygen? From blood. Blood cells flow through the vessels of the human circulatory system. But what exactly is blood? It does transport oxygen, but it also has other functions.

The Composition of Blood

Blood is a fluid connective tissue. It circulates around the body through the blood vessels due to the pumping action of the heart. Arterial blood carries oxygen and nutrients to all the body's cells, and venous blood carries carbon dioxide and other metabolic wastes away from the cells.

In addition to the transport of gases, nutrients, and wastes, blood has many other functions:

- The removal of waste, such as carbon dioxide, urea, and lactic acid, from the body tissues.
- Defending the body against infections by microorganisms or parasites.
- The repair of damaged body tissues.
- The transport of chemical messages such as hormones and hormone-like substances.
- The control of body pH (the normal pH of blood is in the range of 7.35 - 7.45).
- The control of body temperature.

Blood is a colloidal solution; it is made up of particles suspended in a fluid. It accounts for about 7% of the human body weight. The average adult has a blood volume of roughly 5 liters, which is composed of a fluid called plasma and several kinds of cells. Within the blood plasma are erythrocytes (red blood cells), leukocytes (white blood cells), thrombocytes (platelets), and other substances. The cells that make up the blood can be seen in **Figure** 4.1.

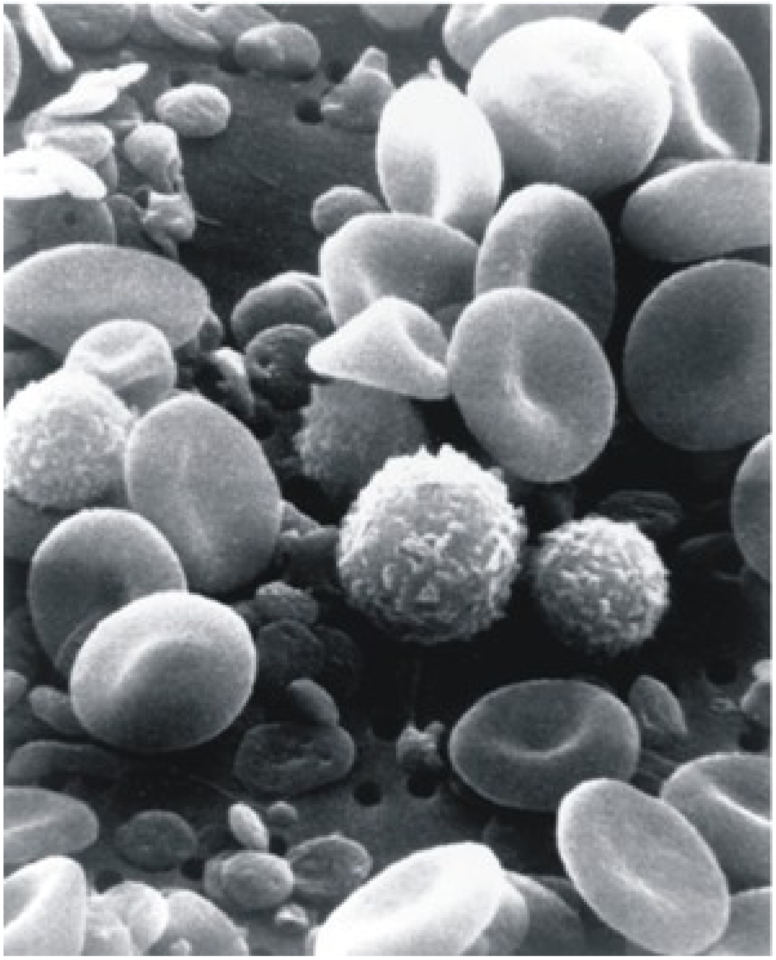


FIGURE 4.1
A scanning electron microscope (SEM) image of normal circulating human blood. One can see red blood cells, several white blood cells, including knobby lymphocytes, a monocyte, a neutrophil, and many small disc-shaped platelets.

Plasma

Plasma is the golden-yellow liquid part of the blood. Plasma is 90% water and 10% dissolved materials including proteins, glucose, ions, hormones, and gases. It acts as a buffer, maintaining pH near 7.4. Plasma is about 54% the volume of blood; cells and fragments make up about 46% of the volume.

Red Blood Cells

Red blood cells, also known as **erythrocytes,** are flattened, doubly concave cells that carry oxygen. There are about 4 to 6 million cells per cubic millimeter of blood. Red blood cells make up about 45% of blood volume, as shown in **Figure** 4.2. Each red blood cell has 200 million hemoglobin molecules. Humans have a total of 25 trillion red blood cells (about 1/3 of all the cells in the body). Red blood cells are continuously made in the red marrow of long bones, ribs, the skull, and vertebrae. Each red blood cell lives for only 120 days, after which they are destroyed in the liver and spleen.

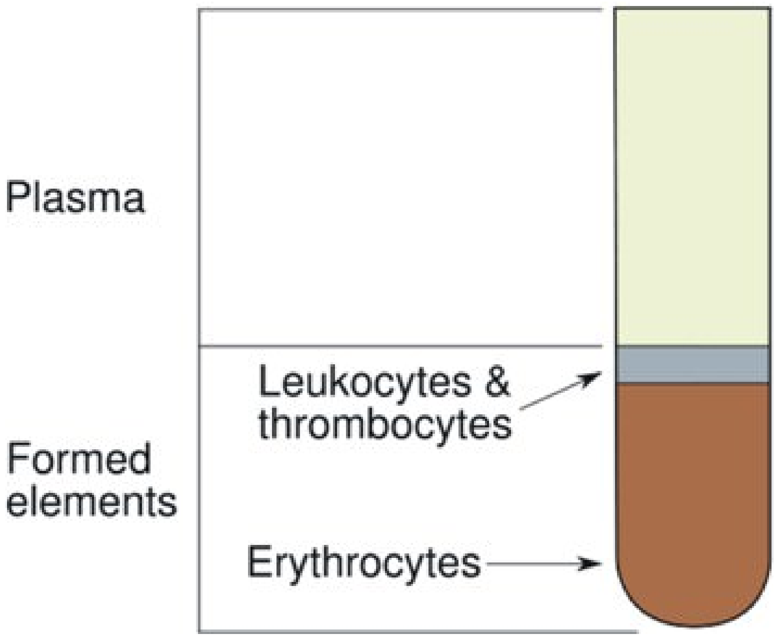


FIGURE 4.2
The components of blood. Red blood cells make up about 45% of the blood volume. White blood cells make up about one percent and platelets less than one percent. Plasma makes up the rest of the blood.

Mature red blood cells do not have nuclei or other organelles. They contain the protein hemoglobin, which gives blood its red color. The iron-containing heme portion of hemoglobin enables the protein to carry oxygen to cells. Heme binds to molecules of oxygen, which increases the ability of the blood to carry the gas.

Iron from hemoglobin is recovered and reused by red marrow. The liver degrades the heme units and secretes them as pigment in the bile, which is responsible for the color of feces. Each second, two million red blood cells are produced to replace those taken out of circulation.

White Blood Cells

White blood cells, also known as **leukocytes,** are generally larger than red blood cells, as shown in **Figure** 4.3. They have a nucleus but do not have hemoglobin. White blood cells make up less than one percent of the blood's volume. They are made from stem cells in bone marrow. They function in the cellular immune response system. There are five types of white blood cells. Neutrophils enter the tissue fluid by squeezing through capillary walls and phagocytize (swallow) foreign bodies. Macrophages also swallow and destroy cell debris and bacteria or viruses. In **Figure** 4.4, a white blood cell is shown phagocytizing two bacteria. Macrophages also release substances that cause the numbers of white blood cells to increase. Antigen-antibody complexes are swallowed by macrophages. Lymphocytes fight infection. T-cells attack cells containing viruses. B-cells produce antibodies. To learn more about the role of white blood cells in fighting infection, refer to the *Immune System* concepts.

Platelets

Platelets, also known as **thrombocytes,** are important in blood clotting. Platelets are cell fragments that bud off bone marrow cells called megakaryocytes. A platelet is shown in **Figure** 4.5. They make up less than one percent of blood volume. Platelets carry chemicals essential to blood clotting. They change fibrinogen into fibrin, a protein that creates a mesh onto which red blood cells collect, forming a clot. This clot stops more blood from leaving the body and also helps prevent bacteria from entering the body. Platelets survive for 10 days before being removed by the liver and spleen. There are 150,000 to 300,000 platelets in each milliliter of blood. Platelets stick to tears in blood vessels, and they release clotting factors.

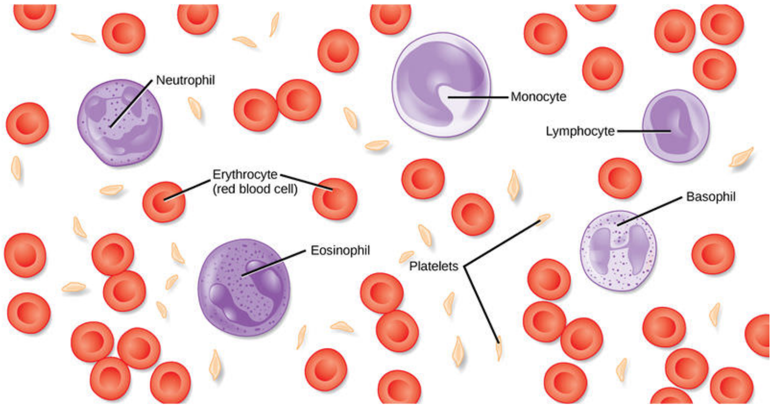


FIGURE 4.3
The relative sizes of red and white blood cells. Neutrophils, eosinophils, basophils, monocytes, and lymphocytes are white blood cells.

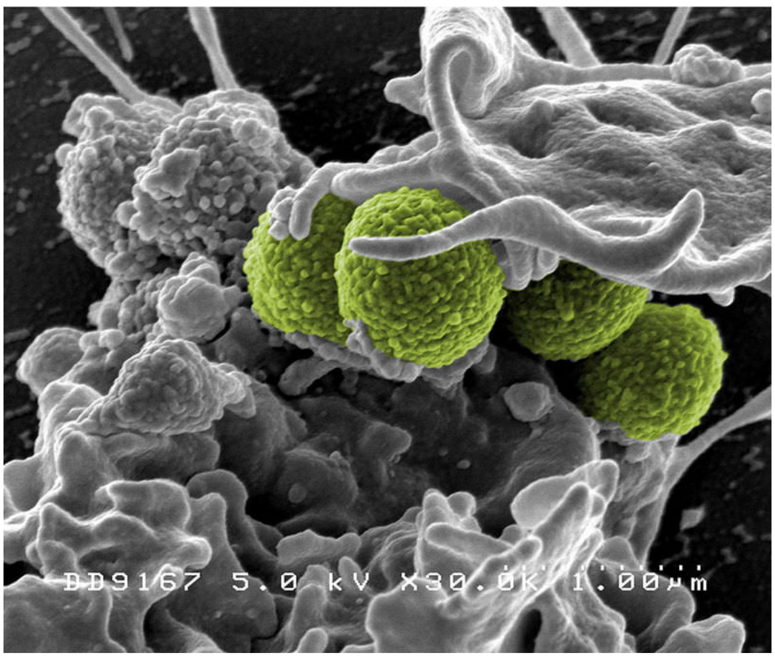


FIGURE 4.4
A white blood cell showing cytoplasmic extensions that allow it to "swallow" particles or pathogens.

Other Blood Components

Blood plasma also contains substances other than water. Some important components of blood include the following:

- Serum albumin: a plasma protein that acts as a transporter of hormones and other molecules.
- Antibodies: proteins that are used by the immune system to identify and destroy foreign objects such as bacteria and viruses.
- Hormones: chemical messengers that are produced by one cell and carried to another.
- Electrolytes such as sodium (Na^+) and chloride (Cl^-) ions.

Production and Breakdown of Blood Cells

Blood cells are produced in the red and yellow bone marrow in a process called **hematopoiesis.** The currently accepted theory of hematopoiesis is called the monophyletic theory. It simply postulates that a single type of stem

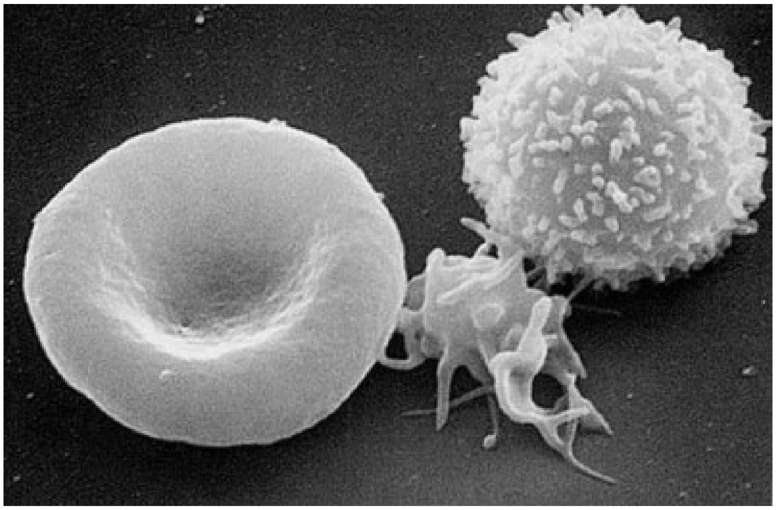


FIGURE 4.5
Cells of the blood. From left to right: red blood cell, platelet, white blood cell. The concave side of the red blood cell can be seen. Both sides of red blood cells are concave. The biconcave shape gives the red blood cells a smaller surface to volume ratio, which allows them to pick up large amounts of oxygen.

cell gives rise to all the mature blood cells in the body. This stem cell is an example of a pluripotent stem cell.

Blood cells are broken down by the spleen and certain cells in the liver. The liver also clears some proteins, lipids, and amino acids from the blood. The kidney actively secretes waste products of the blood into the urine.

Summary

- Functions of blood include transport of nutrients, removal of waste, defense of the body, repair of damaged tissue, transport of chemical messages, control of pH, and control of temperature.
- Blood is composed of 54% plasma and 46% cells/fragments. Red blood cells make up about 45% of the volume.
- White blood cells are made from stem cells in bone marrow and function in the cellular immune response system.
- Platelets are cell fragments that bud off bone marrow cells called megakaryocytes; platelets carry chemicals essential to blood clotting.

Review

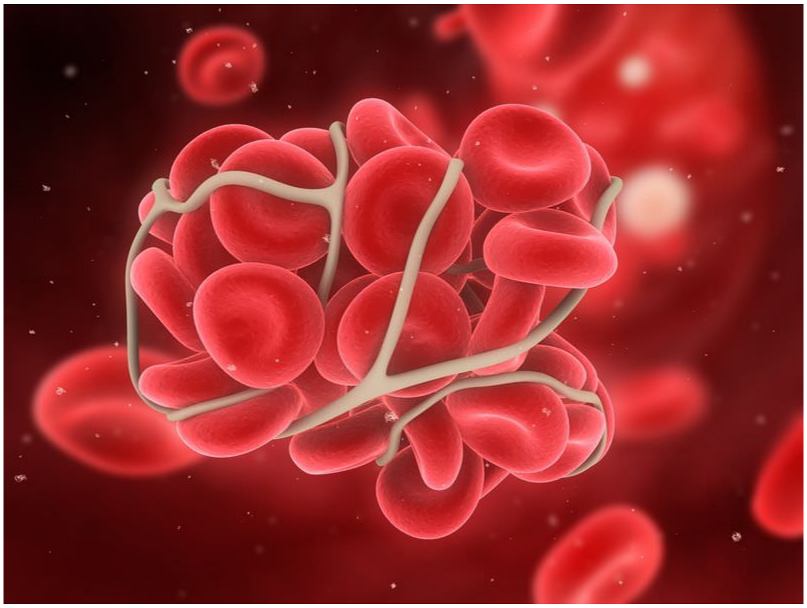
1. What type of solution is blood an example of?
2. How many liters of blood does an average adult have?
3. Where are red blood cells made?
4. What distinguishes mature red blood cells?
5. How do platelets begin the blood clotting process?

References

1. . http://visualsonline.cancer.gov/details.cfm?imageid=2129 . Public Domain
2. MesserWoland. http://commons.wikimedia.org/wiki/Image:Illu_blood_components.svg . CC-BY-SA 3.0
3. N/A Rice University. http://cnx.org/contents/185cbf87-c72e-48f5-b51e-f14f21b5eabd@9.45:210#fig-ch40_02_01 . CC-BY-3.0
4. NIAID. https://www.flickr.com/photos/niaid/5950870300/ . CC-BY-2.0

5. . fin . Public Domain

CONCEPT 5 Blood Diseases and Disorders



What must your blood do when you cut yourself?

It must clot, as depicted above. The ability to clot is essential for survival, and it occurs through a cascade of processes. But what happens if your blood cannot clot? Hemophilia is a serious disorder in which the clotting cascade is interrupted. So what happens?

Homeostatic Imbalances of the Blood

Problems can occur with red blood cells, white blood cells, platelets, and other components of the blood. Many blood disorders are genetic or are a result of nutrient deficiency, while others are cancers of the blood.

Sickle-cell disease is a group of genetic disorders caused by abnormally shaped hemoglobin called sickle hemoglobin. In many forms of the disease, the red blood cells change shape because the abnormal hemoglobin proteins stick to each other, causing the cell to have a rigid surface and sickle shape, as shown in **Figure** 5.1. This process damages the membrane of the red blood cell and can cause the cells to get stuck in blood vessels. This clotting causes oxygen starvation in tissues, which may cause organ damage such as a stroke or a heart attack. The disease is chronic and lifelong. Individuals are most often well, but their lives are punctuated by periodic painful attacks. Sickle-cell disease occurs more commonly in people (or their descendants) from parts of the world, such as sub-Saharan Africa, where malaria is or was common. It also occurs in people of other ethnicities. As a result, those with sickle cell disease are resistant to malaria since the red blood cells are not favored by the malaria parasites. The mutated hemoglobin allele is recessive, meaning it must be inherited from each parent for the individual to have the disease.

Iron deficiency anemia is the most common type of anemia. It occurs when the dietary intake or absorption of iron is less than what is needed by the body. As a result, hemoglobin, which contains iron, cannot be made. In the United States, 20 percent of all women of childbearing age have iron deficiency anemia, compared with only 2 percent of adult men. The principal cause of iron deficiency anemia in premenopausal women is blood lost during menstruation.

Leukemia is a cancer that originates in the bone marrow and is characterized by an abnormal production of white blood cells (rarely red blood cells) that are released into the bloodstream. **Lymphoma** is a cancer of the lymphatic

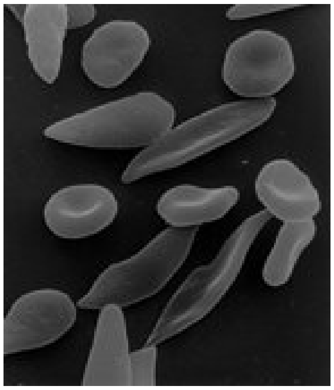


FIGURE 5.1

Sickle-cell disease. The abnormal shape of the red blood cells damages the red blood cells, which causes them to get stuck in blood vessels. The blocked capillaries reduce the blood flow to an organ and can result in pain and organ damage.

system, which helps to filter blood. Lymphoma can be categorized as either Hodgkin's lymphoma or non-Hodgkin's lymphoma.

Hemophilia is the name of a group of hereditary genetic diseases that affect the body's ability to control blood clotting. Hemophilia is characterized by a lack of clotting factors in the blood. Clotting factors are needed for a normal clotting process. When a blood vessel is injured, a temporary scab does form, but the missing coagulation factors prevent the formation of fibrin, which is needed to maintain the blood clot. Therefore, a person who has hemophilia is initially able to make a clot to stop the bleeding, but, because fibrin is not produced, the body is unable to maintain the clot for long. The risks of re-bleeding of an injury and internal bleeding are increased in hemophilia, especially into muscles, joints, or closed spaces. Hemophilia A is the most common type of hemophilia. It is also known as factor VIII deficiency or classic hemophilia. 5-10% of patients with hemophilia A are affected because they make a dysfunctional version of the factor VIII protein, while the remainder are affected because they produce insufficient amounts of factor VIII. Hemophilia B is the second most common type of hemophilia. It is known as factor IX deficiency or Christmas disease.

Haemochromatosis is a hereditary disease that is characterized by a buildup of iron in the body. Iron accumulation can eventually cause organ damage, most importantly in the liver and pancreas (manifesting as liver failure and diabetes mellitus respectively). It is estimated that roughly one in every 300-400 people is affected by the disease. People of Northern European and especially people of Irish, Scottish, Welsh, and English descent are more susceptible.

Summary

- In many forms of sickle-cell disease, the red blood cells change shape because the abnormal hemoglobin proteins stick to each other, causing the cell to have a rigid surface and sickle shape. This process damages the membrane of the red blood cell and can cause the cells to get stuck in blood vessels.
- Hemophilia is characterized by a lack of clotting factors in the blood that are needed for a normal clotting process.

Review

1. What is unique about where sickle-cell disease occurs most commonly?
2. Why do people with hemophilia have trouble forming blood clots?
3. Why does iron deficiency cause anemia?

References

1. Drs. Noguchi, Rodgers, and Schechter of NIDDK. http://en.wikipedia.org/wiki/Image:Sicklecells.jpg . Public Domain

Concept 6 Circulatory System

- Outline pathways of the pulmonary and systemic circulations.

How does oxygen get into the blood?

The main function of the circulatory system is to pump blood carrying oxygen around the body. But how does that oxygen get into the blood in the first place? You may already know that this occurs in the lungs. So the blood must also be pumped to the lungs, and this happens separately from the rest of the body.

Pulmonary and Systemic Circulations

The circulatory system actually consists of two separate systems: pulmonary circulation and systemic circulation.

Pulmonary Circulation

Pulmonary circulation is the part of the circulatory system that carries blood between the heart and lungs (the term "pulmonary" means "of the lungs"). It is illustrated in **Figure** 6.1. Deoxygenated blood leaves the right ventricle through pulmonary arteries, which transport it to the lungs. In the lungs, the blood gives up carbon dioxide and picks up oxygen. The oxygenated blood then returns to the left atrium of the heart through pulmonary veins.

Systemic Circulation

Systemic circulation is the part of the circulatory system that carries blood between the heart and body. It is illustrated in **Figure** 6.2. Oxygenated blood leaves the left ventricle through the aorta. The aorta and other arteries

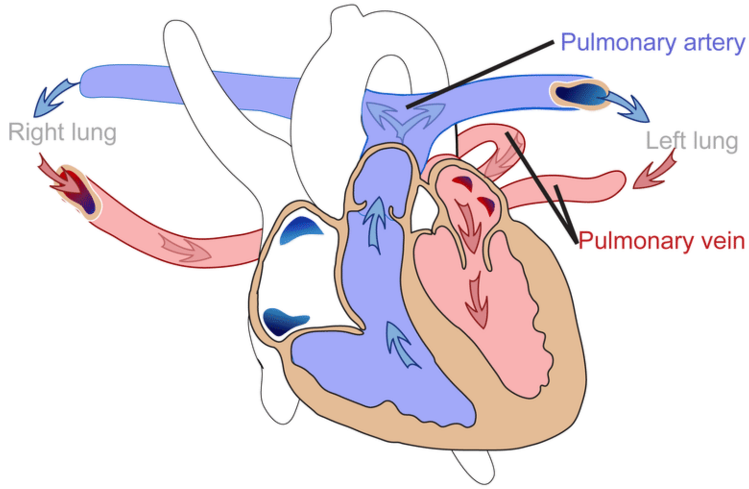


FIGURE 6.1
The pulmonary circulation carries blood between the heart and lungs.

transport the blood throughout the body, where it gives up oxygen and picks up carbon dioxide. The deoxygenated blood then returns to the right atrium through veins.

MEDIA
Click image to the left or use the URL below.
URL: https://www.ck12.org/flx/render/embeddedobject/91519

Summary

- The pulmonary circulation carries blood between the heart and lungs.
- The systemic circulation carries blood between the heart and body.

Review

1. Compare and contrast pulmonary and systemic circulations.

References

1. Mariana Ruiz Villarreal (LadyofHats) for CK-12 Foundation. Pulmonary circuit illustrated . CC BY-NC 3.0
2. Mariana Ruiz Villarreal (LadyofHats) for CK-12 Foundation. Systematic circuit illustrated . CC BY-NC 3.0

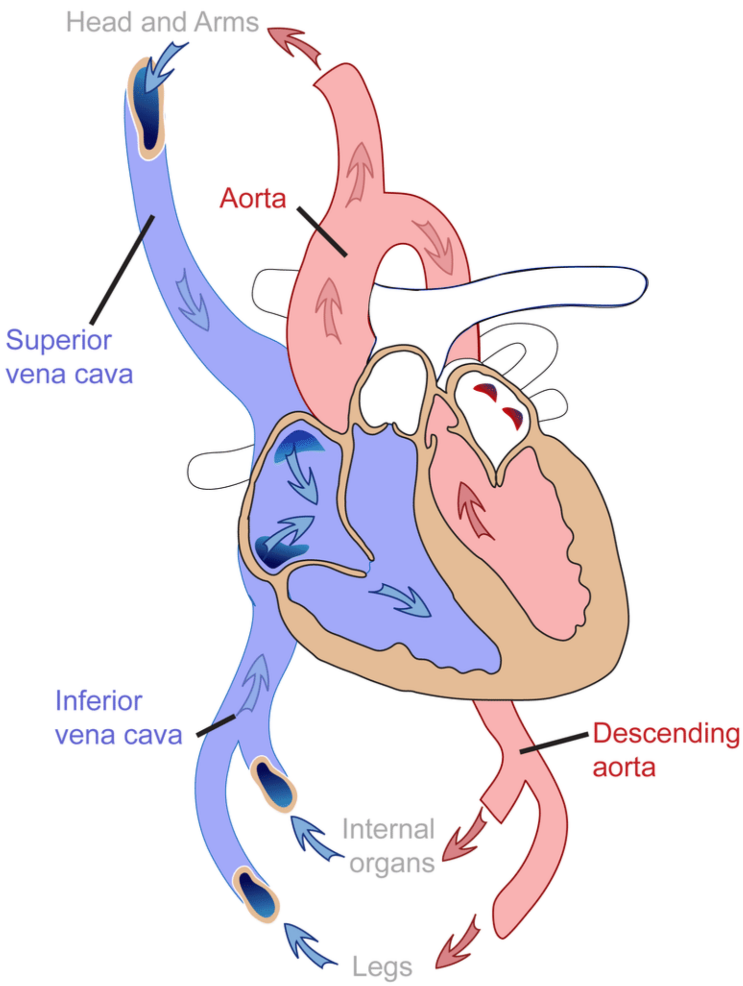
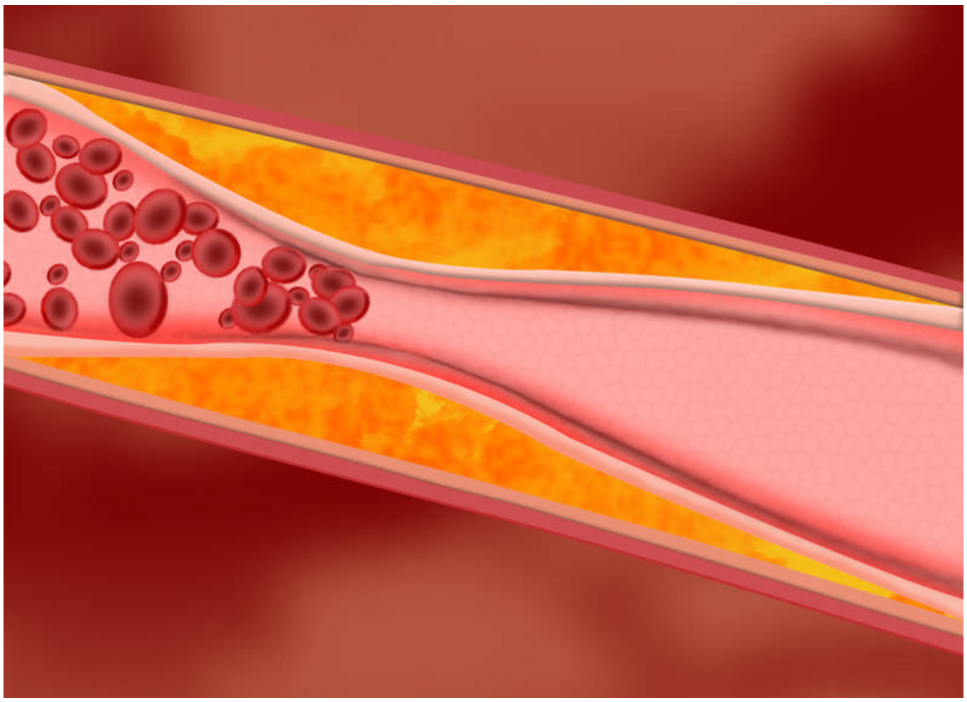


FIGURE 6.2
The systemic circulation carries blood between the heart and body.

CONCEPT 7 Circulatory System Diseases

- Define cardiovascular disease, atherosclerosis, and heart attack.
- List risk factors for cardiovascular disease.



Eat healthy, exercise, and don't smoke. Why?

Normally blood needs to flow freely through our arteries. Plaque in an artery can restrict the flow of blood. As you can probably imagine, this is not an ideal situation. And eating right, exercising, and not smoking can help keep your arteries healthy.

Cardiovascular Disease

Diseases of the heart and blood vessels, called **cardiovascular diseases (CVD)**, are very common. The leading cause of CVD is atherosclerosis.

Atherosclerosis

Atherosclerosis is the buildup of plaque inside arteries (see **Figure** 7.1). **Plaque** consists of cell debris, cholesterol, and other substances. Factors that contribute to plaque buildup include a high-fat diet and smoking. As plaque builds up, it narrows the arteries and reduces blood flow.

Atherosclerosis normally begins in late childhood and is typically found in most major arteries. It does not usually have any early symptoms. Causes of atherosclerosis include a high-fat diet, high cholesterol, smoking, obesity, and diabetes. Atherosclerosis becomes a threat to health when the plaque buildup prevents blood circulation in the heart

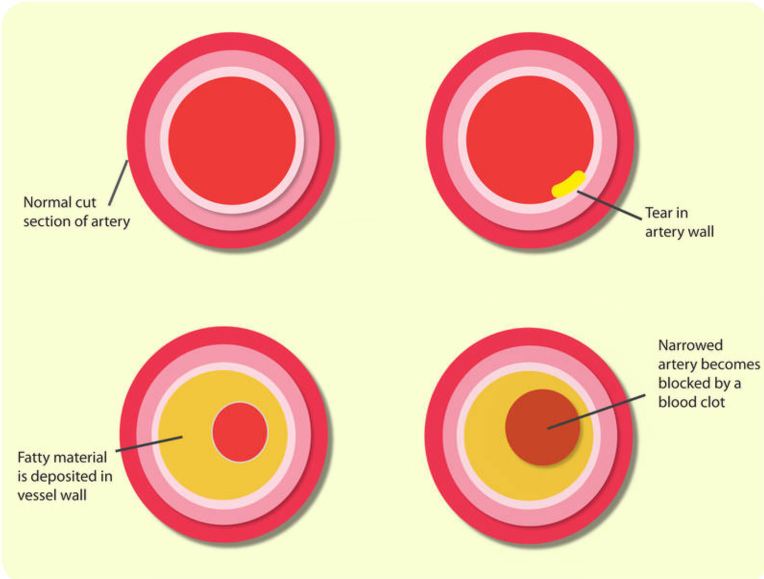


FIGURE 7.1
The fatty material inside the artery on the right is plaque. Notice how much narrower the artery has become. Less blood can flow through it than the normal artery.

or the brain. A blocked blood vessel in the heart can cause a heart attack. Blockage of the circulation in the brain can cause a stroke.

Ways to prevent atherosclerosis include eating healthy foods, getting plenty of exercise and not smoking. A diet high in saturated fat and cholesterol can raise your body's cholesterol levels, which can lead to increased plaque in your arteries. Cholesterol and saturated fat are found mostly in animal products, such as meat, eggs, milk and other dairy products.

MEDIA
Click image to the left or use the URL below.
URL: https://www.ck12.org/flx/render/embeddedobject/177110

Coronary Heart Disease

Atherosclerosis of arteries that supply the heart muscle is called **coronary heart disease**. This disease may or may not have symptoms, such as chest pain. As the disease progresses, there is an increased risk of heart attack. A **heart attack** occurs when the blood supply to part of the heart muscle is blocked and cardiac muscle fibers die. Coronary heart disease is the leading cause of death of adults in the United States.

The image below shows the way in which a blocked coronary artery can cause a heart attack. The loss of oxygen to the heart muscle cause that part of the tissue to die. Maybe one day, stem cell therapy will allow for the replacement of the dead cells with new cardiac muscle cells.

FIGURE 7.2
A blockage in a coronary artery stops oxygen from getting to part of the heart muscle, so areas of the heart that depend on the blood flow from the blocked artery are starved of oxygen.

MEDIA
Click image to the left or use the URL below.
URL: https://www.ck12.org/flx/render/embeddedobject/177114

Stroke

Atherosclerosis in the arteries of the brain can also lead to a stroke. A **stroke** is a loss of brain function due to a blockage of the blood supply to the brain. Risk factors for stroke include old age, high blood pressure, having a previous stroke, diabetes, high cholesterol, and smoking. The best way to reduce the risk of stroke is to have low blood pressure.

Preventing Cardiovascular Disease

Many factors may increase the risk of developing coronary heart disease and other CVDs. The risk of CVDs increases with age and is greater in males than females at most ages. Having a close relative with CVD also increases the risk. These factors cannot be controlled, but other risk factors can, including smoking, lack of exercise, and high-fat diet. By making healthy lifestyle choices, you can reduce your risk of developing CVD.

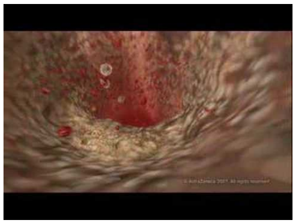
Summary

- A disease that affects the heart or blood vessels is called a cardiovascular disease (CVD).
- The leading cause of CVD is atherosclerosis, or the buildup of plaque inside arteries.
- Healthy lifestyle choices can reduce the risk of developing CVD.

Review

1. What is atherosclerosis? What is the result of atherosclerosis?
2. List controllable factors that increase the risk of cardiovascular disease.
3. What is the leading cause of death of adults in the Inited States?
4. How can you reduce your risk of developing CVD?

Resources



MEDIA

Click image to the left or use the URL below.

URL: https://www.ck12.org/flx/render/embeddedobject/177112

References

1. Rupali Raju. Cross section of plaque development . CC BY-NC 3.0

Concept 8 Respiration

- Define respiration.
- Distinguish respiration from cellular respiration.

Where does oxygen get into blood?

Red blood cells are like trucks that transport cargo on a highway system. Their cargo is oxygen, and the highways are blood vessels. Where do red blood cells pick up their cargo of oxygen? The answer is the lungs. The lungs are organs of the respiratory system. The respiratory system is the body system that brings air containing oxygen into the body and releases carbon dioxide into the atmosphere.

Respiration

The job of the **respiratory system** is the exchange of gases between the body and the outside air. This process, called **respiration**, actually consists of two parts. In the first part, oxygen in the air is drawn into the body and carbon dioxide is released from the body through the respiratory tract. In the second part, the circulatory system delivers the oxygen to body cells and picks up carbon dioxide from the cells in return. The **lungs** are organs of the respiratory system. It is in the lungs where oxygen is transferred from the respiratory system to the circulatory system.

The use of the word “respiration” in relation to gas exchange is different from its use in the term **cellular respiration**. Recall that cellular respiration is the metabolic process by which cells obtain energy by “burning” glucose. Cellular respiration uses oxygen and releases carbon dioxide. Respiration by the respiratory system supplies the oxygen and takes away the carbon dioxide.

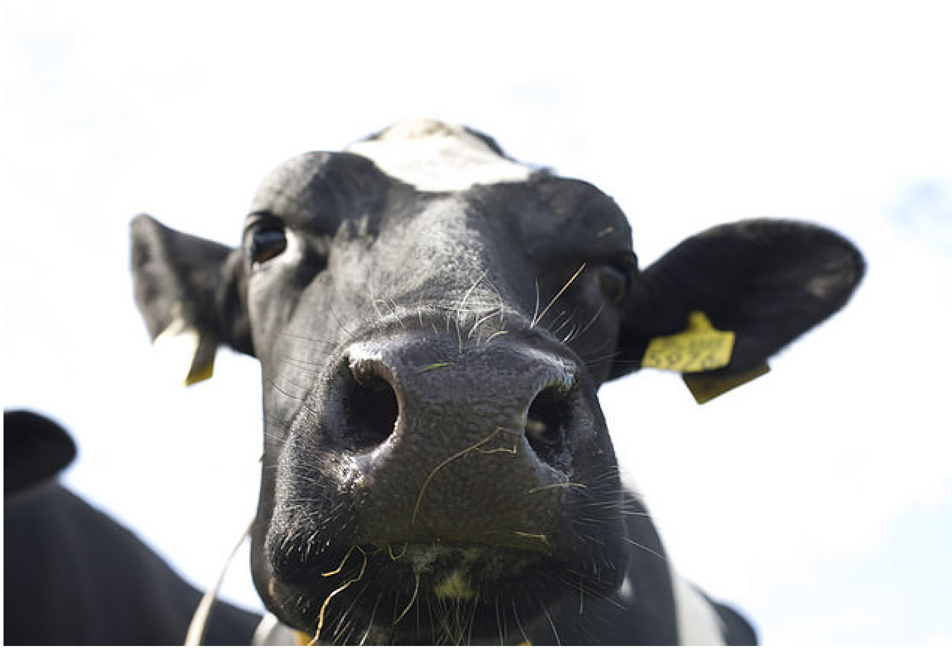
- Respiration is the process in which gases are exchanged between the body and the outside air.
- The lungs and other organs of the respiratory system bring oxygen into the body and release carbon dioxide into the atmosphere.

Review

1. What is respiration?
2. Describe the two parts of respiration.
3. How is respiration different from cellular respiration?

CONCEPT 9 Respiratory System Organs

- Identify the organs of the respiratory system.
- Distinguish the upper respiratory tract from the lower respiratory tract.
- Describe the pharynx, larynx, trachea, and bronchi.



Are all noses alike?

It all starts with the nose. OK, in humans maybe not the nose pictured above, but one similar to the nose below. Though the passage of air is probably similar in cows and humans. Air comes in and then where does it go?

Organs of the Respiratory System

The organs of the respiratory system that bring air into the body are divided among the upper **respiratory tract** and lower respiratory tract. These organs are shown in **Figure** 9.1. In addition to the **lungs**, these organs include the pharynx, larynx, trachea and bronchi. The **nasal cavity** is also part of the respiratory system. The nose and nasal

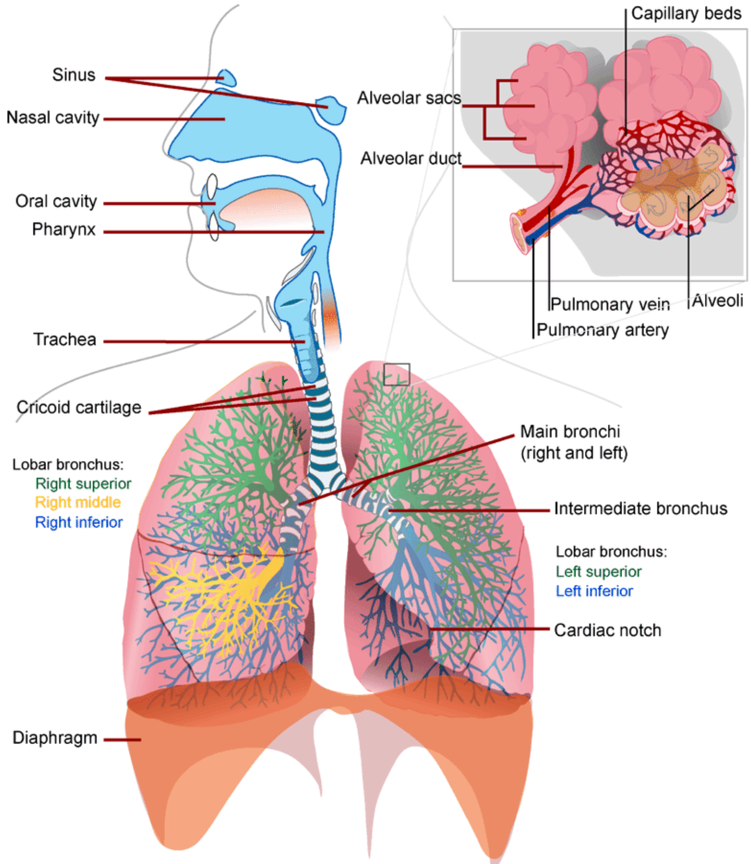
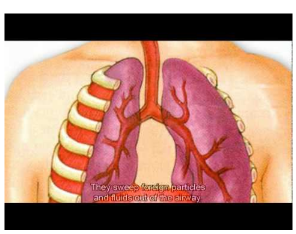


FIGURE 9.1
The organs of the respiratory system move air into and out of the body.

cavity filter, warm, and moisten the air we inhale. Hairs and mucus produced in the nose trap particles in the air and prevent them from reaching the lungs.



MEDIA
Click image to the left or use the URL below.
URL: https://www.ck12.org/flx/render/embeddedobject/94256

- The **pharynx** is a long tube that is shared with the digestive system. Both food and air travel through the pharynx.
- The **larynx**, or voice box, contains vocal cords, which allow us to produce vocal sounds. Air passes through thin tissues in the larynx, producing sound.
- The **trachea**, or wind pipe, is a long tube that leads down to the chest.
- The trachea divides as it enters the lungs to form the right and left **bronchi**, which branch into smaller bronchioles within each lung. The bronchioles lead to alveoli, the sites of gas exchange.

Summary

- The organs of the respiratory system include the lungs, pharynx, larynx, trachea, and bronchi.

Review

1. Describe the main organs of the respiratory system.

References

1. Mariana Ruiz Villarreal (User:LadyofHats/Wikimedia Commons). Respiratory system organs . Public Domain

CONCEPT 10 Respiratory System Regulation

- Explain how the rate of breathing is regulated.

What allows you to take a deep breath?

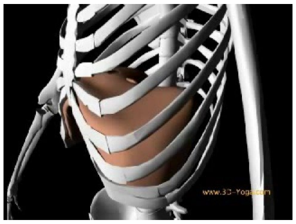
Deep breath in. . . now blow out those candles. We've all done that. Taking that deep breath in is an active process. You can usually feel your chest move. Why? Obviously, muscles in your chest are doing the work.

Regulation of Breathing

To understand how breathing is regulated, you first need to understand how breathing occurs.

How Breathing Occurs

Inhaling is an active movement that results from the contraction of a muscle called the diaphragm. The **diaphragm** is large, sheet-like muscle below the lungs (see **Figure** 10.1). When the diaphragm contracts, the ribcage expands and the contents of the abdomen move downward. This results in a larger chest volume, which decreases air pressure inside the lungs. With lower air pressure inside than outside the lungs, air rushes into the lungs. When the diaphragm relaxes, the opposite events occur. The volume of the chest cavity decreases, air pressure inside the lungs increases, and air flows out of the lungs, like air rushing out of a balloon.



MEDIA
Click image to the left or use the URL below.
URL: https://www.ck12.org/flx/render/embeddedobject/1728

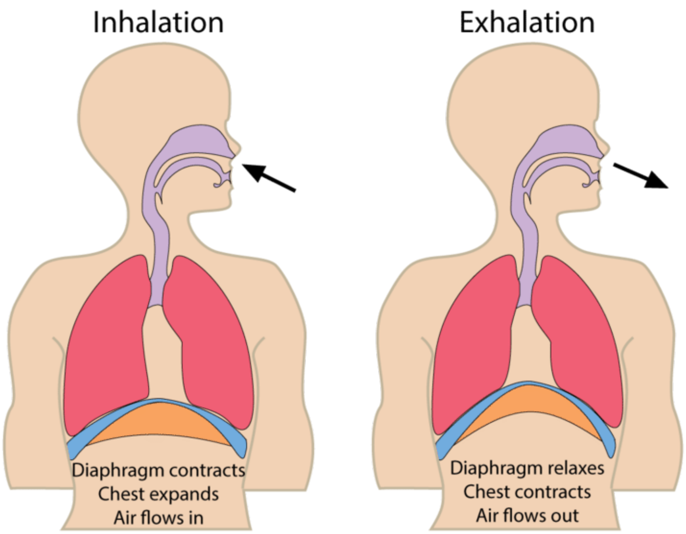


FIGURE 10.1
Breathing depends on contractions of the diaphragm.

Control of Breathing

The regular, rhythmic contractions of the diaphragm are controlled by the brain stem. It sends nerve impulses to the diaphragm through the autonomic nervous system. The brain stem monitors the level of carbon dioxide in the blood. If the level becomes too high, it "tells" the diaphragm to contract more often. Breathing speeds up, and the excess carbon dioxide is released into the air. The opposite events occur when the level of carbon dioxide in the blood becomes too low. In this way, breathing keeps blood pH within a narrow range.

Summary

- Breathing occurs due to repeated contractions of a large muscle called the diaphragm.
- The rate of breathing is regulated by the brain stem. It monitors the level of carbon dioxide in the blood and triggers faster or slower breathing as needed to keep the level within a narrow range.

Review

1. Explain why contraction of the diaphragm causes the lungs to fill with air.
2. Explain how the rate of breathing is controlled.

References

1. Zachary Wilson. Diagphragm causing inhalation and exhalation . CC BY-NC 3.0

Concept 11 Respiratory System Diseases

- Identify diseases of the respiratory system.
- Describe triggers for asthma.
- Compare pneumonia to emphysema.

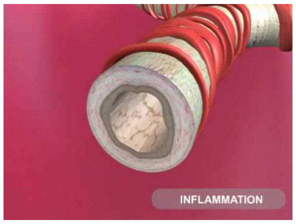
Does making ATP start with the lungs?

The importance of a nice pair of healthy lungs is obvious. We all need oxygen to get into our lungs, so the oxygen can be transferred to the blood, so it can be transported around our body, so each cell can receive its fair share of oxygen, allowing oxygen to serve as the final electron acceptor during the electron transport chain of cellular respiration, allowing the cell to produce lots of ATP. And it all starts with the lungs.

Diseases of the Respiratory System

When you have a cold, your nasal passages may become so congested that it's hard to breathe through your nose. Many other diseases also affect the respiratory system, most of them more serious than the common cold. Some lung diseases, such as lung cancer, can be especially dangerous. The following list includes just a sample of respiratory system diseases.

- **Asthma** is a disease in which the air passages of the lungs periodically become too narrow, often with excessive mucus production. This causes difficulty breathing, coughing, and chest tightness. An asthma attack may be triggered by allergens, strenuous exercise, stress, or other factors.



MEDIA

Click image to the left or use the URL below.

URL: https://www.ck12.org/flx/render/embeddedobject/1718

- **Pneumonia** is a disease in which some of the alveoli of the lungs fill with fluid so gas exchange cannot occur. Symptoms usually include coughing, chest pain, and difficulty breathing. Pneumonia may be caused by an infection or injury of the lungs.
- **Emphysema** is a lung disease in which walls of the alveoli break down so less gas can be exchanged in the lungs (see **Figure** 11.1). This causes shortness of breath. The damage to the alveoli is usually caused by smoking and is irreversible.

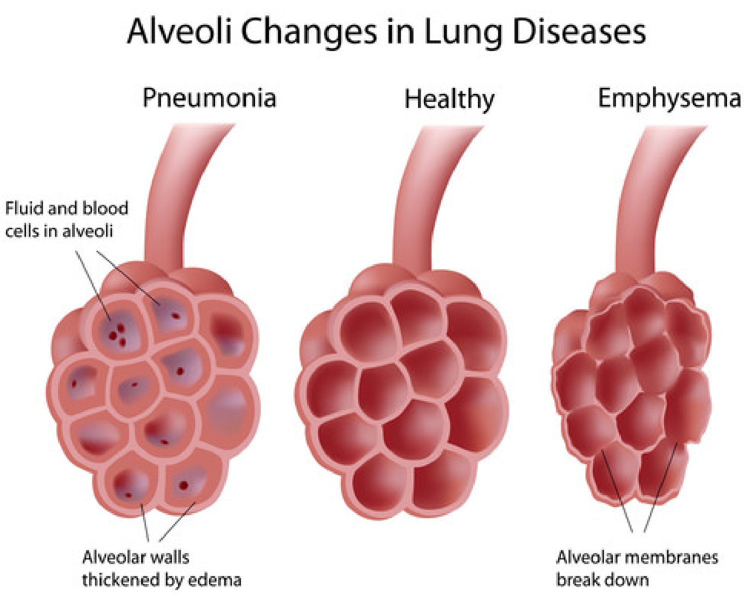


FIGURE 11.1

Pneumonia and emphysema are caused by damage to the alveoli of the lungs.

Causes of Respiratory Diseases

Many respiratory diseases are caused by pathogens. Certain bacteria, viruses, and fungi are pathogens of the respiratory system. The common cold and flu are caused by viruses. Tuberculosis, whooping cough, and acute bronchitis are caused by bacteria. The pathogens that cause colds, flu, and TB can be passed from person to person by coughing and sneezing.

Air pollution is another significant cause of respiratory disease. The quality of the air you breathe can affect the health of your lungs. Asthma, heart and lung diseases, allergies, and several types of cancers are all linked to air quality. Air pollution is not just found outdoors; indoor air pollution can also be responsible for health problems.

Smoking is the most significant cause of respiratory disease as well as cardiovascular disease and cancer. Exposure to tobacco smoke by smoking or by breathing air that contains tobacco smoke is the leading cause of preventable death in the United States. Regular smokers die about 10 years earlier than nonsmokers. The Centers for Disease Control and Prevention (CDC) describes tobacco use as "the single most important preventable risk to human health in developed countries and an important cause of [early] death worldwide."

Summary

- Diseases of the respiratory system include asthma, pneumonia, and emphysema.

Review

1. Identify and describe three diseases of the respiratory system, and state what triggers or causes each disease.

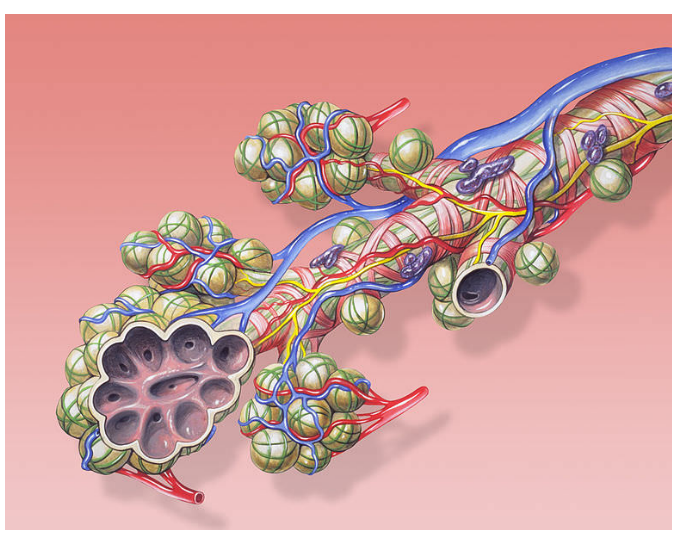
References

1. Image copyright Alila Medical Media, 2014. Alveoli: healthy, pneumonia, and emphysema. . Used under license from Shutterstock.com

CONCEPT 12 A Breath of Air

Grapes. Why? What do these have in common with a breath of air?

Shown below are the parts of the lungs where oxygen moves from the lungs into the blood. If the alveoli below were purple, they could resemble a bunch of grapes. Of course, as the alveoli are in the lungs, they must be very small to provide enough area for the exchange of gases. In fact, there are about 300-600 million alveoli in the adult lung.



The Journey of a Breath of Air

In air-breathing vertebrates, such as humans, respiration of oxygen includes four stages:

1. **Ventilation** from the atmosphere into the alveoli of the lungs.
2. Pulmonary gas exchange from the alveoli into the pulmonary capillaries.
3. Gas transport from the pulmonary capillaries through the circulation to the peripheral capillaries in the organs.
4. Peripheral gas exchange from the tissue capillaries into the cells and mitochondria.

Ventilation: From the Air to the Alveoli

Air enters the body through the nose where it is warmed, filtered, and passed through the nasal cavity. Air passes the pharynx (which has the epiglottis that prevents food from entering the trachea). The upper part of the trachea contains the larynx. The vocal cords are two bands of tissue that extend across the opening of the larynx. After passing the larynx, the air moves into the trachea. The trachea is a long tube that divides into two smaller tubes called bronchi, which lead into each lung, as shown in **Figure** 12.1. Bronchi are reinforced to prevent their collapse and are lined with ciliated epithelium and mucus-producing cells. Bronchi branch into smaller and smaller tubes called bronchioles. Bronchioles end in grape-like clusters called alveoli. Alveoli are surrounded by a network of thin-walled capillaries, as shown in **Figure** 12.1.

Breathing in, or inhaling, is usually an active movement. A contraction of the diaphragm muscles is necessary, and it uses ATP. The **diaphragm** is a muscle that is found below the lungs. Contraction of the diaphragm causes the volume of the chest cavity to increase, and the air pressure within the lungs decreases. The pressure difference causes air to rush into the lungs. Relaxation of the diaphragm causes the lungs to recoil, and air is pushed out of the lungs. Breathing out, or exhaling, is normally a passive process powered by the elastic recoil of the chest, similar to letting the air out of a balloon.

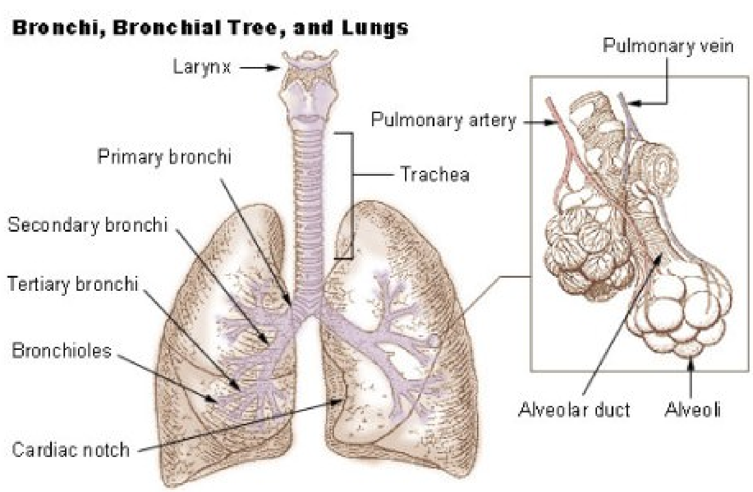


FIGURE 12.1
The alveoli are the tiny grape-like structures within the lungs, and they are the site of pulmonary gas exchange.

Pulmonary Gas Exchange: From the Alveoli into the Pulmonary Capillaries

Breathing is only part of the process of delivering oxygen to where it is needed in the body. The process of **gas exchange** occurs in the alveoli by diffusion of gases between the alveoli and the blood in the lung capillaries, as shown in **Figure** 12.2. Recall that diffusion is the movement of substances from an area of higher concentration to an area of lower concentration. The difference between the high concentration of O_2 in the alveoli and the low

O_2 concentration of the blood in the capillaries is enough to cause O_2 molecules to diffuse across the thin walls of the alveoli and capillaries and into the blood. CO_2 moves out of the blood and into the alveoli in a similar way. The greater the concentration difference, the greater the rate of diffusion. Breathing also results in a loss of water from the body. Exhaled air has a relative humidity of 100 percent because of the diffusion of water from the moist surfaces of the breathing passages and the alveoli into the warm exhaled air.

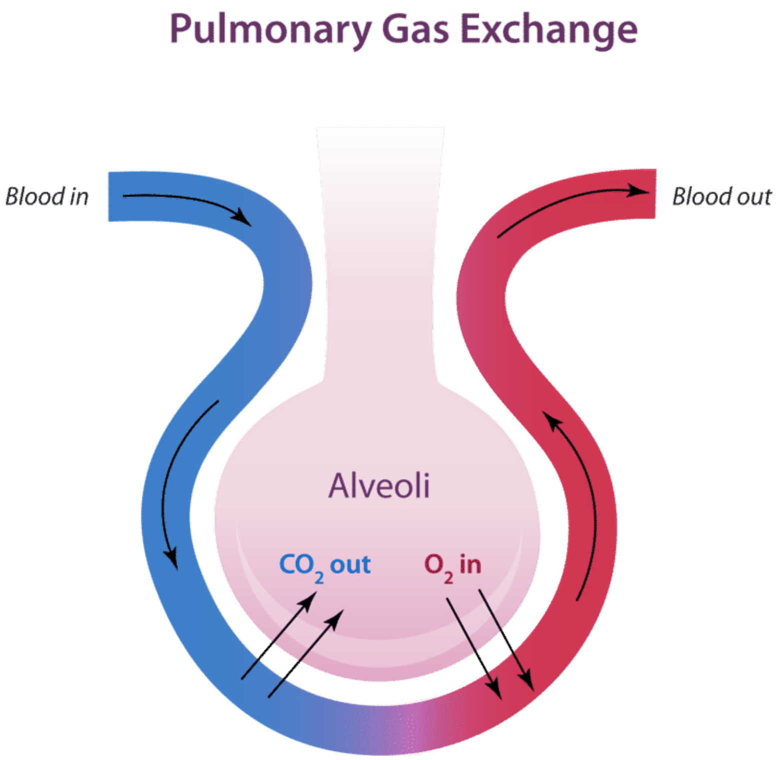


FIGURE 12.2
Alveoli are tiny sacs in the lungs where gas exchange takes place.

In the lungs, oxygen diffuses across the thin membranes of the alveoli and capillary walls and is attracted to the hemoglobin molecules within red blood cells.

After leaving the lungs, the oxygenated blood returns to the heart to be pumped through the aorta and around the body. The oxygenated blood travels through the aorta to the smaller arteries, arterioles, and finally the peripheral capillaries where gas exchange occurs.

Peripheral Gas Exchange: From Capillaries into Cells, and from Cells into Capillaries

The oxygen concentrations in body cells are low, while the blood that leaves the lungs is 97 percent saturated with oxygen. So, oxygen diffuses from the blood into the body cells when it reaches the peripheral capillaries (the capillaries in the systemic circulation).

Carbon dioxide concentrations in metabolically active cells are much greater than in capillaries, so carbon dioxide diffuses from the cells into the capillaries. Most of the carbon dioxide (about 70 percent) in the blood is in the form of bicarbonate (HCO_3^-). A small amount of carbon dioxide dissolves in the water of the plasma to form carbonic acid (H_2CO_3). Carbonic acid and bicarbonate play an important role in regulating the pH of the body.

In order to remove CO_2 from the body, the bicarbonate is picked up by red blood cells and is again turned into carbonic acid. A water molecule (H_2O) is then taken away from the carbonic acid, and the remaining CO_2 molecule is expelled from the red blood cells and into the alveoli where it is exhaled. The following equation shows this process:

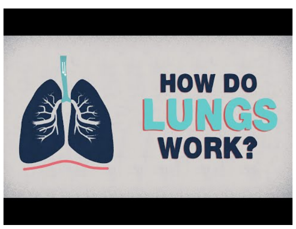
$HCO_3^- + H^+ \rightleftharpoons H_2CO_3 \rightleftharpoons CO_2 + H_2O$

Gas exchange between your body and the environment occurs in the alveoli. The alveoli are lined with pulmonary capillaries, the walls of which are thin enough to permit the diffusion of gases. Inhaled oxygen diffuses into the pulmonary capillaries where it binds to hemoglobin in the blood. Carbon dioxide diffuses in the opposite direction—from capillary blood to alveolar air. At this point, the pulmonary blood is oxygen-rich, and the lungs are primarily holding carbon dioxide. Exhalation follows, thereby ridding the body of the carbon dioxide and completing the cycle of respiration.

Gas Exchange and Homeostasis

The equilibrium between carbon dioxide and carbonic acid is very important for controlling the acidity of body fluids. As gas exchange occurs, the pH balance of the body is maintained as part of homeostasis. If proper respiration is interrupted, two things can occur:

1. Respiratory acidosis, in which arterial blood contains too much carbon dioxide, causing a drop in blood pH.
2. Respiratory alkalosis results from increased respiration (or hyperventilation), which causes a drop in the amount of carbon dioxide in the blood plasma. The drop in carbon dioxide concentration causes the blood pH to rise.



MEDIA

Click image to the left or use the URL below.

URL: https://www.ck12.org/flx/render/embeddedobject/187050

Summary

- Breathing in, or inhaling, is usually an active movement. Contraction of the diaphragm causes the volume of the chest cavity to increase, and the air pressure within the lungs decreases.
- Diffusion is the movement of substances from an area of higher concentration to an area of lower concentration.
- The process of gas exchange occurs in the alveoli by diffusion of gases between the alveoli and the blood in the lung capillaries.
- Carbon dioxide concentrations in metabolically active cells are much greater than in capillaries, so carbon dioxide diffuses from the cells into the capillaries.
- The equilibrium between carbon dioxide and carbonic acid is very important for controlling the acidity of body fluids. As gas exchange occurs, the pH balance of the body is maintained as part of homeostasis.

Review

1. What are the four stages of respiration?
2. Why does breathing result in a loss of water?
3. What is respiratory acidosis?
4. What can cause respiratory alkalosis?

References

1. USFG. http://training.seer.cancer.gov/anatomy/respiratory/passages/bronchi.html . Public Domain
2. delldot, modified by CK-12 Foundation. http://commons.wikimedia.org/wiki/File:Fluid-filled_alveolus1.svg . CC-BY-SA 3.0