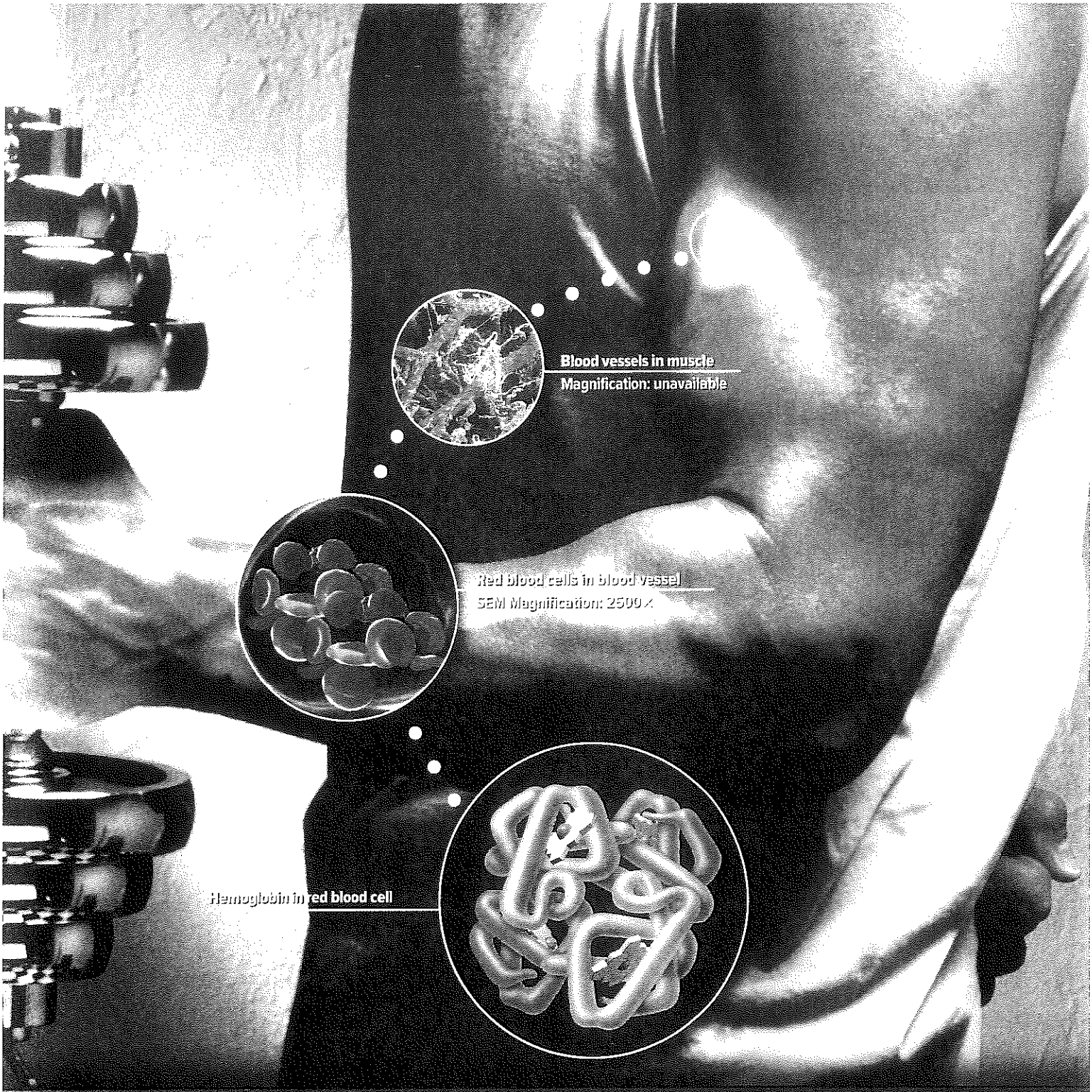

THEME FOCUS **Stability and Change**
The circulatory, respiratory, and excretory systems regulate the internal environment of the human body to maintain conditions needed for life.

BIG Idea These systems function together to maintain homeostasis by delivering important substances to the body's cells while removing wastes.

Section 1 • Circulatory System

Section 2 • Respiratory System

Section 3 • Excretory System

Reading Preview

Essential Questions

- What are the main functions of the circulatory system?
- How does the blood flow through the heart and body?
- What are the similarities and differences between the major components of the blood?

Review Vocabulary

muscle contraction: muscle cells or fibers shorten in response to stimuli

New Vocabulary

artery
capillary
vein
valve
heart
pacemaker
plasma
red blood cell
platelet
white blood cell
atherosclerosis

Multilingual eGlossary

Circulatory System

MAIN Idea **The circulatory system transports blood to deliver important substances, such as oxygen, to cells and to remove wastes, such as carbon dioxide.**

Real-World Reading Link Fast-moving highway traffic gets people to and from work quickly. Similarly, blood flowing in your body supplies nutrients and removes waste products quickly. When either traffic or blood flow is blocked, normal functions slow down or stop.

Functions of the Circulatory System

Cells must have oxygen and nutrients and must also get rid of waste products. This exchange is accomplished by the circulatory system–the body's transport system. The circulatory system consists of blood, the heart, blood vessels, and the lymphatic system. Blood carries important substances to all parts of the body. The heart pumps blood through a vast network of tubes inside your body called blood vessels. The lymphatic system is considered part of the circulatory and immune systems. All of these components work together to maintain homeostasis in the body.

The circulatory system transports many important substances, such as oxygen and nutrients. The blood also carries disease-fighting materi-als produced by the immune system. The blood contains cell fragments and proteins for blood clotting. Finally, the circulatory system distributes heat throughout the body to help regulate body temperature.

Figure 1

From Cadavers to Artificial Hearts

The human circulatory system has been studied for thousands of years, leading to great advances in medical technology.

350 B.C. Greek physician Praxagoras recognizes that veins and arteries are two different kinds of vessels.

1628 The first accurate description is made of the human heart—a pump that circulates blood in a one-way system.

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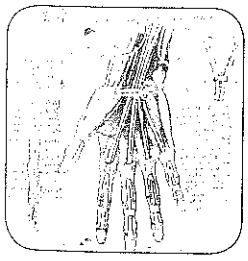
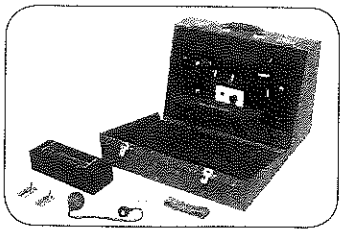


1452–1519 Leonardo da Vinci conducts extensive research on human cadavers. It is believed that he dissected about 30 corpses in his lifetime.



1903 The first electrocardiograph records the electrical activity of the heart.

(t)FineArt/ Alamy; (r)SSPL/The Image Works

Blood Vessels

Highways have lanes that separate traffic. They also have access ramps that take vehicles to and from roads. Similarly, the body has a network of channels—the blood vessels. Blood vessels circulate blood throughout the body and help keep the blood flowing to and from the heart. The fact that there are different kinds of blood vessels was first observed by the Greek physician Praxagoras, as noted in **Figure 1.** The three major blood vessels are arteries, capillaries, and veins, as illustrated in **Figure 2.**

Arteries Oxygen-rich blood, or oxygenated blood, is carried away from the heart in large blood vessels called **arteries.** These strong, thick-walled vessels are elastic and durable. They are capable of withstanding high pressures exerted by blood as it is pumped by the heart.

As shown in **Figure 2,** arteries are composed of three layers: an outer layer of connective tissue, a middle layer of smooth muscle, and an inner layer of endothelial tissue. The endothelial layer of the artery is thicker than that of the other blood vessels. The endothelial layer of arteries needs to be thicker because blood is under higher pressure when it is pumped from the heart into the arteries.

Capillaries Arteries branch into smaller vessels called arterioles, which become smaller in diameter as they grow farther away from the main vessel. The smallest branches are capillaries. **Capillaries** are microscopic blood vessels where the exchange of important substances and wastes occurs. Capillary walls are only one cell thick, as illustrated in **Figure 2.** This permits the easy exchange of materials between the blood and body cells through the process of diffusion. Capillaries are so small that red blood cells move single-file through these vessels.

The diameter of blood vessels changes in response to the needs of the body. For example, when you are exercising, muscle capillaries expand, or dilate. This increases blood flow to working muscles, which brings more oxygen to cells and removes extra wastes from cells.

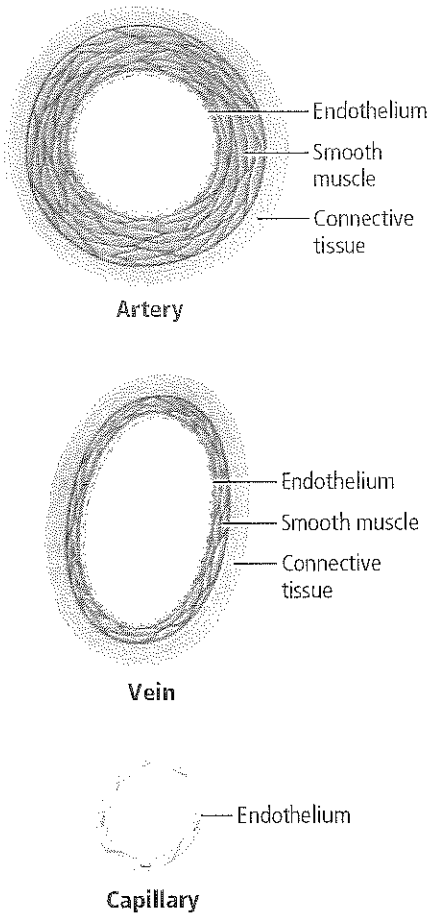
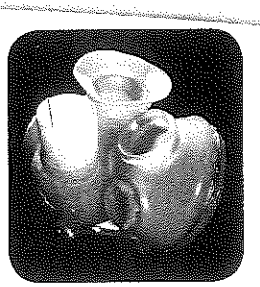


Figure 2 The three major blood vessels in the body are arteries, veins, and capillaries.
Predict *By what process do you think materials cross the walls of capillaries?*

Animation



1982 The first artificial heart intended for permanent use is implanted by William DeVries, a surgeon.

2004 Research shows that cardiac stem cells can generate new muscle cells. This opens up new treatment possibilities for treating heart failure.

1930 — 1965 — 2000

1940–1941 Dr. Charles R. Drew establishes the first blood banks for blood transfusions.

1967–1969 Surgeons perform the first heart transplant. An artificial heart keeps the patient alive until a donated heart replaces it.

2008 Scientists successfully transplant rat hearts grown from the rats' own stem cells.

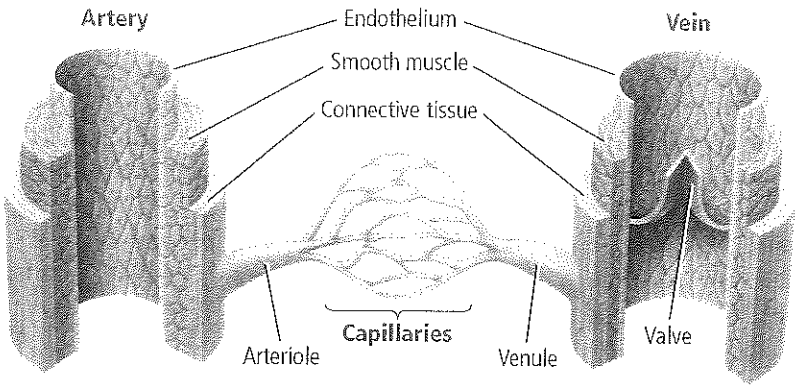


Figure 3 Blood circulates throughout the body inside blood vessels.
Hypothesize *how body temperature can be regulated by the diameter of blood vessels.*

Veins After blood moves through the tiny capillaries, it enters the larger vessels called venules, and then enters the largest blood vessels, called veins. **Veins** carry oxygen-poor blood, or deoxygenated blood, back to the heart. The endothelial walls of veins are much thinner than the walls of arteries. The pressure of the blood decreases when the blood flows through capillaries before it enters the veins. By the time blood flows into the veins, the heart's original pushing force has less effect on making the blood move. So how does the blood keep moving? Many veins are located near skeletal muscles, and the contraction of these muscles helps keep the blood moving. Larger veins in the body also have flaps of tissue called **valves,** such as the one in **Figure 3,** which prevent blood from flowing backward. Lastly, breathing movements exert a squeezing pressure against veins in the chest, forcing blood back to the heart.

Virtual Lab

BrainPOP

Reading Check **Describe** the differences in structure among arteries, capillaries, and veins.

The Heart

The **heart** is a muscular organ that is about as large as your fist and is located at the center of your chest. This hollow organ pumps blood throughout the body. The heart performs two pumping functions at the same time. The heart pumps oxygenated blood to the body, and it pumps deoxygenated blood to the lungs.

Structure of the heart Recall that the heart is made of cardiac muscle. It is capable of conducting electrical impulses for muscular contractions. The heart is divided into four compartments called chambers, as illustrated in **Figure 4.** The two chambers in the top half of the heart, the right atrium and the left atrium (plural, atria), receive blood that is returning to the heart. Below the atria are the right and left ventricles, which pump blood away from the heart. A strong muscular wall separates the left side of the heart from the right side of the heart. The right and left atria have thinner muscular walls and do less work than the ventricles. Notice the valves in **Figure 4** that separate the atria from the ventricles and keep blood flowing in one direction. Valves, such as the aortic valve shown in a closed position in **Figure 4,** are also located between each ventricle and the large blood vessels that carry blood away from the heart.

CAREERS IN BIOLOGY

Exercise Physiologist Scientists who study the effects of exercise on the body are called exercise physiologists. They develop exercise programs and administer medical tests, such as stress tests. Their responsibilities might include monitoring heart activity and monitoring blood pressure levels.

Reading Preview

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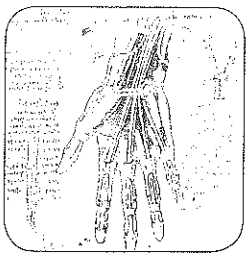

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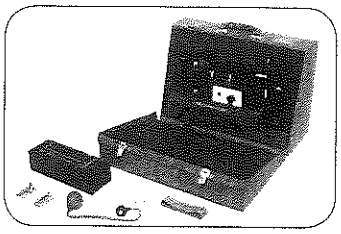


1903 The first electrocardiograph records the electrical activity of the heart.

(l)FineArt/ Alamy; (r)SSPL/The Image Works

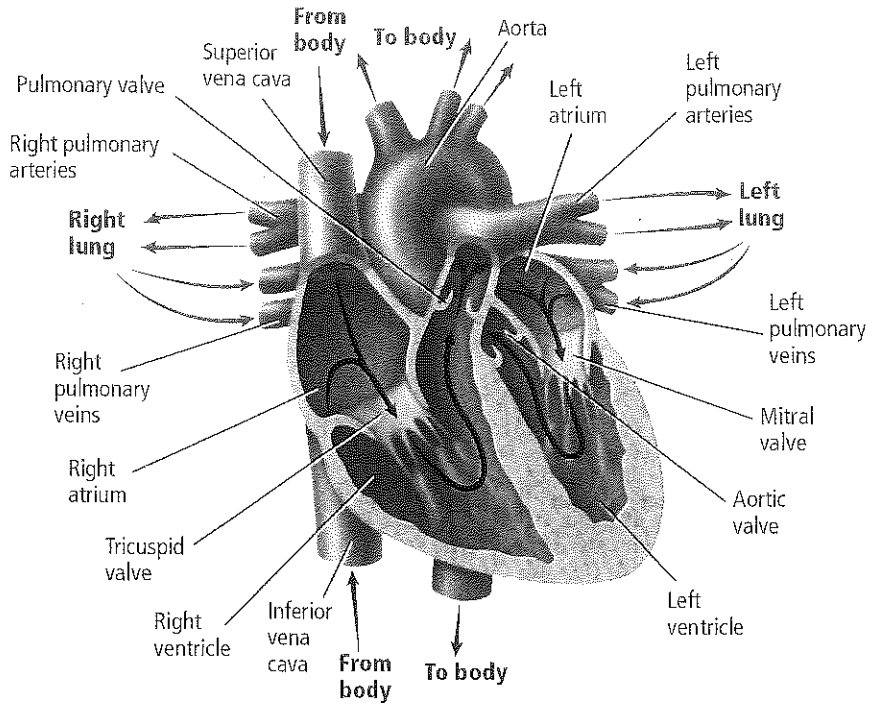
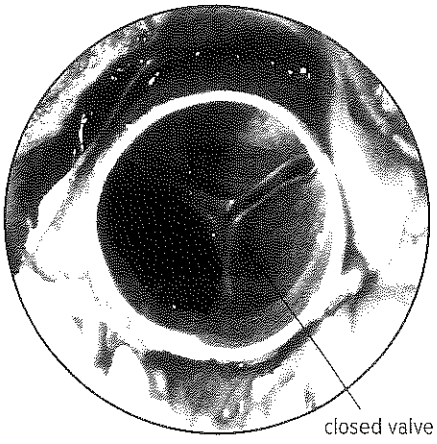


Figure 4 The arrows map the path of blood as it circulates through the heart. **Diagram** ***the path of blood through the heart.***

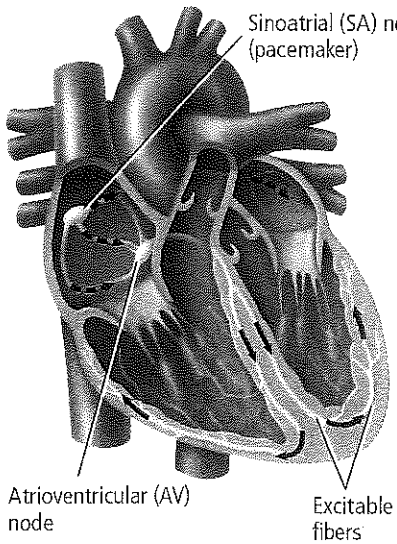


Aortic valve in a closed position

How the heart beats The heart acts in two main phases. In the first phase, the atria fill with blood. The atria contract, filling the ventricles with blood. In the second phase, the ventricles contract to pump blood out of the heart, into the lungs, and forward into the body.

The heart works in a regular rhythm. A group of cells located in the right atrium, called the **pacemaker** or sinoatrial (SA) node, send out signals that tell the heart muscle to contract. The SA node receives internal stimuli about the body's oxygen needs, and then it responds by adjusting the heart rate. The signal initiated by the SA node causes both atria to contract. Then the signal travels to another area in the heart called the atrioventricular (AV) node, as illustrated in **Figure 5.** The signal moves through fibers, causing both ventricles to contract. This two-step contraction makes up one complete heartbeat.

Figure 5 The SA node initiates the contraction of the heart, which spreads through both atria to the AV node. The AV node transmits the signal through excitable fibers that stimulate both ventricles.



Pulse The heart pulses about 70 times each minute. If you touch the inside of your wrist just below your thumb, you can feel a pulse in the artery in your wrist rise and fall. This pulse is the alternating expansion and relaxation of the artery wall caused by the contraction of the left ventricle. The number of times the artery in your wrist pulses is the number of times your heart beats.

Blood pressure Blood pressure is a measure of how much pressure is exerted against the vessel walls by the blood. Blood-pressure readings can provide information about the condition of arteries. The contrac-tion of the heart, or systole (SIS tuh lee), causes blood pressure to rise to its highest point, and the relaxation of the heart, or diastole (di AS tuh lee), brings blood pressure down to its lowest point. The ideal normal blood-pressure reading for a healthy adult is 120 (systolic pressure)/80 (diastolic pressure).

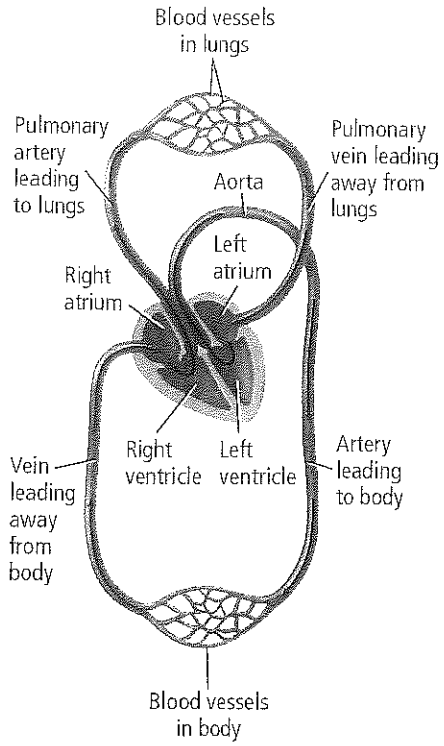


Figure 6 Blood flow through the body consists of two different circulatory loops.

Animation

Blood flow in the body If you follow the flow of blood shown in **Figure 6,** you will notice that it flows in two loops. First, the blood travels from the heart to the lungs and back to the heart. Then, the blood is pumped in another loop from the heart through the body and back. The right side of the heart pumps deoxygenated blood to the lungs, and the left side of the heart pumps oxygenated blood to the rest of the body.

To the lungs and back When blood from the body flows into the right atrium, it has a low concentration of oxygen but a high concentration of carbon dioxide. This deoxygenated blood is dark red. The blood flows from the right atrium into the right ventricle and is pumped into the pulmonary arteries that lead to the lungs, as shown in **Figure 6.**

Eventually, blood flows into capillaries in the lungs that are in close contact with the air that enters the lungs. The air in the lungs has a greater concentration of oxygen than the blood in the capillaries does, so oxygen diffuses from the lungs into the blood. At the same time, carbon dioxide diffuses in the opposite direction–from the blood into the airspace in the lungs. Oxygenated blood, which is now bright red, flows to the left atrium of the heart to be pumped out to the body.

To the body and back The left atrium fills with oxygenated blood from the lungs, beginning the second loop. As shown in **Figure 6,** the blood then moves from the left atrium into the left ventricle. The left ventricle pumps the blood into the largest artery in the body called the aorta. Eventually, blood flows into the capillaries that branch throughout the body. Importantly, the capillaries are in close contact with body cells. Oxygen is released from the blood into the body cells by diffusion, and carbon dioxide moves from the cells to the blood by diffusion. The deoxygenated blood then flows back to the right atrium through veins.

MiniLab 1

Investigate Blood Pressure

MiniLab

How does blood pressure change in response to physical activity? Blood pressure changes from day to day and throughout the day. It is affected by physical, psychological, behavioral, and inherited factors.

Procedure

1. Read and complete the lab safety form.
2. Watch the instructor demonstrate how to safely measure blood pressure. Practice using a **blood-pressure cuff** to measure a partner's blood pressure. Refer to a **blood-pressure chart** to interpret the reading.
3. Predict how exercise will affect systolic and diastolic blood pressure.
4. Take the resting blood-pressure reading of one of your classmates.
5. Have the person whose blood pressure you took do a rhythmic exercise for one minute.
6. Take a second blood-pressure reading and compare it to the resting blood-pressure reading.

Analysis

1. **Identify** the experimental constants, the independent and dependent variables, and the control in your experiment.
2. **Conclude** whether your prediction was supported. Explain.

Blood Components

Blood is the fluid of life because it transports important substances throughout the body. Blood is made up of a liquid medium called plasma, red blood cells, platelets, and white blood cells.

Plasma The clear, yellowish fluid portion of blood is the **plasma.** More than 50 percent of blood is plasma. Ninety percent of plasma is water, and nearly 10 percent is dissolved materials. Plasma carries the broken-down products of digested food, such as glucose and fats. Plasma also transports vitamins, minerals, and chemical messengers including hormones that signal body activities, such as the uptake of glucose by the cells. In addition, waste products from the cells are carried away by plasma.

There are three groups of plasma proteins that give plasma its yellow color. One group helps to regulate the amount of water in blood. The second group, produced by white blood cells, helps fight disease. The third group helps to form blood clots.

Reading Check **Explain** the functions of plasma.

Red blood cells The **red blood cells** carry oxygen to all of the body's cells. Red blood cells resemble discs with pinched-in centers, as shown in **Figure 7.** Recall that red blood cells develop in the marrow—the center portion of large bones. Red blood cells have no nuclei and live for only about 120 days.

Red blood cells mostly consist of an iron-containing protein called hemoglobin. Hemoglobin chemically binds with oxygen molecules and carries oxygen to the body's cells.

Platelets Have you ever cut your finger? If so, you probably noticed that in a short while, the blood flowing from the cut slowed down and then stopped as a blood clot formed a scab. **Platelets** are cell fragments, shown in **Figure 7,** that are important in forming blood clots.

When a blood vessel is cut, platelets collect and stick to the vessel at the site of the wound. The platelets then release chemicals that produce a protein called fibrin. Fibrin weaves a network of fibers across the cut that traps blood platelets and red blood cells, as shown in **Figure 8.** As more and more platelets and blood cells are trapped, a blood clot forms.

Color-Enhanced SEM Magnification: 3200×

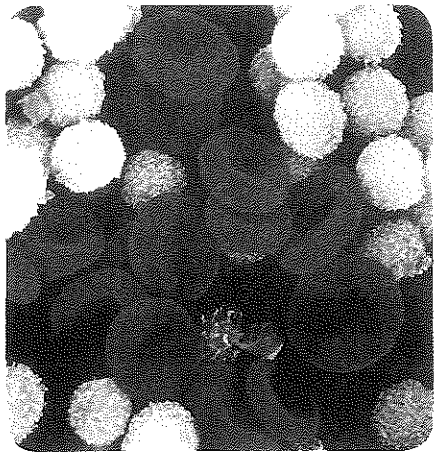
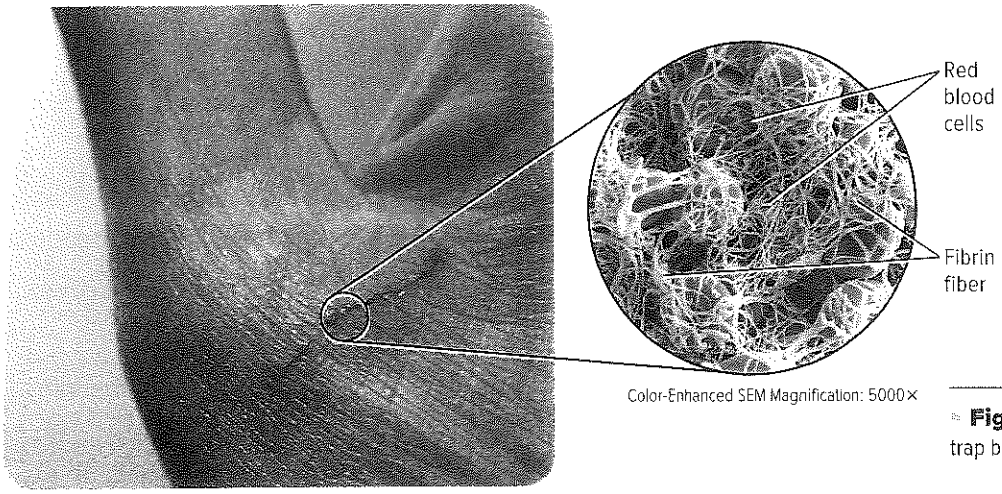


Figure 7 Blood is composed of liquid plasma, red blood cells (dimpled discs), white blood cells (irregularly shaped cells), and platelets (flat fragments).
Infer ***What might be occurring if there are too many white blood cells?***



Color-Enhanced SEM Magnification: 5000×

Figure 8 A scab forms as fibrin threads trap blood cells and platelets.

(t)Stem Jems/Photo Researchers; (b)Lauren Shear/Photo Researchers; (br) STEVE GSCHMEISSNER/Science Photo Library RF/Getty Images

Study Tip

Graphic Organizer Make a word map with the word *blood* in a large circle in the middle. Place the words *components, blood groups, circulation,* and *heart* in smaller circles around the large circle. Find information you learned in the chapter and add it to the appropriate smaller circles.

Personal Tutor

FOLDABLES

Incorporate information from this section into your Foldable.

White blood cells The body's disease fighters are the **white blood cells.** Like red blood cells, white blood cells are produced in bone marrow. Some white blood cells recognize disease-causing organisms, such as bacteria, and alert the body that it has been invaded. Other white blood cells produce chemicals to fight the invaders. Still, other white blood cells surround and kill the invaders.

White blood cells are different from red blood cells in important ways. Many white blood cells move from the marrow to other sites in the body to mature. Unlike red blood cells, there are fewer white blood cells–only about one white blood cell for every 500 to 1000 red blood cells. Also, white blood cells have nuclei. Finally, most white blood cells live for months or years.

Blood Groups

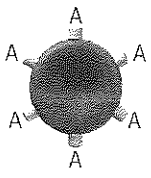
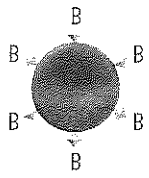
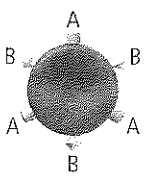
How do you know what type of blood you have? There are marker molecules attached to red blood cells. These markers are called blood groups, which determine blood type.

ABO blood group There are four types of blood: A, B, AB, and O. If your blood type is A, you have A markers on your blood cells. If your blood type is B, you have B markers on your blood cells. If your blood type is AB, you have both A and B markers. If your blood type is O, you do not have A or B markers.

Importance of blood type If you ever need a blood transfusion, you will be able to receive only certain blood types, as shown in **Table 1.** This is because plasma contains proteins called antibodies that recognize red blood cells with foreign markers and cause those cells to clump together. For example, if you have blood type B, your blood contains antibodies that cause cells with A markers to clump. If you received a transfusion of type-A blood, your clumping proteins would make the type-A cells clump together. Clumping of blood cells can be dangerous because it can block blood flow.

Table 1 Blood Types

Interactive Table

Blood type	A	B	AB	O
Marker molecule and antibody	Marker molecule: A Antibody: anti-B	Marker molecules: B Antibody: anti-A	Marker molecules: AB Antibody: none	Marker molecules: none Antibodies: anti-A, anti-B
Example				
Can donate blood to:	A or AB	B or AB	AB	A, B, AB, or O
Can receive blood from:	A or O	B or O	A, B, AB, or O	O

Rh blood group Another marker found on the surface of red blood cells is called the Rh factor. A person with A positive blood has A markers and Rh markers on their blood cells. The Rh marker can cause a problem when an Rh-negative person, someone without the Rh factor, receives a transfusion of Rh-positive blood that has the Rh marker. This can result in clumping of red blood cells, because Rh-negative blood contains Rh antibodies against Rh-positive cells.

The Rh factor can cause complications during some pregnancies. If the Rh-positive blood of a fetus mixes with the mother's Rh-negative blood, the mother will make anti-Rh antibodies. If the mother becomes pregnant again, these antibodies can cross the placenta and can destroy red blood cells if the fetus has Rh-positive blood. Rh-negative mothers are given a substance that prevents the production of Rh antibodies in the blood so that these problems can be avoided.

Circulatory System Disorders

Several disorders of the blood vessels, heart, and brain are associated with the circulatory system. Blood clots and other matter, such as fat deposits, can reduce the flow of oxygen-rich and nutrient-rich blood traveling through arteries. Physicians refer to the condition of blocked arteries as **atherosclerosis** (a thuh roh skluh ROH sus). When blood flow is reduced or blocked, the heart must work even harder to pump blood, and vessels can burst.

Atherosclerosis can lead to a heart attack or stroke. A heart attack occurs when blood does not reach the heart muscle. This can result in damage to the heart, and can even result in death if not treated. A stroke occurs when clots form in the blood vessels that supply oxygen to the brain. This can lead to ruptured blood vessels and internal bleeding, as shown in **Figure 9.** Parts of the brain die because brain cells are deprived of oxygen.

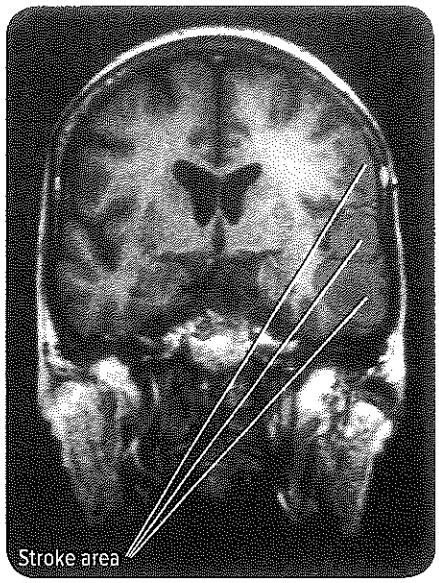


Figure 9 A stroke is associated with ruptured blood vessels in the brain, as shown in red.

Section 1 Assessment

Section Summary

- Blood vessels transport important substances throughout the body.
- The top half of the heart is made up of two atria, and the bottom half is made up of two ventricles.
- The heart pumps deoxygenated blood to the lungs, and it pumps oxygenated blood to the body.
- Blood is made up of plasma, red blood cells, white blood cells, and platelets.
- Blood is classified by the following four blood types: A, B, AB, and O.

Understand Main Ideas

1. MAIN Idea **Explain** the main functions of the circulatory system.
2. **Diagram** the path of blood through the heart and body.
3. **Compare and contrast** the structure of arteries and the structure of veins.
4. **Calculate** the average number of red blood cells for every 100 white blood cells in the human body.
5. **Summarize** the functions of the four components of blood.

Think Critically

6. **Cause and Effect** If a pacemaker received faulty signals from the brain, what would happen?
7. **Hypothesize** why exercise helps to maintain a healthy heart.

MATH in Biology

8. Count the number of times your heart beats during 15 seconds. What is your heart rate per minute?

Online Quiz

Section 2

Reading Preview

Essential Questions

- What is the difference between internal and external respiration?
- What is the path of the air through the respiratory system?
- What changes occur in the body during breathing?

Review Vocabulary

ATP: biological molecule that provides the body's cells with chemical energy

New Vocabulary

breathing
external respiration
internal respiration
trachea
bronchus
lung
alveolus

Multilingual eGlossary

BrainPOP

Respiratory System

Key Idea The function of the respiratory system is the exchange of oxygen and carbon dioxide between the atmosphere and the blood and between the blood and the body's cells.

Real-World Reading Link Air filters separate dust and other particles from the air before they enter a car's engine. This prevents engine problems and helps ensure good air flow. Similarly, your respiratory system has features that ensure that enough clean air gets into your lungs.

The Importance of Respiration

Your body's cells require oxygen. Recall that oxygen and glucose are used by cells to produce energy-rich ATP molecules needed to maintain cellular metabolism. This process is called cellular respiration. In addition to releasing energy, cellular respiration releases carbon dioxide and water.

Breathing and respiration The respiratory system sustains cellular respiration by supplying oxygen to body cells and removing carbon dioxide waste from cells. The respiratory system can be divided into two processes: breathing and respiration. First, air must enter the body through breathing. **Breathing** is the mechanical movement of air into and out of your lungs. **Figure 10** illustrates air being released from the lungs into the air. Second, gases are exchanged in the body. **External respiration** is the exchange of gases between the atmosphere and the blood, which occurs in the lungs. **Internal respiration** is the exchange of gases between the blood and the body's cells.

Lauri Rotko/Folio Images/Getty Images

Figure 10 Exhaled air from a person's lungs can be seen on a chilly evening.
Infer *how the air that you inhale is different from the air that you exhale.*

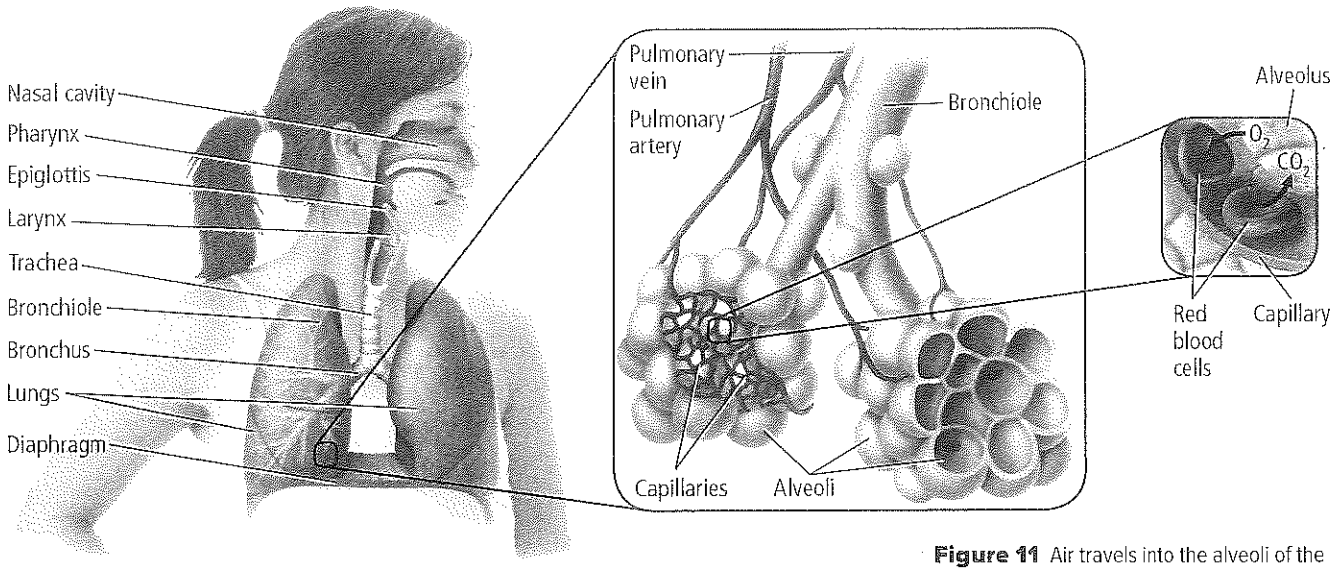


Figure 11 Air travels into the alveoli of the lungs, where gases are exchanged across thin capillary walls.
Diagram ***Trace the path of oxygen from the atmosphere to the alveoli in the lungs.***

The Path of Air

The respiratory system is made up of the nasal passages, pharynx (FER ingks), larynx (LER ingks) or voice box, epiglottis, trachea, lungs, bronchi, bronchioles, alveoli (al VEE uh li), and diaphragm. Air travels from the outside environment to the lungs, where it passes through the alveoli, as shown in **Figure 11.**

First, air enters the mouth or nose. Hairs in the nose filter out dust and other large particles in the air. Hairlike structures called cilia, shown in **Figure 12,** also line the nasal passages, as well as other respiratory tubes. Cilia trap foreign particles from the air and sweep them toward the throat so that they do not enter the lungs. Mucous membranes beneath the cilia in the nasal passages, also shown in **Figure 12,** warm and moisten the air while trapping foreign materials.

Filtered air then passes through the upper throat, called the pharynx. A flap of tissue called the epiglottis, which covers the opening to the larynx, prevents food particles from entering the respiratory tubes. The epiglottis allows air to pass from the larynx to a long tube in the chest cavity called the **trachea,** or windpipe. The trachea branches into two large tubes, called **bronchi** (BRAHN ki) (singular, bronchus), which lead to the lungs. The **lungs** are the largest organs in the respiratory system, and gas exchange takes place in the lungs. Each bronchus branches into smaller tubes called bronchioles (BRAHN kee ohlz), which continue to branch into even smaller passageways. Each of these ends in an individual air sac called an **alveolus** (plural, alveoli). Each alveolus has a thin wall–only one cell thick–and is surrounded by very thin capillaries.

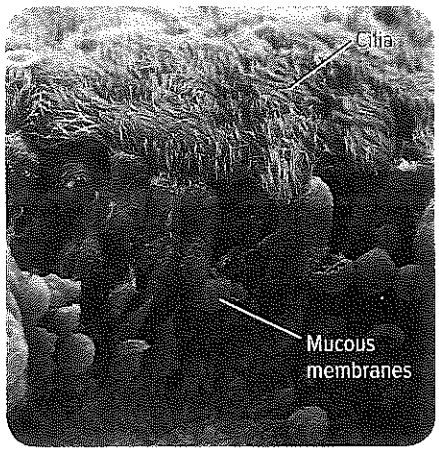
Gas exchange in the lungs Air travels to individual alveoli, where oxygen diffuses across the moist, thin walls into capillaries and then into red blood cells. The oxygen is then transported to be released to tissue cells in the body during internal respiration. Meanwhile, carbon dioxide in the blood crosses capillary walls and diffuses into the alveoli to be returned to the atmosphere during external respiration. Carbon dioxide in the blood is found as carbonic acid in the red blood cells, dissolved in plasma, and bound to hemoglobin in plasma.

VOCABULARY

Word Origin

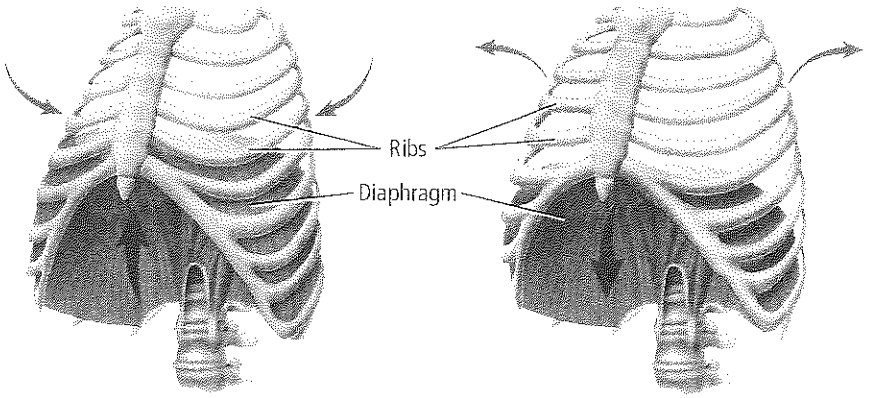
Alveolus
comes from the Latin word *alveus,* meaning *belly* or *hollow space*

Figure 12 Hairlike cilia line the mucous membranes of the nasal cavity.



Color-Enhanced SEM Magnification: 2000×

Figure 13 Rib and diaphragm muscles contract and relax during breathing.
Analyze how air pressure is involved in breathing.



Breathing

The brain directs the rate of breathing by responding to internal stimuli that indicate how much oxygen the body needs. When the concentration of carbon dioxide in the blood is high, the breathing rate increases because cells need more oxygen.

Inhalation is the act of taking air into the lungs. During inhalation, as shown in **Figure 13,** the diaphragm contracts. This causes the chest cavity to expand as the diaphragm moves down, allowing air to move into the lungs. During exhalation, the diaphragm relaxes and returns to its normal resting position. This reduces the size of the chest cavity as the diaphragm moves up. Air naturally flows out from the greater pressure of the lungs. Follow **Figure 14** to learn how circulation and respiration work together to supply the needed oxygen and to get rid of carbon dioxide.

Launch Lab

Review Based on what you've read about respiration, how would you now answer the analysis questions?

MiniLab 2

Recognize Cause and Effect

MiniLab

Does exercise affect metabolism? Most of the chemical reactions that occur in your cells make up your metabolism. In this lab, you will explore how exercise affects the circulatory and respiratory systems and infer how this affects metabolism.

Procedure

1. Read and complete the lab safety form.
2. Record the number of heartbeats and number of breaths per minute for ten classmates.
3. Instruct the same students to walk in place for five minutes. At the end of that time, record each person's heartbeat per minute and the number of breaths per minute.
4. After students have rested for five minutes, instruct them to jog or walk briskly in place for five minutes. Then record each person's heartbeat per minute and the number of breaths per minute.
5. Plot your results on **graph paper.** Each coordinate point should indicate breaths per minute on the horizontal axis and heartbeats per minute on the vertical axis.

Analysis

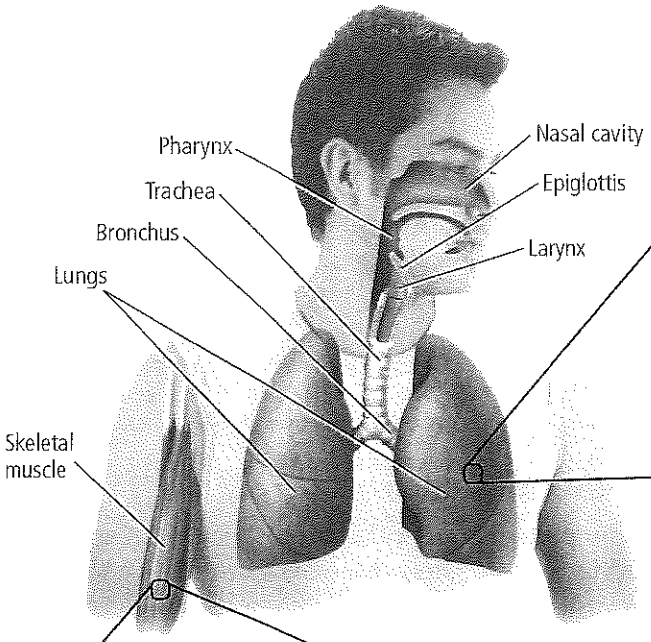
1. **Interpret** the relationship between the two dependent variables of your experiment—heart rate and breathing rate.
2. **Conclude** whether exercise affects metabolism. Why?
3. **Hypothesize** why students might have different numbers of heartbeats per minute and breaths per minute even though they all walked or jogged for the same amount of time.

Visualizing Gas Exchange

Figure 14

Gases are exchanged in the lungs and in the tissue cells of the body.

In the lungs, oxygen (O_2) that is inhaled moves into capillaries and is transported to body cells. Carbon dioxide (CO_2) leaves the capillaries and is exhaled from the lungs.



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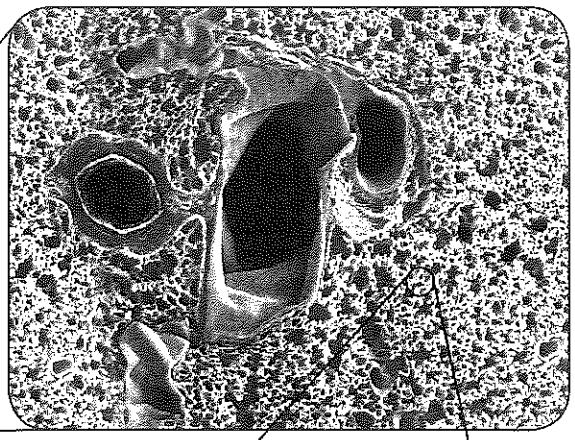

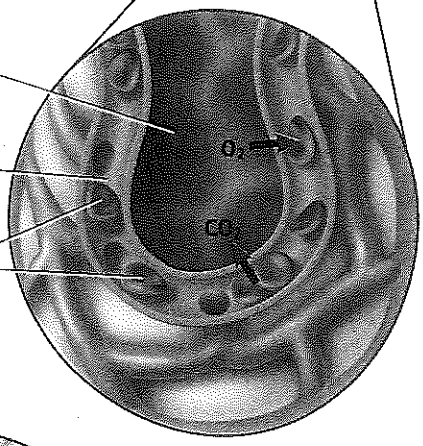

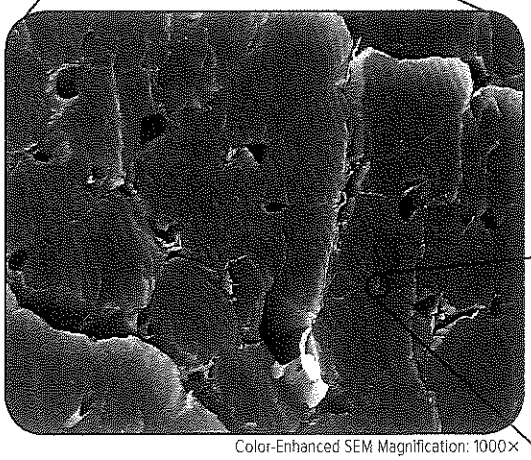

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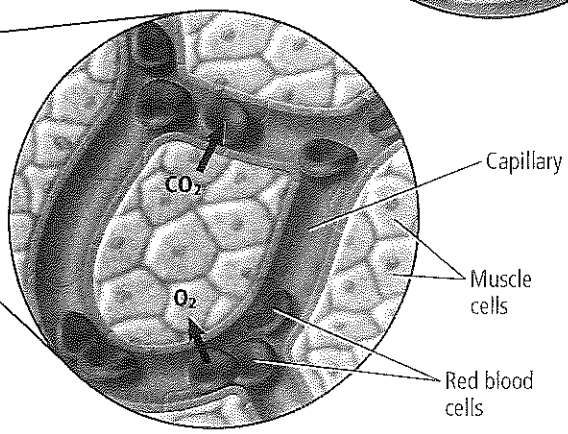


In body tissues, such as muscle tissues, oxygen (O_2) moves from capillaries into tissue cells. Carbon dioxide (CO_2) produced by cellular respiration leaves tissue cells and moves into capillaries, and then it is transported to the lungs.

Animation

(l)Steve Gschmeissner/Photo Researchers; (r)Dr. Keith Wheeler/Science Source

Table 2 Common Respiratory Disorders

Interactive Table

Lung Disorder	Brief Description
Asthma	Respiratory pathways become irritated, and bronchioles constrict.
Bronchitis	Respiratory pathways become infected, resulting in coughing and production of mucus.
Emphysema	Alveoli break down, resulting in reduced surface area needed for gas exchange with the alveoli's blood capillaries.
Pneumonia	Infection of the lungs causes the alveoli to collect mucous material.
Pulmonary tuberculosis	A specific bacterium infects the lungs, resulting in less elasticity of the blood capillaries surrounding the alveoli, thus decreasing effective gas exchange between the air and blood.
Lung cancer	Uncontrolled cell growth in lung tissue can lead to a persistent cough, shortness of breath, bronchitis, or pneumonia, and can lead to death.

Respiratory Disorders

Some diseases and disorders irritate, inflame, or infect the respiratory system, as described in **Table 2.** These disorders can produce tissue damage that reduces the effectiveness of the bronchi and alveoli. When these tissues become damaged, respiration becomes difficult. Smoking also causes chronic irritation to respiratory tissues and inhibits cellular metabolism. Finally, exposure to airborne materials, such as pollen, can produce respiratory problems in some people who have allergic reactions.

Section 2 Assessment

Section Summary

- Alveoli in the lungs are the sites of gas exchange between the respiratory and circulatory systems.
- The pathway of air starts with the mouth or nose and ends at the alveoli located in the lungs.
- Inhalation and exhalation are the processes of taking in and expelling air.
- Respiratory disorders can inhibit respiration.

Understand Main Ideas

1. **Identify** the main function of the respiratory system.
2. **Distinguish** between internal and external respiration.
3. **Sequence** the path of air from the nasal passages to the bloodstream.
4. **Describe** the mechanics of inhalation and exhalation.
5. **Infer** how the respiratory system would compensate for a circulatory disorder.
6. **Describe** three disorders of the respiratory system.

Think Critically

7. **Hypothesize** an advantage of heating and moisturizing air before it reaches the alveoli.

MATH in Biology

8. The total surface area of the alveoli tissue in your lungs is approximately 70 m^2. This is more than 40 times the surface area of the skin. What is the surface area of your skin?

Online Quiz

Section 3

Reading Preview

Essential Questions

- What is the function of the kidney in the body?
- What are the steps of the excretion of wastes from the Bowman's capsule to the urethra?
- What is the difference between filtration and reabsorption in the kidneys?

Review Vocabulary

pH: the measure of acidity or alkalinity of a solution

New Vocabulary

kidney
urea

Multilingual eGlossary

Excretory System

MAIN IDEA **The kidneys maintain homeostasis by removing wastes and excess water from the body and by maintaining the pH of blood.**

Real-World Reading Link Suppose that you cleaned your bedroom by first moving everything except large items into the hallway. You then return only the items that you will keep in your bedroom and leave the items that you do not want any longer in the hallway for later disposal. This is similar to how your kidneys filter materials in your blood.

Parts of the Excretory System

The body collects wastes, such as toxins, waste products, and carbon dioxide, that result from metabolic functions of the body. The excretory system removes these toxins and wastes from the body. In addition, the excretory system regulates the amount of fluid and salts in the body, and it maintains the pH of the blood. All of these functions help to maintain homeostasis.

The components that make up the excretory system include the lungs, skin, and kidneys, as illustrated in **Figure 15.** The lungs primarily excrete carbon dioxide. The skin primarily excretes water and salts contained in sweat. The kidneys, however, are the major excretory organs in the body.

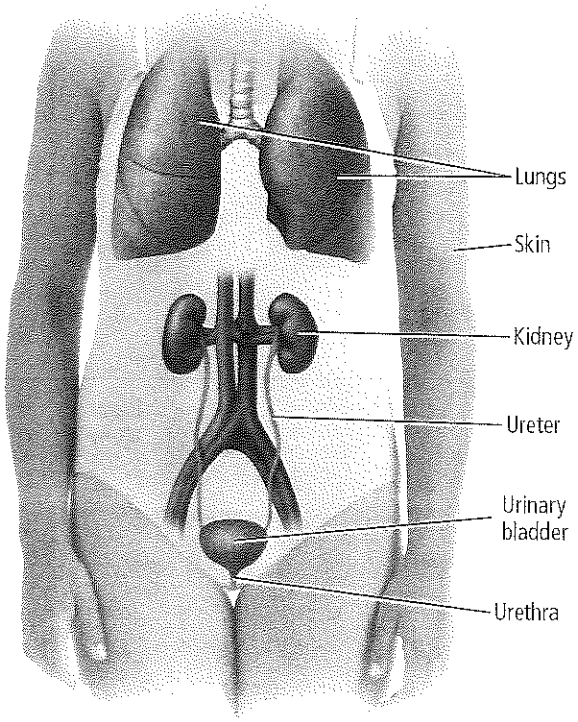


Figure 15 The organs of excretion work together to eliminate wastes from the body. These organs include the lungs, skin, and kidneys.

Tim Fuller

The Kidneys

As shown in **Figure 16**, the **kidneys** are bean-shaped organs that filter out wastes, water, and salts from the blood. The kidneys are divided into two distinct regions, also illustrated in **Figure 16.** The outer portion is called the renal cortex and the inner region is called the renal medulla. Each of these regions contains microscopic tubes and blood vessels. In the center of each kidney is a region called the renal pelvis, where urine collection occurs. Follow **Figure 16** as you read about how the kidneys function.

Nephron filtration Each kidney contains approximately one million filtering units called nephrons. Blood enters each nephron through a long tube that is surrounded by a ball of capillaries called the glomerulus (gluh MER uh lus) (plural, glomeruli). The glomerulus is surrounded by a structure called the Bowman's capsule.

The renal artery transports nutrients and wastes to the kidney and branches into smaller and smaller blood vessels, eventually reaching the tiny capillaries in the glomerulus. The walls of the capillaries are very thin, and the blood is under great pressure. As a result, water and substances dissolved in the water, such as the nitrogenous waste product called **urea,** are pushed through the capillary walls into the Bowman's capsule. Larger molecules, such as red blood cells and proteins, remain in the bloodstream.

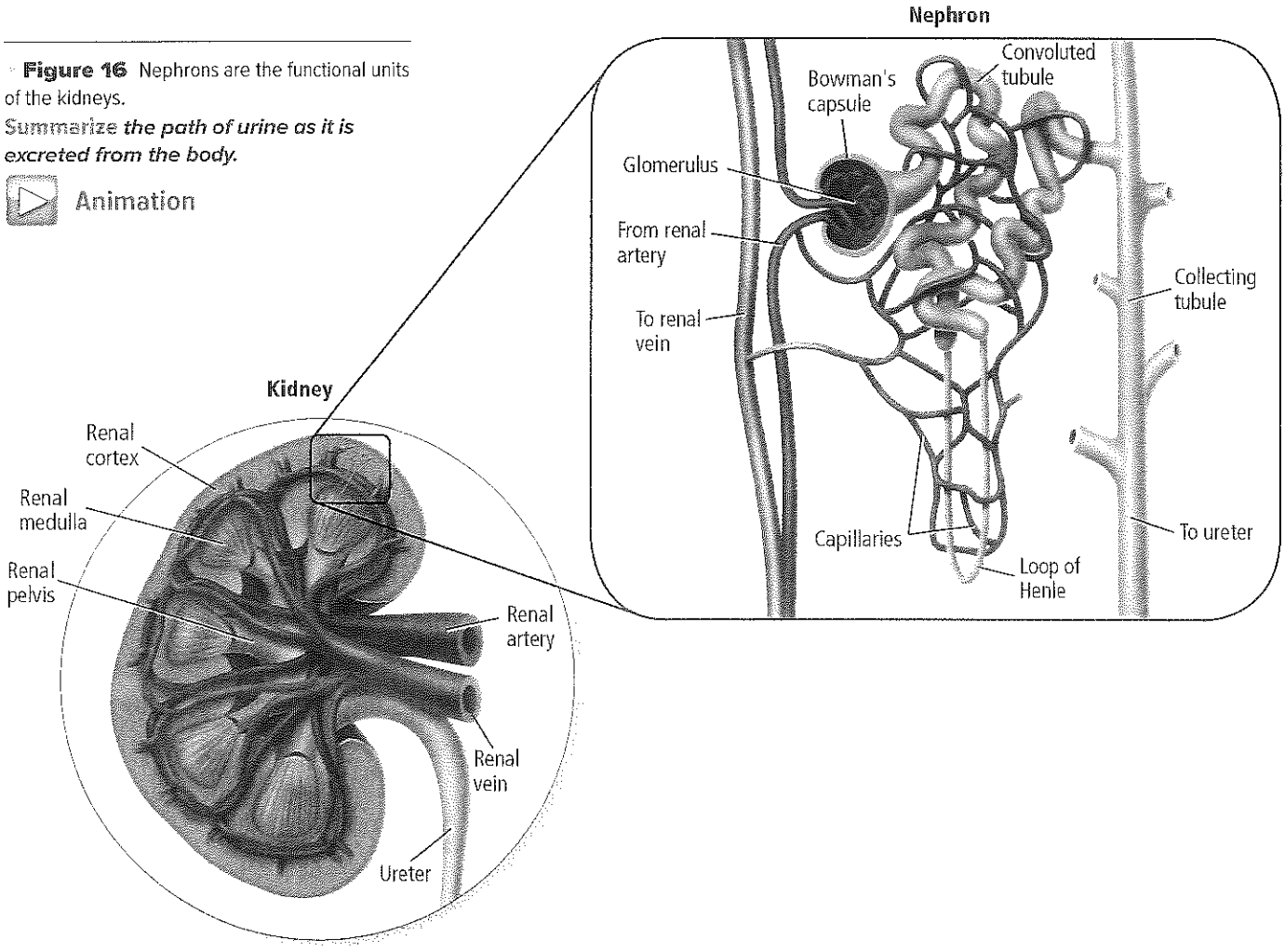


Figure 16 Nephrons are the functional units of the kidneys.
Summarize the path of urine as it is excreted from the body.

Animation

Reabsorption and the formation of urine The filtrate collected in the Bowman's capsule flows through the renal tubule, which consists of the convoluted tubule, the loop of Henle, and the collecting tubule, as illustrated in **Figure 16.** Much of the lost water and useful substances, such as glucose and minerals, are reabsorbed into the capillaries surrounding the renal tubule. This process is called reabsorption. At the same time, excess fluids and toxic substances in the capillaries are passed to the collecting tubules. This waste product is called urine. Urine leaves the kidney through ducts called the ureters (YOO ruh turz), as shown in **Figure 16.** Urine is then stored in the urinary bladder and exits the body through the urethra.

The kidneys filter about 180 L of blood each day in adults but produce only about 1.5 L of urine. The processes of filtration and reabsorption from the blood require large amounts of energy. Although kidneys account for only one percent of body weight, they use 20 to 25 percent of the body's oxygen intake for their internal energy requirements.

Connection to Chemistry The kidneys can help maintain a normal pH in the blood by adjusting the acid-base balance. Recall that low pH results when there is an abundance of H^+. When the blood pH is too low, the kidneys can increase pH levels in the body by excreting hydrogen (H^+) ions and ammonia into the renal tubules. The kidneys can decrease pH levels by reabsorbing buffers such as bicarbonate (HCO_3^+) and sodium (Na^+) ions. Because biological processes normally require pH between 6.5 and 7.5, the kidneys help to maintain homeostasis by keeping pH levels within the normal range.

CAREERS IN BIOLOGY

Urologist A urologist is a medical doctor who has specialized knowledge about problems of the male and female urinary systems. Responsibilities can include examining patients, performing laboratory tests, interpreting test results and examination findings, and treating injuries and disorders.

DATA ANALYSIS LAB 1

Based On Real Data*

Interpret the Data

How do extreme conditions affect the average daily loss of water in the human body? The body obtains water by absorbing it through the digestive tract. The body loses water primarily by excreting it in urine from the kidneys, through sweat, and through the lungs.

Think Critically

1. **Identify** what the major source of water loss is during normal temperatures.
2. **Hypothesize** why more water is lost in sweat during rigorous exercise than in urine.
3. **Calculate** the percent of water loss for each of the three conditions.

Data and Observations

The table shows data collected for normal temperatures, for high temperatures, and during rigorous exercise.

Average Daily Water Loss in Humans (in mL)

Source	Normal Temperatures	High Temperatures	Rigorous Exercise
Kidneys	1500	1400	750
Skin	450	1800	5000
Lungs	450	350	650

*Data obtained from: Beers, M. 2003. *The Merck Manual of Medical Information, Second Edition* West Point, PA.: Merck & Co. Inc.

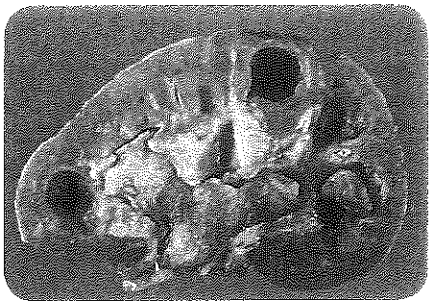


Figure 17 Kidney stones form as minerals, such as calcium, become solid masses.

Kidney Disorders

Sometimes kidney function can be inhibited or impaired by infections or disorders. When kidney function is impaired, the body cannot rid itself of wastes and homeostasis might be disrupted.

Infections Symptoms of a kidney infection include fever, chills, and mid- to low-back pain. Kidney infections often start as urinary bladder infections that spread to the kidneys. Obstructions in the kidneys also can cause an infection. If the infection is not treated, the kidneys can become scarred and their function might be permanently impaired. Antibiotics usually are effective in treating bacterial infections.

Nephritis Another common kidney problem is nephritis (nih FRIH tus), which often is caused by inflammation or painful swelling of some of the glomeruli, as listed in **Table 3.** This occurs for many reasons, such as when large particles in the bloodstream become lodged in some of the glomeruli. Symptoms of this condition include blood in the urine, swelling of body tissues, and protein in the urine. If this condition does not improve on its own, the patient may need a special diet or prescription drugs to treat the infection.

VOCABULARY

Inhibit
to hold back, restrain, or block the action or function of something
The concentration of the protein in the blood inhibited the organ from producing more of the same protein.

Kidney stones Kidney stones are another type of kidney disorder, as listed in **Table 3** and shown in **Figure 17.** A kidney stone is a crystallized solid, such as calcium compounds, that forms in the kidney. Small stones can pass out of the body in urine; this can be quite painful. Larger stones often are broken into small pieces by ultrasonic sound waves. The smaller stones then can pass out of the body. In some cases, surgery might be required to remove large stones.

Kidneys also can be damaged by other diseases present in the body. Diabetes and high blood pressure are the two most common reasons for reduced kidney function and kidney failure. In addition, kidneys can be damaged by prescription and illegal drug use.

Table 3 Common Excretory Disorders — Interactive Table

Excretory Disorder	Brief Description
Nephritis	Inflammation of the glomeruli can lead to inflammation of the entire kidneys. This disorder can lead to kidney failure if it is left untreated.
Kidney stones	Hard deposits form in the kidneys that might pass out of the body in urine. Larger kidney stones can block urine flow or irritate the lining of the urinary tract, leading to possible infection.
Urinary tract blockage	Malformations present at birth can lead to blockage of the normal flow of urine. If it is untreated, this blockage can lead to permanent damage of the kidneys.
Polycystic (pah lee SIHS tihk) kidney disease	This is a genetic disorder distinguished by the growth of many fluid-filled cysts in the kidneys. This disorder can reduce kidney function and lead to kidney failure.
Kidney cancer	Uncontrolled cell growth often begins in the cells that line the tubules within the kidneys. This can lead to blood in the urine or a mass in the kidneys, or it can affect other organs as the cancer spreads, which can lead to death.

Dr E. Walker/Photo Researchers

Kidney Treatments

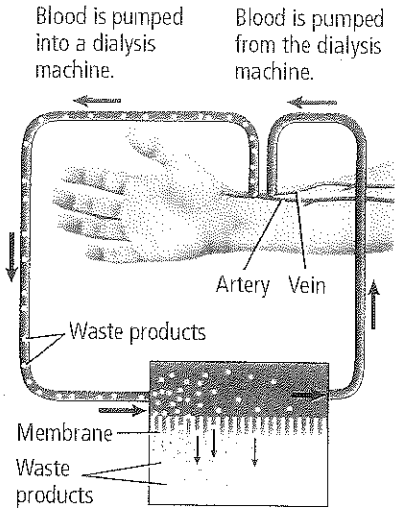
A large percentage of kidney function can be lost before kidney failure becomes apparent. If kidney problems are left untreated, the buildup of waste products in the body can lead to seizures, a comatose state, or death. However, modern medicine offers two possible treatments for reduced kidney function or complete kidney failure.

Dialysis Dialysis (di AH luh sus) is a procedure in which an artificial kidney machine filters out wastes and toxins from a patient's blood. There are two different types of dialysis, one of which is illustrated in **Figure 18.** Blood is passed through a machine that temporarily filters and cleanses the blood. The filtered blood is then returned to the patient's body. The procedure lasts about three to four hours and requires three sessions per week.

In the second type of dialysis, the membrane lining the abdomen acts as an artificial kidney. The abdominal cavity is injected with a special fluid through a small tube attached to the body. The patient's fluid, which contains wastes from the blood, is drained. This procedure is performed on a daily schedule for 30 to 40 minutes.

Kidney transplant A kidney transplant is the surgical placement of a healthy kidney from another person, called a donor, into the patient's body. Kidney transplants have shown increasing success in recent years. However, there is a limited supply of donated kidneys. The number of patients waiting for kidney transplants far exceeds the organs available for transplant.

The major complication of a transplant is possible rejection of the donated organ. Rejection is prevented with medications such as steroids and cyclosporine. Cyclosporine is a drug given to transplant recipients to help prevent organ rejection. Many transplant patients also need blood-pressure medication and other drugs to prevent infections.



In the dialysis machine, waste products are filtered from the blood through an artificial membrane.

Figure 18 Dialysis is used to filter wastes and toxins from a patient's blood.

Personal Tutor

Section 3 Assessment

Section Summary

- The kidneys are the main excretory organs in the body.
- Nephrons are independent filtration units in the kidneys.
- Water and important substances are reabsorbed into the blood after filtration.
- The kidneys produce a waste product called urine.

Understand Main Ideas

1. **MAIN IDEA** Explain how the kidneys help maintain homeostasis.
2. **Diagram** the excretion of waste from the Bowman's capsule to the urethra.
3. **Compare and contrast** filtration and reabsorption in a nephron.
4. **Identify** three types of kidney disorders.

Think Critically

5. **Hypothesize** why kidney failure without dialysis can result in death.

WRITING in Biology

6. Research the effects of a high-protein diet on the excretory system. Summarize your findings in a public service announcement.

MATH in Biology

7. Calculate the average amount of urine that the body produces in a week.

Online Quiz

CUTTING-EDGE BIOLOGY

ENGINEERING HEARTS

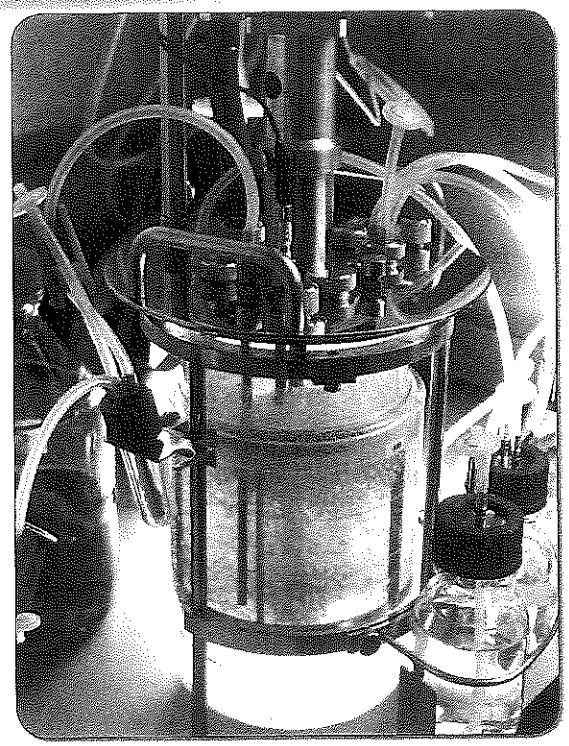
By Thomas Matthiesen, Tissue Engineer, Chicago, IL

Heart disease is a global killer—with over 22 million people affected worldwide. For many people with heart failure the only treatment option is to seek cardiac transplantation. However, because a there is a severe shortage of donor organs, most patients die waiting for a new heart.

Can science build organs? In the relatively new field of *Tissue Engineering* scientists are studying methods to generate new tissues in the lab by combining scaffolds and stem cells. Underlying nearly any biological tissue is a scaffold of proteins that forms the basis of its shape, structure, and support. This support scaffold is a major component of the *extracellular matrix* and allows for proper cell alignment and function. To-date, scientists have successfully engineered small vessels, hollow organs, and two-dimensional cardiac patches by stacking together plastics or polymer sheets to form a scaffold and coating them with cells.

In 2008, **Dr. Harald Ott** and colleagues published an article on how the extracellular matrix of a rat heart could be isolated by a process called *detergent perfusion decellularization*. This technique removes all cellular components from a cadaver organ, but keeps intact its natural vessel system and three-dimensional architecture. This vital network of vasculature (arteries and veins) can then be used to deliver nutrients to cells placed back into the matrix in a process called *recellularization*.

An important milestone On April 10, 2006, Ott and Matthiesen first observed that when they placed immature cardiac cells back into the extracellular matrix, and then delivered nutrients and a small electric charge, the recellularized heart began to beat! Using these biocompatible scaffolds gives the potential to use a patient's own stem cells and bioengineer a custom organ.



Bioreactors are used to grow human cells and tissues in the laboratory.

This means that a patient's immune system would not recognize the bioengineered organ as a foreign object and reject it.

Looking forward, tissue engineering offers hope, yet holds many mysteries. Cells, scaffolds, and special machines called *bioreactors*, shown above, must be optimized to allow scientists to develop this technology in years to come.

WRITING in Biology

Research Investigate donor organ shortages in the United States—especially heart. What is a donor organ wait list? Which organs can be harvested and transplanted? How could tissue engineering help solve some of the donor shortages?

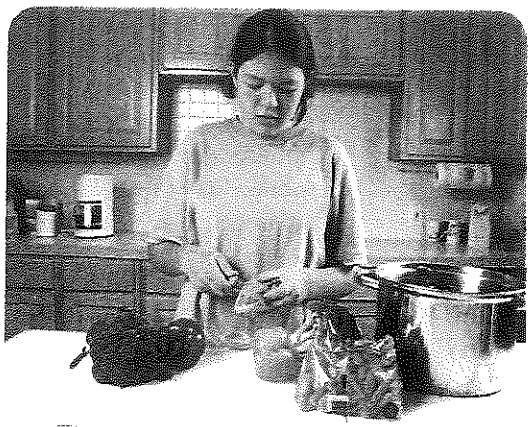
WebQuest

BIOLAB

INTERNET: MAKE POSITIVE HEALTH CHOICES

Background: **Both heredity and lifestyle choices affect overall health. Achieving optimal health involves making wise choices regarding exercise, nutrition, drugs and alcohol, stress management, and smoking. Because body systems function together to maintain homeostasis, changes in one system can impact overall health. In this lab, you will design a presentation that focuses on how specific health choices influence the functionality of body systems.**

Question: *How do lifestyle choices affect the function of the circulatory, respiratory, and excretory systems?*



Materials

Choose materials that would be appropriate for creating the type of presentation that you create.

Possible materials include:

resource materials about health choices from the school library or classroom

Procedure

1. Read and complete the lab safety form.
2. Develop an outline of information that you would like to include in your presentation. Include information about how specific health choices affect the respiratory, circulatory, and excretory systems.
3. Use resources and data that you collected in this chapter's labs to determine the effects of specific health choices on your body.
4. Choose a presentation medium. Ideas include a multimedia presentation, video, poster, or pamphlet. The medium you choose should appeal to a specific audience.
5. Share your presentation with your target audience. If this is not possible, share your presentation with your class or another group of people from your school.
6. Use the evaluation information provided by your teacher to evaluate the effectiveness of the presentation.

Analyze and Conclude

1. **Describe** What is the intended audience for your presentation? How did you modify the information included to target this audience?
2. **Summarize** Identify the key points of your presentation.
3. **Explain** How do the health choices you described affect multiple body systems?
4. **Evaluate** Do you think your presentation will influence the health choices of your target audience? Explain.
5. **Critique your presentation** How could you increase the effectiveness of your presentation?

COMMUNITY INVOLVEMENT

Create Choose one or more health-promoting behaviors from your presentation. Design a survey to gather data about the choices that members of your target audience make regarding this health-promoting behavior. If possible, use the Internet to distribute your survey to members of your community and gather data.

Chapter 34 Study Guide

THEME FOCUS Stability and Change The circulatory, respiratory, and excretory systems regulate the internal environment of the human body to maintain conditions needed for life.

BIG Idea These systems function together to maintain homeostasis by delivering important substances to the body's cells while removing wastes.

Section 1 Circulatory System

artery (p. 993)
capillary (p. 993)
vein (p. 994)
valve (p. 994)
heart (p. 994)
pacemaker (p. 995)
plasma (p. 997)
red blood cell (p. 997)
platelet (p. 997)
white blood cell (p. 998)
atherosclerosis (p. 999)

BIG Idea The circulatory system transports blood to deliver important substances, such as oxygen, to cells and to remove wastes, such as carbon dioxide.

- Blood vessels transport important substances throughout the body.
- The top half of the heart is made up of two atria, and the bottom half is made up of two ventricles.
- The heart pumps deoxygenated blood to the lungs, and it pumps oxygenated blood to the body.
- Blood is made up of plasma, red blood cells, white blood cells, and platelets.
- Blood is classified by the following four blood types: A, B, AB, and O.

Section 2 Respiratory System

breathing (p. 1000)
external respiration (p. 1000)
internal respiration (p. 1000)
trachea (p. 1001)
bronchus (p. 1001)
lung (p. 1001)
alveolus (p. 1001)

BIG Idea The function of the respiratory system is the exchange of oxygen and carbon dioxide between the atmosphere and the blood and between the blood and the body's cells.

- Alveoli in the lungs are the sites of gas exchange between the respiratory and circulatory systems.
- The pathway of air starts with the mouth or nose and ends at the alveoli located in the lungs.
- Inhalation and exhalation are the processes of taking in and expelling air.
- Respiratory disorders can inhibit respiration.

Section 3 Excretory System

kidney (p. 1006)
urea (p. 1006)

BIG Idea The kidneys maintain homeostasis by removing wastes and excess water from the body and by maintaining the pH of blood.

- The kidneys are the main excretory organs in the body.
- Nephrons are independent filtration units in the kidneys.
- Water and important substances are reabsorbed into the blood after filtration.
- The kidneys produce a waste product called urine.

Vocabulary eGames

Chapter 34 Assessment

Section 1

Vocabulary Review

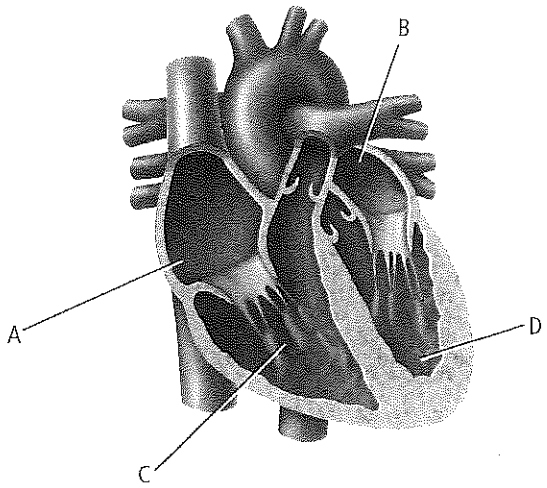
Match each of the following definitions with the correct vocabulary term from the Study Guide page.

1. a vessel carrying oxygen-rich blood
2. involved in blood vessel repair
3. stimulates the heart to contract

Understand Main Ideas

4. When blood leaves the heart, where does it exit?
   - **A.** the aorta
   - **B.** the capillaries
   - **C.** the lungs
   - **D.** the pulmonary vein

Use the diagram below to answer questions 5 and 6.



5. Which represents the right ventricle?
   - **A.** A
   - **B.** B
   - **C.** C
   - **D.** D

6. Into what part of the heart does oxygen-rich blood enter?
   - **A.** A
   - **B.** B
   - **C.** C
   - **D.** D

7. If a teenager with type A blood is injured in an auto accident and needs a blood transfusion, what type of blood will he or she receive?
   - **A.** only type A
   - **B.** type A or type O
   - **C.** only type AB
   - **D.** only type O

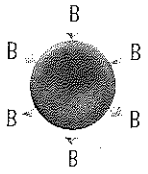
8. Where are one-way valves in the circulatory system located?
   - **A.** arteries
   - **B.** capillaries
   - **C.** veins
   - **D.** white blood cells

9. When a small blood vessel in your hand is cut open, which plays an active defensive role against possible disease?
   - **A.** plasma
   - **B.** platelets
   - **C.** red blood cells
   - **D.** white blood cells

Constructed Response

10. Differentiate between the function of the atria and the function of the ventricles.

Use the diagram to answer question 11.



11. **Short Answer** A person has the blood type represented above. What type of blood can the person receive in a transfusion? Explain.

Think Critically

12. **Hypothesize** an advantage of your heart containing two pumping systems within the same organ, rather than two separate pumping organs.
13. **Deduce** which ABO blood type–A, B, AB or O– is the most valuable to medical personnel in an extreme emergency situation and explain why.

Section 2

Vocabulary Review

Use the vocabulary terms from the Study Guide page to answer the following questions.

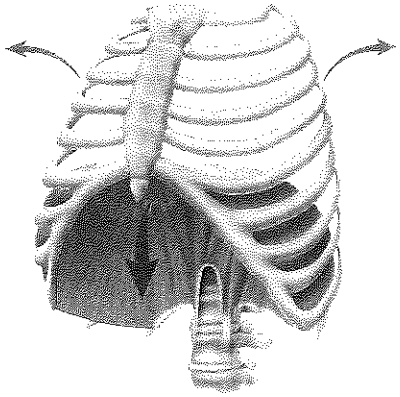
14. In what structure does external respiration take place?
15. Which term defines the exchange of gases between the blood and the body's cells?
16. Which part of the air pathway branches off the trachea?

Online Test Practice

Chapter 34 Assessment

Understand Main Ideas

Use the diagram below to answer questions 17 and 18.



17. Which process is shown above?
    A. inhalation
    B. exhalation
    C. cellular respiration
    D. filtration

18. Which structure moves down as its muscles contract?
    A. trachea
    B. diaphragm
    C. pharynx
    D. ribs

19. Which process occurs inside the tissue cells in your legs?
    A. filtration
    B. breathing
    C. external respiration
    D. internal respiration

20. Which process causes the diaphragm to move back up?
    A. cellular respiration
    B. exhalation
    C. inspiration
    D. internal respiration

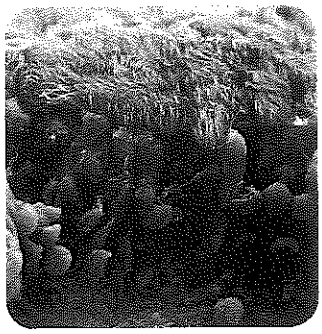
21. Which gas is needed by all cells?
    A. sulfur
    B. hydrogen
    C. carbon dioxide
    D. oxygen

22. How many breaths will a person take in one day if he or she takes 12 breaths per minute?
    A. about 1000
    B. about 10,000
    C. about 17,000
    D. about 1,000,000

Constructed Response

23. **Short Answer** Differentiate between asthma, bronchitis, and emphysema.

Use the photo below to answer question 24.



24. **Short Answer** Describe the function of the structures above. Where would these structures be found?

Think Critically

25. THINK Hypothesize an advantage in breathing more deeply during exercise compared to another person engaged in similar exercise breathing at a normal rate.

Section 3

Vocabulary Review

Review the vocabulary terms found on the Study Guide page. Use the terms to answer the following questions.

26. Where are nephrons located?

27. Which waste product is found in urine?

Understand Main Ideas

28. Where is the loop of Henle?
    A. renal tubule
    B. glomerulus
    C. Bowman's capsule
    D. urethra

29. THEME FOCUS Stability and Change Which one of the kidney functions conserves water in the body?
    A. absorption
    B. filtration
    C. reabsorption
    D. breathing

30. Which process returns glucose to the blood?
    A. excretion
    B. filtration
    C. reabsorption
    D. exhalation

Eye of Science/Photo Researchers

Online Test Practice

Use the table below to answer questions 31, 32, and 33.

Reabsorption of Some Substances in the Kidneys

Chemical substance	Amount Filtered by Kidneys (g/day)	Amount Excreted by Kidneys (g/day)	Percent of Filtered Chemical Reabsorbed (per day)
Glucose	180	0	100
Urea	46.8	23.4	50
Protein	1.8	1.8	0

31. Based on the data from the table above, how much urea is reabsorbed by the kidneys?
   - **A.** 0.50 g/day
   - **B.** 23.4 g/day
   - **C.** 46.8 g/day
   - **D.** 50.0 g/day

32. Based on the table data above, what happens to glucose in the kidneys?
   - **A.** It is reabsorbed into the blood.
   - **B.** It is permanently filtered out of the blood.
   - **C.** It is treated in the kidney like creatinine.
   - **D.** It is treated in the kidney like urea.

33. Infer why proteins are not removed by nephrons.
   - **A.** The collecting ducts are too small.
   - **B.** Proteins cannot be filtered.
   - **C.** Proteins never enter the nephron.
   - **D.** Proteins are reabsorbed by nephrons.

Constructed Response

34. **Short Answer** How many liters of blood flow through your kidneys in one hour?

35. BIG Idea Explain the differences between filtration and reabsorption in the kidneys.

36. **Open Ended** Infer why kidneys require so much energy to function.

Think Critically

37. CAREERS IN BIOLOGY Formulate a list of questions one might ask a a urologist regarding urinary problems.

Summative Assessment

38. BIG Idea What are the important substances that the circulatory and respiratory systems deliver to body cells? Why are these substances important? Give two examples of wastes that the excretory system removes from the body.

39. WRITING in Biology Construct an analogy about the circulatory system that is based on your local highway system in your town, city, or rural area.

Document-Based Questions

The following data compare the state of five subjects whose circulation was monitored. (The weight, age, and sex of all five subjects were the same.) All of Subject A's data were within normal limits; the other four were not.

Data obtained from: Macey, R. 1968. *Human Physiology.* Englewood Cliffs, NJ: Prentice Hall.

Subject	Hemoglobin (Hb) content of blood (Hb/100 mL blood)	Oxygen contents of blood in arteries (mL O_2/100 mL blood)	Oxygen content of blood in veins (mL O_2/100 mL blood)
A	15	19	15
B	15	15	12
C	8	9.5	6.5
D	16	20	13
E	15	19	18

40. Which subject might be suffering from a dietary iron deficiency? Explain your choice.

41. Which subject might have lived at a high altitude where the atmospheric oxygen is low? Explain your choice.

42. Which subject might have been poisoned by carbon monoxide that prevents tissue cells from using oxygen? Explain your choice.

Online Test Practice

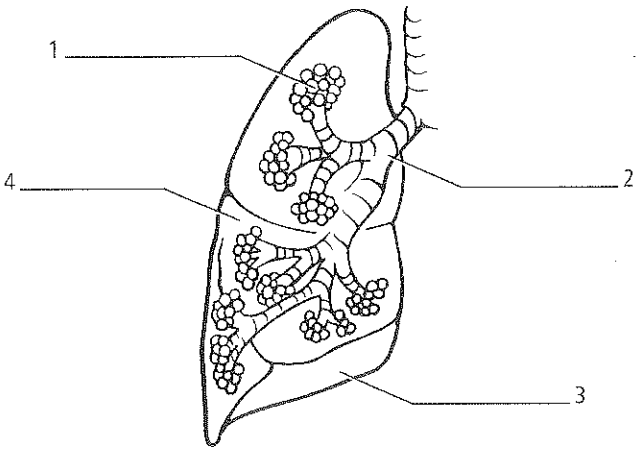
Standardized Test Practice

Cumulative

Multiple Choice

1. What happens to a skeletal muscle when the actin fibers are pulled toward the center of the sarcomeres?
   - A. It contracts.
   - B. It grows.
   - C. It relaxes.
   - D. It stretches.

Use the diagram to answer questions 2 and 3.



2. Which part of the respiratory system has hairs to filter particles from the air?
   - A. 1
   - B. 2
   - C. 3
   - D. 4

3. In which numbered location does gas exchange take place?
   - A. 1
   - B. 2
   - C. 3
   - D. 4

4. Which is an example of operant conditioning?
   - A. A dog salivates when it hears a bell.
   - B. A horse becomes accustomed to street noises.
   - C. A newborn forms an attachment to the first animal seen after birth.
   - D. A rat learns that it can get food by pulling a lever.

5. Which is an example of nurturing behavior?
   - A. An animal in a colony spots a predator and warns the whole colony.
   - B. A female chimpanzee takes care of her infant for three years.
   - C. A male peacock displays its feathers in front of a female.
   - D. A squirrel chatters at another squirrel to drive it away.

Use the table below to answer question 6.

Muscle Type	Function
Skeletal muscles	attached to bones and tighten when contracted causing movement
Smooth muscles	line the hollow internal organs such as stomach, intestines, bladder, and uterus
Cardiac muscles	

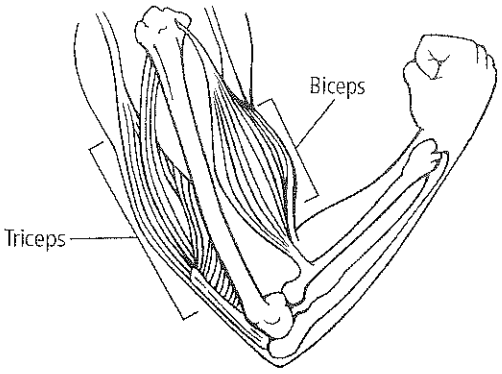
6. Where is the muscle type that is missing a description in the table located?
   - A. in the heart
   - B. in the kidneys
   - C. lining the blood vessels
   - D. lining the lymph vessels

7. Which answer choice is a result of parasympathetic stimulation?
   - A. decreased heart rate
   - B. decreased mucus production
   - C. increased digestive activity
   - D. increased pupil size

8. Which characteristic directly affects homeostatic temperature control in mammals?
   - A. four-chambered heart
   - B. high metabolic rate
   - C. milk production
   - D. signaling devices in fur

Short Answer

Use the diagram below to answer questions 9 and 10.



9. Describe how the biceps and triceps allow movement in the arm.

10. Explain why muscles are always in antagonistic pairs.

11. Some drugs cause an increased level of dopamine in nerve synapses. Name one of these drugs and relate the increased dopamine level to other effects that result from using the drug.

12. Use a table to organize information about the autonomic and somatic nervous systems. List the types of responses, systems affected, and include an example.

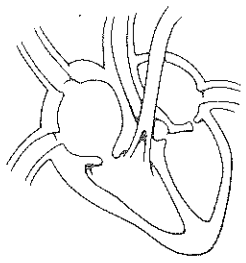
13. Monotremes are mammals that are similar to reptiles in some ways. Classify monotreme characteristics as similar to reptiles or similar to mammals.

14. A rare disease called amyotrophic lateral sclerosis (ALS) causes motor neurons in the body to lose myelin. What do you think would be the initial symptoms a person with ALS would have?

15. Explain how nephrons filter blood.

Extended Response

Use the illustration below to answer question 16.



16. The illustration above shows a four-chambered mammalian heart. Write an explanation of the role of the four-chambered heart in circulating oxygenated blood throughout the body.

17. Compare and contrast apical meristems and lateral meristems in plants.

18. The invention of the microscope allowed scientists to discover hundreds of tiny living organisms that were never seen before. Distinguish, in a written statement, between an advance in technology and an advance in science using this historical example.

Essay Question

The human nervous system consists of a complex arrangement of voluntary and involuntary responses and activities. The presence of these different types of responses has evolved in humans to help with survival.

Using the information in the paragraph above, answer the following question in essay format.

19. From what you know about different nervous system responses, write a well-organized essay explaining how different types of involuntary response systems in humans are helpful for survival.

NEED EXTRA HELP?

If You Missed Question . . .	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Review Section . . .	32.3	34.2	34.2	31.1	31.2	32.3	33.2	30.1	32.3	32.3	33.4	33.2	22.1	33.1	34.3	30.2	22.1	1.2	33.2