The Cardiovascular System: Moving Blood through the Body

Circulation: The Heart and Blood Vessels

Be Not Still, My Beating Heart!

YOUR heart is the most durable muscle in your body. It begins beating about a month after conception and keeps going despite pacemaker malfunctions, the heart may stop beating—an event called sudden cardiac arrest. Each year more than 300,000 people in the United States suffer sudden cardiac arrest. In older people, heart disease is the usual cause. In those under age 35, an inborn heart defect often is to blame.

Jugular Veins
- Receive blood from brain and from tissues of head
- Deliver blood to neck, head
- Carotid Arteries
- Carry oxygenated blood away from heart; the largest artery
- Provides blood pressure measurement

Ascending Aorta
- Carries oxygenated blood away from heart; the largest artery
- Provides blood pressure measurement

Pulmonary Arteries
- Deliver oxygen-poor blood from the heart to the lungs
- In Matt’s case, a bystander ran to get the school’s automated external defibrillator (AED). This device, about the size of a laptop computer, provides simple voice instructions on its use and makes no mistakes about identifying what to do. After the shock, it automatically stops, but the rescuer must call 911.

Pulmonary Veins
- Deliver oxygenated blood from the lungs to the heart
- The public health value of AEDs now is widely recognized. Many schools, senior centers, shopping malls, hotels, and airports keep one of these lifesavers on hand.

In this chapter you will learn about the structure and function of the cardiovascular system—the heart and blood vessels. Several topics will help you to understand the biology that underlies CPR and the use of an AED. If you would like to learn how to save lives with these methods, the American Heart Association, the American Red Cross, and many other community organizations provide training. Taking time to learn these skills is something we all can do for one another.

Circulating Blood
The cardiovascular system transports oxygen, nutrients, hormones, and other substances to body cells. It also clears away wastes and cell products.

Pumping Blood
The heart is a muscular pump. Heart contractions provide the force that drives blood through the cardiovascular system's arteries and veins.

Disorders of the Circulatory System and Homeostasis

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The heart and blood vessels make up the cardiovascular system

"Cardiovascular" comes from the Greek kardia (heart) and the Latin vasculum (vessel). As you can see in Figure 7.1, the cardiovascular system has two main elements, the heart and blood vessels:

- The heart is a muscular pump that generates the pressure required to move blood throughout the body.
- Blood vessels are tubes of different diameters that transport blood.

The heart pumps blood into arteries, which have a large diameter. From these blood flows into smaller and narrower vessels called arterioles, which branch into even narrower capillaries. Blood flows from capillaries into small venules, then into larger-diameter veins that return blood to the heart.

As you will read later on, the volume of blood flowing to a particular part of the body and the rate at which it flows both are adjustable. This flexibility permits the cardiovascular system to deliver blood in ways that suit conditions in different parts of the body. For example, blood flows rapidly through arteries, but in capillaries it must flow slowly so that there is time for substances moving to and from cells to diffuse into and out of extracellular fluid (Figure 7.2). This slow flow takes place in capillary beds, where blood moves through vast numbers of slender capillaries. By dividing up the blood flow, the capillaries handle the same total volume of flow as the large-diameter vessels, but at a slower pace.

Blood circulation is essential to maintain homeostasis.

You may hear someone refer to the cardiovascular system as the "circulatory system." This name is given because blood circulates through the system, bringing body cells such essentials as oxygen, nutrients from food, and secrets such as hormones. Circulating blood also takes away the wastes produced by our metabolism, along with excess heat. In fact, cells depend on blood to make constant pickups and deliveries of an amazingly diverse range of substances, including those that move into or out of the digestive system and the respiratory and urinary systems (Figure 7.2).

Homeostasis is one of our constant themes in this book, so it's good to keep in mind that maintaining it would be impossible were it not for our circulating blood. Cells

must exchange substances with blood because that is a key way cells adapt to changes in the chemical makeup of the extracellular fluid around them—part of the "internal environment" in which they live.

The cardiovascular system is linked to the lymphatic system.

The heart's pumping action puts pressure on blood flowing through the cardiovascular system. Partly because of this pressure, small amounts of water and some proteins dissolved in blood are forced out and become part of interstitial fluid (the fluid between cells). An elaborate network of drainage vessels picks up excess extracellular fluid and usable substances in it—such as water and proteins—and returns them to the cardiovascular system. This vessel network is part of the lymphatic system, which we consider in Chapter 9.

Take-Home Message

What is the cardiovascular system?

- The cardiovascular system consists of the heart and the blood vessels.
- The cardiovascular system transports substances to and from the fluid that bathes all living cells.

7.2 The Heart: A Double Pump

- In a lifetime of 70 years, the human heart beats some 2.5 billion times. This durable pump is the centerpiece of the cardiovascular system.
- Links to Epithelium 4.1, Muscle tissue 4.3

Roughly speaking, your heart is located in the center of your chest (Figure 7.2a). Its structure reflects its role as a long-lasting pump. The heart is mostly cardiac muscle tissue, the myocardium (Figure 7.2b). A tough, fibrous sac, the pericardium (per - around), surrounds, protects, and lubricates it. The heart's chambers have a smooth lining (endocardium) composed of connective tissue and a layer of epithelial cells. The epithelial cell layer known as endothelium also lines the interior of blood vessels.

The heart has two halves and four chambers.

A thick wall, the septum, divides the heart into two halves, right and left. Each half has two chambers: an atrium (plural: atria) located above a ventricle. Flaps of membrane separate the two chambers and serve as one-way atrioventricular valve (AV valve) between them. The AV valve in the right half of the heart is called the bicuspid valve or mitral valve. Tough, collagen-reinforced strands (chordae tendineae, or "heartstrings") connect the AV valve flaps to cone-shaped muscles that extend out from the ventricle wall. When a blood-filled ventricle contracts, this arrangement prevents the flaps from opening backward into the atrium. Each half of the heart also has a half-moon-shaped semilunar valve between the ventricle and the arteries leading away from it. During a "heartbeat," this valve opens and closes in ways that keep blood moving in one direction through the body.

The heart has its own "coronary circulation." Two coronary arteries lead into a capillary bed that services most of the cardiac muscle (Figure 7.4). They branch off the aorta, the major artery carrying oxygenated blood away from the heart.

In a "heartbeat," the heart's chambers contract, then relax.

Blood is pumped such that the heart beats. It takes less than a second for a "heartbeat"—one sequence of contraction and relaxation of the heart chambers. This sequence occurs almost simultaneously in both sides of the heart. The contraction phase is called systole (sin-toh-lee), and the relaxation phase is called diastole (dy-ah-sto-lee). This sequence is the cardiac cycle diagrammed in Figure 7.5.

CIRCULATION: THE HEART AND BLOOD VESSELS

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CHAPTER 7

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During the cycle, the ventricles relax before the atria contract, and the ventricles contract when the atria relax. When the relaxed atria are filling with blood, the fluid pressure inside them rises, and the AV valves open. Blood flows into the ventricles, which have 80 percent filled by the time the ventricle contracts. As the filled ventricles begin to contract, fluid pressure inside them increases, forcing the AV valves shut. The rising pressure then forces the semilunar valves open—and blood flows out of the heart and into the aorta and pulmonary artery. Now the ventricles relax, and the semilunar valves close. For about half a second the atria and ventricles are all in diastole. Then blood-filled atria contract, and the cycle repeats.

The amount of blood each ventricle pumps in a minute is called the cardiac output. On average, every sixty seconds the cardiac output from each ventricle is about 5 liters—nearly all the blood in the body. This means that in a year each half of your heart pumps at least 2.5 million liters of blood. That is more than 600,000 gallons!

Take-Home Message
Here are the heart’s roles as a double pump:
• Each half of the heart is divided into an atrium and a ventricle.
• During a cardiac cycle, contraction of the atria helps fill the ventricles. Contraction of the ventricles pumps blood out the heart.

### 7.3 The Two Circuits of Blood Flow

Each half of the heart pumps blood. The two side-by-side pumps are the back of two cardiovascular circuits through the body, each with its own set of arteries, arterioles, capillaries, venules, and veins.

In the pulmonary circuit, blood picks up oxygen in the lungs

The pulmonary circuit, which is diagrammed in Figure 7.6a at right, receives blood from tissues and circulates it through the lungs for gas exchange. The circuit begins as blood from tissues enters the right atrium, then moves through the AV valve into the right ventricle. As the ventricle fills the atrium contracts. Blood arriving in the right ventricle is fairly low in oxygen and high in carbon dioxide. When the ventricle contracts, the blood moves through the right semilunar valve into the main pulmonary artery, then into the right and left pulmonary arteries. These arteries carry the blood to the two lungs, where (in capillaries) it picks up oxygen and gives up carbon dioxide that will be exhaled. The freshly oxygenated blood returns through two sets of pulmonary veins to the heart’s left atrium, completing the circuit.

In the systemic circuit, blood travels to and from tissues

In the systemic circuit (Figure 7.6b), oxygenated blood pumped by the left half of the heart moves through the body and returns to the right atrium. This circuit begins when the left atrium receives blood from pulmonary veins, and this blood moves through an AV (bicuspid) valve to the left ventricle. This chamber contracts with great force, sending blood coursing through a semilunar valve into the aorta.

As the aorta descends into the torso (see Figure 7.1), major arteries branch off it, funneling blood to organs and tissues where $O_2$ is used and $CO_2$ is produced. For example, in a resting person, each minute a fifth of the blood pumped into the systemic circulation enters the kidneys (Figure 7.6c) via renal arteries. Deoxygenated blood returns to the right half of the heart, where it enters the pulmonary circuit. Notice that in both the pulmonary and the systemic circuits, blood travels through arterioles, capillaries, and venules, finally returning to the heart in veins. Blood from the head,
Unlike skeletal muscle, which contracts only when orders arrive from the nervous system, cardiac muscle contracts—and the heart beats—spontaneously. Electrical signals from “pacemaker” cells drive the heart’s contractions. Junctions called intercalated discs span both plasma membranes of neighboring cells (Figure 7.8). With each heartbeat, signals calling for contraction spread rapidly across the junctions that cardiac muscle cells branch and link to one another at their endings. Conduction in the AV node is an important part of this sequence. It gives the atria time to finish contracting before the ventricles contract. Of all cells of the cardiac conduction system, the SA node chronically malfunctions may have an artificial pacemaker implanted to provide a regular stimulus for cardiac muscle contraction. Because the cardiac conduction system is independent of the nervous system, the heart will keep right on beating even if all nerves leading to the heart are severed! The nervous system adjusts heart activity. The centers for neural control of heart functions are in the spinal cord and parts of the brain. They are discussed more about this topic in Chapter 11.

**Take-Home Message**
- The SA node is the cardiac pacemaker—it establishes a regular heartbeat. Its spontaneous, repeated excitation signals spread along a system of muscle cells that stimulate a rhythmic cycle of contraction in the heart’s atria, then the ventricles.
- The nervous system initiates the contraction of skeletal muscle, but it can only adjust stimulation by another set of nerves can slow heart activity. Stimulation by one set of nerves can make the heart contract more forcefully.

**Animated!**
- Each half of the heart pumps blood
- The (C) superior vena cava sends blood from the body to the heart.
- The (P) pulmonary circuits carry blood through the lungs for gas exchange.
- The (C) distribution of the brain and organs is to the body.
- The (P) hepatic portal vein brings nutrient-laden blood to the liver.
- The (C) systemic circuits transport blood to and from tissues.
Blood Pressure

Heart contractions generate blood pressure, which propels blood through the cardiovascular system. High blood pressure is a “silent killer” that can lead to stroke or heart attack.

Arteries branch into narrower arterioles, which have a wall of smooth muscle and elastic fibers. The outer layer is mainly collagen, which anchors the vessel to the tissue it runs through. A thick middle layer containing elastin bulges slightly under the pressure surge caused when a ventricle contracts and pushes blood into the aorta. The second number, diastolic pressure, measures the lowest blood pressure in the aorta, when blood is flowing out of it. The outer layer of an artery wall is called the tunica externa, which is mainly collagen. The innermost layer is a thin sheet of endothelium. Together these layers form a thick, durable wall of vessels called the tunica media. It contains the smooth muscle that can constrict or dilate the vessel (Figure 7.12).

Capillaries are specialized for diffusion. Their walls are only one cell thick—a single layer of flat endothelial cells. Values for systolic and diastolic pressure provide only a snapshot of one moment in time. Over time, the arterial pressure required to maintain a normal blood supply can be influenced by factors such as age, fitness, and diet (Section 7.3B). The chart in Figure 7.13 provides values for normal blood pressure at different ages. Hypertension is defined as a systolic pressure of 130 mm Hg or higher and a diastolic pressure of 80 mm Hg or higher. Values higher than this are considered hypertension. Blood pressures of up to 120/80 are said to be normal. Values below 120/80 are considered hypotension. Hypotension can be a dangerous condition called circulatory shock when the blood pressure is too low to supply enough water to the body’s tissues and organs. A white-coat effect is a surge in blood pressure when you are in an unfamiliar setting or with a new clinician. But this effect is usually temporary and is not considered hypertension.

Take-Home Message

1. Smoked
2. Obesity
3. Sedentary lifestyle
4. High cholesterol
5. Diabetes
6. Excessive salt intake
7. A diet low in fruits, vegetables, dairy foods, and other sources of potassium and calcium
8. Excessive alcohol consumption
9. History of heart disease
10. Chronic stress

Risk Factors for Hypertension

Values for systolic and diastolic pressure provide only a snapshot of one moment in time. Over time, the arterial pressure required to maintain a normal blood supply can be influenced by factors such as age, fitness, and diet. Hypertension is defined as a systolic pressure of 130 mm Hg or higher and a diastolic pressure of 80 mm Hg or higher. Values higher than this are considered hypertension. Blood pressures of up to 120/80 are said to be normal. Values below 120/80 are considered hypotension. Hypotension can be a dangerous condition called circulatory shock when the blood pressure is too low to supply enough water to the body’s tissues and organs. A white-coat effect is a surge in blood pressure when you are in an unfamiliar setting or with a new clinician. But this effect is usually temporary and is not considered hypertension.
Blood enters the systemic circulation moving swiftly. Venous valves prevent backflow of blood. Skeletal muscles next to the vein contract, helping blood flow forward. Skeletal muscles relax and valves in the vein shut, preventing backflow.

Venous valves are part of the circulatory system and help control blood flow. They are found in veins, especially in the lower limbs, to prevent blood from flowing backward. These valves are critical for maintaining venous return to the heart, especially during activities like standing or exercising.

### Capillaries: Where Blood Exchanges Substances with Tissues

- **Blood enters the systemic circulation moving swiftly in the aorta, but this speed has to slow in order for substances to move into and out of the blood stream.**
- **Link to Diffusion 3.30**

A vast network of capillaries brings blood close to nearly all body cells. Your body is equipped with one arteriole, a few hundred branching arteries and veins, more than half a billion arterioles and capillaries, and as many as 40 billion capillaries. Capillaries are so thin that it would take 100 of them to equal the thickness of a human hair. And at least one of these tiny vessels is next to every cell in nearly all body tissues.

### Capillary Blood Flow

- Blood is oxygenated in the lungs and carries oxygen to the tissues. As blood moves through the systemic circulation, oxygen is released from hemoglobin to the tissue cells. The cells use oxygen for energy production.
- Blood also delivers nutrients and hormones to the cells and removes waste products.

### Capillary Function

- **Capillary beds are diffusion zones.** Blood moves back to the heart through veins and valves. Veins in veins prevent the backflow of blood due to gravity.
- **Take-Home Message**: Are the different types of blood vessels?
  - **Arteries** are the main pipelines for oxygenated blood. Because arteries can dilate or constrict, they are control points for blood flow and pressure.
  - **Capillary beds** are diffusion zones. Blood moves back to the heart through veins and valves. Veins in veins prevent the backflow of blood due to gravity.

### Capillaries and Blood Pressure

- Blood pressure is maintained by the heart, blood vessels, and the autonomic nervous system. Baroreceptors are pressure sensors in the aorta, carotid arteries, and elsewhere. They monitor changes in systemic blood pressure and help maintain blood pressure within normal limits in the face of sudden changes—such as when you leap up from a chair.

### Capillaries and Oxygen Exchange

- Oxygen and carbon dioxide concentrations differ between the arterial and venous sides of the capillary bed. Oxygen is released from hemoglobin to the tissue cells, and carbon dioxide is transported back to the lungs.

By controlling the rate and strength of heartbeats with changes in the diameter of arterioles and capillaries, the nervous system helps maintain adequate blood pressure over time. Venous valves help prevent backflow of blood due to gravity, and the heart maintains a constant pump rate to ensure blood flow to all parts of the body.
Cardiovascular Disease

What are your chances of developing a cardiovascular disorder? Some major risk factors include a family history of heart trouble, high levels of blood lipids such as cholesterol and trans fats, hypertension, obesity, smoking, lack of exercise, and simply getting older. Interestingly, however, more than half of people who suffer heart attacks do not have any of these risk factors.

To help explain this puzzle, scientists have focused on inflammation, which is a defense response discussed in Chapter 9. Sometimes, though, inflammation does harm. In the cardiovascular system, it can promote the formation of the artery-blocking plaques described shortly. Infections can trigger inflammation, which in turn causes the liver to make C-reactive protein, which is also implicated in heart disease. This link is why infection-related inflammation and C-reactive protein are listed in Table 7.2. Another suspect is homocysteine, an amino acid that is released as certain proteins are broken down. Too much in the blood also may cause damage that is a first step in a major cardiovascular disorder, atherosclerosis.

Inflammation, or "hardening of the arteries," arteries become thicker and stiffer. In atherosclerosis, this condition gets worse as cholesterol and other lipids build up in the artery wall. When this atherosclerotic plaque grows large enough to protrude into the artery, there is less room for blood (Figure 7.18). Coronary arteries and their branches are narrow and vulnerable to clogging by plaques. When the artery is narrowed further to one-quarter of its starting diameter, symptoms can range from mild chest pain, called angina pectoris, to a full-scale heart attack.

Arteries can clog or weaken

The cardiovascular system's extensive network of narrow capillaries helps sustain life. At the point where a capillary branches into the capillary bed, a precapillary sphincter regulates the flow of blood into the capillary. The smooth muscle is sensitive to chemical changes in the capillary bed. It can contract and prevent blood from entering the capillary, or it can relax and let blood flow in.

Take-Home Message

What is the function of capillaries?

• The cardiovascular system's extensive network of narrow capillaries ensures that every living cell is only a short distance from a capillary.
• In capillary beds, substances move between the blood and extracellular fluid by diffusion, through capillary pores, or by bulk flow.
• Movements of water and other substances into and out of capillaries help maintain blood pressure and the proper fluid balance between blood and tissues.

Blood in capillaries flows onward to venules

Capillary beds are the "turnaround points" for blood in the cardiovascular system. They receive blood from arterioles, and after the blood flows through the bed it enters channels that converge into venules—the beginning of its return trip to the heart (Figure 7.17). At the point where a capillary branches into the capillary bed, a precapillary sphincter regulates the flow of blood into the capillary. The smooth muscle is sensitive to chemical changes in the capillary bed. It can contract and prevent blood from entering the capillary, or it can relax and let blood flow in.
Infections, Cancer, and Heart Defects

TABLE 7.2 Major Risk Factors for Cardiovascular Disease

1. Inherited predisposition
2. Elevated blood lipids (cholesterol, trans fats)
3. Hypertension
4. Obesity
5. Smoking
6. Lack of exercise
7. Age 50+
8. Inflammation due to infections by viruses, bacteria
9. High levels of C-reactive protein in blood
10. Elevated blood levels of the amino acid homocysteine

Infections may seriously damage the heart. Infections related to an untreated "strep throat," certain dental procedures, or IV drug abuse are in this category.

Heart damage can lead to heart attack and heart failure. A heart attack is damage or death of heart muscle. Warning signs of a heart attack include sensations of pain or squeezing behind the breastbone, pain or numbness radiating down the left arm, sweating, and nausea. Women more often experience neck and back pain, fatigue, a sense of indigestion, a fast heart rate, shortness of breath, and low blood pressure. Risk factors include hypertension, a circulating blood clot (also called an embolus), and atherosclerosis.

Heart failure (HF), the heart is weakened and so does not pump blood as well as it should. Even a basic exertion such as walking can become difficult. Because patients may require repeated hospitalization, HF has become the nation’s most costly health problem.

Arrhythmias are abnormal heart rhythms. An electrocardiogram, or ECG, is a recording of the electrical activity of the cardiac cycle (Figure 7.19a). ECGs reveal arrhythmias, or irregular heart rhythms. Some arrhythmias are abnormal, others are not. For example, endurance athletes may have a below-average resting cardiac rate, or bradycardia, which is an adaptation to regular strenuous exercise. A cardiac rate above 100 beats per minute, called tachycardia, occurs normally during exercise or stressful situations. Serious tachycardia can be triggered by drugs (including caffeine, nicotine, alcohol, and cocaine), excessive thyroid hormones, and other factors.

Arrhythmias of ventricular fibrillation is the most dangerous arrhythmia. In parts of the ventricles, the cardiac muscle contracts haphazardly, so blood isn’t pumped normally. This is what happens in sudden cardiac arrest, as described in the chapter introduction. Like Matt Nader’s cardiac arrest described in the chapter introduction, ventricular fibrillation is a medical emergency. With luck, a strong electrical jolt to the patient’s heart from an AED, or the use of defibrillating drugs, can restore a normal rhythm before the damage is too serious.

A heart-healthy lifestyle may help prevent cardiovascular disease. Everybody ages, and none of us can control the genes we inherit. Even so, each of us can take steps to improve our chances of living free of serious cardiovascular disease. Watching our intake of foods rich in cholesterol and trans fats, getting regular exercise, and not smoking are three strategies, and they provide multiple benefits. A diet that’s moderate in fats may also help keep weight under control. Exercise helps with weight control, too. It also relieves stress and helps keep muscles and bones fit and strong. Smoking is bad for just about every body system; you’ll get a closer look at its devastating impact on the respiratory system in Chapter 10.

7.9 Infections, Cancer, and Heart Defects

Infections may seriously damage the heart. As described in Section 7.8, bacterial and viral infections that first take hold outside the cardiovascular system may eventually harm the heart. Infections related to an untreated “strep throat,” certain dental procedures, or IV drug abuse are in this category.

"Strep" infections are caused by strains of Streptococcus bacteria (Figure 7.20). If the illness isn’t treated with an antibiotic, it may lead to rheumatic fever. In this disorder, the body produces defensive antibodies that attack the invading bacteria—but they also mistakenly attack heart valves. Although in affluent countries most people who develop a strep infection get treatment, rheumatic fever still is the most common cause of heart valve disease. It is an example of an autoimmune disorder, a topic we will discuss in Chapter 9.

Microbes that enter the bloodstream during dental surgery or on a contaminated IV needle may attack heart valves directly. This condition is called endocarditis ("inside the heart"). People who have an existing valve problem due to aging or some other heart disorder often are advised to take an antibiotic before having dental work. Endocarditis is a major hazard for IV drug users. It can rapidly destroy infected valves and cause sudden heart failure.

Heart problems also can be a complication of Lyme disease, which is caused by the bacterium Borrelia burgdorferi and spread by ticks. At first this body responds to a Lyme infection with a “bull’s-eye” rash (Figure 7.21). Later the infection may seriously damage the heart. Depending on the problem, one or more surgeries may be required to repair it.
Adjustments to blood flow at the skin’s surface help regulate body temperature. Blood clotting mechanisms help repair skin injuries. Stem cells in bone marrow produce blood cells. Circulating blood delivers calcium and phosphate used to form bone tissue.

Circulating blood distributes heat produced by active skeletal muscles. Contraction of leg muscles helps return venous blood to the heart.

Blood pumped by the heart picks up inhaled oxygen from the lungs and delivers carbon dioxide to the lungs to be exhaled.

Blood pressure is the fluid pressure blood exerts against vessel walls. It is highest in the aorta, which receives blood pumped by the left ventricle, and drops along the systemic circuit.

Blood vessels help control blood pressure. Arterioles dilate when centers in the brain detect an abnormal rise in blood pressure. If blood pressure falls below a set point, the kidneys filter impurities and other unnecessary substances from blood and form urine that removes them from the body. The kidney hormone angiotensin stimulates the formation of red blood cells.

Blood pressure is measured in millimeters of mercury (mmHg). Typically, the systolic pressure is read first, followed by the diastolic pressure. For example, a reading of 120/80 mmHg indicates that the blood pressure is at 120 mmHg during systole and 80 mmHg during diastole.

Blood vessels of the placenta help maintain homeostasis in a developing fetus.

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10. Match these three circulation components with their descriptions.

<table>
<thead>
<tr>
<th>Capillary beds</th>
<th>Type of blood vessel</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Two atria, two ventricles</td>
<td>a. Arterioles</td>
<td>Blood transport and pressure</td>
</tr>
<tr>
<td>b. Driving force for blood transport</td>
<td>b. Capillaries</td>
<td>Diffusion</td>
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<tr>
<td>c. Zones of diffusion</td>
<td>c. Veins</td>
<td>Reservoirs</td>
</tr>
</tbody>
</table>

Critical Thinking

1. A person suffering from hypertension may receive drugs that decrease the heart's output, dilate arterioles, or increase urine production. In each case, how would the drug treatment help relieve hypertension?

2. Henry smokers often develop abnormally high blood pressure. The nicotine in tobacco is a potent vasoconstrictor. Explain the connection between these two facts, including what kind of blood vessels are likely affected.

3. Before antibiotics were available, it wasn't uncommon for people in the United States (and elsewhere) to develop rheumatic fever. The infection can trigger an inflammation that ultimately damages valves in the heart. How might this disease affect the heart's functions? What kinds of symptoms would arise as a consequence?

4. The highly publicized deaths of several airline travelers led to warnings about "economy-class syndrome." The idea is that economy-class passengers don't have as much leg room as passengers in more costly seating, so they are more likely to sit essentially motionless for long periods on flights—conditions that may allow blood to pool and clots to form in the legs. This condition is called deep-vein thrombosis, or DVT. In addition, low oxygen levels in airplane cabins may increase clotting. If a clot gets large enough to block blood flow or breaks free and is carried to the lungs or brain, it can lethally block an artery.

There could be a time lag between when a clot forms and health problems, so an air traveler who later develops DVT might easily overlook the possible connection with a flight. Studies are now under way to determine whether economy-class travel represents a significant risk of DVT. Given what you know about blood flow in the veins, explain why periodically getting up and moving around in the plane's cabin during a long flight may lower the risk that a clot will form.

EXPLORE ON YOUR OWN

As described in Section 7.6, a pulse is the pressure wave created during each cardiac cycle as the body's elastic arteries expand and then recoil. Common pulse points—places where an artery lies close to the body surface—include the inside of the wrist, where the radial artery travels, and the carotid artery at the front of the neck. Monitoring your pulse is an easy way to observe how a change in your posture or activity affects your heart rate.

To take your pulse, simply press your fingers on a pulse point and count the number of "beats" during one minute. For this exercise, take your first measurement after you've been lying down for a few minutes. If you are a healthy adult, it's likely that your resting pulse will be between 60 and 100 beats per minute. Now sit up, and take your pulse again. Did the change in posture correlate with a change in your pulse? Now run in place for 30 seconds and take your pulse rate once again. In a short paragraph, describe what changes in your heart's activity led to the pulse differences.