Lesson Breakdown

Lesson 1: Cardiovascular Anatomy and Physiology
Pages 150-160

Lesson 2: Respiratory Anatomy and Physiology
Pages 160-162

Lesson 3: Effects of Exercise and Environments
Pages 162-168

In This Chapter:

Teaching Materials

- **Graphics package (PowerPoint slides)**
- **Student workbook (answer key)**
  Pages 83-96
  15 activities
- **Online resources**
  Flash cards
  Crosswords
  Quiz questions
  Lesson websites
- **Teacher's guide supplement**
  TGS 8.1 to TGS 8.6

THE HEART AND LUNGS AT WORK

CHAPTER 8

After completing this chapter you should be able to:

- explain the function and control of the cardiovascular and respiratory systems;
- describe the relationship between the cardiorespiratory system and energy production;
- explain the measures that are used to evaluate and describe the various components of the cardiovascular and respiratory systems;
- describe the acute and chronic effects of physical activity on the body;
- analyze the effects of different environmental conditions on the body during physical activity.

149

Curriculum Link

By the end of the course, students will:

- Explain the relationship between the cardiorespiratory system, the production of energy, and the removal of waste products in the working muscles (e.g., the transportation of nutrients and oxygen and the removal of lactic acid).
- Describe the acute and chronic effects of physical activity on the body (e.g., acute effects such as increased heart rate and breathing frequency, increased cardiac output and stroke volume, increased endorphin levels and chronic effects such as muscular hypertrophy, increased cardiorespiratory endurance).

Chapter Learning Objectives

Formative Assessment

- **Student workbook**
  Pages 83-92
- **Online resources**
  Flash cards
  Crossword
  Quiz questions

Summative Assessment

- **Student workbook**
  Check Your Understanding quiz
  (pp. 93-94)
  Chapter Culminating Assignment
  (pp. 95-96)
- **Online quiz**

LESSON 1: Cardiovascular Anatomy and Physiology

The BIG Idea

- Explain the function and control of the cardiovascular system and the terms that are used to evaluate and describe its various components.

Teaching Materials

- **Graphics package: PowerPoint slides**
- **Student workbook** (7)
- **Online resources**
  Flash cards
- **Teacher's guide supplement**
  TGS 8.1 to TGS 8.2

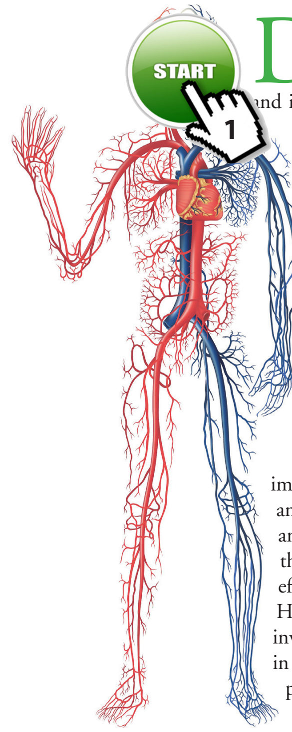
LESSON 1 Key Terms

For a summary of key terms, see TGS 8.1.

Discussion Guiding Question

▶ What are the three primary layers of tissue that make up the heart, and what role do they each play?

*The **endocardium** is the innermost layer of smooth muscle that lines the chambers of the heart and allows blood to flow smoothly; the **myocardium** is the thick and muscular middle layer that is responsible for physically pumping the blood; and the **epicardium** is the thin outer layer that helps protect the heart.*



During an average human life the heart will beat about three billion times, beginning soon after conception and continuing until death. The heart is one of the first organs to begin functioning and is often associated with life and death. This life-sustaining organ that pumps blood throughout our bodies is only one part of our circulatory system. The others – blood vessels (the passageways) and blood (the transport medium) – complete the transport system that delivers supplies to the tissues that need them for survival and growth. Oxygen is perhaps the most important supply to be delivered at rest and during periods of physical activity.

The systems of the body, however, are by no means independent of one another. Pulmonary structure and function are closely linked with the cardiovascular system; without getting oxygen into the body through breathing (ventilation), diffusion, and gas exchange in the lungs, there is no oxygen to transport to the body's tissues. Thus, the body's systems must work together in order to function most efficiently.

Because cardiovascular function is so vital to our existence, it is important to be aware of the advantages that can result from training, and their implications for health. Exercise offers numerous benefits, and enhanced cardiovascular function is one of them. Understanding the changes that occur during exercise will enable you to train more effectively for performance and will improve your cardiovascular health. How are blood flow and blood volume controlled? What is actually involved in the transport of oxygen? And what role does hemoglobin play in oxygen transport? The answers to these and other questions will be presented in this chapter; this material will provide the foundation you will need to attain and maintain optimal cardiovascular health.

Cardiovascular Anatomy

The primary role of the cardiovascular system is supplying muscles and organs with the oxygen and nutrients they need to function properly, and removing metabolic by-products from areas of activity. Optimal functioning of this system is critical for human performance. The anatomy and physiology of the heart and blood vessels are described in this section.

The Heart

Structure

The heart is an organ that pumps blood through the human body. It is made up of specialized muscle cells that form three distinct layers of tissue: the endocardium, the myocardium, and the epicardium. The **endocardium** is the innermost layer of smooth muscle that lines the chambers of the heart and allows blood to flow smoothly; the **myocardium** is the thick and muscular middle layer that is responsible for physically pumping the blood; and the **epicardium** is the thin outer layer that helps protect the heart. Just outside the epicardium lies the **pericardium**, a protective sac that loosely surrounds the entire heart, allowing it to expand and contract freely.

Terminology A!ert

Like most anatomical terms, the layers of the heart can be figured out by identifying the root words involved: *endo-* (within), *myo-* (muscle), *epi-* (upon), *peri-* (around), and *-cardium* (heart).

Differentiated Instruction WEB

Icebreaker

Spoken from the Heart

Set up a visit by a guest speaker from the American Red Cross or the American Heart Association as an introduction to the chapter. A brief presentation on blood types and the importance of blood donation might be additional topics for discussion.
Arranging a class trip for blood donation might also be a good idea to start a good lifelong habit of donation. People can donate starting at age 17, or 16 with the consent of a parent or guardian if allowed by state law.

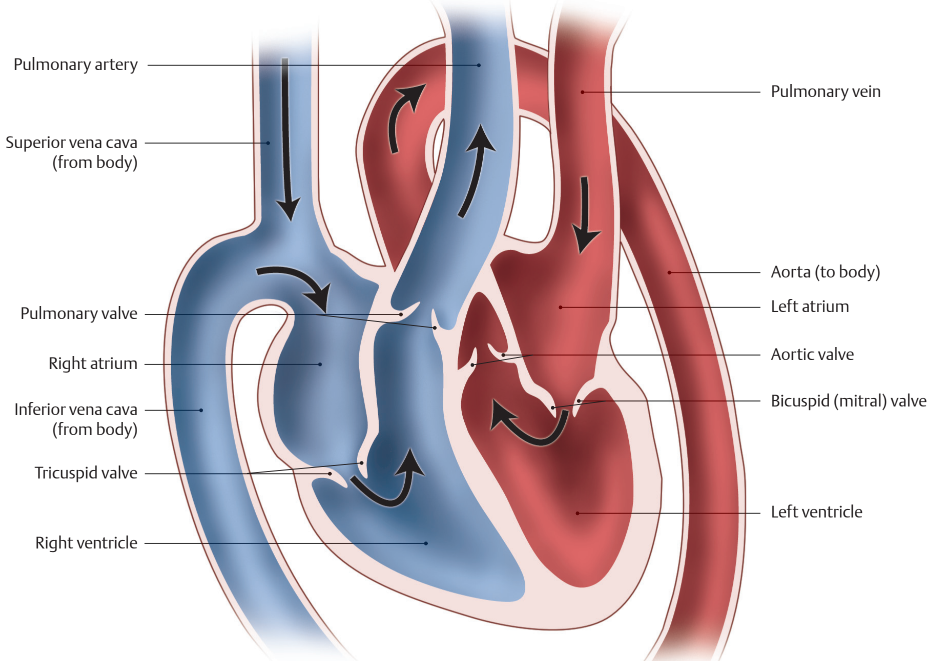


Figure 8.1 The chambers, vessels, and valves of the heart work together efficiently to supply all parts of the body with blood and oxygen.

Heart Chambers and Vessels The heart pumps blood through the body by using two different pumps called ventricles (Figure 8.1). The right ventricle pumps deoxygenated blood to the lungs via the pulmonary artery (the only artery in the body that carries deoxygenated blood), and the left ventricle pumps oxygenated blood to the rest of the body through the aorta – the largest artery in the human body. Since the left ventricle has to pump blood through the entire body, it is larger and its muscle walls are stronger than that of the right ventricle, which has to pump blood only a short distance to the lungs.

The heart also has two smaller chambers called atria (singular = *atrium*), which pump blood into the ventricles for distribution to the lungs and other areas of the body. Deoxygenated blood from the peripheral organs and tissues enters the right atrium of the heart through two large veins called the superior vena cava (from the upper part of the body) and the inferior vena cava (from the lower part of the body). From here, the blood passes into the right ventricle, which then pumps the blood to the lungs. Once oxygenated, the blood returns to the left atrium of the heart via the pulmonary vein (the only vein in the body that carries oxygenated blood) before continuing on its path into the left ventricle and to the rest of the body.

The human heart has four separate chambers: two upper atria and two lower ventricles, with one atrium and one ventricle on each side of the heart. Each of the four chambers has a specific function that keeps this life-sustaining organ pumping efficiently.

Heart Valves Blood in the heart flows from one chamber to another through two sets of valves, which open and close to ensure that blood flows in the proper direction. The two semilunar valves allow blood to flow into the arteries during ventricular contraction and prevent backflow

Diagnostic Assessment

Assess previous knowledge by asking students to identify what type of muscle the heart is (cardiac). They should be able to recall this information from Chapter 3.

Discussion Guiding Question

- How many chambers make up the human heart? Which ones pump blood to the lungs and to the body?

The human heart has four separate chambers: two upper atria and two lower ventricles, with one atrium and one ventricle on each side of the heart. The right ventricle pumps deoxygenated blood to the lungs, and the left ventricle pumps oxygenated blood to the body.

KISS (Keep It Super Simple)

Getting to the Root

For most terms in scientific fields of study, their meaning can be determined by looking at the root words involved: *endo-* (within), *myo-* (muscle), *epi-* (upon), *peri-* (around), and *-cardium* (heart), describing the various layers of the heart, are perfect examples. Similar examples can be found throughout the chapter, so point them out as often as possible. For example, the semilunar valves are so called because of their crescent moon shape, and the bicuspid and tricuspid valves are so named because they have two (*bi-*) and three (*tri-*) flaps, respectively.

Practical Application

Circuitry of the Heart

Have students complete **student workbook activity 8.1.3** on page 85 to assess their understanding of the circuitry of the heart.

Discussion Guiding Question

- What valves regulate blood flow between the atria and ventricles?

*The two **atrioventricular valves** regulate blood flow between the atria and ventricles, allowing blood to flow from the right atrium into the right ventricle (**tricuspid valve**) and from the left atrium into the left ventricle (**bicuspid** or **mitral valve**), but not in the opposite direction.*

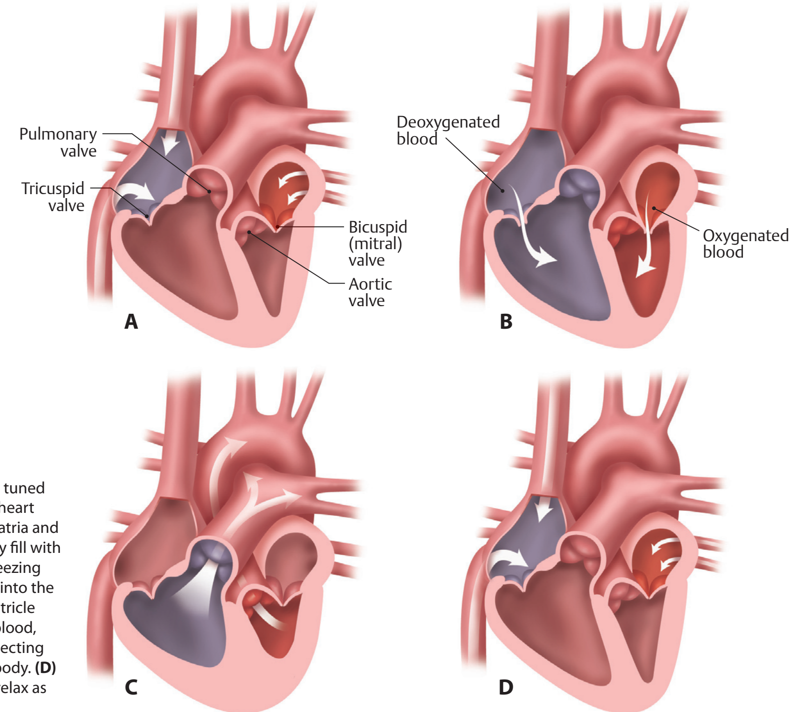


Figure 8.2 The finely tuned cardiac cycle. **(A)** As the heart relaxes in diastole, both atria and ventricles simultaneously fill with blood. **(B)** The atria, squeezing into systole, force blood into the ventricles. **(C)** As the ventricle compartments fill with blood, they contract, thereby ejecting blood to the lungs and body. **(D)** The atria and ventricles relax as the cycle begins anew.

during ventricular relaxation. Blood flow from the right ventricle into the pulmonary artery is regulated by the pulmonary valve, while the aortic valve controls blood flow from the left ventricle into the aorta.

Similarly, the two atrioventricular valves regulate blood flow between the atria and ventricles, allowing blood to flow from the right atrium into the right ventricle (tricuspid valve) and from the left atrium into the left ventricle (bicuspid or mitral valve), but not in the opposite direction.

Function

The heart contracts in a constant rhythm that may speed up or slow down depending on the need for blood (and oxygen) in the body. For example, if you start running, your leg muscles will need more oxygen to do the work. The heart needs to pump more oxygen-carrying blood to those working muscles and will have to beat more rapidly in order to supply that blood.

Located in the right atrium, the sinus node generates the electrical impulse that controls the rate of beating of the heart.

The beating of the heart is governed by an automatic electrical impulse that is generated by the sinus node – a small bundle of nerve fibers that are found in the wall of the right atrium near the opening of the superior vena cava. The sinus node generates an electrical charge called an action potential that causes the muscle walls of the heart to contract. The atria contract before the ventricles contract, which allows for the blood to be quickly pumped into the ventricles from the atria and then from the ventricles to the lungs and the rest of the body (Figure 8.2). The sinus node determines the rate of beating of the entire heart.

Differentiated Instruction WEB

Cooperative Learning

Verifying the Valves

The students form pairs. One student in each pair will read about the semilunar valves, the other about the atrioventricular valves. The partners then take turns teaching each other about what they have just learned.

Practical Application

Fatigue Resistance

Although the heart is a muscle, it is made up of specialized muscle cells that don't fatigue as easily as skeletal muscle. Have students clench and unclench their fists continuously for one or two minutes and then comment on how their muscles feel after such sustained activity.

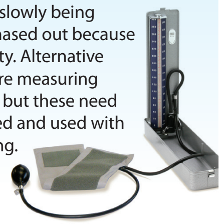
Blood Pressure

There are two components to the measure of blood pressure, which is an important measure of cardiac function. The first component is the pressure in the ventricles when they are contracting and pushing blood out into the body. This is called **systole**. **Systolic pressure** provides an estimate of how hard the heart is working and the strain against the arterial walls during the contraction. In healthy young adults, systolic pressure is normally around 120 mm Hg.

The second component of blood pressure is used to describe the pressure in the heart when it is in the relaxation phase of the cardiac cycle (the ventricles are relaxed and being filled with blood), called **diastole**. **Diastolic pressure** is used as an indicator of peripheral blood pressure (the blood pressure in the body outside the heart). It provides an indication of the ease with which the blood flows from the arterioles into the capillaries. The normal diastolic pressure in healthy young adults is about 70 to 80 mm Hg.

DID YOU KNOW

Mercury **sphygmomanometers** have been routinely used in medicine as the gold standard for measuring blood pressure, but mercury-containing products are slowly being banned or phased out because of their toxicity. Alternative blood pressure measuring devices exist, but these need to be validated and used with proper training.



SILENT BUT DEADLY

Often referred to as the "silent killer" because it shows no early warning signs or symptoms, high blood pressure (**hypertension**) increases the risk of heart disease and stroke – two leading causes of death in North America. The problem is many people don't realize they have it, which is why it is so important to get your blood pressure checked regularly. The good news is that you can do many things to help control high blood pressure, including changes to your diet and exercise habits.


Getting regular blood pressure checks is key to maintaining cardiovascular health.

Cardiac Output

The amount of blood that is pumped into the aorta each minute by the heart is known as the **cardiac output** (measured in liters per minute). Cardiac output is the product of stroke volume (measured in milliliters per beat) and heart rate (measured in beats per minute) and is therefore representative of the quantity of blood that flows to the peripheral circulation. Cardiac output can be described by the simple equation presented below:

Cardiac output = Stroke volume x Heart rate

Stroke Volume The amount of blood that is pumped out of the left ventricle with each heartbeat is the **stroke volume**. The stroke volume of the heart is measured in milliliters (1 liter = 1,000 ml). A typical stroke volume for a normal heart is about 70 ml of blood. Regular exercise and sports training can increase stroke volume.

Discussion Guiding Question

- Describe the two components of blood pressure. What do they measure?

*The two components of blood pressure are systole and diastole. **Systole** measures the pressure in the ventricles when they are contracting and pushing blood out into the body. **Diastole** describes the pressure in the heart when the ventricles are relaxed and are being filled with blood. It is used as an indicator of peripheral blood pressure (the blood pressure in the body outside the heart). The normal blood pressure during systole is about 120 mm Hg, and during diastole it is about 70 to 80 mm Hg.*

KISS (Keep It Super Simple)

The Cardiac Cycle

Systole = the blood-filled heart pushes blood from top to bottom (atria to ventricles) and from the bottom (ventricles) to the body.

Diastole = the empty heart fills up with blood.

Icebreaker

You Make My Blood Boil

Point out to students that blood pressure can rise acutely during periods of anger, stress, and intense physical activity as well as in response to the consumption of high amounts of sodium.

Practical Application

Measuring Blood Pressure

If you have access to the proper equipment, set up areas in the classroom where students can measure their blood pressure. Remember, a normal blood pressure reading for healthy young adults is around 120/80 mm Hg.

Emphasize to students that although many people who have high blood pressure know what their readings are, many don't know how to explain what they mean.

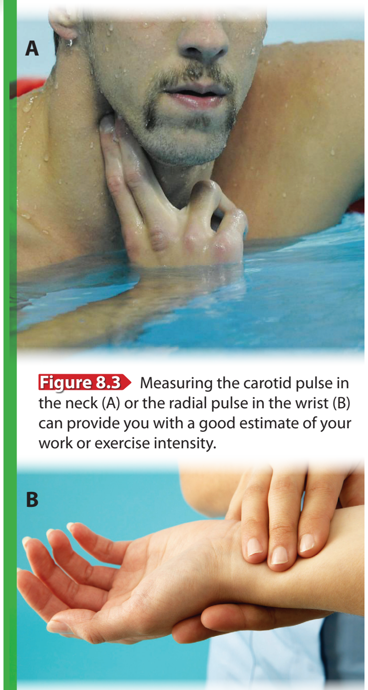


Figure 8.3 Measuring the carotid pulse in the neck (A) or the radial pulse in the wrist (B) can provide you with a good estimate of your work or exercise intensity.

Heart Rate The rhythmical contraction of the walls of the heart is commonly known as a heartbeat. Heart rate is the number of times the heart beats in one minute and is measured in beats per minute (bpm). At rest the normal heart rate of an adult can range from 40 bpm in a highly trained athlete to 70 bpm in a normal healthy person. During intense exercise, the heart rate may increase to up to 200 bpm and occasionally even higher. The maximum expected heart rate for most people can be estimated by using the following equation:

Maximum heart rate = 220 – Age (in years)

Intensity of Work The intensity of aerobic exercise can be estimated by measuring heart rate as the two are highly related. The higher the intensity of exercise the higher the heart rate per minute. Since heart rate is a measure that is easily obtained, it becomes very practical for estimation of intensity of work and/or exercise. The heart rate can easily be measured by feeling the carotid or radial pulses with the middle three fingers as in Figure 8.3. By placing two or three fingers and applying light pressure between the trachea and the sternocleidomastoid muscle in the neck you can feel the carotid pulse. Then count the number of beats in 10 seconds and multiply the figure by 6 to get the number of beats per minute.

For example, a count of 17 beats in 10 seconds multiplied by 6 would result in a heart rate of 102 beats per minute. This elementary procedure allows you to quickly determine how hard you are working without any specialized equipment.

The Peripheral Circulatory System

All of the blood vessels in the human body are made up of multiple layers of tissue. Smooth muscle cells allow these vessels to contract, which allows the peripheral circulatory system to regulate blood flow and alter the pattern of circulation throughout the body.

The peripheral circulatory system includes the vessels that carry blood away from the heart to the muscles and organs (lungs, brain, stomach, intestines) and those that return the blood to the heart (Figure 8.4). The vessels that carry blood away from the heart are called arteries and the vessels that return blood to the heart are called veins. These are discussed in the following sections.

Arteries

Arteries branch into smaller and smaller vessels called arterioles, which branch into even smaller vessels called capillaries.

As the arteries carry blood away from the heart they branch into smaller and smaller vessels called arterioles. The arterioles also branch into smaller and smaller vessels until they are made up of vessels that are about the width of one red blood cell (Figure 8.5). At this point they are called capillaries. The capillaries are small vessels composed of only endothelial cells that allow for the exchange of oxygen and nutrients from the blood to muscles and organs and also allow blood to pick up the waste products and carbon dioxide from metabolism.

Discussion Guiding Question

- Define and provide the units for heart rate, cardiac output, and stroke volume.

***Heart rate** (beats/min): the number of times the heart beats in one minute*

***Cardiac output** (L/min): the amount of blood that is pumped into the aorta each minute by the heart; the product of stroke volume and heart rate*

***Stroke volume** (ml): the amount of blood that is pumped out of the left ventricle with each heartbeat*

Differentiated Instruction WEB

Practical Application

How Hard Am I Working?

Have students practice taking their carotid and radial pulses with a partner. Then have them complete **student workbook activity 8.1.5** on pages 86-87 to determine their minimum and maximum training target heart rates.

KISS (Keep It Super Simple)

Tree of Life

Use a tree analogy when describing arteries, arterioles, and capillaries to students. The trunk of the tree is the artery, and the branches are arterioles. The branches (arterioles) separate into even smaller twigs (capillaries).

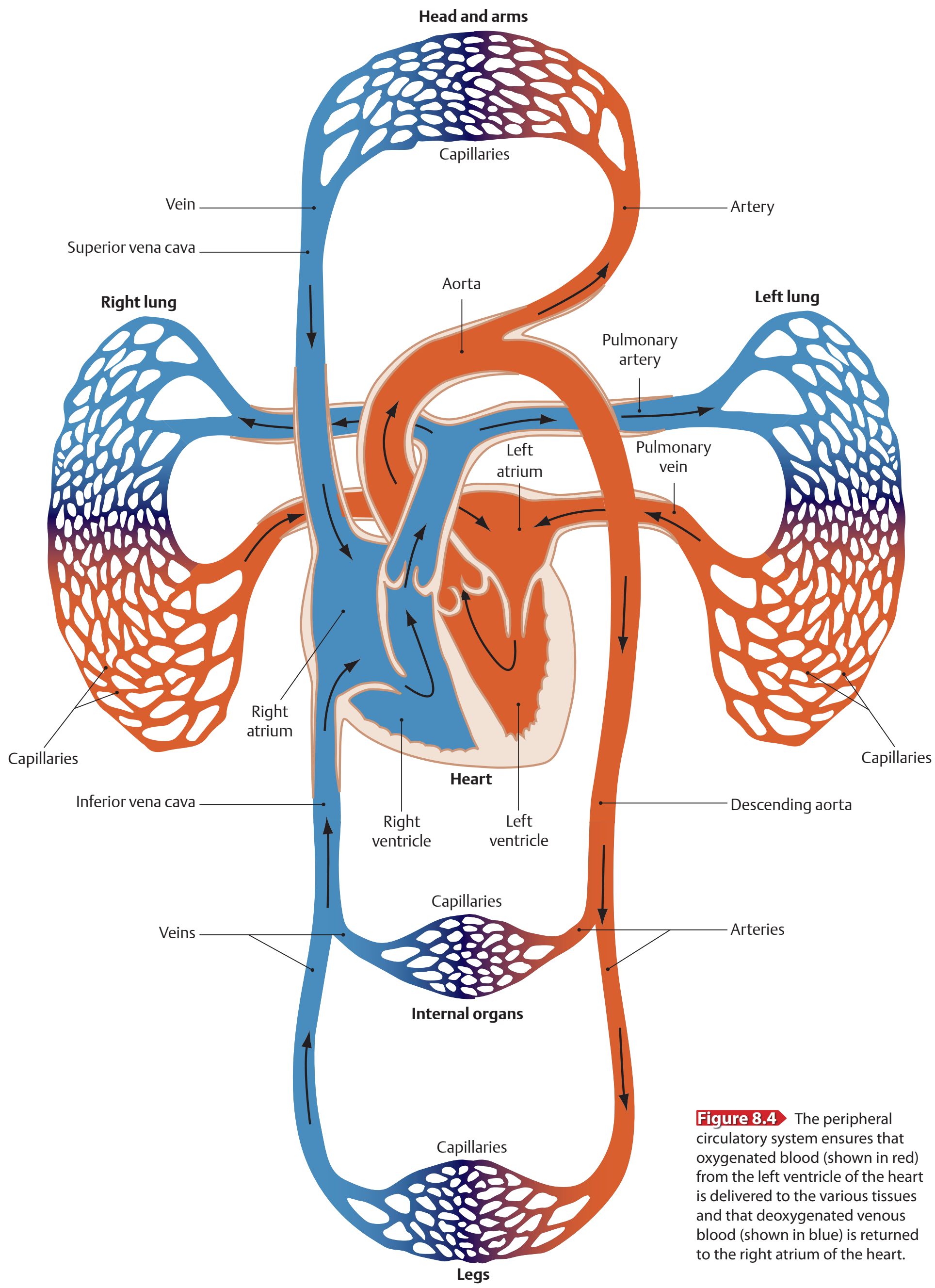


Figure 8.4 The peripheral circulatory system ensures that oxygenated blood (shown in red) from the left ventricle of the heart is delivered to the various tissues and that deoxygenated venous blood (shown in blue) is returned to the right atrium of the heart.

Discussion Guiding Question

- Which vessels carry blood away from the heart and which return blood to the heart?

*The vessels that carry blood away from the heart to the muscles and organs are called **arteries**, and the vessels that return blood to the heart are called **veins**. Arteries branch into smaller and smaller vessels called **arterioles**, which branch into even smaller vessels called **capillaries**. As the blood begins to return to the heart, the capillaries connect to form larger and larger vessels called **venules**. The venules then merge into larger vessels called **veins**.*

KISS (Keep It Super Simple)

The Path to Success

Use the analogy of highways, main roads, and residential roads (side streets) to describe the circulatory system. Imagine that you are blood, the heart is where you work, and the muscles are where you live. You need to pass through the lungs to get your money (oxygenated blood) before you go home (where you pay bills). In order to get home from work with money, you need to take the highway (arteries), exit the highway to the main roads (arterioles), and then enter the side streets (capillaries). Once home (muscles), you must pay the bills (with oxygen), and the cycle continues. You head back to work with no money (deoxygenated blood), taking the side streets (capillaries) to the main roads (venules), until you reach the highway (veins) that return to work (heart) where the cycle continues.

Cooperative Learning

From Work to Home and Back Again

After presenting the analogy described in the previous activity to the left, divide students into small groups and have them illustrate the concept on paper or on the blackboard. They must include the heart, lungs, arteries, arterioles, capillaries, muscles, venules, and veins in their visual representation of the circulatory system. The groups can exchange their drawings and have them reviewed by another group for accuracy.