exercise 20

Anatomy of the Heart

The major function of the **cardiovascular system** is transportation. Using blood as the transport vehicle, the system carries oxygen, digested foods, cell wastes, electrolytes, and many other substances vital to the body's homeostasis to and from the body cells. The propulsive force is the beating heart, which is essentially a muscular pump equipped with one-way valves. As the heart contracts, it forces blood into a closed system of large and small plumbing tubes (blood vessels) within which the blood circulates. This exercise deals with the structure of the heart. The anatomy of the blood vessels is considered separately in Exercise 21.

Gross Anatomy of the Human Heart

Objective 1: Describe the location of the heart in the body.

The **heart,** a cone-shaped organ approximately the size of a fist, is located within the medial cavity of the thorax. It is flanked laterally by the lungs, posteriorly by the vertebral column, and anteriorly by the sternum (Figure 20.1). Its more pointed **apex** extends slightly to the left and rests on the diaphragm, approximately at the level of the fifth intercostal space. Its broader **base,** from which the great vessels emerge, lies beneath the second rib and points toward the right shoulder. In the body, the right ventricle of the heart forms most of its anterior surface.

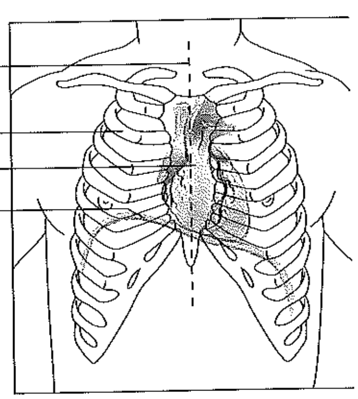

Figure 20.1 Location of the heart in the thorax.

Before You Begin:

- Read the chapter on heart structure in your textbook.
- Scan the exercise for the objectives you will be expected to accomplish during this laboratory session.
- Brush up on the structure of cardiac muscle cells.

Materials

- ❑ Torso model or laboratory chart showing heart anatomy
- ❑ Red and blue pencils
- ❑ Three-dimensional models of cardiac and skeletal muscle
- ❑ Heart model (three-dimensional)
- ❑ X ray of the human thorax for observation of the position of the heart *in situ;* X-ray viewing box
- ❑ Preserved sheep heart, pericardial sacs intact (if possible)
- ❑ Dissecting pan and instruments
- ❑ Pointed glass rods for probes
- ❑ Protective skin cream or disposable gloves
- ❑ Demonstration area: Compound microscope set up with a longitudinal section cardiac muscle; pointer on an intercalated disc

If an X ray of a human thorax is available, verify the relationships described above; otherwise Figure 20.1 will suffice.

The heart is enclosed within a double-walled serous sac called the pericardium. The thin **visceral pericardium,** or **epicardium,** is closely applied to the outer heart surface. It is continuous at the base of the heart with its companion serous membrane, the outer, loosely applied **parietal pericardium.** The parietal pericardium is reinforced on its superficial face by dense fibrous connective tissue, which protects the heart and anchors it to the diaphragm. Serous fluid produced by these membranes allows the heart to beat in a relatively frictionless environment.

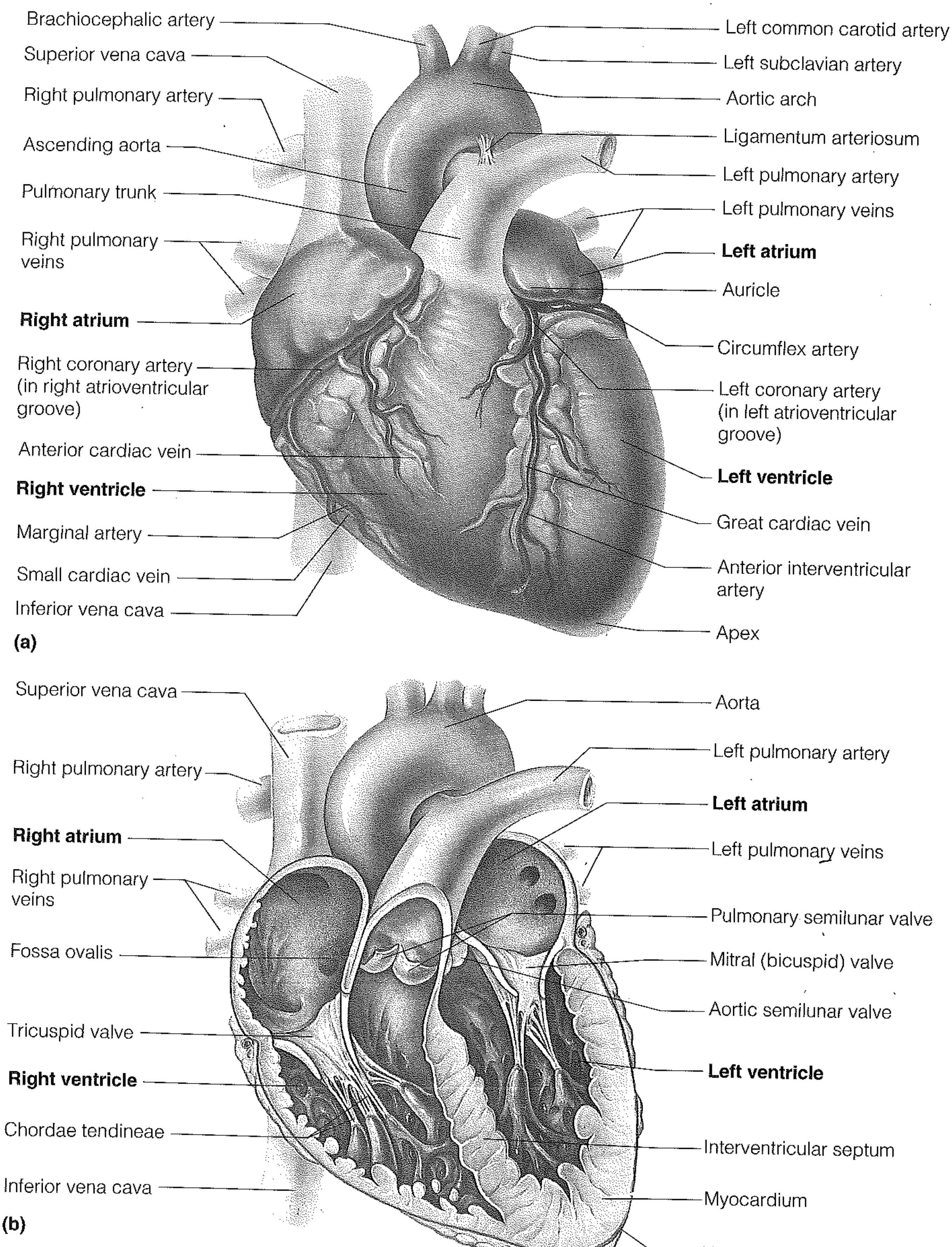

Figure 20.2 Anatomy of the human heart. (a) External anterior view. (b) Frontal section.

The walls of the heart are composed primarily of cardiac muscle—the **myocardium**—which is reinforced internally by a dense fibrous connective tissue network that is thicker in certain areas, for example, around the valves.

Figure 20.2 shows two views of the heart—an external anterior view and a frontal section. As its anatomical areas are described in the text, consult the figure.

Heart Chambers

The heart has four chambers: two superior **atria** and two inferior **ventricles,** each lined by a thin serous membrane called the **endocardium.** The septum that divides the heart longitudinally is referred to as the **interatrial** or **interventricular septum,** depending on which chambers it partitions. Functionally, the atria are receiving chambers and are relatively unimportant as pumps. The right atrium receives relatively oxygen-poor blood from the body via the **superior** and **inferior venae cavae.** Four **pulmonary veins** deliver oxygen-rich blood from the lungs to the left atrium.

The inferior ventricles, which form the bulk of the heart, are the discharging chambers. They force blood out of the heart into the large arteries that emerge from its base. The right ventricle pumps blood into the **pulmonary trunk,** which sends blood to the lungs to be oxygenated. The left ventricle discharges blood into the **aorta,** from which all systemic arteries of the body diverge to supply the body tissues. Discussions of the heart's pumping action usually refer to the activity of the ventricles.

Heart Valves

Four valves enforce a one-way blood flow through the heart chambers. The **atrioventricular (AV) valves,** located between the atrium and ventricle on each side, prevent backflow into the atria when the ventricles are contracting. The left atrioventricular valve, also called the **mitral** or **bicuspid valve,** has two cusps, or flaps, of endocardium. The right atrioventricular valve, the **tricuspid valve,** has three cusps (Figure 20.2b). Tiny white collagenic cords called the **chordae tendineae** (literally, "heart strings") anchor the cusps to the ventricular walls.

When the heart is relaxing, blood flows passively into the atria and then into the ventricles. At first, the AV valve flaps hang limply into the ventricular chambers, and then they are carried passively toward the atria by accumulating blood. When the ventricles contract and compress the blood in their chambers, the intraventricular pressure rises, forcing the valve flaps superiorly, which closes the AV valves. The chordae tendineae anchor the flaps in a closed position that prevents backflow into the atria during ventricular contraction.

The second set of valves, the **pulmonary** and **aortic semilunar valves,** guards the bases of the two large arteries leaving the ventricular chambers. Each semilunar valve has three cusps that fit tightly together when the valve is closed. The valve cusps are forced open and flatten against the walls of the artery as the ventricles pump their blood into the large arteries during systole. However, when the ventricles relax and blood flows backward toward the heart, the cusps fill with blood, closing the semilunar valves and preventing arterial blood from reentering the heart.

Objective 2: Identify the major anatomical areas and structures of the heart when provided with a heart model, diagram, or sheep heart.

Activity:

Using the Heart Model to Study Heart Anatomy

When you have pinpointed in Figure 20.2 all the structures described so far, observe the human heart model and reidentify the same structures without referring to the figure. ■

Pulmonary, Systemic, and Cardiac Circulations

Objective 3: Trace the pathway of blood through the heart, and compare the pulmonary and systemic circulations.

Pulmonary and Systemic Circulations

The heart is a double pump. The right side serves as the **pulmonary circulation** pump, sending the carbon dioxide–rich blood entering its chambers to the lungs to unload carbon dioxide and pick up oxygen, and then back to the left side of the heart (Figure 20.3). This circuit strictly provides for gas exchange. The second circuit, the **systemic circulation,** carries oxygen-rich blood from the left heart through the body tissues and back to the right heart. It supplies the functional blood supply to all body tissues.

Activity:

Tracing the Path of Blood Through the Heart

Trace the pathway of blood through the heart by adding arrows to the frontal section diagram (Figure 20.2b). Use red arrows for the oxygen-rich blood and blue arrows for the less oxygen-rich blood. ■

Cardiac Circulation

Objective 4: To name and follow the functional blood supply of the heart.

Even though the heart chambers are bathed with blood almost continually, this blood does not nourish the myocardium. The blood supply that nourishes the heart is provided by the right and left coronary arteries (see Figure 20.2a). The **coronary arteries** branch from the base of the aorta and encircle the heart in the **atrioventricular groove** at the junction of the atria and ventricles. They then branch over the heart's surface, the right coronary artery supplying the posterior surface of the ventricles and the lateral aspect of the

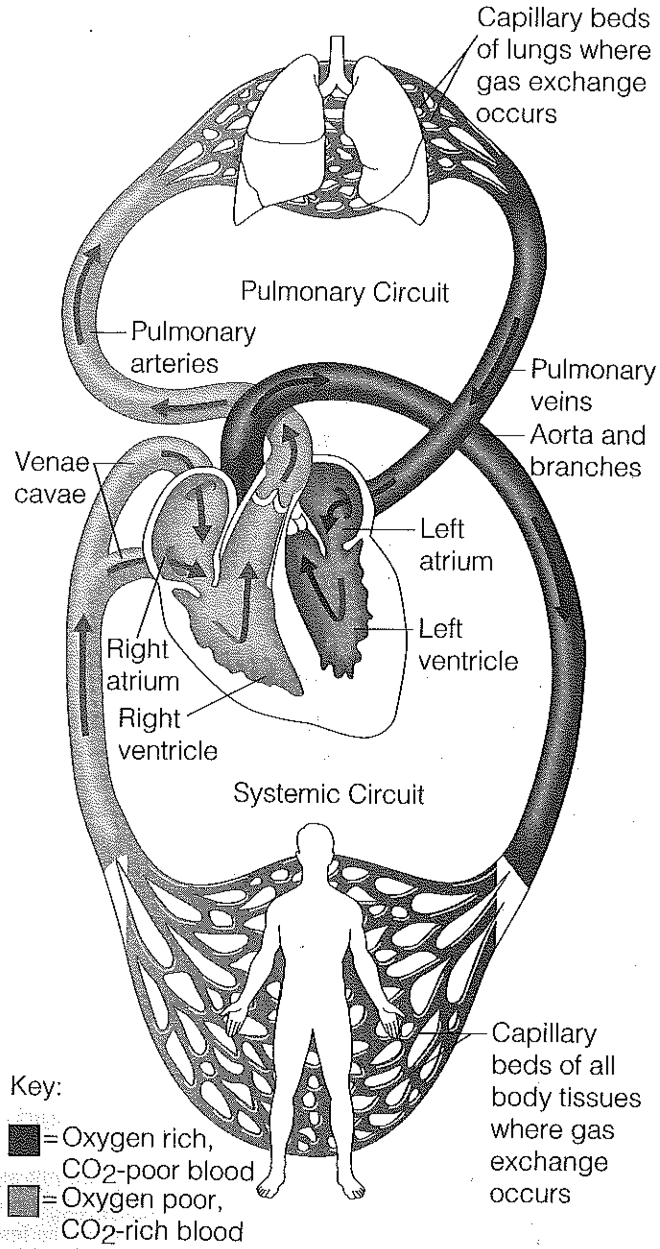

Figure 20.3 The systemic and pulmonary circuits. The heart is a double pump that serves two circulations. The right side of the heart pumps blood through the pulmonary circuit to the lungs and back to the left heart. (For simplicity, the actual number of two pulmonary arteries and four pulmonary veins has been reduced to one each.) The left heart pumps blood via the systemic circuit to all body tissues and back to the right heart. Notice that blood flowing through the pulmonary circuit gains oxygen and loses carbon dioxide. Blood flowing through the systemic circuit loses oxygen and picks up carbon dioxide.

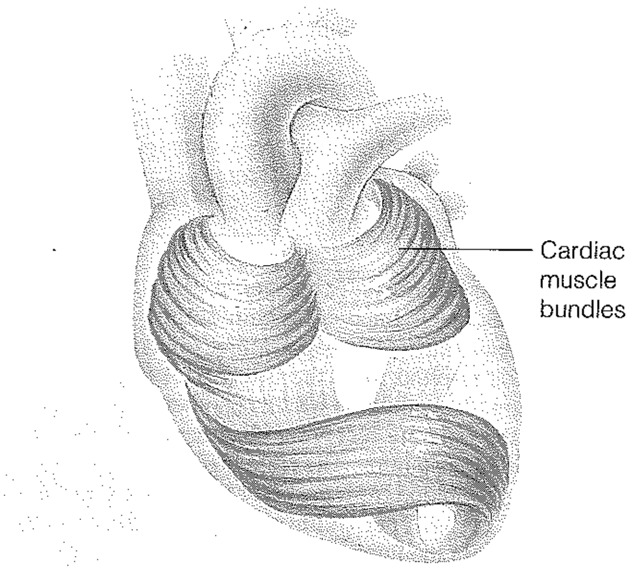

Figure 20.4 Longitudinal view of the heart chambers showing the spiral arrangement of the cardiac muscle fibers.

right side of the the heart, largely through its **posterior interventricular** and **marginal artery** branches. The left coronary artery supplies the anterior ventricular walls and the laterodorsal part of the left side of the heart via the **anterior interventricular artery** and the **circumflex artery.** The coronary arteries and their branches are compressed during systole and fill when the heart is relaxed.

The myocardium is drained by several **cardiac veins,** which empty into the **coronary sinus** (an enlarged vessel on the backside of the heart). The coronary sinus, in turn, empties into the right atrium. In addition, several **anterior cardiac veins** empty directly into the right atrium.

Microscopic Anatomy of Cardiac Muscle

Objective 5: Describe the microscopic structure of cardiac muscle and indicate the importance of intercalated discs.

Cardiac muscle is found in only one place—the heart. Because the heart acts as a blood pump, propelling blood to all tissues of the body, cardiac muscle is very important to life. Cardiac muscle is involuntary, ensuring a constant blood supply.

The cardiac cells are arranged in spiral or figure-8-shaped bundles (Figure 20.4). When the heart contracts, its internal chambers become smaller (or are temporarily obliterated), forcing the blood upward into the large arteries leaving the heart.

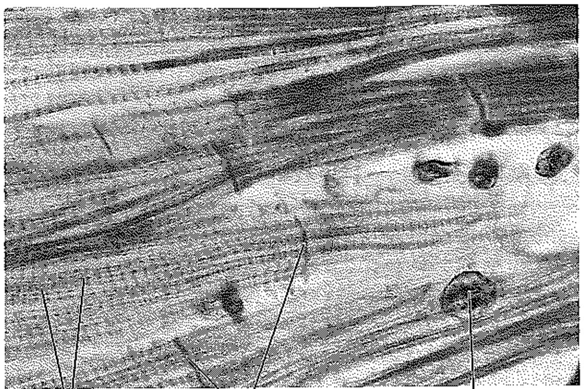

Figure 20.5 Photomicrograph of cardiac muscle (688×).

Activity:
Examining Cardiac Muscle Cells

1. Observe the three-dimensional model of cardiac muscle, examining its branching cells and the areas where the cells interdigitate, the **intercalated discs.** These two structural features provide a continuity to cardiac muscle not seen in other muscle tissues and allow coordinated heart activity.

2. Compare the model of cardiac muscle to the model of skeletal muscle. Note the similarities and differences between the two kinds of muscle tissue.

3. Go to the microscope at the demonstration area and observe a longitudinal section of cardiac muscle under high power. Identify the nucleus, striations, intercalated discs (pointed out), and sarcolemma of the individual cells and then compare your observations to Figure 20.5. ■

Dissection:
The Sheep Heart

Dissection of a sheep heart is valuable because it is similar in size and structure to the human heart. Also, dissection allows you to view structures in a way not possible with models and diagrams. Refer to Figure 20.6 as you proceed with the dissection.

1. Obtain a preserved sheep heart, a dissection tray, dissecting instruments, a glass probe and, if desired, protective skin cream or gloves. Rinse the sheep heart in cold water. Now you are ready to make your observations.

2. Observe the texture of the pericardium. Also, find its point of attachment to the heart. Where is it attached?

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3. If the serous pericardial sac is still intact, slit open the parietal pericardium and cut it from its attachments. Observe the visceral pericardium (epicardium). Using a sharp scalpel, carefully pull a little of this serous membrane away from the myocardium. How do its position, thickness, and apposition to the heart differ from those of the parietal pericardium?

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4. Examine the external surface of the heart. Notice the accumulation of adipose tissue, which in many cases marks the separation of the chambers and the location of the coronary arteries. Carefully scrape away some of the fat with a scalpel to expose the coronary blood vessels.

5. Identify the base and apex of the heart, and then identify the two wrinkled **auricles,** earlike flaps of tissue projecting from the atrial chambers. The balance of the heart muscle is ventricular tissue. To identify the left ventricle, compress the ventricular chambers on each side of the longitudinal fissures carrying the coronary blood vessels. The side that feels thicker and more solid is the left ventricle. The right ventricle is much thinner and feels somewhat flabby when compressed. This difference reflects the greater demand placed on the left ventricle, which must pump blood through the much longer systemic circulation. Hold the heart in its anatomical position (Figure 20.6a), with the anterior surface uppermost. In this position the left ventricle composes the entire apex and the left side of the heart.

6. Identify the pulmonary trunk and the aorta leaving the superior aspect of the heart. The pulmonary trunk is more anterior, and you may see its division into the right and left pulmonary arteries if it has not been cut too close to the heart. The thicker-walled aorta, which branches almost immediately, is located just beneath the pulmonary trunk. The first branch of the sheep aorta, the **brachiocephalic artery,** can be identified unless the aorta has been cut immediately as it leaves the heart. The brachiocephalic artery splits to form the right carotid and subclavian arteries, which supply the right side of the head and right forelimb, respectively.

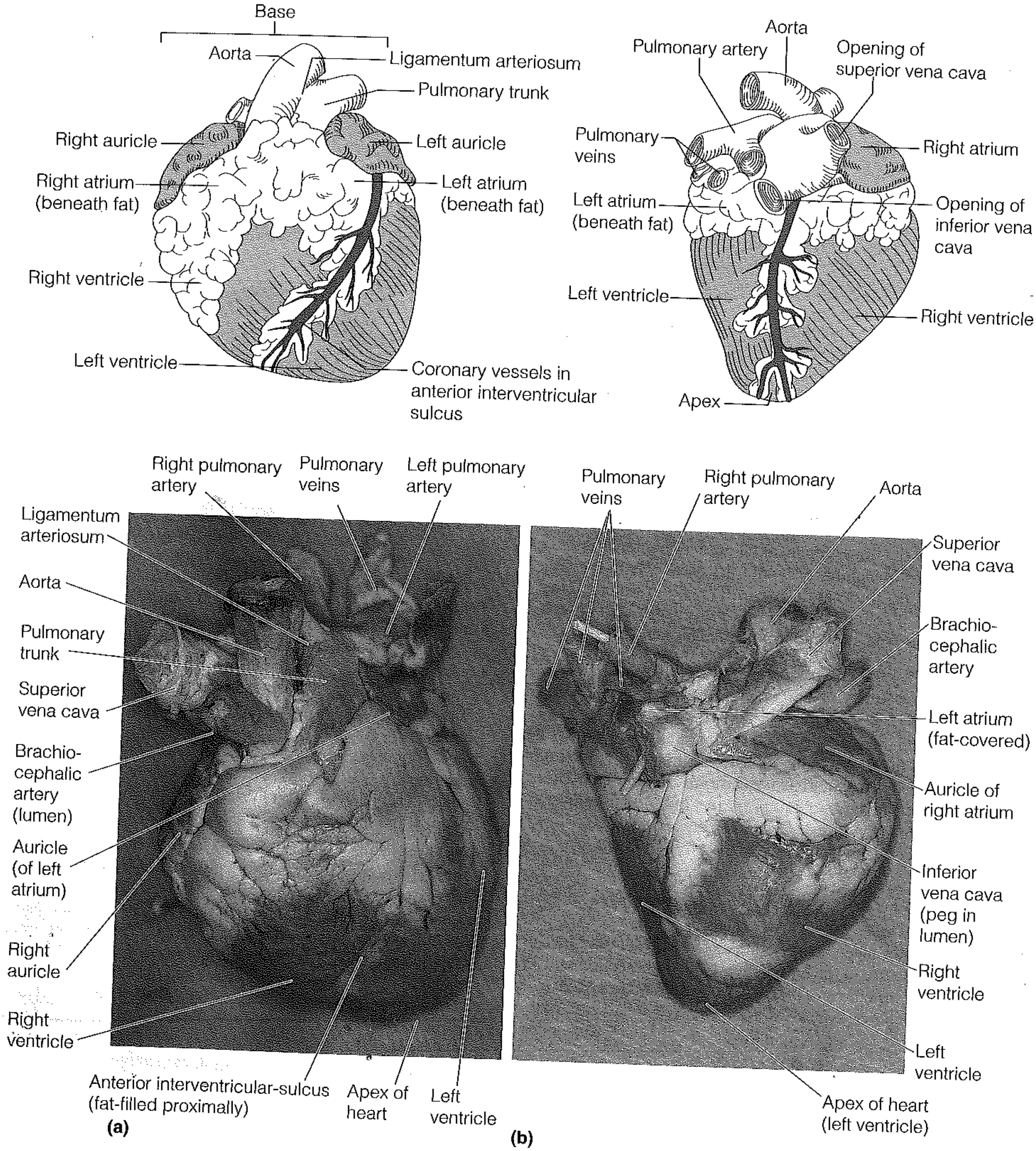

Figure 20.6 Anatomy of the sheep heart. (a) Anterior view. (b) Posterior view. Diagrammatic views at top; photographs at bottom.

. Carefully clear away the fat between the pulmonary trunk and the aorta to expose the **ligamentum arteriosum,** a remnant of the **ductus arteriosus.** (In the fetus, the ductus arteriosus allows blood to pass directly from the pulmonary trunk to the aorta, thus bypassing the nonfunctional fetal lungs.)

7. Cut through the wall of the aorta until you see the aortic semilunar valve. Identify the two openings into the coronary arteries just above the valve. Insert a probe into one of these holes to see if you can follow the course of a coronary artery across the heart.

8. Turn the heart to view its posterior surface. The heart will appear as shown in Figure 20.6b. Notice that the right and left ventricles appear equal-sized in this view. Try to identify the four thin-walled pulmonary veins entering the left atrium. (It may or may not be possible to locate the pulmonary veins from this vantage point, depending on how they were cut as the heart was removed.) Identify the superior and inferior venae cavae entering the right atrium. Compare the approximate diameter of the superior vena cava with that of the aorta.

Which is larger? ______________________

Which has thicker walls? ______________________

Why do you suppose these differences exist?

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Objective 6: Explain the operation of the heart valves.

9. Insert a probe into the superior vena cava and use scissors to cut through its wall so that you can see the interior of the right atrium. Do not extend your cut entirely through the right atrium or into the ventricle. Observe the right atrioventricular valve.

How many flaps does it have? ______________________

Pour some water into the right atrium and allow it to flow into the ventricle. *Slowly and gently* squeeze the right ventricle to watch the closing action of this valve. (If you squeeze too vigorously, you'll get a face full of water!) Drain the water from the heart before continuing.

10. Return to the pulmonary trunk and cut through its anterior wall until you can see the pulmonary semilunar valve. Pour some water into the base of the pulmonary trunk to observe the closing action of this valve. How does its action differ from that of the atrioventricular valve?

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11. After observing semilunar valve action, drain the heart once again. Return to the superior vena cava, and continue the cut made in its wall through the right atrium and right atrioventricular valve into the right ventricle.

12. Next, make a longitudinal incision through the aorta and continue it into the left ventricle. Notice how much thicker the myocardium of the left ventricle is than that of the right ventricle. Compare the *shape* of the left ventricular cavity to the shape of the right ventricular cavity.

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Are the chordae tendineae observed in the right ventricle also present in the left ventricle? ______________________

Count the number of cusps in the left atrioventricular valve. How does this compare with the number seen in the right atrioventricular valve?

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How do the sheep valves compare with their human counterparts?

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13. Continue your incision from the left ventricle superiorly into the left atrium. Reflect the cut edges of the atrial wall, and try to locate the entry points of the pulmonary veins into the left atrium. Follow the pulmonary veins to the heart exterior with a probe. Notice how thin-walled these vessels are.

14. Properly dispose of the organic debris, and clean the dissecting tray and instruments before leaving the laboratory. ■