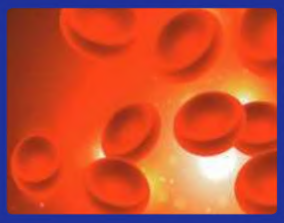
CHAPTER 4


Anatomy and Physiology of the Circulatory System

OBJECTIVES

After studying this chapter, you should be able to:

1. Describe the characteristics of different types of blood cells.
2. Describe the major difference between the walls of the arteries and the walls of the veins.
3. Differentiate between serum and plasma.
4. Name the parts of the heart and describe their function.
5. Trace the flow of blood through the heart.
6. Locate the veins in the arm and explain how each would be used in venipuncture.
7. Explain systolic and diastolic pressure.
8. Explain the conductive system of the heart.

NAACLS Competencies Relevant to Chapter 4

Demonstrate basic understanding of the anatomy and physiology of body systems and anatomic terminology in order to relate major areas of the clinical laboratory to general pathologic conditions associated with the body systems.

- Describe the basic functions of each of the main body systems, and demonstrate basic knowledge of the circulatory, urinary, and other body systems necessary to perform assigned sample collection tasks.
- Identify the veins of the arms, hands, legs, and feet on which phlebotomy is performed.
- Explain the functions of the major constituents of blood, and differentiate among whole blood, serum, and plasma.
- Discuss the properties of arterial blood, venous blood, and capillary blood.

KEY TERMS

Antecubital Fossa	The portion of the arm that is in front of the bend of the elbow. The most prominent veins for venipuncture are located in this area.
Anticoagulant	Chemical substance that prevents blood from clotting.
Basilic Vein	The vein on the little-finger side of the arm that runs the length of the arm.
Buffy Coat	Layer of cells in an anticoagulant tube of blood that is positioned between the red blood cells and the plasma layers. The buffy coat consists of white blood cells and platelets.
Centrifuge	Instrument that spins and separates blood into layers depending on the weight of each layer. The heavier elements are pushed to the bottom due to centrifugal force.
Cephalic Vein	The vein on the thumb side of the arm that runs the length of the arm.
Diastolic	Blood pressure when the heart is at rest.
Endocarditis	Infection of the inner membrane of the heart.
Erythrocytes	Formed blood element; also known as red blood cells.
Hemopoiesis (Hematopoiesis)	Formation of blood cells.
Leukocytes	Formed blood element; also known as white blood cells.
Median Cubital Vein	The vein in the antecubital fossa area of the arm that bridges the cephalic and basilic veins.
Occluded	Blocked; the normal flow of blood is prevented.
Plasma	Fluid portion of the blood when no clotting has taken place.
Pulmonary System	System circulating blood through the lungs.
Serum	Fluid portion of the blood after clotting has taken place.
Systemic System	System circulating blood throughout the body with the exception of the lungs.
Systolic	Blood pressure when the heart is fully contracted.
Thrombocytes	Formed blood element; also known as platelets.

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CIRCULATORY SYSTEM

Each body system works simultaneously to provide other body systems the necessary products or energy they need. The circulatory system is the transportation system for the body to transfer substances and waste from one system to another. There are two parts of the circulatory system: the **pulmonary system** and the **systemic system** (Figure 4.1). The pulmonary system circulates the blood through the lungs, where the blood is enriched with oxygen and the waste carbon dioxide is removed. The systemic system supplies the cells with oxygen, fats, carbohydrates, and other energy sources while at the same time removing waste products. The phlebotomist must be most knowledgeable of the circulatory system. The remainder of this chapter discusses the circulatory system in detail.

ANATOMY AND PHYSIOLOGY OF THE CIRCULATORY SYSTEM

To be prepared to collect blood, the phlebotomist must understand the system that carries this blood: the circulatory system. The bone marrow is the primary factory for production of blood cells. The lymph nodes, thymus, and spleen are also sites for the production of blood cells. The function of blood is to carry oxygen to body tissues and to remove the waste product carbon dioxide. The blood also carries nutrients to all parts of the body and moves the products to the lungs, kidneys, liver, and skin.

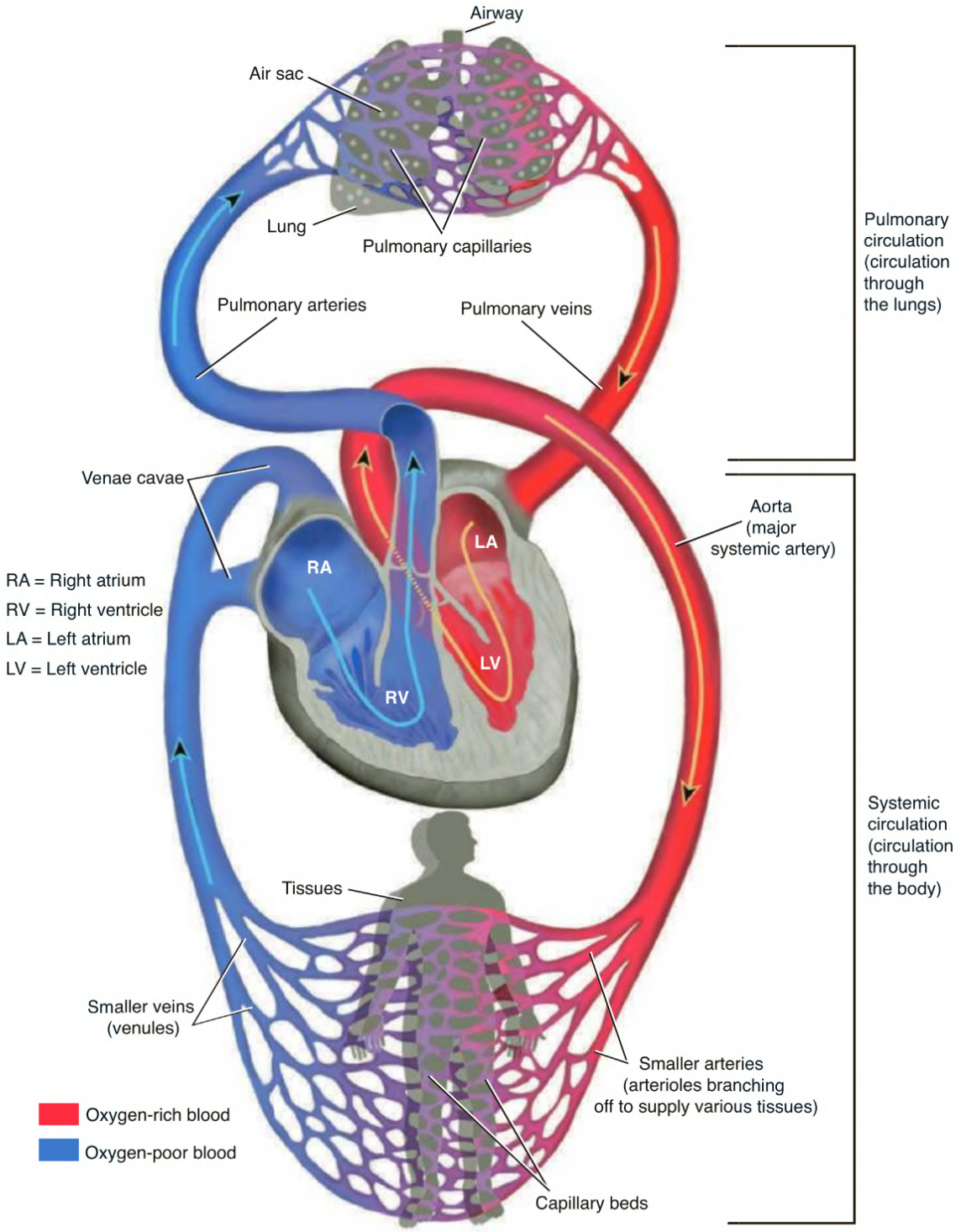
An adult body that weighs 150 pounds (lb.) (68 kilograms) contains approximately 5 liters of blood. Blood volume varies depending on the size of the individual. A preterm infant weighing 1 kilogram (2.2 lb.) will have only 100 milliliters (mL) of blood. During one blood draw only 2.5 percent of an individual's blood can be taken. For a preterm infant that would be 2.5 milliliters of blood. No more than 5 percent of the total patient's blood volume should be taken within a 30-day period. This usually is not a concern for an adult but an infant can exceed this 5 percent limit quickly with multiple blood tests. All infants and children must have the amount of blood removed at each draw documented in order to stay within the limit. Appendix D presents a chart that indicates the limits for different ages and weights of patients.

> **Helpful Hint**
>
> If the test calls for 2 milliliters of serum, you will need to collect a minimum of 4 milliliters of blood.

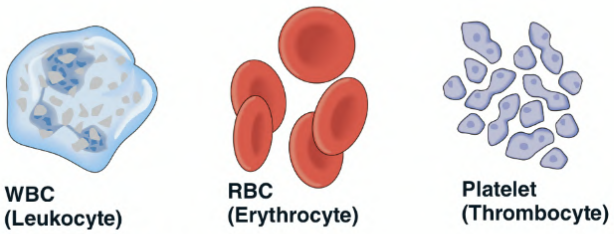
Blood consists of both liquid and formed cellular elements. 45 percent of blood consists of formed cellular elements, and 55 percent is a fluid portion, called plasma. Generally, 2 milliliters of blood yields about 1 milliliter of fluid. The formed cellular elements consist of **erythrocytes** (red blood cells [RBCs]), **leukocytes** (white blood cells [WBCs]), and **thrombocytes** (platelets) (Figure 4.2 and Table 4.1).

The blood cells begin their formation in the bone marrow and lymph nodes as undifferentiated hemopoietic stem cells. Through **hemopoiesis (hematopoiesis)** they continue to mature through different stages, slowly decreasing in size. When the cells leave the bone marrow and enter the bloodstream, they consist of mature cells. If immature cells are found in the bloodstream, this is indicative of a hematologic problem (Figure 4.3).

Mature erythrocytes average 7 to 8 micrometers in diameter and are biconcave. They live about 120 days once they enter the bloodstream. Mature erythrocytes have no nucleus. The cells consist of a membrane that encases hemoglobin. Hemoglobin is the iron-containing



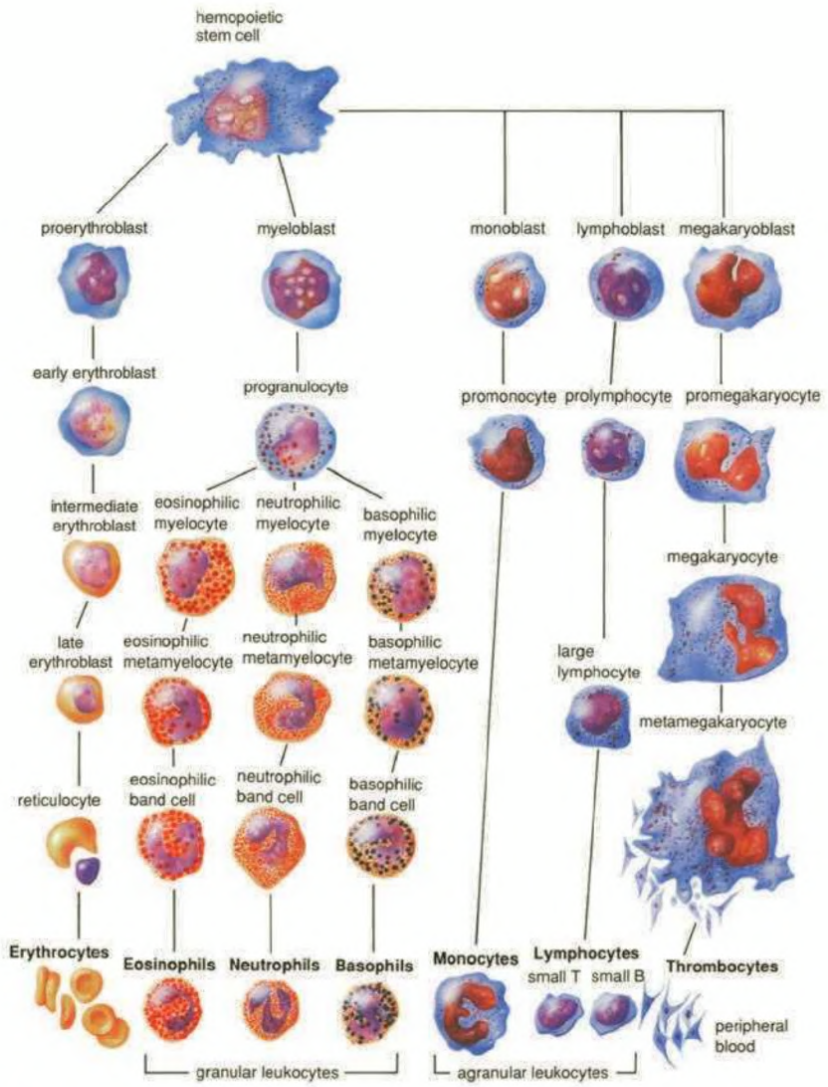
▲ FIGURE 4.1 Schematic drawing of blood circulation through the lungs and body.



▲ FIGURE 4.2 Formed cellular elements of the blood.

TABLE 4.1 Cellular Elements of the Blood

	WBC (*Leukocyte*)	RBC (*Erythrocyte*)	Platelet (*Thrombocyte*)
Function	Body defense	Transport of oxygen and carbon dioxide (intravascular)	Stoppage of bleeding
Formation	Bone marrow, lymphatic tissue	Bone marrow	Bone marrow
Size/shape	9–16 micrometers; different size, shape, color; nucleus (core)	6–7 micrometers, biconcave disc; normally no nucleus in mature cells found in bloodstream	1–4 micrometers; fragments of megakaryocytes
Life span	Varies; 24 hours–years	100–120 days	9–12 days
Reference values	3,500–11,000/cubic millimeter	3.8–5.9 million/cubic millimeter	150,000–400,000/cubic millimeter
Removal	Bone marrow, liver, spleen	Bone marrow, liver, spleen	Spleen



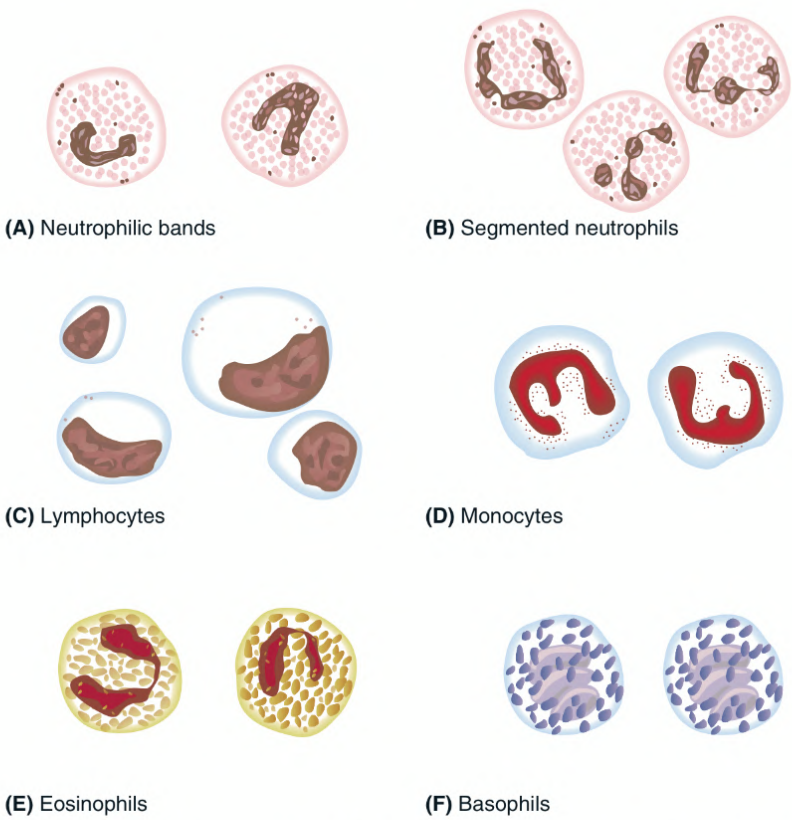
▲ FIGURE 4.3 Hemopoiesis (hematopoiesis) showing blood cells and platelet formation starting with the hemopoietic stem cell.

pigment of the RBCs. The hemoglobin holds oxygen molecules that were absorbed through the membrane as the erythrocytes passed through the lungs. The hemoglobin then releases the oxygen to tissues and brings carbon dioxide back to the lungs to be released as a waste product. A person who is anemic has too little hemoglobin. Many individuals with anemia also have a decreased number of erythrocytes.

The membrane of the erythrocyte does more than just encase the hemoglobin. The erythrocytes contain antigens on the surface that determine the individual's blood type and a variety of other factors specific for that individual. Antibodies that can react with antigens foreign to the individual are found in the patient's plasma. These antigen–antibody reactions are important when blood is transfused into an individual. The process of determining if a person will react after a transfusion is called a type and cross-match (T&C). The blood bank section of the laboratory performs the T&C. It is of critical importance that the phlebotomist drawing a blood sample be absolutely positive about patient identification. From the sample the phlebotomist draws, the blood bank determines what blood to give the patient.

The bone marrow and lymph nodes produce the leukocytes. The leukocytes start as undifferentiated stem cells just like the erythrocytes and then form into blast cells, maturing through several stages until they are released into the blood as mature cells (see Figure 4.3).

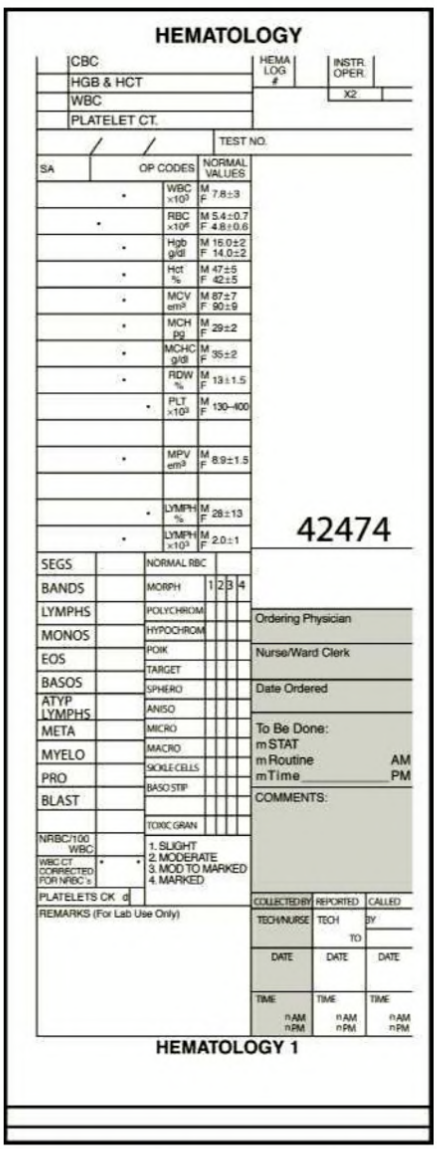
Leukocytes vary greatly in size. They appear as large white cells that have purple centers (nuclei) when viewed in a stained blood smear. Some of the cells also have granules that stain pink, blue, or orange. These staining characteristics help to identify the different cells. When a technologist counts at least a hundred of these leukocytes and classifies them according to the percentage of cell types that are found, the physician receives a report called a white blood cell differential count. This differential count changes depending on the disease process that is taking place. A differential count can indicate whether a person has a viral infection, bacterial infection, appendicitis, and so on. Figure 4.4 illustrates the six basic types of mature leukocytes and their comparative sizes.



▲ FIGURE 4.4 Various divisions of leukocytes from a stained blood smear.

This differential count is only part of a complete blood cell count (CBC). The rest of the CBC contains the number of WBCs and RBCs, as well as the patient's hemoglobin and hematocrit. Calculations involving the hemoglobin, hematocrit, and RBCs give the physician facts called the indices of the RBC. All this information can give the physician a general screening of the patient's health. Figure 4.5 shows a CBC report form.

The thrombocytes (platelets) are the smallest of the formed elements. They are fragments of cells that break off from a large cell called a metamegakaryocyte, which is found in the bone marrow. The function of the thrombocytes is to aid in the clotting process. When a person is cut, the platelets are the first cells to go to the site. They start sticking together to try to plug the hole. Then other clotting factors become active to complete the clotting process. The thrombocyte matures from an undifferentiated stem cell just like the erythrocytes and leukocytes (see Figure 4.3).



▲ FIGURE 4.5 Complete blood cell count report form.

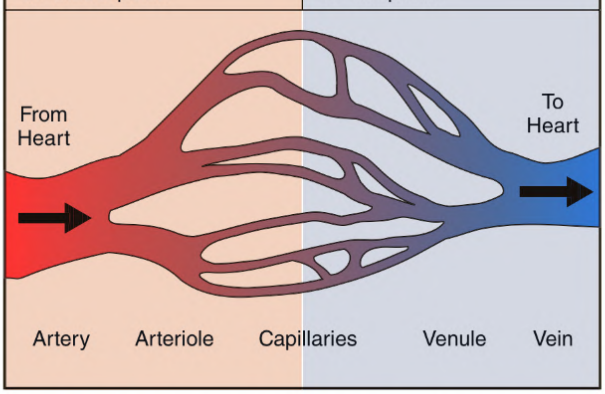
EXERCISE 1 Fill in the Blanks

Directions: Fill in the table for the cellular elements of the blood.

	White Blood Cells	Red Blood Cells	Platelets
Function			
Formation			
Size/shape			
Life span			
Normal values			
Removal			

The heart pumps blood through the body by way of tubing called arteries, veins, and capillaries. When blood flows away from the heart, it flows in the arteries. Blood flowing back to the heart flows in the veins. Connecting most of the arteries and veins are the capillaries (Figure 4.6).

ARTERIES VERSUS VEINS	
Arteries	**Veins**
1. Carry blood from the heart, carry oxygenated blood (except pulmonary artery)	1. Carry blood to the heart, carry deoxygenated blood (except pulmonary vein)
2. Normally bright red in color	2. Normally dark red in color
3. Elastic walls that expand with surge of blood	3. Thin walls/less elastic
4. No valves	4. Valves
5. Has a pulse	5. No pulse



▲ FIGURE 4.6 Blood flow: Oxygenated blood in the arteries becomes deoxygenated upon leaving the capillaries and entering the veins.

EXERCISE 2 Short Answer

Directions: Write in the correct term or phrase to complete each sentence.

1. The average individual's blood contains _____ % formed elements
2. The average individual's blood will produce _____ % serum or plasma.
3. The test you are collecting blood for requires 5 milliliters of serum. To get this much serum from an average individual, you would need to collect at least _____ milliliters of blood.
4. The formed elements of the blood are:
   a.
   b.
   c.
5. The five parts of a CBC (complete blood count) are:
   a.
   b.
   c.
   d.
   e.

The artery has a thick wall that helps it withstand the pressure of the pumping heart. We can use the analogy of the bodybuilder who has built up his muscles to be stronger and thicker. The arteries are constantly expanding and contracting and therefore have a thicker, stronger wall. The arteries start branching off to form arterioles that branch even more to become capillaries. The capillaries then start forming together to create venules, and the venules then become veins. As blood flows through the body, it follows this path of artery–capillary–vein. Oxygenated arterial blood leaves the heart and carries this oxygen to the tissue by releasing the oxygen through the cell walls of the capillaries. At the same time, carbon dioxide is being absorbed by the blood and then transported to the lungs to be exhaled as a waste product. The flow of the blood also regulates body temperature. When the body gets warm, the capillaries in the extremities dilate (enlarge in diameter) and let off heat. This process then cools the body. If the body becomes cold, the capillaries constrict (get smaller in diameter) and less blood flows through, therefore conserving heat for the rest of the body. That is why our feet and fingers get cold before other parts of the body. When we discuss microcollection in Chapter 7, we see that heat stimulation of blood flow is very useful.

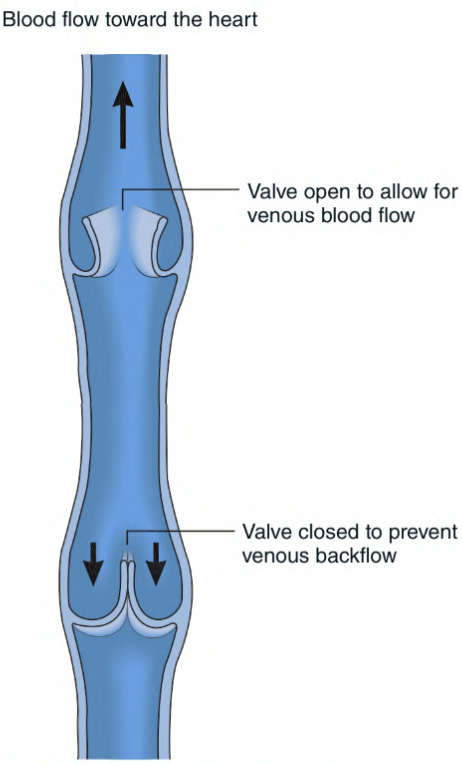
To keep the blood flowing in a one-way direction, the veins in the extremities contain structures called valves. These valves let the blood pass through but close if the blood tries to flow backward (Figure 4.7).

If you look more closely at the structure of the arteries and veins, you can see that they are not made of one monolayer but multiple layers of tubing. The cells in these layers run in different directions and give strength to the arteries and veins (Figure 4.8). The structure is like a piece of plywood. Plywood is stronger than a piece of wood the same thickness because the lamination of the plywood has given it strength. This layering also helps keep the arteries and veins from rupturing and splitting when punctured with a needle to draw blood.

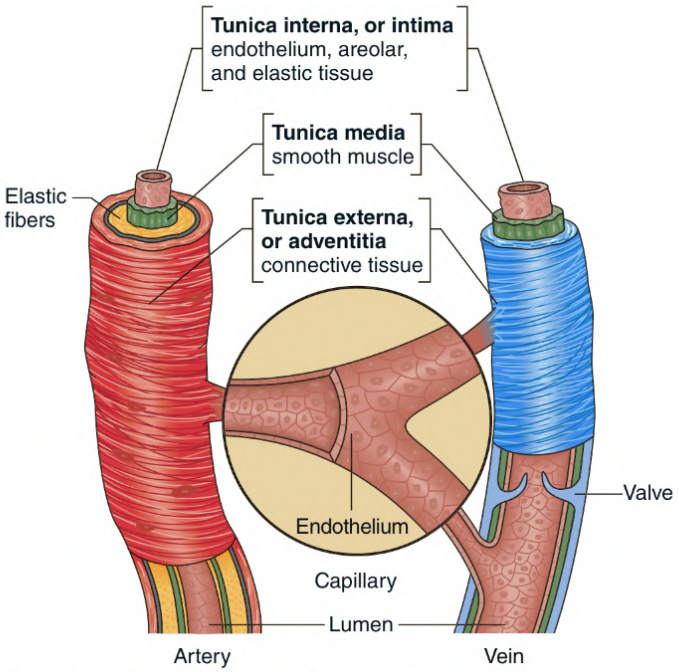
Helpful Hint

These different cell layers work to close the hole after a venipuncture. Each layer pushes in a different direction and seals the hole.

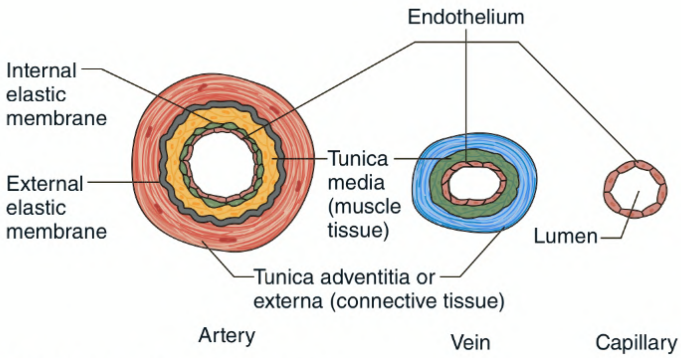
As already explained, the formed elements of the blood make up only 45 percent of the total volume. The remaining 55 percent is liquid. In the body, the liquid portion is called **plasma.** When the blood is removed from the body, the blood clots and the liquid portion is called **serum.** The clot contains all the formed elements intertwined together in a fibrin mass. Blood that is flowing through the body contains a protein called fibrinogen. Once



▲ FIGURE 4.7 Valves in the veins.



(A) Types of blood vessels and their general structure



(B) Cross section of blood vessels

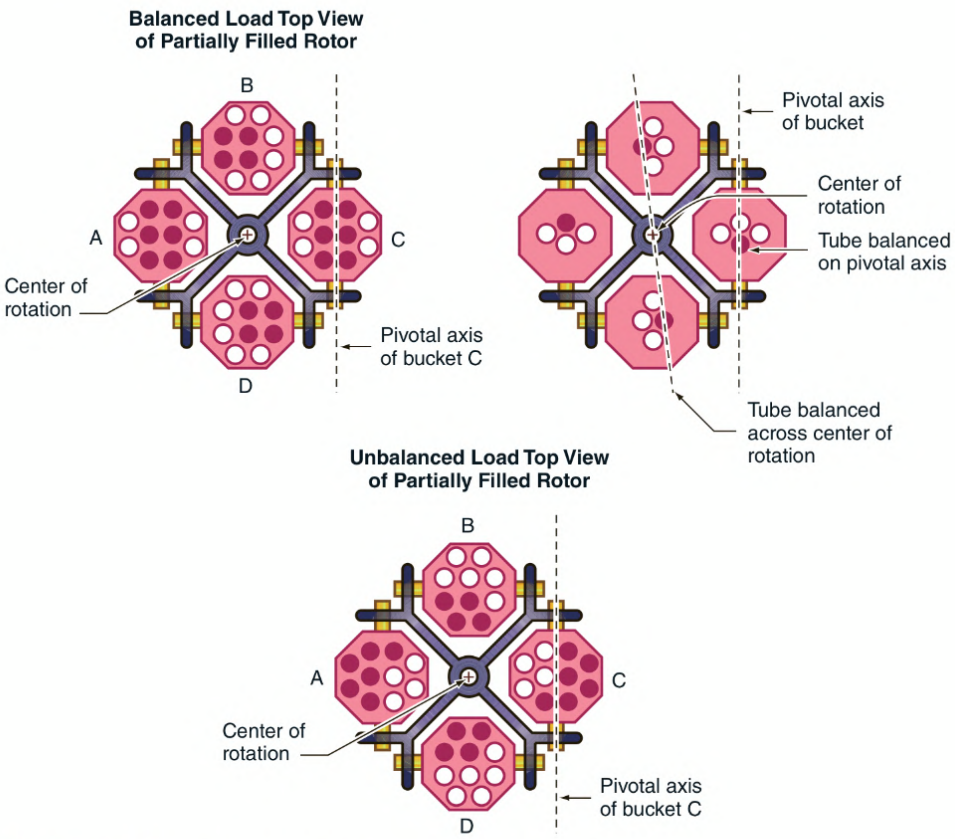
▲ FIGURE 4.8 Different types of blood vessels and their cross-sectional views.

1. Uncoagulated blood
2. Calcium utilized
3. Prothrombin converts to thrombin
4. Fibrinogen converts to fibrin
5. Clot formation with serum extracted

▲ FIGURE 4.9 Steps to a clot.

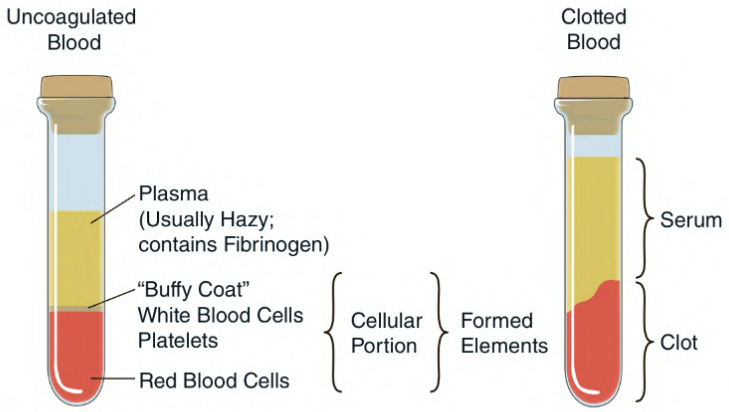
the blood leaves the body, the fibrinogen turns into fibrin. This fibrin is like a sticky spider web and traps the formed elements into the fibrin mass, which is called a clot. The clot then contracts, and the liquid (serum) portion is extracted (Figure 4.9). This serum is a clear straw-colored liquid that is used for many of the tests done in the laboratory. To speed the removal of the serum, an instrument called a **centrifuge** spins the blood (Figure 4.10). A carrier holds the tubes of blood in an upright position, and when the centrifuge is started, the carriers spin in a circle. This is similar to a weight on the end of a string. The string is vertical, but as the weight is swung in a circle, the weight assumes a horizontal position. The carriers in the centrifuge must be balanced and assume a horizontal position to push

▲ FIGURE 4.10 Centrifuges.



▲ FIGURE 4.11 Centrifuge balance.

the blood clot to the bottom of the tube, much like what happens in a washing machine as the clothes are pushed to the outside of the washer (Figure 4.11). The blood separates according to weight. The clot then goes to the bottom of the tube, and the serum is on the top layer. This separation of the blood is due to the centrifugal force on the blood.



▲ FIGURE 4.12 Blood tubes.

Helpful Hint

Before centrifuging a blood sample for serum, the blood must clot for at least 30 minutes.

To produce a plasma sample, clotting must be prevented. An **anticoagulant** is a chemical substance that prevents the blood from clotting by preventing the fibrinogen from converting to fibrin. Adding a small amount of anticoagulant to a test tube prevents the blood from clotting and keeps it in a condition similar to how it was in the body. An anticoagulated tube of blood that has been centrifuged layers the formed elements and plasma according to weight. The bottom layer contains the erythrocytes, and there is a thin layer called the **buffy coat**. The buffy coat contains a mixture of leukocytes and thrombocytes. On top of all these layers is the plasma layer. The plasma contains fibrinogen and usually is slightly hazy (Figure 4.12).

EXERCISE 3 Ordering/Sorting

Directions: Number the steps in the clotting of blood in the correct order, 1, 2, 3, and so on.

A. _____ Fibrinogen converts to fibrin

B. _____ Calcium is utilized

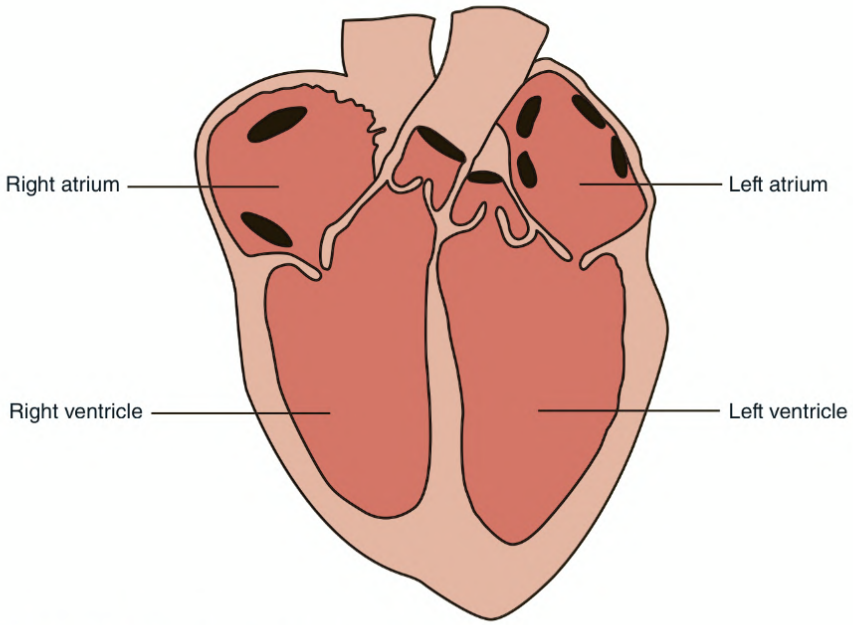
C. _____ Blood is uncoagulated

D. _____ Clot forms with serum extraction

E. _____ Prothrombin converts to thrombin

THE HEART

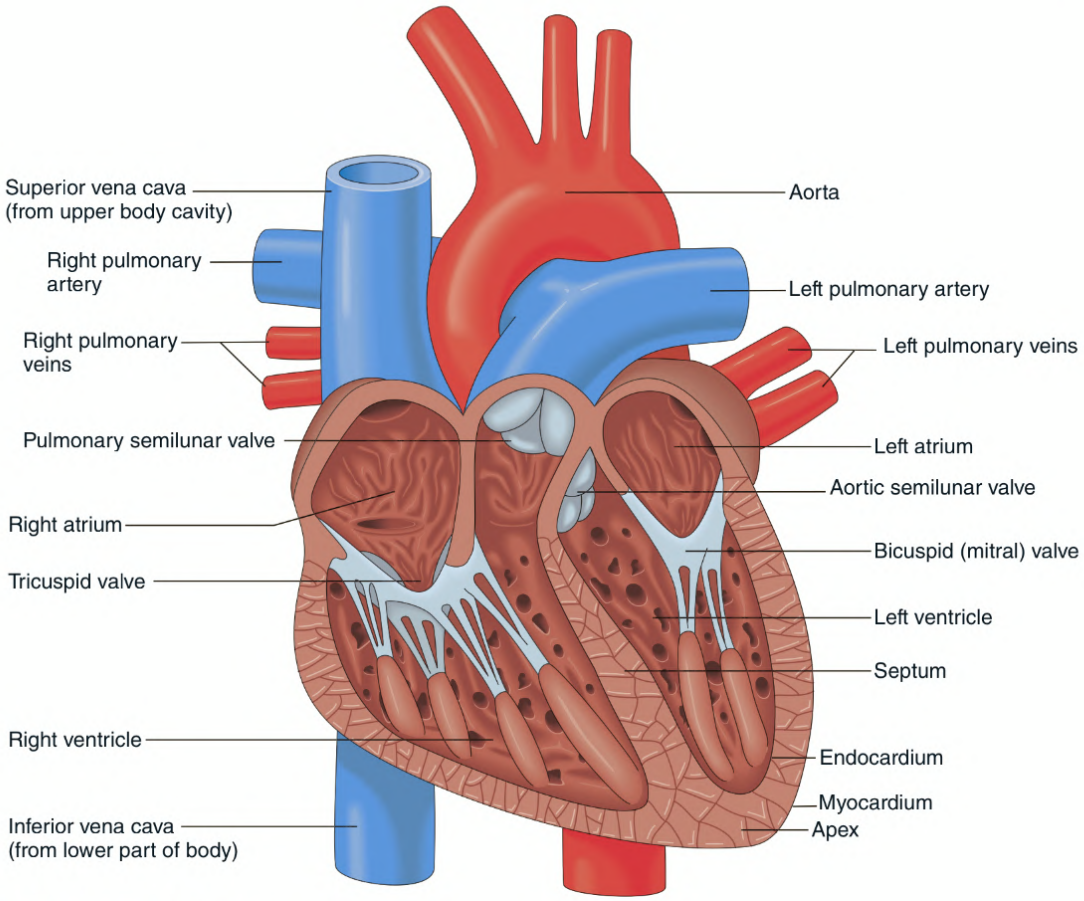
The heart, the organ that keeps all this blood flowing, is a muscle with four distinct chambers: right atrium, right ventricle, left atrium, and left ventricle (Figure 4.13). Blood enters the heart through the right atrium and left atrium. Blood leaves the heart by way of the right and left ventricles. The right ventricle of the heart is responsible for oxygenating the blood by pumping it to the lungs. The left ventricle of the heart has the task of pumping the blood to all parts of the body. The blood flows through the body via the arteries, arterioles, capillaries, venules, and veins (Table 4.2). A muscular wall called the septum divides the right and left sides of the heart.



▲ FIGURE 4.13 Heart chambers.

TABLE 4.2 Blood Flow Chart

Superior/Inferior Vena Cava
↓
Right Atrium
↓
Right Ventricle
↓
Pulmonary Artery to Lungs
↓
Pulmonary Vein from Lungs
↓
Left Atrium
↓
Left Ventricle
↓
Aorta
↓
Arteries
↓
Arterioles
↓
Capillaries
↓
Venules
↓
Veins
↓
Back to Superior/Inferior Vena Cava



▲ FIGURE 4.14 Cross-section of the heart.

Referring to Figure 4.14, you can follow the flow of blood through the heart. Blood that has given up its oxygen (deoxygenated blood) enters the heart from the upper part of the body by way of the *superior vena cava.* Blood from the lower part of the body enters the heart by way of the *inferior vena cava.* The first chamber of the heart this deoxygenated blood enters is the *right atrium.* The blood then passes through the *tricuspid valve* and enters the *right ventricle.* The tricuspid valve is a one-way valve that keeps the blood from flowing back into the right atrium. From the right ventricle the deoxygenated blood passes through the *pulmonary semilunar valve* (pulmonary valve) into the right and left *pulmonary arteries.* The pulmonary arteries leave the heart and enters the lungs. The pulmonary artery branches in the lungs into millions of capillaries. In the lungs, the blood releases the carbon dioxide it picked up while passing through the body and becomes oxygenated. The pulmonary arteries are the only aarteries in the body that carries deoxygenated blood.

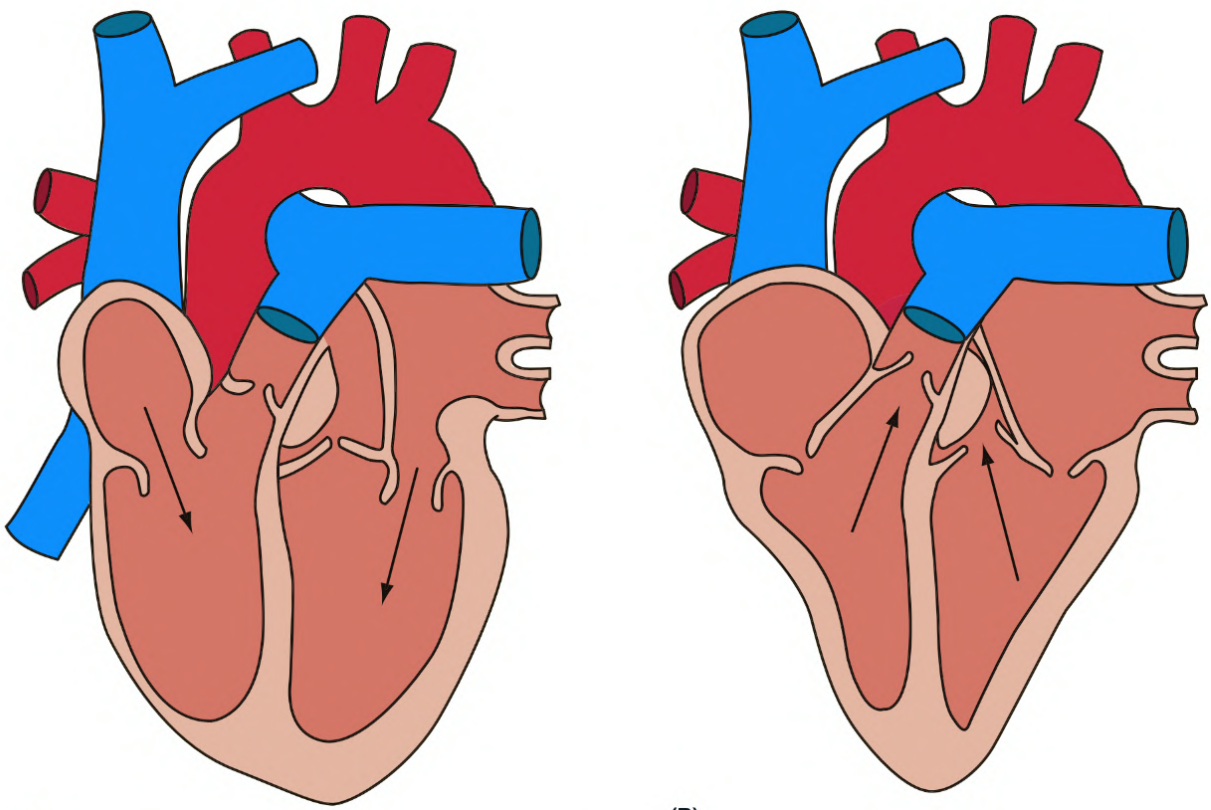
Once the blood leaves the lungs it enters the *pulmonary veins* for its trip back to the heart. The pulmonary veins are the only veins in the body that carries oxygenated blood. The blood now has a bright red appearance because of the oxygen it is holding. The pulmonary veins enter the heart at the left atrium. The oxygenated blood of the left atrium flows through the *bicuspid valve* (also known as mitral valve) into the *left ventricle.* The left ventricle pumps the blood through another valve called the *semilunar valve* (also known as aortic valve). From here the blood enters the largest artery in the body, the *aorta.* The aorta branches to become the entire artery system of the body. To pump this blood to all parts of the body, the left ventricle produces extreme pressure. This one last pump has to be sufficient to pump the blood all the way to the tip of the toes and back to the heart. This is why the left ventricle has such a thick wall. This chamber of the heart has built up its muscles to be thicker and stronger.

EXERCISE 4 Ordering/Sorting

Directions: Place the flow of the blood through the heart in the correct order, 1, 2, 3, and so on.

A. _____ Left atrium
B. _____ Superior/inferior vena cava
C. _____ Pulmonary artery to lungs
D. _____ Left ventricle
E. _____ Arteries
F. _____ Veins
G. _____ Venules
H. _____ Right atrium
I. _____ Capillaries
J. _____ Arterioles
K. _____ Right ventricle
L. _____ Aorta
M. _____ Back to superior/inferior vena cava
N. _____ Pulmonary vein from the lungs

The chambers of the heart do not pump independently, with each chamber pumping at a different time. The heart is a double pump with both sides of the heart pumping almost simultaneously (Figure 4.15). Both ventricles expand at the same time while the atria are



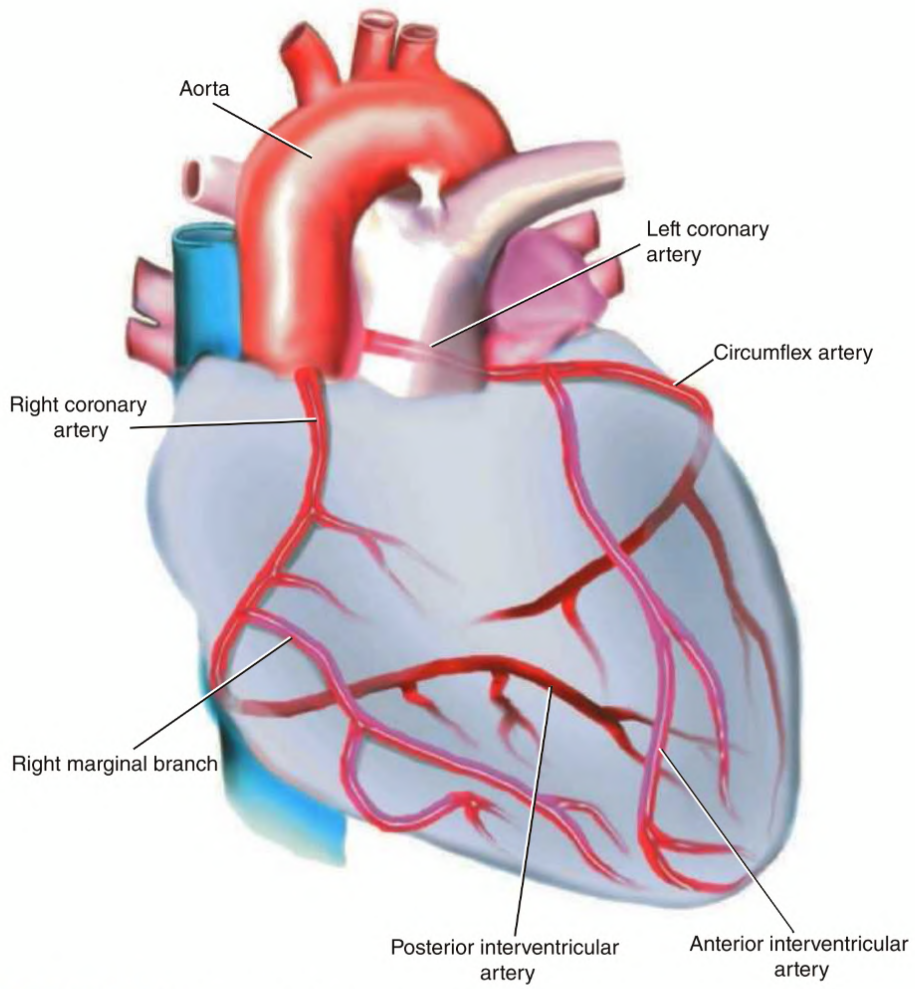
▲ FIGURE 4.15 Illustration of the cardiac cycle. (A) Blood flows from the right atrium to the left atrium, simultaneously filling both ventricles. (B) The right ventricle and left ventricle both contract at approximately the same time to pump blood to the lungs and through the lungs to the aorta.

contracting, pulling blood from the right and left atria. The appropriate valves close, and the ventricles then contract to push the blood to the lungs and through the aorta at the same time. As the atria are contracting to pump the blood, the ventricles are expanding to accept the blood. As the ventricles contract to pump blood out of the heart, the atria are expanding to accept blood.

A sac called the pericardium encloses the heart. The heart itself has three layers of tissue. The *endocardium* is a membrane layer that lines the inner chambers of the heart and the valves. The *myocardium* is the muscle of the heart itself. The *epicardium* is the outermost membrane layer of the heart. **Endocarditis** is an infection of the endocardium of the heart. If untreated, the endocarditis can destroy the heart valves by eating away part of the tissue. This causes the valves to fail to open or close properly. In severe cases the valve may need to be replaced in open heart surgery.

The heart pumps oxygenated blood to all parts of the body. While the blood is in the heart, it does not supply oxygen to the heart. Coronary arteries supply this oxygen to the surface of the heart. Coronary veins on the surface of the heart remove the carbon dioxide (Figure 4.16). The arteries branch off the aorta and supply the heart with the oxygen it needs to survive. If one or more of these coronary arteries become **occluded**, the myocardium in that area of the heart dies and a myocardial infarction (heart attack) results. Numerous surgical techniques can correct these occlusions if caught soon enough.

There are a variety of tests that the physician can order to check for a heart attack or heart failure (Table 4.3). The physician's diagnosis is usually not based on one test but the outcome of several tests.



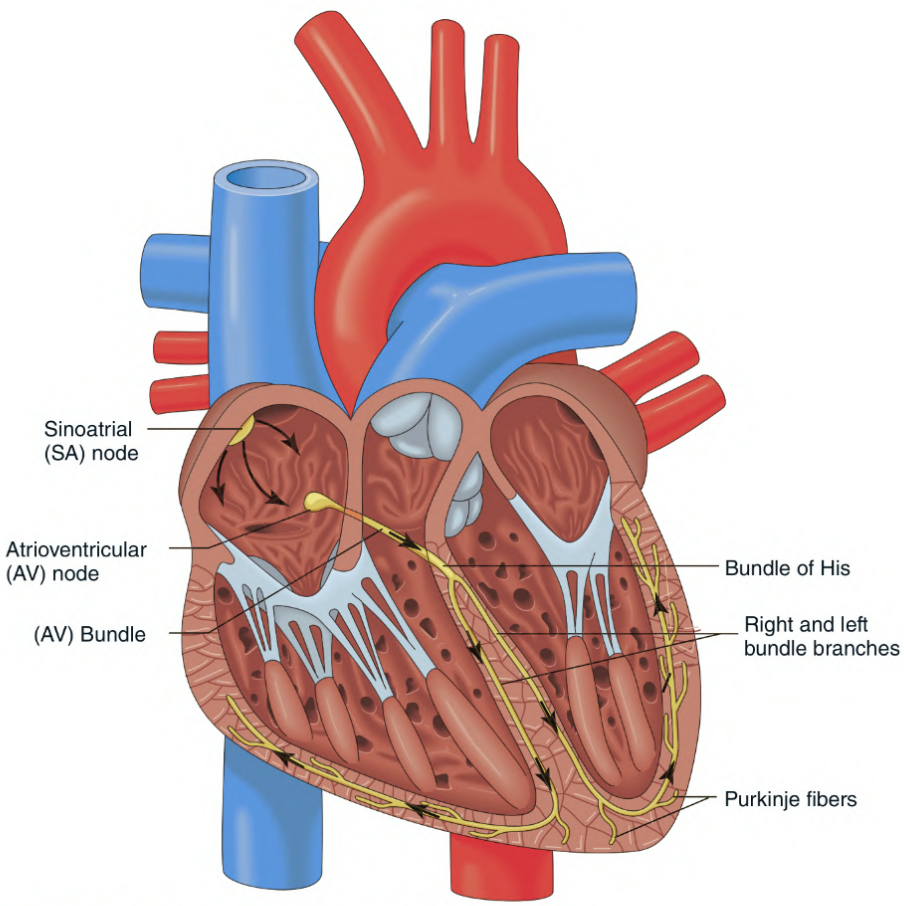
▲ FIGURE 4.16 Coronary arteries.

Electrical stimuli control the pumping action of the heart. The specialized cardiac tissue controlling the electrical stimuli is the conduction system of the heart (Figure 4.17). The sinoatrial node (SA node) begins the process. The SA node needs no outside stimulus to cause it to start a heartbeat. Therefore, the SA node is known as the pacemaker of the heart. The SA node creates an electrical impulse that is transmitted to the atrioventricular node

TABLE 4.3 Examples of Tests for Heart Disease

• Alanine aminotransferase (ALT)
• Aspartate aminotransferase (AST)
• Blood gases
• Brain natriuretic peptide (BNP)
• CK isoforms (creatine kinase isoforms)
• CK-MB (creatine kinase, MB)
• Complete blood count (CBC)
• Comprehensive metabolic panel (CMP)
• C-reactive protein (CRP)
• Homocysteine
• LDH1 (lactase dehydrogenase 1)
• Myoglobin
• Troponin

Source: labtestsonline.org, accessed December 2015.



▲ FIGURE 4.17 Conduction system of the heart.

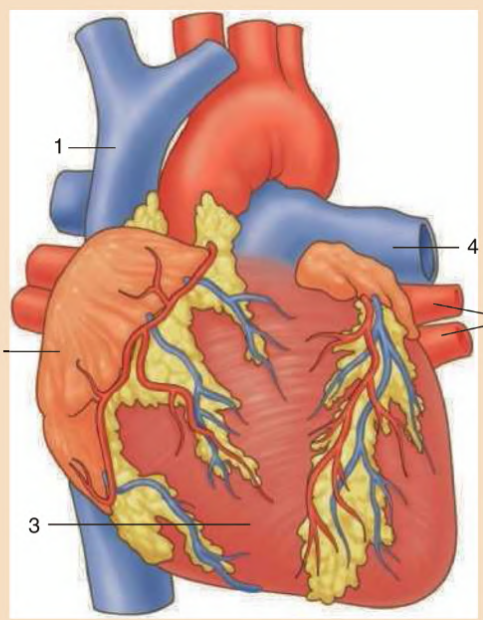
(AV node). The AV node then causes the atria to contract. The electrical impulse then travels a length of conduction fibers called the bundle of His (atrioventricular bundle) to the right and left ventricles. The right and left ventricles have Purkinje fibers running up and down them, which cause the ventricles to contract. If this electrical pathway starts to fail, it may be corrected by a cardiac pacemaker.

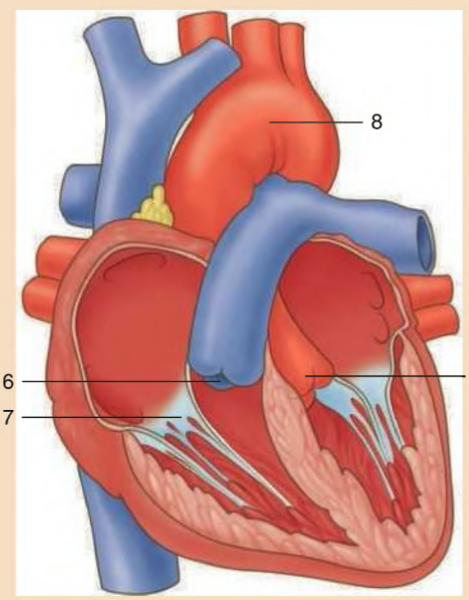
As the heart pumps, it creates a pressure in the arteries of the body. The **systolic** pressure is the pressure when the heart is contracted. The contraction and pressure push the blood through the arteries, exerting pressure on the artery walls. The **diastolic** pressure is the pressure when the heart is relaxed between beats. During this relaxation the chambers refill with blood. A blood pressure cuff (sphygmomanometer) is used to measure blood pressure. For example, blood pressure is read as 120/80: The 120 is the systolic pressure, and the 80 is the diastolic pressure. The pressures are recorded as 120 mm Hg and 80 mm Hg. The mm Hg refers to millimeters of mercury.

EXERCISE 5 Image Labeling

Directions: Identify the numbered items on the accompanying figure of the heart.

1. superior _____
2. right _____
3. right _____
4. left pulmonary _____
5. left pulmonary _____
6. pulmonary _____ valve
7. _____ valve
8. _____
9. _____ semilunar valve



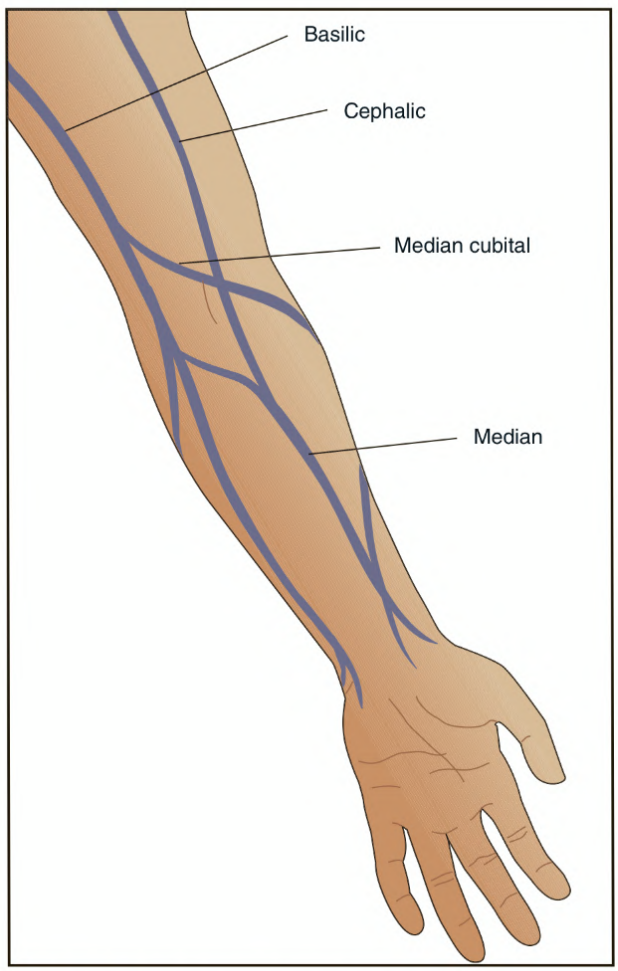


VEINS AND ARTERIES OF THE CIRCULATORY SYSTEM

In addition to the heart, the veins and arteries are part of the circulatory system. Veins that the phlebotomist will use are located in the **antecubital fossa** (bend of the arm), the back of the hand, the wrist, and the ankle or foot. Arteries may also be used to obtain samples for specific blood tests, but only after special training.

The antecubital fossa is the usual location where the phlebotomist chooses to draw blood. The veins are near the surface and large enough to give access to the blood (Figure 4.18). They frequently form an M- or H-shaped pattern on the arm. The **median cubital vein** is in the center of the antecubital fossa. The median cubital vein forms a bridged pathway between the **cephalic** and **basilic veins**. The median cubital vein is the vein that is used the majority of the time. It is the easiest to palpate and has less tendency to roll than other veins.

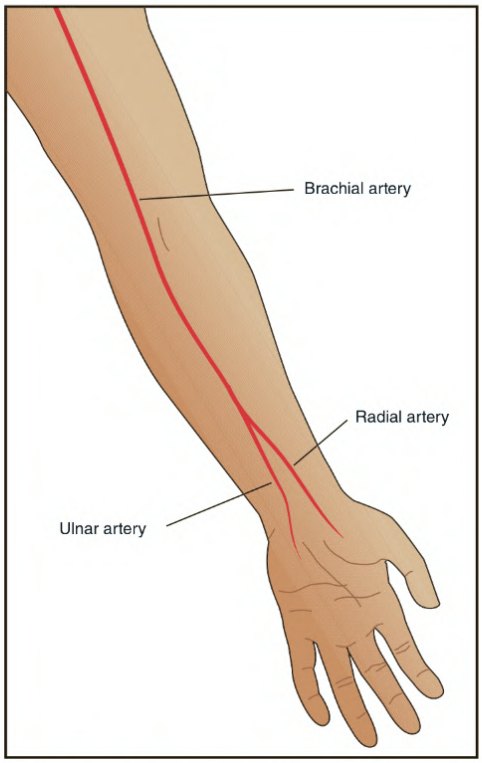
The cephalic vein is the second choice for venipuncture. It follows along the thumb side of the arm. It is not prone to rolling, but it is slightly more difficult to feel. The basilic vein is the third choice for venipuncture. It is more difficult to feel and has a tendency to roll. Venipuncture from this vein should be approached with caution. Underlying this vein is the brachial artery and median cutaneous nerve. Without careful venipuncture either of these can be easily damaged, causing serious problems for the patient. The superficial veins in the hand would be an alternate venipuncture site but would require special techniques for collection (see Procedure 6-5).



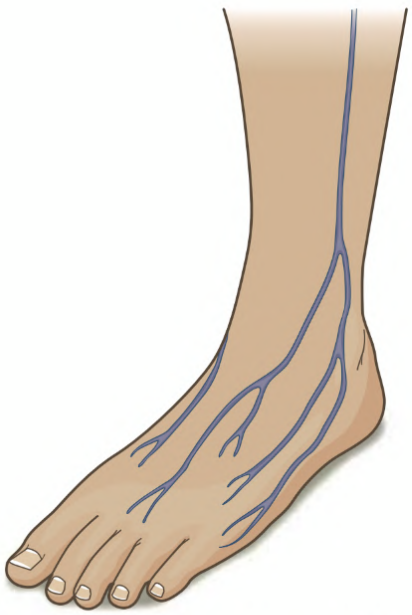
▲ FIGURE 4.18 Superficial veins of the arm.

The arteries in the arm consist of the brachial artery in the brachial region of the arm and the radial and ulnar arteries in the wrist (Figure 4.19). Puncturing of arteries requires special techniques that are used when obtaining a blood gas sample. Arterial punctures and the techniques used to draw blood from these locations for blood gas testing are explained in Chapter 6.

The veins of the feet are an alternative when the arms are not available. A physician's permission is needed before drawing blood from the veins of the legs and feet (Figure 4.20). The physician may not want the patient's leg or foot veins punctured because the act of drawing blood may cause clots to form. These clots could dislodge and cause a blockage elsewhere in the body.



▲ FIGURE 4.19 Arteries of the arm.



▲ FIGURE 4.20 Superficial veins of the legs and feet.

EXERCISE 6 Matching/Identification

Directions: Mark whether each item is true for an artery (A) or a vein (V).

1. _____ No valves
2. _____ Normally a dark red color
3. _____ Elastic walls that expand with the surge of blood
4. _____ Carries oxygenated blood to the arms and legs
5. _____ Carries deoxygenated blood from the arms and legs
6. _____ Has a pulse
7. _____ Thin walls, less elastic
8. _____ Valves are located here
9. _____ Normally bright red
10. _____ Does not have a pulse

REVIEW QUESTIONS

Multiple Choice

Choose the one best answer.

1. The formed elements make up about _____ percent of the whole blood volume.
   a. 30
   b. 60
   c. 55
   d. 45
2. The two components of blood found in a tube of blood drawn *without* anticoagulant are
   a. plasma and clot.
   b. buffy coat and erythrocytes.
   c. serum and buffy coat.
   d. serum and clot.
3. The buffy coat consists of
   a. leukocytes and thrombocytes.
   b. leukocytes only.
   c. erythrocytes and leukocytes.
   d. leukocytes and plasma.
4. The difference between plasma and serum is
   a. serum comes from anticoagulated blood; plasma does not.
   b. plasma contains fibrinogen; serum does not.
   c. serum contains fibrinogen; plasma does not.
   d. plasma is only found inside the body.
5. The fluid portion of the whole blood that contains fibrinogen is called
   a. the buffy coat.
   b. erythrocytes.
   c. plasma.
   d. serum.
6. The fluid portion of blood after clotting has taken place is called
   a. the buffy coat.
   b. erythrocytes.
   c. plasma.
   d. serum.
7. The main function of the circulatory system is to provide
   a. absorption.
   b. elimination.
   c. protection.
   d. transportation.
8. Blood returns to the heart from the lungs into the
   a. aorta.
   b. left atrium.
   c. pulmonary artery.
   d. right atrium.

9. The ventricles of the heart are principally responsible for
   a. lubrication.
   b. portal circulation.
   c. pumping blood.
   d. receiving blood.
10. Which of the following does *not* carry oxygenated blood?
   a. aorta
   b. pulmonary artery
   c. pulmonary vein
   d. all of the above
11. Which of the following is referred to as the "pacemaker" of the heart?
   a. AV node
   b. sinoatrial node
   c. bundle of His
   d. Purkinje fibers
12. What is the function of the coronary arteries?
   a. carry oxygenated blood back to the heart
   b. cause the blood to become oxygenated at the lungs
   c. supply oxygenated blood to the heart muscle
   d. none of the above

CRITICAL THINKING

1. Explain the difference between serum and plasma samples.
2. One of the coronary arteries becomes occluded. What could possibly happen to this patient?