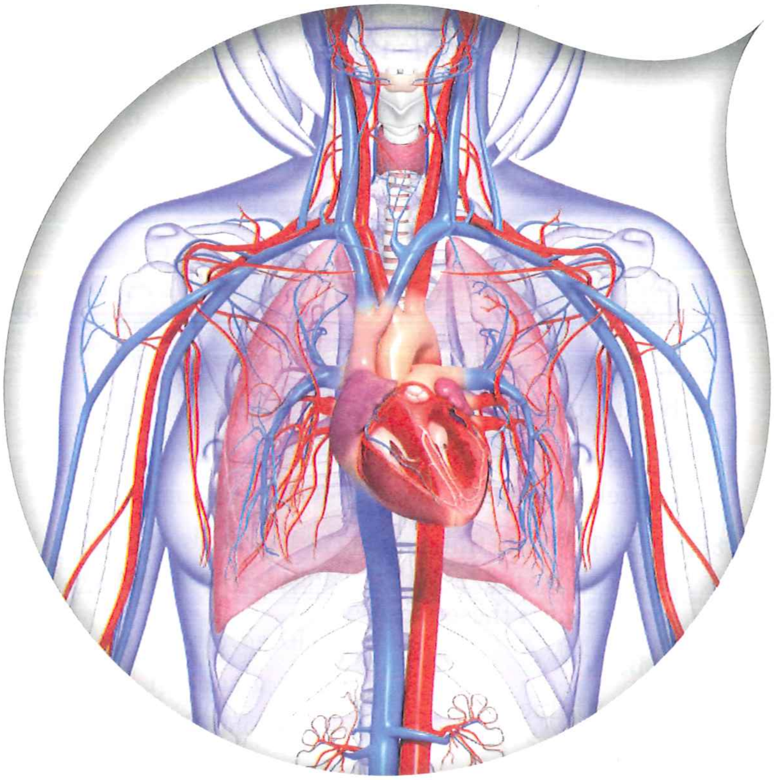
6 The Cardiovascular System

essential terms

agglutination
antecubital fossa
antibody
anticoagulant
antigen
aorta
arteriole
artery
atrium (atria)
basilic vein
basophil
B lymphocyte (B-cell)
biconcave
blood type
capillary
centrifugation
cephalic vein
coagulation
cytoplasm
deoxygenated
diapedesis
eosinophil
erythrocyte
fibrin
fibrinogen
granulocyte
hematoma
hematopoietic
hemoglobin
hemolysis
hemostasis
jaundice
leukocyte
lymphocyte
lymphoid
median cubital vein
monocyte
mononuclear
myeloid
natural killer (NK) cell
neutrophil
oxygenated
phagocytosis
plasma
polymorphonuclear
pulmonary artery
pus
Rh antigen
septum
serum
T lymphocyte (T-cell)
thrombin
thrombocyte
tunica adventitia
tunica intima
tunica media
valves
vein
venae cavae
ventricles
venule



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LEARNING OUTCOMES

6.1 Describe circulation and the purpose of the vascular system.

6.2 Identify and describe the structures and functions of the different types of blood vessels.

6.3 Locate and name the veins most commonly used for phlebotomy procedures.

6.4 Identify the major components of blood and describe the major functions of each.

6.5 Define hemostasis and describe the basic coagulation process.

6.6 Describe how ABO and Rh blood types are determined.

Related NAACLS Competencies

3.3 Identify the veins of the arms and hands on which phlebotomy is performed.

3.4 Explain the functions of the major constituents of blood, and differentiate between serum and plasma.

3.5 Define hemostasis.

3.6 Describe the stages of coagulation.

3.7 Discuss the properties of arterial blood, venous blood, and capillary blood.

Introduction

Knowledge of the cardiovascular system helps phlebotomists understand the effects blood collection procedures can have on results obtained for tests. This chapter takes a deeper look into the cardiovascular system and its components and functions as well as its impact on blood tests specifically done for the cardiovascular system.

6.1 The Heart and Circulation

As discussed in the chapter *Body Systems and Related Laboratory Tests*, the cardiovascular system is responsible for circulating blood throughout the body. The heart, the blood vessels, and the blood that flows through these structures make up this system.

The average adult has about 8 to 12 pints of blood. A pint is about the same amount as a unit of blood. A unit is transfused to a patient when blood is needed. This is the usual amount of blood given during a blood transfusion. Eight pints equal a gallon. Think of a gallon jug of milk. Your body contains at least this much blood at any given time.

The blood is continually distributed through more than 70,000 miles of tubes (blood vessels), collectively known as the vascular system. If these tubes were lined up end to end, they would reach between New York City and San Francisco over 24 times.

The phlebotomist must have an understanding of the circulation of blood, as well as its composition and functions. In addition to blood's cellular and liquid composition, the phlebotomist must also understand how the closed circuit of blood vessels transports blood. Knowing the location of blood vessels, especially the most commonly used veins, and the composition of blood is essential to performing venipuncture.

Circulation and the Vascular System

The vascular system consists of several tube-like structures called blood vessels. These tubes, which vary in size and structure, are all interconnected, forming a closed circuit. This closed circuit, along with the heart, is responsible for the circulation of blood throughout the body.

The heart is a large muscle that pumps blood through the vascular system. The heart performs as a dual-pump system, propelling both oxygenated and deoxygenated blood. A look inside the heart reveals a wall of muscle, called a **septum,** that divides it down the middle into left and right sides. The right side of the heart carries deoxygenated blood. The left side carries oxygenated blood. Another wall separates the rounded top part of the heart from the cone-shaped bottom part. Thus, there are four chambers (spaces) inside the heart. Each top chamber is called an **atrium** (**plural: atria**). The bottom chambers are called **ventricles.** See Figure 6-1.

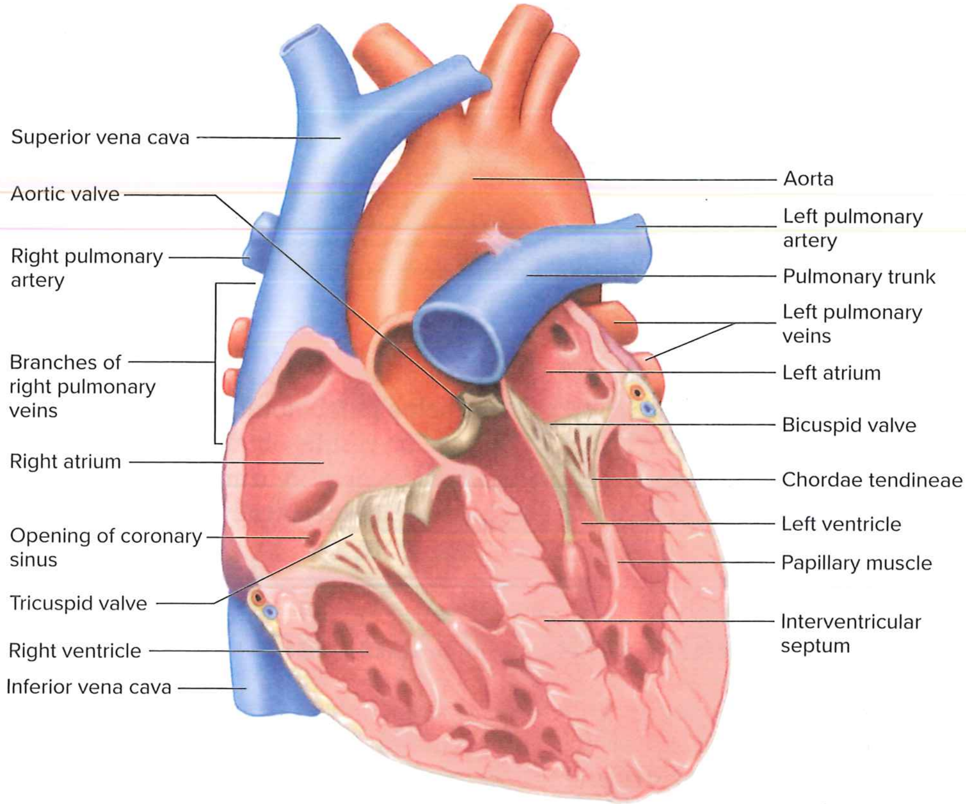


Figure 6-1 The heart is a muscular pump with four chambers; it distributes the blood to the lungs and the body.

The heart consists of three layers. The inside layer is the endocardium. It is lined with endothelial cells similar to the lining of blood vessels. The myocardium is the muscular middle layer. The left ventricle has the thickest myocardium because it is responsible for pumping blood to the rest of the body. The outermost layer is the epicardium. This layer consists of two membranes: the inner, serous visceral membrane attached to the heart and the outer, fibrous parietal membrane. These two membranes are separated by the pericardial fluid, which is secreted by the visceral (serous) membrane. The two membranes and the fluid within are known as the pericardial sac. See Figure 6-2.

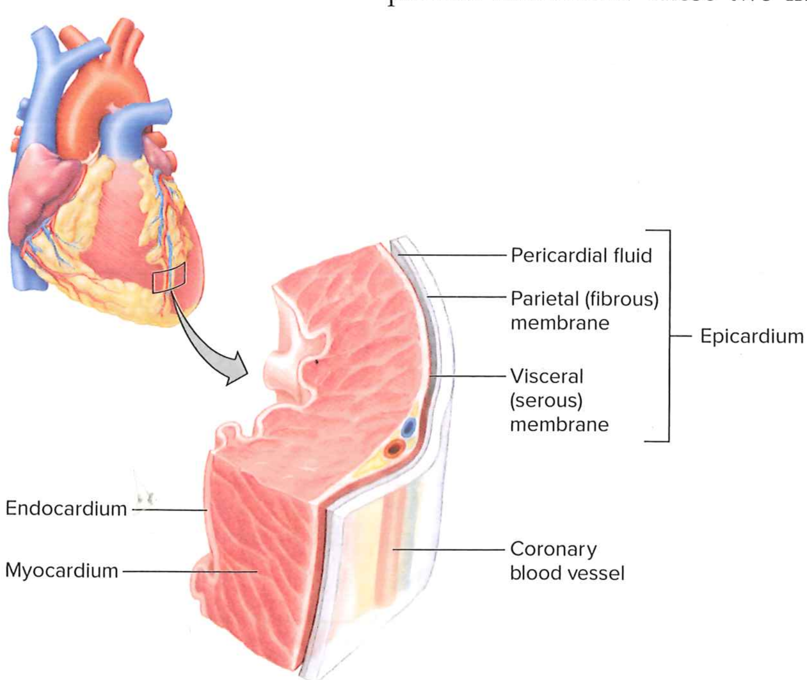


Figure 6-2 Layers of the heart.

Blood flows from the atria down into the ventricles because there are openings in the walls that separate the ventricles. These openings are called **valves** because they open in one direction—like trapdoors—to let the blood pass through. Then they close, so that the blood cannot flow backward into the atria. The valve between the right atrium and right ventricle is the tricuspid valve. The valve between the left atrium and left ventricle is the mitral (bicuspid) valve. With this system, blood flows in only one direction inside the heart.

There are also valves separating the heart from the large arteries, the **aorta** and the **pulmonary artery,** that carry blood throughout the body. These valves are known as the pulmonary semilunar valve and the aortic semilunar valve. They keep the blood from flowing backward into the heart once it has been pumped out.

The heart and vascular system are responsible for the transportation of blood through the heart, lungs, and body. These three types of circulation are known as coronary (heart), pulmonary (lungs), and systemic (body). See Figure 6-3.

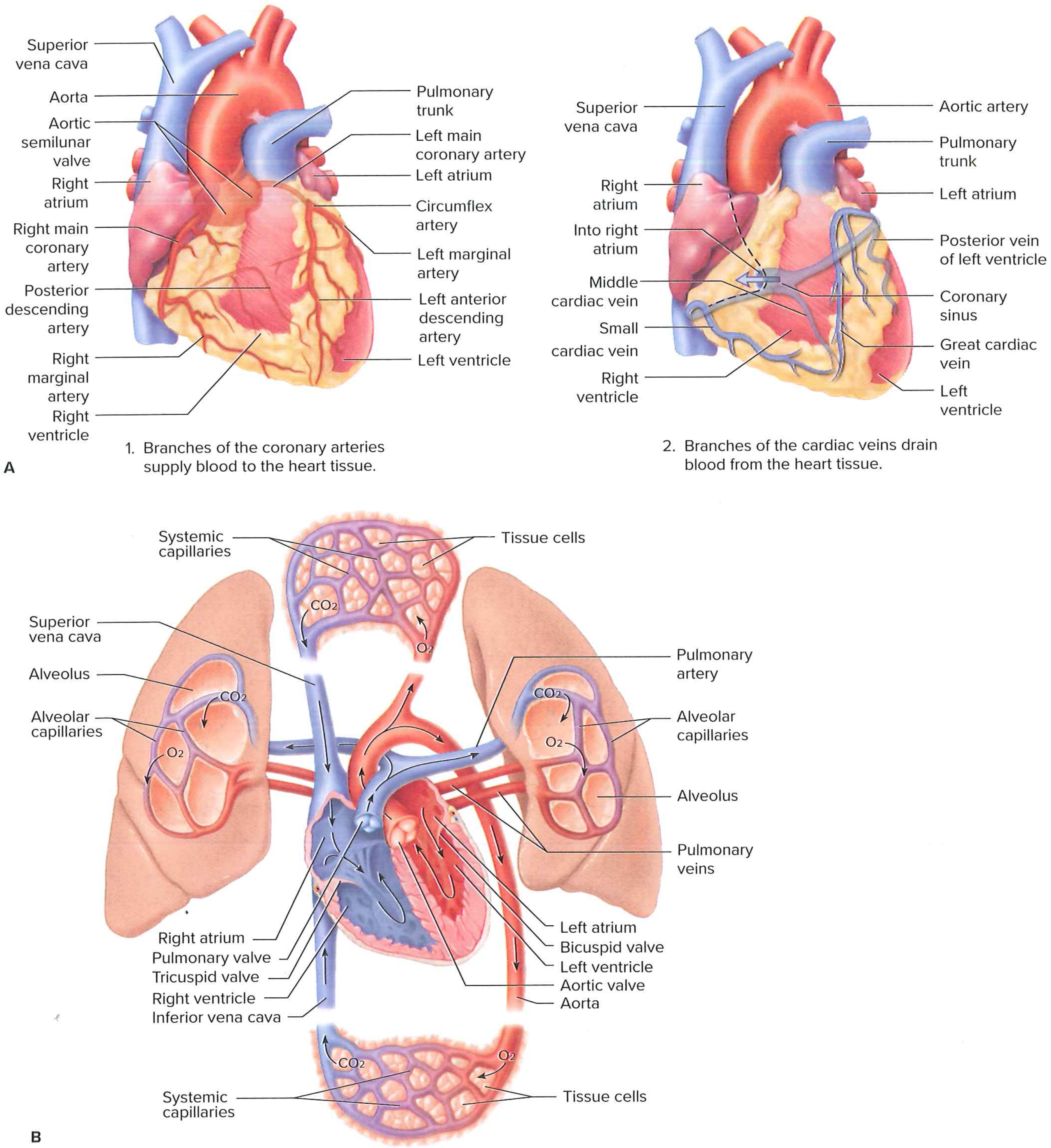


Figure 6-3 (A) Coronary circulation. (B) The right side of the heart pumps blood to the lungs (pulmonary circulation). The left side of the heart delivers blood to the body (systemic circulation).

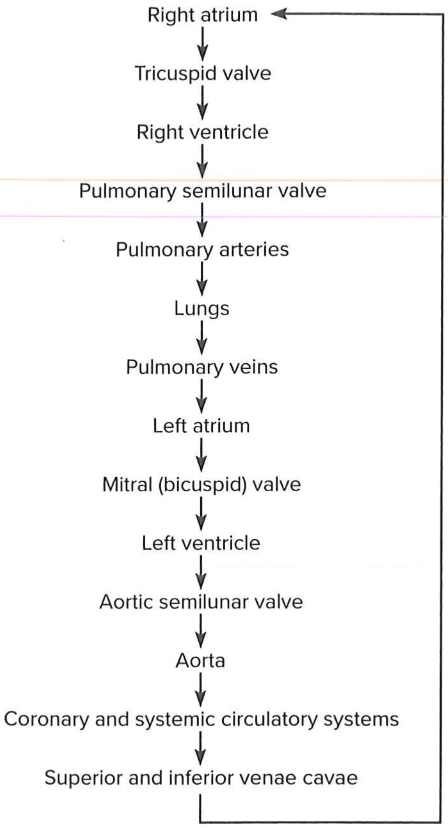


Figure 6-4 Pulmonary circulation blood pathway.

Coronary Circulation

Coronary circulation supplies blood to the heart. Oxygenated blood travels from the left ventricle, through the aorta, and directly into the coronary arteries. There are two main coronary arteries (left and right). The left main artery has more branches because the left side of the heart is more muscular and requires a larger blood supply. Once the oxygen is distributed to the heart, the blood without oxygen travels through the coronary veins and is collected in the coronary sinus. The coronary sinus is a group of coronary veins joined together. This sinus empties the blood directly into the right atrium.

Pulmonary Circulation

Blood from the body enters the heart through the right atrium. This blood is **deoxygenated** and has a high concentration of carbon dioxide, in the form of bicarbonate ions, a waste gas that it picks up from the body's cells. Pulmonary circulation consists of the path the blood takes through the lungs to become **oxygenated.** From the right atrium, the blood travels to the right ventricle and then through the pulmonary arteries to the lungs. In the lungs, it picks up oxygen and releases carbon dioxide, which is then exhaled. This process takes place in the alveoli (air sacs) of the lungs. The oxygenated blood flows through the pulmonary veins to the left atrium of the heart then to the left ventricle. This oxygenated blood supply is ready to be pumped throughout the body. Figure 6-4 shows the path of the blood in pulmonary circulation.

Systemic Circulation

Systemic circulation is responsible for delivering nutrient-rich, oxygenated blood to all other parts of the body. It starts in the left atrium, with oxygenated blood provided from the lungs. The blood travels through the left ventricle, which pumps it out through the aorta to all of the body tissues. In the digestive tract, it picks up essential nutrients such as carbohydrates, proteins, and vitamins. The blood then distributes these nutrients, along with oxygen, to all of the body's cells. It also picks up waste products, such as urea and carbon dioxide, from the body cells. As the blood passes through the kidneys, urea and other liquid wastes are filtered out to form urine. The deoxygenated blood returns to the right atrium of the heart, where pulmonary circulation begins.

Checkpoint Questions 6.1

1. Briefly describe the purpose of the three types of circulation in the human body.
2. Describe the basic structure of the heart.

6.2 Blood Vessels

The three main types of blood vessels are arteries, veins, and capillaries. **Arteries** are vessels that transport blood away from the heart. All arteries except the pulmonary arteries contain oxygenated blood, and all veins except the pulmonary veins carry deoxygenated blood. The pulmonary arteries transport deoxygenated blood away from the heart to the lungs. The pulmonary veins carry oxygenated blood from the lungs back to the heart. The important fact to remember is that all arteries carry blood away from the heart and all veins transport blood toward the heart.

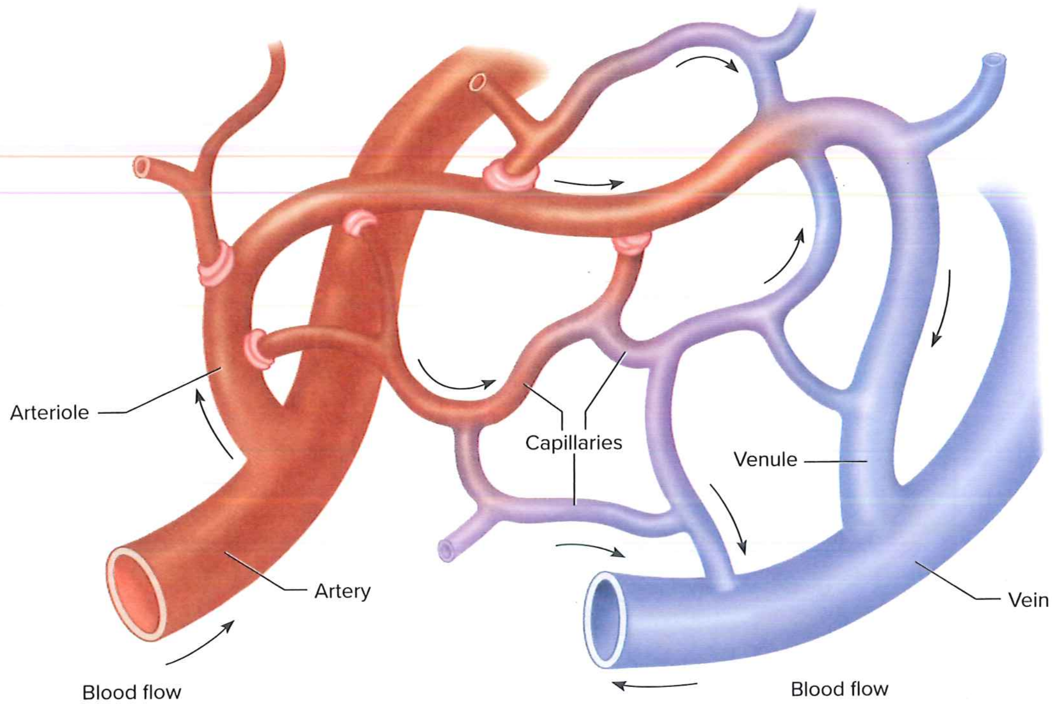


Figure 6-5 Arteries carry oxygen-rich blood through capillaries, where gas exchange occurs. Veins carry deoxygenated blood back to the heart.

The largest artery, the aorta, transports oxygenated blood from the heart. The aorta branches into smaller arteries, which divide further to become even smaller **arterioles,** until they reach the capillaries. The **capillaries** are the smallest of all the blood vessels; they are also the most numerous blood vessels in the human body. Capillaries serve as the connecting points between the arterioles and the **venules** (small veins). They deliver oxygen from the blood to the tissues. Capillaries then join together to form venules, which in turn gather together to form larger **veins.** Finally, the largest veins—the superior and inferior **venae cavae** (singular: **vena cava**)—return the deoxygenated blood to the right atrium of the heart. This cycle continues over and over again, with blood traveling through each of the body's blood vessels, forming a closed vascular network. See Figure 6-5.

Structure of Blood Vessels

Blood vessels are structured to perform specific functions according to their type. Both arteries and veins are composed of the following three layers of tissue (see Figure 6-6):

- **Tunica intima**—the innermost, smooth layer in direct contact with the blood
- **Tunica media**—the middle, thickest layer, capable of contracting and relaxing
- **Tunica adventitia**—the outer covering, which protects and supports the vessel

Capillaries, the smallest blood vessels, have only one layer of tissue. This single-layer vessel is so small that blood cells have to pass through it in single file.

Arteries

Arteries are considered *efferent* vessels because they carry blood away from the heart. Artery walls are elastic, muscular, and much thicker than the walls of veins and capillaries. They must be thicker and stronger to withstand the pressure with which blood is pumped from the heart. Each time the heart "beats,"

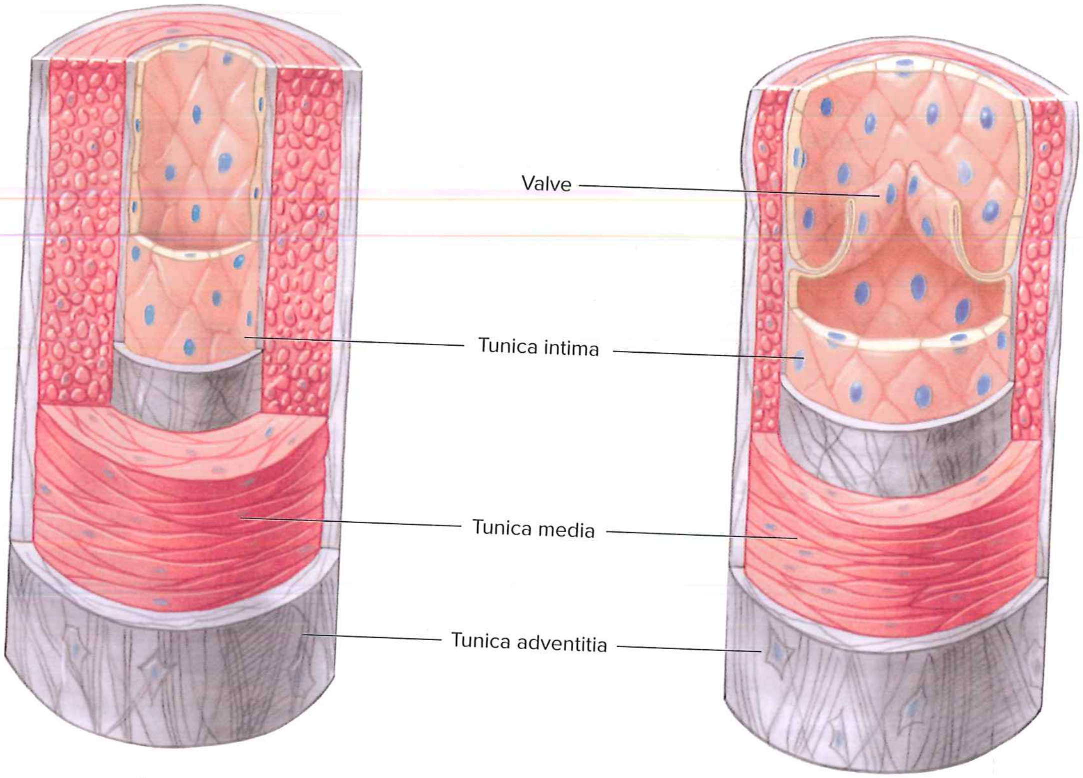


Figure 6-6 Arteries and veins are composed of three layers of tissue.

or contracts, it pushes blood through the arteries under high pressure. This results in the pulse that can be felt at specific sites on the body, including the radial pulse at the wrist and the carotid pulse at the neck. Because most arteries carry oxygenated blood, arterial blood is a bright red color. Many arteries are paired, meaning that there is a left and a right artery with the same name. See Figure 6-7.

Capillaries

All gas exchange occurs in the vessels that form a link between the arterioles and venules, known as the *capillaries.* Capillaries can be seen only through a microscope. Their walls are made up of a single layer of cells to allow for selective permeability, so substances can pass into and out of the blood. Nutrients, molecules, and oxygen pass out of the capillaries and into surrounding cells and tissues.

Waste products, such as carbon dioxide and nitrogenous waste, pass from the body's cells and tissues back into the bloodstream for excretion by means of the respiratory, urinary, integumentary, and digestive systems.

Veins

Because veins carry blood toward the heart, they are considered *afferent* vessels. See Figure 6-8. Large veins usually have the same names as the arteries they run beside.

The pressure from the heart is diminished by the time the blood reaches the veins; therefore, the force is not as great as it is in the arteries. Muscle movement helps push blood through the veins. However, veins flow against gravity in many areas of the body. To prevent blood from flowing backward

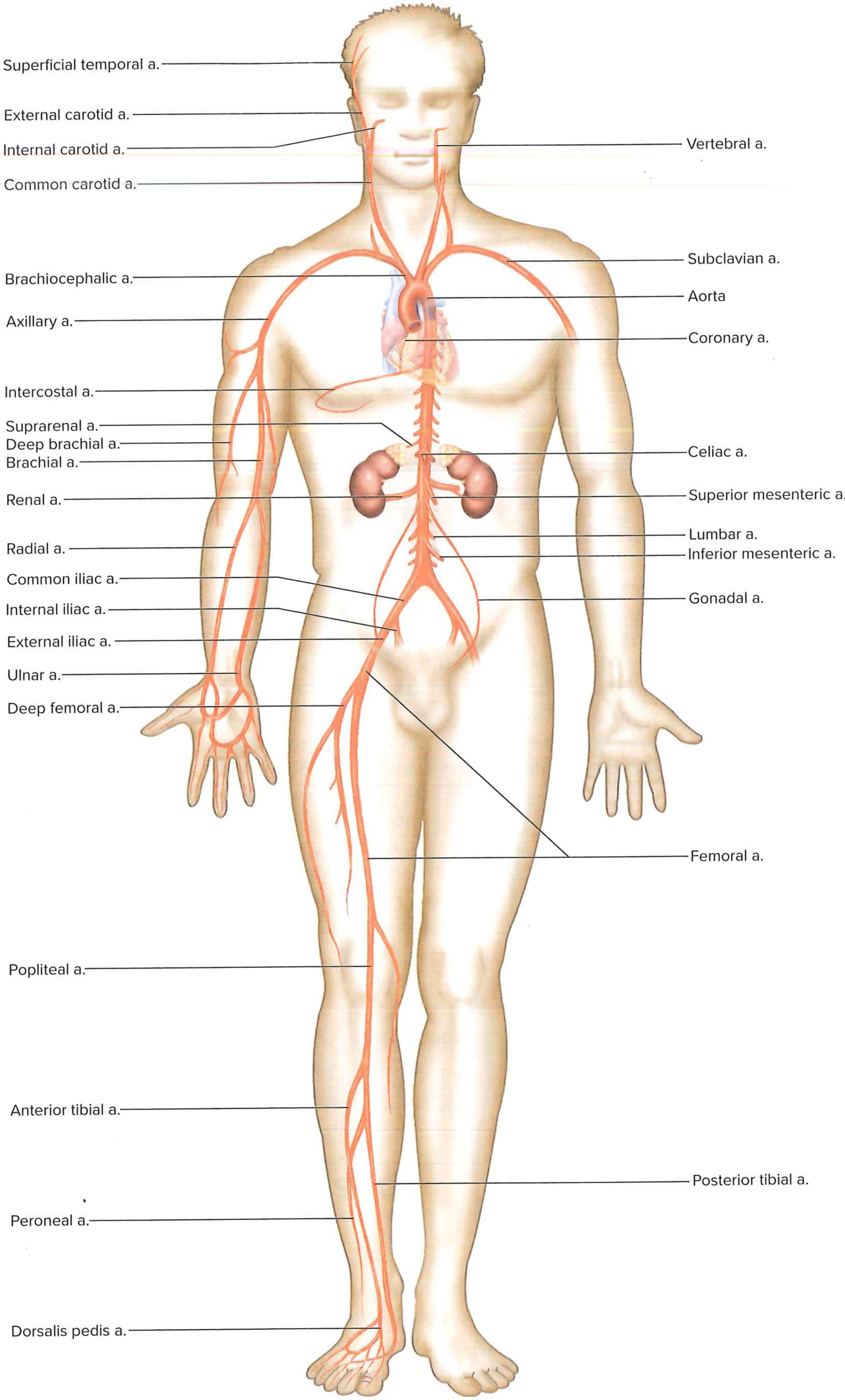


Figure 6-7 Arteries carry blood away from the heart (a. = artery).

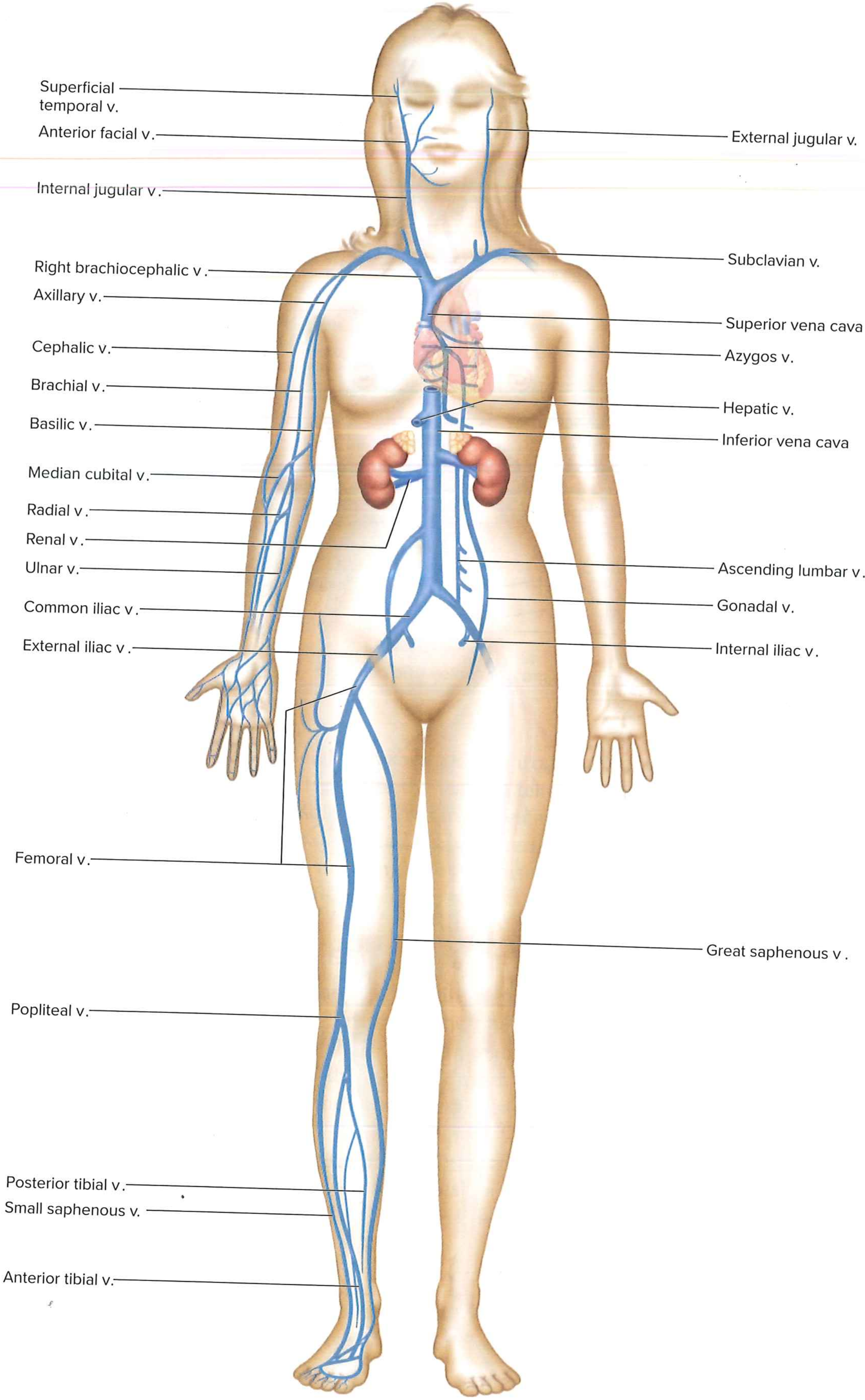


Figure 6-8 Veins carry blood toward the heart (v. = vein).

through the veins due to gravity, veins have one-way valves that force the blood to flow only toward the heart. Figure 6-9 shows how these valves prevent backflow.

Another important function of veins is to serve as reservoirs. The veins store about 65% to 70% of the body's total blood volume. This blood is a darker red color because it contains less oxygen. It flows in a slow, oozing manner, unlike the fast, pulsating flow of arterial blood. Because veins store a large amount of blood, have thinner walls, and have lower pressure, they are the vessels of choice for blood collection.

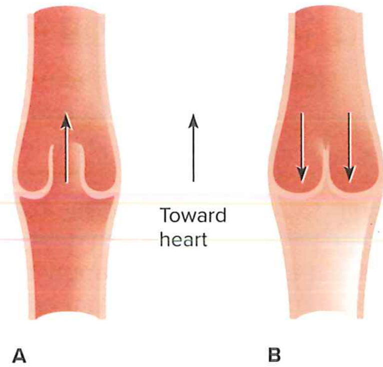


Figure 6-9 One-way valves, found only in veins, permit blood to flow only toward the heart.

Communicate & Connect

Artery or Vein?

It is important to know how to tell the difference between an artery and a vein and what happens when an artery is punctured. When looking for a venipuncture site, remember that a vein will feel bouncy and will have a resiliency to it, and an artery will feel firmer and will pulsate. In the event of an accidental artery puncture, the blood will appear bright red instead of dark red. The flow will usually be more forceful and may pulsate. If this occurs, immediately remove the tourniquet, withdraw the needle, and apply firm pressure for at least 5 minutes. Once the bleeding has stopped, apply a taut gauze dressing. Instruct the patient to keep the arm relatively still for a short period to minimize the flow of blood. This will help prevent a **hematoma.** A hematoma occurs when blood collects under the skin, forming a black and blue mass. A hematoma can form as a result of inserting a needle through a vein or an artery. Fragile veins can also break or leak, causing hematoma formation. To prevent accidental arterial puncture, do not select a vein that lies over or close to an artery. When an accidental arterial puncture does occur, stop the bleeding, then immediately notify a nurse (or supervisor, in the case of outpatient draws).

Checkpoint Questions 6.2

1. Why are veins considered more suitable for phlebotomy than arteries?
2. Name and describe the three types of blood vessels.

6.3 Veins Commonly Used for Phlebotomy

Phlebotomists must be familiar with the veins commonly used for phlebotomy. Such knowledge makes it easier to obtain blood specimens, even from patients with limited sites to access. The most commonly used veins for venipuncture are located in the middle of the arm and in front of the elbow. This area is called the **antecubital fossa** and is the site of the most preferred veins for venipuncture. It is also known as the *elbow pit.*

The veins of the antecubital fossa vary among patients. The two most common arrangements of veins are the H pattern and the M pattern (see Figure 6-10).

Communicate & Connect

Site Selection

Selecting the best vein is not always easy. The patient may have only one arm available for use and the skin on that arm may be sensitive to touch. In the event of dermatitis (inflammation of the skin in which the area is red and may contain skin lesions) or other conditions, and when there are no other sites available, you may use the arm, but do not place the tourniquet directly on the arm. Instead, place the tourniquet over the patient's gown or clothing, or wrap the arm in gauze and then apply the tourniquet.

Do not draw blood from an arm that has an intravenous infusion (IV) because the contents of the infusion will alter the blood specimen results. In addition, for patients who have had a mastectomy (breast removal) or stroke, do not draw blood from the arm on the affected side of the body because circulation may be impaired. Check with the physician or supervisor or chart as needed. Signs for inpatients should be posted in the room that read "NO BLOOD PRESSURES OR VENIPUNCTURES" for the affected arm.

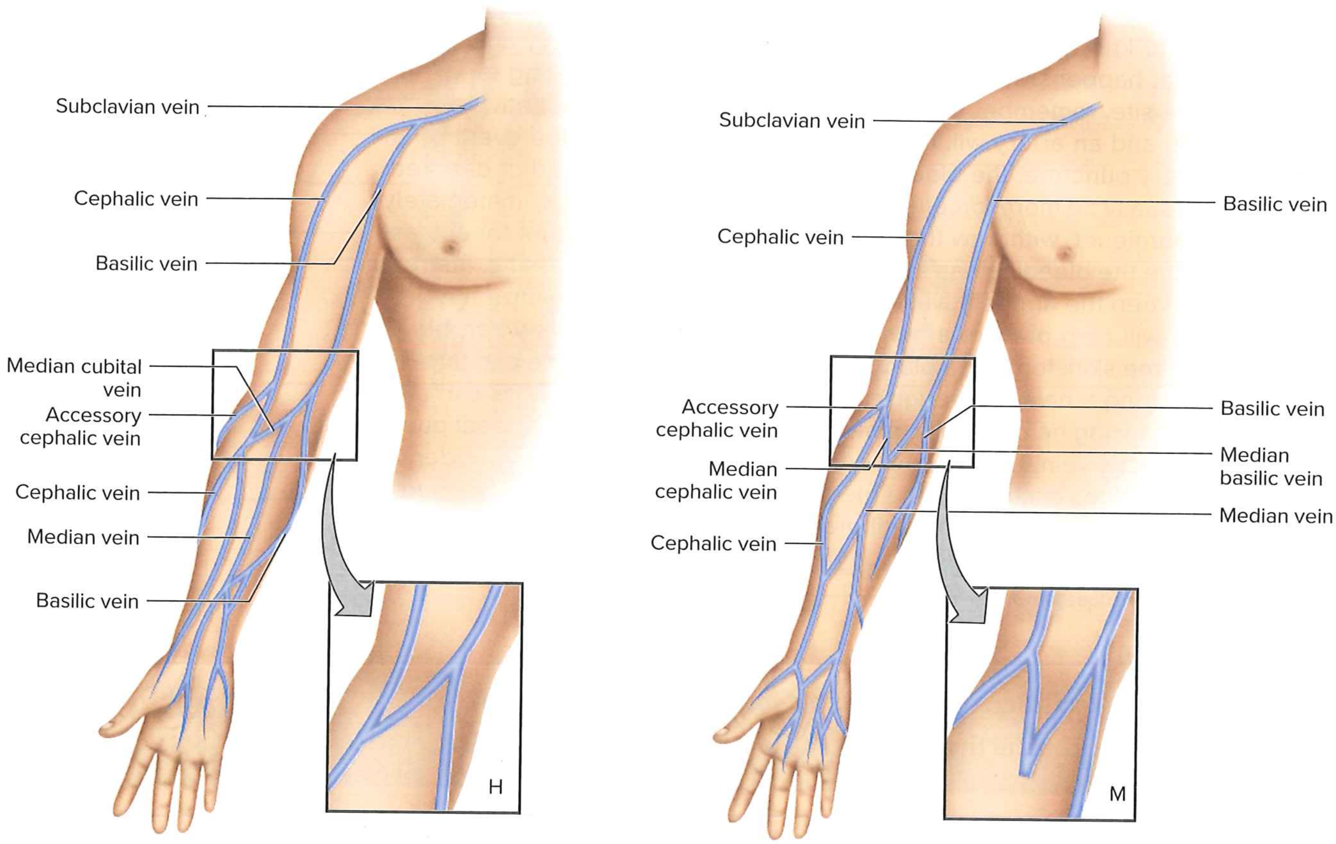


Figure 6-10 The location of the veins in the antecubital fossa vary. The two most common patterns are the H pattern and the M pattern.

The veins most commonly used for venipuncture with the H pattern are the median cubital, cephalic, and basilic veins. The **median cubital vein** is located in the middle of the forearm. The median cubital vein is larger, closer to the surface, and well anchored (least moving) making it the favored site for venipuncture. The next-best site is the **cephalic vein,** which is also well anchored; however, it may be harder to palpate (feel). When the body is in the anatomical position, the cephalic vein lies lateral to the median cubital vein. The third choice is usually the **basilic vein.** This site, though easier to palpate, is not well anchored. It tends to roll when touched, making it more difficult to access. When the body is in the anatomical position, the basilic vein lies medial to the median cubital vein. Additionally, the basilic vein lies close to the median nerve and the brachial artery, which must be avoided during venipuncture procedures because these structures might be accidentally punctured or damaged.

The veins most commonly used for venipuncture with the M pattern are the median vein, median cephalic vein, and the median basilic veins. The **median vein** is the first choice. It is in the center of the forearm, is well anchored, and tends to be less painful. Being farther away from nerves and blood vessels makes it the safest to puncture. The **median cephalic vein** is also located away from major nerves and arteries making it safe to puncture. The third choice is the **median basilic vein,** which is more painful to puncture. It is located near the anterior and posterior branch of the median cutaneous nerve.

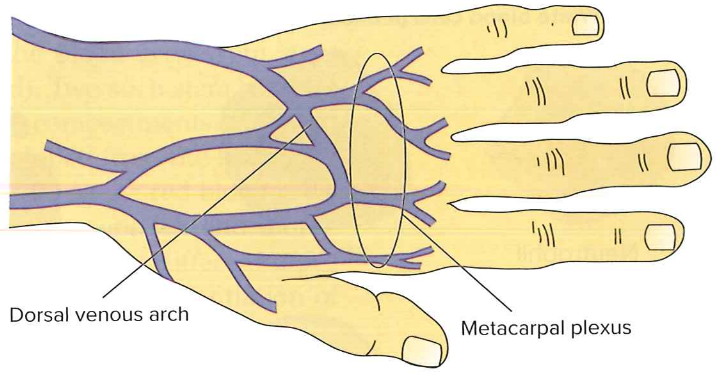


Figure 6-11 Veins in the back of the hand are sometimes used for venipuncture when the antecubital veins are not accessible.

Other sites for venipuncture, such as veins in the back of the hand (dorsal arch), are used when the antecubital veins are not accessible (see Figure 6-11). These hand veins are smaller, less anchored, and sometimes require the use of a smaller-gauge needle, usually a butterfly needle (explained in the chapter *Blood Collection Equipment*). Using hand veins for venipuncture can also be more painful for the patient.

Although physicians sometimes need to obtain blood from blood vessels in the head, legs, or feet, these sites are not acceptable for venipuncture by phlebotomists. More sites for phlebotomy are discussed later in this textbook.

Avoiding a Nerve Injury

Law & Ethics

The phlebotomist must use correct technique after properly selecting the vein. Accidental puncture of the median nerve could result in temporary or permanent loss of function in that arm. This would constitute an act of negligence, and there are cases in which patients have been awarded millions of dollars to compensate them for their losses. The best way to prevent injuring the median or any other nerve is to avoid "probing around" at the site.

Checkpoint Questions 6.3

1. What are the two most common locations for venipuncture?
2. List the three most commonly used veins in venipuncture in order of preference from most to least preferred, and explain why they are ranked in this order.

6.4 Composition of Blood

Blood is the primary transporting fluid of the body. Its composition is complex and essential to sustaining life. Blood has many important functions and plays a role in numerous body functions:

- Blood transports oxygen and nutrients to the body's cells and tissues.
- It transports hormones to their target area, so that the body can function in its proper capacity.

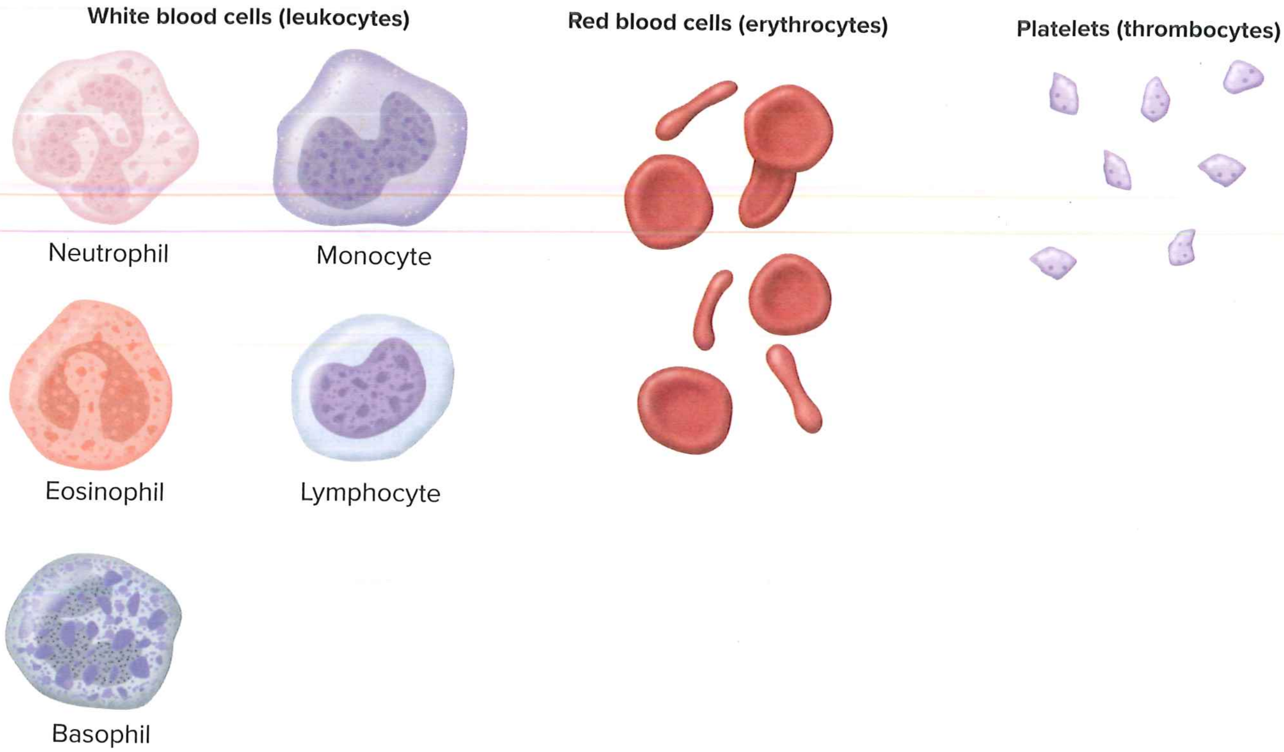


Figure 6-12 The formed elements of blood include white blood cells, red blood cells, and platelets.

- It eliminates waste materials from the body's cells.
- It maintains water balance for the body's cells and tissues.
- It transports antibodies and protective substances throughout the body, so that they can attack pathogens (disease-producing microorganisms).
- It assists with regulating body temperature.
- It helps maintain acid-base balance.

When a tube of anticoagulated blood (blood kept from clotting) stands undisturbed, it will separate into two parts, or components. One part is cellular (formed elements) and the other is liquid (plasma). Formed elements include red blood cells (erythrocytes), white blood cells (leukocytes), and platelets (thrombocytes). See Figure 6-12.

Formed elements make up about 45% of blood's total volume. Almost 99% of the circulating cells are red blood cells. See Table 6-1. Blood cells originate mostly from inside the bone marrow. The liquid component, or plasma, is a straw-colored or pale yellow fluid that is mostly water. Plasma makes up about 55% of blood's total volume, and it contains 90% to 92% water and 8% to 10% *solutes* (dissolved chemicals). These solutes consist of electrolytes, enzymes, glucose, hormones, lipids, proteins, and metabolic substances.

TABLE 6-1 Cellular Components of Blood

Blood Cells	Normal Quantity*	Description
Erythrocytes (red blood cells)	M. 4.5–6.2 million/mm^3 F. 4.2–5.4 million/mm^3	Contain hemoglobin; transport oxygen and carbon dioxide
Leukocytes (white blood cells)	5,000–10,000/mm^3	Protect against infections
Thrombocytes (platelets)	150,000–450,000/mm^3	Aid in blood clotting

*Blood cell ranges vary according to lab reference materials.

Formed Elements of Blood

The cells that make up the formed elements of the blood arise from stem cells (cells from which specific body cells are formed). Two such stem cells are found in separate **hematopoietic** (blood-forming) compartments: **myeloid** (developed from bone marrow) and **lymphoid** (developed from the lymphatic system). Blood cells formed by myeloid stem cells include the red blood cells, platelets, granulocytes (neutrophils, eosinophils, and basophils), and monocytes. Blood cells formed by lymphoid stem cells include two different types of lymphocytes, B cells and T cells. See Figure 6-13 for the differentiation of blood cells.

Life Span Considerations

Fetal Blood Formation

Blood cells first arise from the yolk sac during the embryonic stages of human development. The liver and spleen form blood cells during the fetal stage and are the primary sites of blood formation until the bones develop and begin to take over the process. At birth, bone marrow is the primary site of blood cell formation.

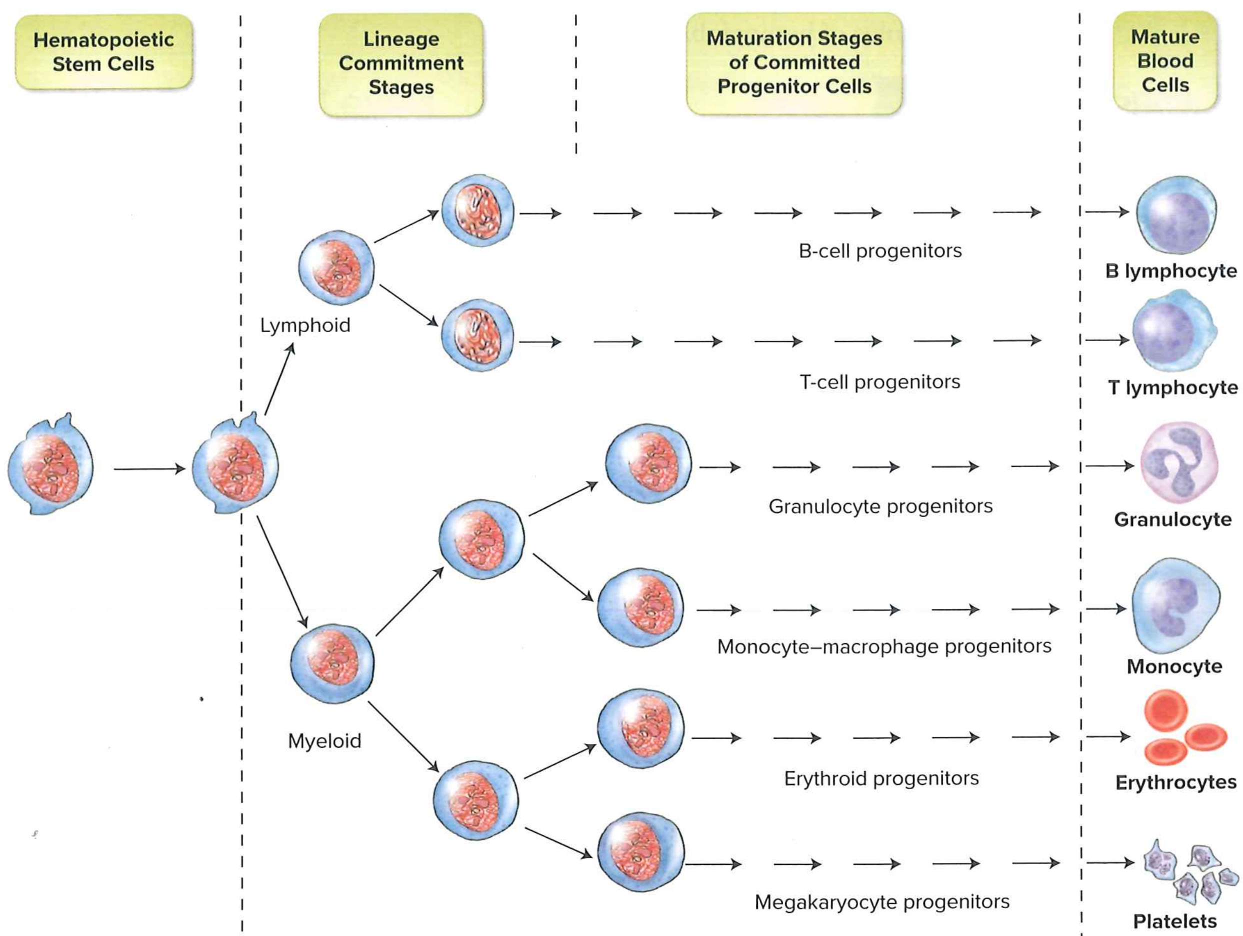


Figure 6-13 Blood cells originate from stem cells. Cells developing in the lymphoid tissues are lymphocytes that become either B cells or T cells. Cells developing in the myeloid tissues (such as bone marrow) become granulocytes, monocytes, erythrocytes (red blood cells), or thrombocytes (platelets).

Erythrocytes (Red Blood Cells)

Erythrocytes (red blood cells, or RBCs) originate in the bone marrow and are the most numerous of all the blood cells. On average, a healthy adult has approximately 4.2 to 6.1 million red blood cells per cubic millimeter (mm^3) of blood. The normal range varies, depending on a person's sex. RBCs average 7 to 8 micrometers (μm) across their diameter, and their average volume is 90 femtoliters (fL). A femtoliter is 10^{-15} liter. At this size, about 18 million RBCs could sit on the head of a pin. When fully mature, erythrocytes resemble the shape of a doughnut without a hole. This appearance is referred to as **biconcave** because both sides of the red blood cell cave inward at the center (see Figure 6-14). This shape allows flexibility, so that the RBCs can pass through blood vessels of various sizes, down to tiny capillaries, in order to perform their functions.

Erythrocytes are constantly being manufactured by the bone marrow. The average life span of a red blood cell is about 120 days. After that, they begin to lose their biconcave shape and ability to carry oxygen. The liver, spleen, and bone marrow sequester (remove), phagocytize (ingest), and destroy old, worn-out red blood cells. Components of the RBCs are recycled and used to manufacture new RBCs. Thousands of red blood cells are formed and destroyed daily.

Red blood cells are responsible for carrying oxygen to every cell in the body and for removing carbon dioxide from the cells. This ability to transport oxygen and carbon dioxide occurs as a result of a very important molecule called **hemoglobin.** Hemoglobin is made up of a protein molecule called *globin* and an iron compound called *heme.* A red blood cell contains several million molecules of hemoglobin.

Life Span Considerations

Pediatric Levels: Red Blood Cells

At birth, infants normally have an increased amount of red blood cells and hemoglobin. Within the first several weeks, however, these levels drop. Red blood cell and hemoglobin levels for children are similar to those for females. However, as children reach adulthood, the values for males and females begin to vary.

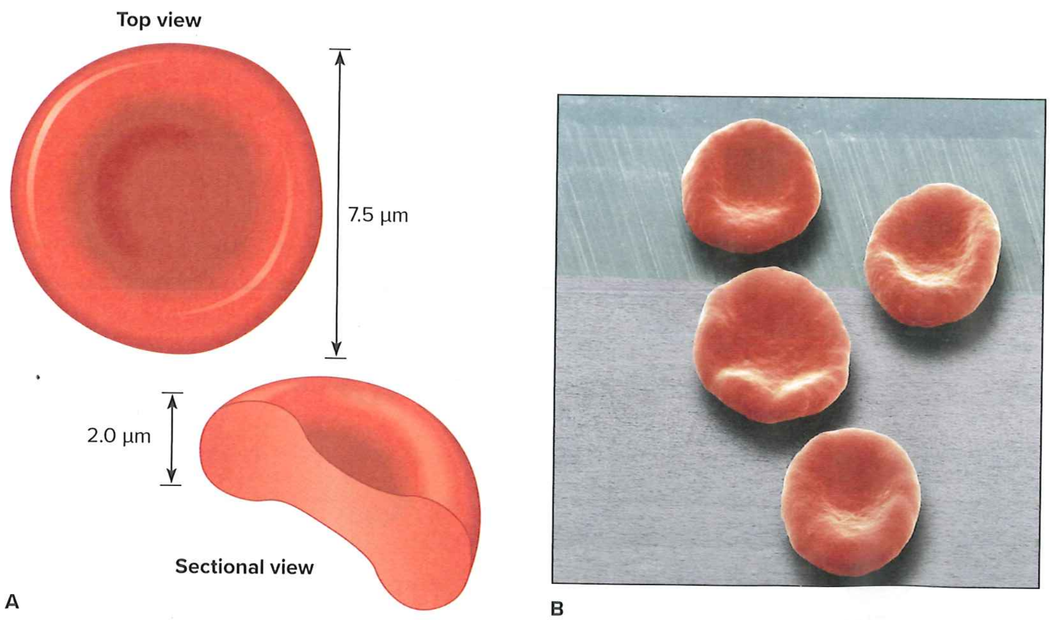


Figure 6-14 (A) Red blood cells have a biconcave shape. (B) Scanning electron micrograph of red blood cells.
A: McGraw Hill B: Steve Gschmeissner/Science Photo Library/Getty Images

Excessive blood loss, the destruction of red blood cells, and/or decreased blood cell formation can all affect the supply of hemoglobin. An abnormally low hemoglobin level and/or a decrease in the number of red blood cells is called *anemia.* Symptoms of anemia include weakness, headache, difficulty breathing, and pale skin color. Several conditions can cause a decrease in hemoglobin and/or RBC numbers:

- Sickle cell anemia
- Hemophilia
- Some forms of cancer
- Drawing too much blood, known as **iatrogenic anemia**
- A dietary deficiency of iron, folate, and/or vitamin B_{12}

Bilirubin produced during the breakdown of red blood cells is processed by the liver, deposited in the intestines, and then eliminated. Low levels of bilirubin are normally present in the blood because of the normal cycle of red blood cell production and destruction. However, some forms of anemia cause RBCs to be destroyed prematurely in the bloodstream. This destruction (**hemolysis**) leads to higher levels of bilirubin in the blood and may cause **jaundice** (yellow coloration of the skin and eyes).

Because the liver is the organ that processes bilirubin, elevated bilirubin levels can occur as a result of liver problems such as hepatitis, cirrhosis, and obstruction of the ducts in the liver. Blood is drawn on these patients to monitor the bilirubin level.

Newborn Bilirubin Levels

Life Span Considerations

When the liver breaks down worn-out red blood cells, one of the by-products is bilirubin. Infants normally are born with an excess of red blood cells and hemoglobin. In some infants, the liver may not be able to keep up with the amount of bilirubin that is being produced by the destruction of RBCs. Excessive amounts of bilirubin may cause damage to organs, such as the brain. Bilirubin is light sensitive, and light can break it down, which is why infants who have elevated bilirubin levels are placed under ultraviolet lamps to help rid their bodies of excess bilirubin. Frequently, blood tests are done to monitor the bilirubin level. When performing a bilirubin blood test, it is important that the light be turned off before collecting the blood.

Leukocytes (White Blood Cells)

Leukocytes, or white blood cells, are primarily responsible for destroying foreign substances, such as pathogens, and removing cellular debris. Leukocytes are not confined to vascular spaces when performing their duties. They can pass through capillaries' thin walls in a process known as **diapedesis** to better access the pathogens or other foreign invaders. Once white blood cells are near enough, they can surround and destroy the foreign substance through a process called **phagocytosis.** In phagocytosis, the leukocytes engulf, or "eat," foreign substances and/or cellular debris.

Leukocytes are round and primarily clear, but they appear white because the light by which they are viewed is white. When stains are applied to leukocytes, they take on various colors based on the cell type. These stains will be explained further later in this chapter. The average adult has between 5000 and 10,000 white blood cells per cubic millimeter (mm^3) of blood, unless an infection or other disorder is present.

Safety & Infection Control

Immunocompromised Patients

The phlebotomist may be required to draw blood from patients who are immunocompromised. Immunocompromised patients have a weakened immune system. One such situation is when the patient has an abnormally low neutrophil count and therefore has a low resistance to infections. Even the slightest infection can prove to be life-threatening to these patients. In addition to standard precautions, phlebotomists must take extra measures to prevent the transmission of pathogens to immunocompromised patients. The phlebotomist must perform meticulous hand hygiene and apply sterile personal protective equipment, to protect themselves and the patient. Should the phlebotomist have a common cold or other symptoms of illness, she should refrain from entering the patient's room to prevent severe illness and even death in patients with low resistance to infections.

During a bacterial infection, the number of white blood cells increases in order to send an army of defender cells to the infection site. Certain diseases, such as leukemia, cause an abnormally elevated number of white blood cells. Other conditions, such as acquired immune deficiency syndrome (AIDS), cause a drastic decrease in the white blood cell count.

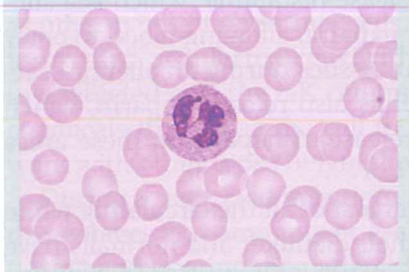
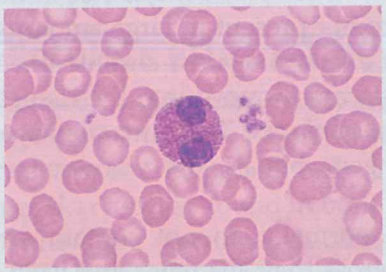
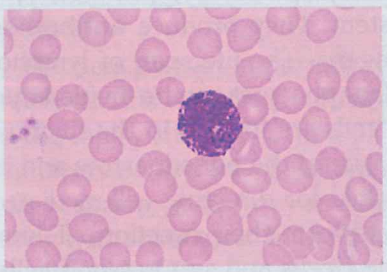
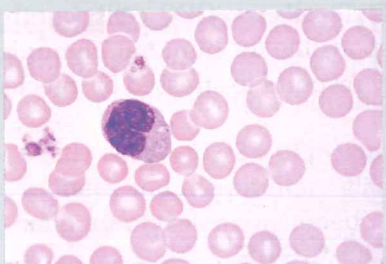
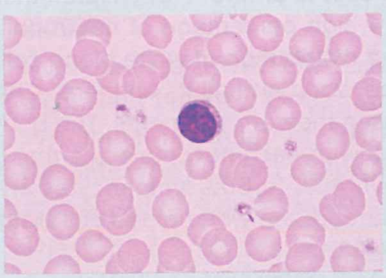
There are several ways to classify the many diverse types of white blood cells. One system divides white blood cells into two main categories: *myeloid* cells (**granulocytes, monocytes**) and **lymphoid** cells (**T lymphocytes, B lymphocytes,** and **natural killer [NK] cells,** also known as large granular lymphocytes). Another system categorizes white blood cells into **polymorphonuclear,** cells that have a nucleus that is segmented into two or more lobes, and **mononuclear,** cells that have a single-lobed nucleus. Table 6-2 describes the various types of myeloid and lymphoid white blood cells that are normally seen in the peripheral blood.

A complete blood count (CBC) with differential, or a white blood cell (WBC) count with differential, is used to determine the percentage of each type of WBC in the blood. If the differential is performed manually, a medical laboratory technician or scientist counts 100 white blood cells on stained slides, keeping track of how many of each type of cell are counted. Automated equipment performs a differential by counting and classifying all of the WBCs in the sample.

The most numerous of all the white blood cells in adults are the **neutrophils,** which average 10 to 16 µm across their diameter and normally have three or four nuclear lobes. The granules in the **cytoplasm** (the area of the cell outside the nucleus) of neutrophils appear tan, pink, or lavender when stained. These granules contain enzymes that are involved in phagocytosis. Neutrophils help defend the body against infections, and their average life span is from 6 hours to a few days. They move quickly to the site of infection and engulf the invader. As the neutrophils kill or neutralize the pathogens, **pus** is formed, which contains neutrophils, pathogens, and parts of the cells at the site of infection or injury.

The second type of granulocytes are the **eosinophils,** which average 10 to 16 µm across their diameter and normally have two nuclear lobes. Eosinophils are present in low numbers compared with neutrophils. Their cytoplasmic granules stain bright red-orange with eosin (an orange-colored dye). The eosinophil's granules contain chemicals that assist in controlling inflammatory reactions to prevent the spread of inflammation. Eosinophils can phagocytize and destroy parasites, respond to allergic reactions, and help kill tumor cells. Eosinophils live for about 8 to 12 days and increase in number in response to parasitic infections and allergic conditions.

TABLE 6-2 Types of White Blood Cells

Cell Type	Description	Adult Normal Range % of Total WBC Count	Function
Polymorphonuclear/Granulocytes			
 Ed Reschke	Neutrophils have distinct nuclei with three or four lobes. They show neutral staining: tan, lavender, or pink.	60%–70%	Aid in immune system defense; release pyrogens (chemicals produced by leukocytes to cause fever); phagocytize (engulf bacteria); use lysosomal enzymes to destroy bacteria; level increases during infection and inflammation.
 Ed Reschke	Eosinophils have a bilobed nucleus and cytoplasmic granules that stain orange-red.	1%–4%	Assist with inflammatory responses; secrete chemicals that destroy certain parasites; level increases with allergies and parasitic infection.
 Ed Reschke	Basophils have a bilobed nucleus and cytoplasmic granules that stain deep blue and may appear black.	0%–1%	Assist with inflammatory response by releasing histamine; release heparin (anticoagulant) and produce a vasodilator; count increases with chronic inflammation and during healing from infection.
Mononuclear			
 ©Ed Reschke	Monocytes have large, kidney-shaped nuclei. They have fine cytoplasmic granules.	2%–6%	Are the largest WBCs; become macrophages; phagocytize dying cells, microorganisms, and foreign substances; level increases during chronic infections, such as tuberculosis (TB).
 Ed Reschke	Lymphocytes have round nuclei and a minimum amount of cytoplasm. Lymphocytes may be B cells, T cells, or natural killer (NK) cells.	20%–30%	B lymphocytes (B cells) assist the immune system by producing antibodies; T lymphocytes (T cells) assist the immune system through interactions with other leukocytes; NK cells quickly respond to stressed cells; lymphocyte levels increase during viral infections.

Basophils are the least common granulocytes. Basophils average 10 to 16 µm across their diameter and normally have two nuclear lobes. Basophils contain cytoplasmic granules that stain dark blue or blue–black with the standard dyes. Body areas containing large amounts of blood, such as the liver and lungs, have the largest number of basophils. Basophils do not phagocytize like eosinophils and neutrophils. Rather, they help to swell a local area in response to an injury or a foreign invader. Basophils release histamine, which is a substance that causes capillary walls to dilate, or expand, allowing blood to enter the infected site. Histamine can accumulate in tissues during an allergic reaction as well. In addition to histamine, basophils also release heparin, which is an **anticoagulant.** It is believed that the release of heparin in these areas prevents the formation of tiny blood clots.

Monocytes are mononuclear and are the largest of all the circulating white blood cells. They average 12 to 18 µm across their diameter and normally have a round to kidney bean–shaped nucleus. The primary function of monocytes is phagocytosis. Monocytes contain fine granules, which play a major role in the destruction of microorganisms. Monocytes are not present in large amounts, but they survive for several months and are effective against chronic infections. They are capable of leaving the bloodstream to move into the tissues, and when they do, they are referred to as *macrophages.* These macrophages are larger cells, and they engulf not only pathogens, but also old, worn-out red blood cells.

Lymphocytes are also mononuclear but normally do not contain any granules. Lymphocytes average 7 to 15 µm across their diameter and have a dense, round nucleus surrounded by very little cytoplasm. Lymphocytes play an important role in the body's immune system. They produce **antibodies** and other substances that help destroy pathogens. The life span of lymphocytes ranges from a few days to several years. Lymphocytes can be divided into three groups: T cells, B cells, and NK cells. T cells are formed in the thymus, whereas B cells are formed in the lymphoid tissue of the bone marrow and in the lymph nodes. T lymphocytes are responsible for directing cell-mediated immune responses (cells helping other cells perform their function). T lymphocytes can further be subdivided into helper T cells and suppressor T cells. Helper T cells, or CD4 cells, help other cells, such as monocytes, perform their functions more efficiently. (T cells are those that are destroyed by the human immunodeficiency virus, or HIV.) Suppressor T cells, or CD8 cells, control or stop another cell's activities. B cells are responsible for humoral immunity (the production of antibodies). NK cells rapidly respond to stressed or infected cells without the need for antibodies.

Life Span Considerations

Pediatric Levels: White Blood Cells

The distribution of the various white blood cells is different for children than it is for adults. At birth, infants have a very high percentage of neutrophils (up to 80%). Lymphocytes soon dominate the distribution of white blood cells in young children as they begin to encounter the world and all its antigens. Children are constantly being exposed to new things in their environments. The body must be ready to produce antibodies, if needed, with each new molecule that is encountered by the body. Children normally have 40% to 60% lymphocytes and 20% to 30% neutrophils. As they approach adulthood, the white blood cell distribution becomes more like adult levels (see Table 6-2).

B lymphocytes are responsible for humoral immunity (the production of antibodies). B cells help defend the body by transforming into plasma cells, which then synthesize, or combine, and release antibody molecules. The antibodies are made to match the specific antigens that triggered their production. This B-cell response is called the humoral response because immunity is in the humors, or fluids, of the body.

NK cells are lymphocytes that target body cells infected by viruses as well as other types of abnormal cells, including cancer cells. They rapidly respond to stressed or infected cells without the need for antibodies. After attaching to a targeted cell, the NK cell breaks through the cell's membrane and injects chemicals that cause the cell to lyse (break up). NK cells are also thought to work with other types of lymphocytes to help control immune responses.

During a suspected infection, it is very helpful for the physician to know the percentages and amounts of each type of white blood cell to assist with diagnosing and treating the patient. For this reason, a CBC with differential is one of the more commonly ordered laboratory tests.

Platelets (Thrombocytes)

Platelets, or **thrombocytes,** are the smallest of all the cellular components, averaging 1 to 4 µm across their diameter. Platelets do not contain a nucleus and are not complete cells. Instead, they are fragments of larger cells, megakaryocytes, found in bone marrow. Megakaryocytes are the largest cells in the bone marrow, exhibiting a very large, multiple-lobed nucleus. Each platelet typically remains in circulation for about 9 to 12 days, and the normal adult range is between 150,000 and 450,000 per cubic millimeter (mm^3) of blood.

Platelets play an important role in preventing blood loss because, when an injury occurs, they are the first components to arrive at the site. Platelets stick to the injury site and form a platelet plug, which slows or stops the bleeding. Platelets also secrete a substance called serotonin, which causes the blood vessels to spasm, or narrow, and decreases blood loss until a clot forms. Platelets, along with substances in the liquid composition of blood, are essential for minimizing blood loss due to an injury. Platelets are formed in the bone marrow, and old platelets are trapped and removed by the spleen.

Liquid Component (Plasma)

The liquid portion of whole blood is called **plasma.** Plasma is a pale yellow fluid that contains the following components:

- *Water* is 90% to 92% of plasma. This percentage is monitored by the kidneys and the pituitary gland and affected by the large intestine and the amount of water consumed.
- *Nutrients* are materials passed through the digestive system directly into the bloodstream. These include cholesterols, fatty acids, amino acids, and glucose.
- *Hormones* assist with chemical reactions and allow the body to maintain a constant balance. One example is thymosin, which helps the immune system battle foreign invaders. A more common hormone is insulin, which regulates the amount of sugar in the bloodstream.
- *Electrolytes* include sodium, potassium, calcium, magnesium, and chloride. These are found in food and are used in chemical processes such as the regulation of the body's water.

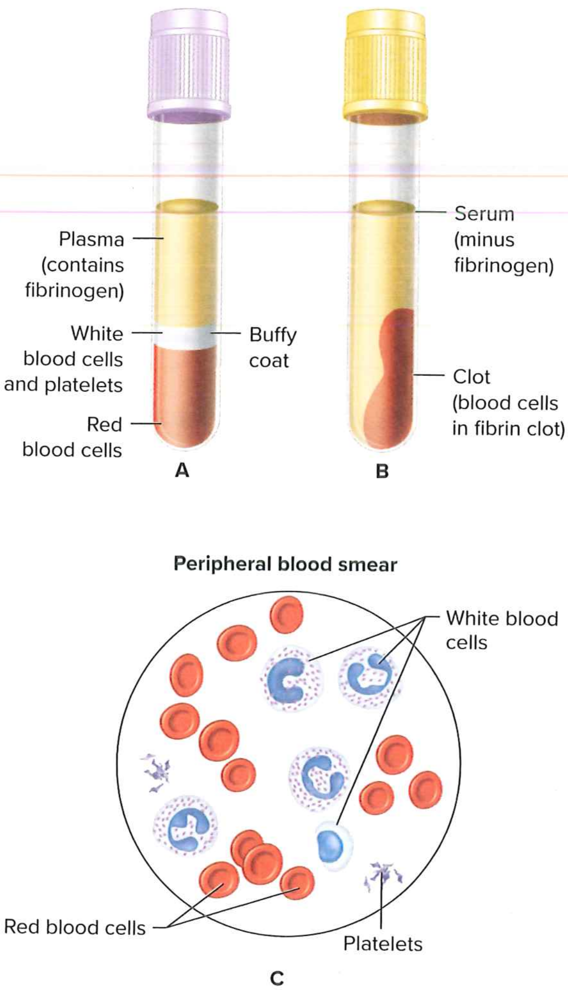


Figure 6-15 Blood samples and peripheral blood smear. (A) Plasma is the liquid that is recovered when unclotted blood has been centrifuged. (B) Serum is the liquid portion of blood after it has been allowed to clot. (C) A peripheral blood smear shows the various blood components of a plasma specimen.

- *Proteins* such as fibrinogen, globulins, and albumin:
  - **Fibrinogen** is a protein that aids in clotting and is manufactured in the liver.
  - *Globulins* are manufactured both in the liver and in the lymphatic system as antibodies, which fight foreign invaders in the body.
  - *Albumin* is the most abundant of all plasma proteins. It is a product of the liver and helps pull water into the bloodstream to assist in regulating blood pressure.
- *Waste* is produced by the chemical reactions that occur in body cells. Plasma is responsible for carrying waste to the organs that remove or excrete it. Examples of waste products are urea, uric acid, creatinine, and xanthine.
- *Protective substances* include antitoxins, opsonins, agglutinin, and bacteriolysins, all of which assist WBCs in the destruction of microorganisms.

The terms *plasma* and *serum* are not synonyms. Plasma is the liquid portion of *unclotted* blood. Blood specimens obtained for tests that require plasma are collected in a tube with an anticoagulant, which prevents clotting. The tubes that are most commonly used with an anticoagulant have purple or lavender tops. **Serum** is the liquid portion of *clotted* blood. Specimens drawn for tests that require serum are collected in a tube without an anticoagulant, so that a clot is allowed to form. A clot forms when fibrinogen converts into fibrin and traps the formed elements of the blood. When the clot forms, some clotting factors are depleted and the fluid that remains is known as serum. This process of clotting is called **coagulation.** Table 6-3 describes the differences between plasma and serum.

Centrifugation is the spinning of test tubes at high speed around a central axis. When laboratory tubes contain an anticoagulant, blood can be separated into cells and plasma by centrifugation. When collected blood without an anticoagulant is centrifuged, it is separated into cells and serum. Recall that plasma is the liquid component of blood and serum is the liquid component of blood without clotting factors. The results of centrifugation are shown in Figure 6-15. Centrifugation will be discussed further in the chapter *Blood Specimen Handling*.

TABLE 6-3 Differences Between Plasma and Serum

Plasma	Serum
Fluid obtained when anticoagulated blood has been centrifuged	Fluid obtained when coagulated blood has been centrifuged
Collected in a tube with an anticoagulant	Collected in a tube without an anticoagulant; will clot within 10 to 30 minutes
Fibrinogen is present	Fibrinogen is absent
Processed by centrifugation and tested immediately	Must be kept in an upright (standing) position to coagulate, then centrifuged before testing

1. List the formed elements of blood and briefly describe the purpose of each.
2. What is the difference between plasma and serum?

Checkpoint Questions 6.4

6.5 Hemostasis and Blood Coagulation

It is important for the phlebotomist to understand how bleeding is controlled naturally. Both venipuncture and dermal puncture create injuries to the blood vessels, and the body's natural defenses must stop the bleeding. The medical term **hemostasis** breaks down into *hemo*, meaning "blood," and *stasis*, meaning "stopping." Following an injury, there are four major events involved in stopping the flow of blood at the injured site. Figure 6-16 illustrates the following four events:

1. Blood vessel spasm (vasoconstriction)
2. Platelet plug formation
3. Blood clotting (coagulation)
4. Fibrinolysis, or dissolving of the clot and return of the vessel to normal function

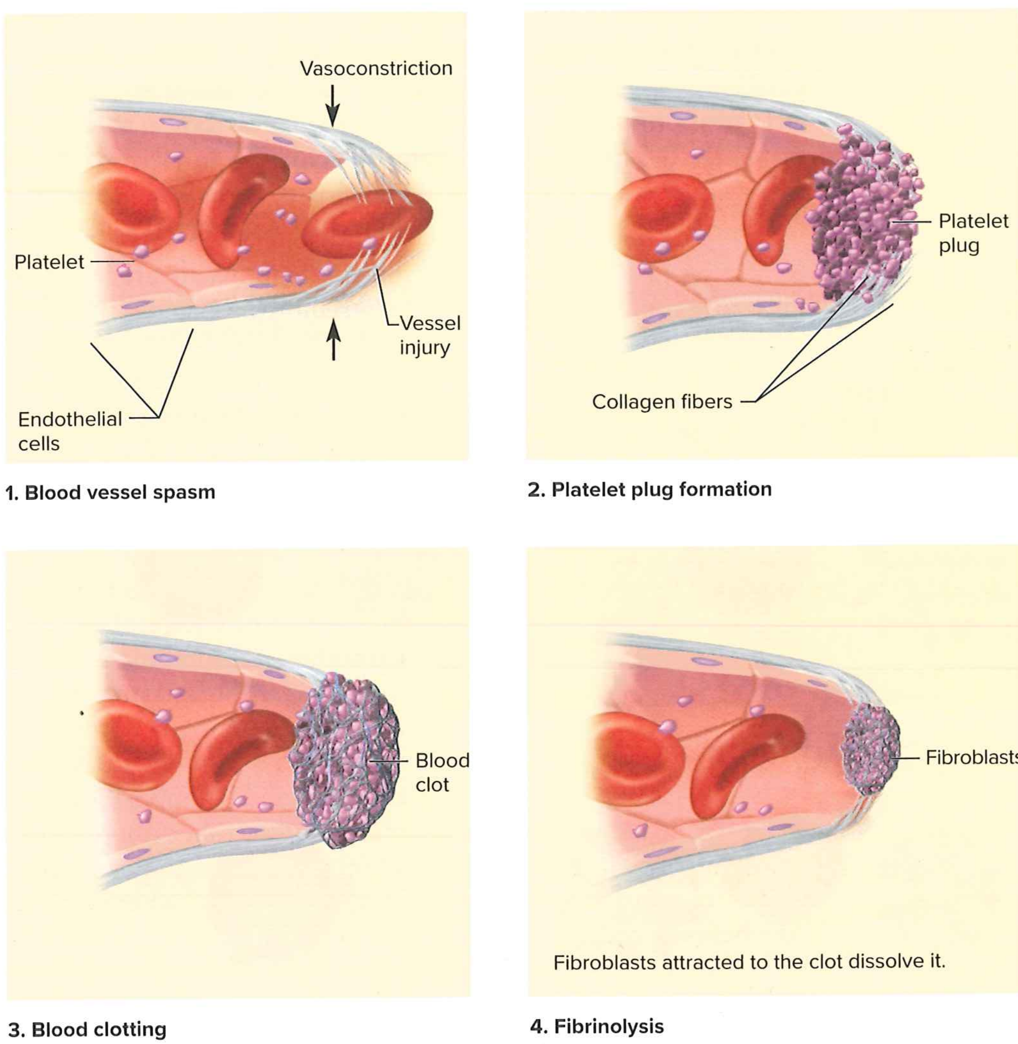


Figure 6-16 Events of hemostasis.

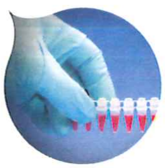
Blood Vessel Spasm

If the blood vessel is small and the injury is limited, a blood vessel spasm alone may stop the bleeding. At the time of injury, the involved blood vessel constricts (becomes narrower in diameter), and this decreases the amount of blood flowing through the vessel, which stops or controls the bleeding.

Platelet Plug Formation

In the event that bleeding continues in spite of the blood vessel spasms, platelets are called into action. The torn, inner lining of the blood vessels releases chemical signals that stimulate platelets to gather at the injury site. These platelets clump together to form a platelet plug, which further decreases the flow of blood from the injured site. This process occurs within seconds after an injury and is known as *primary hemostasis.*

Safety & Infection Control



Lack of Clotting Factors

Not all individuals possess natural clotting factors. Some people are born with medical conditions that cause bleeding disorders, such as hemophilia. Patients taking anticoagulants, such as heparin or warfarin, and those lacking natural clotting ability require close monitoring following venipuncture. The phlebotomist must apply manual pressure to the site for a minimum of 3 to 5 minutes to prevent excessive bleeding.

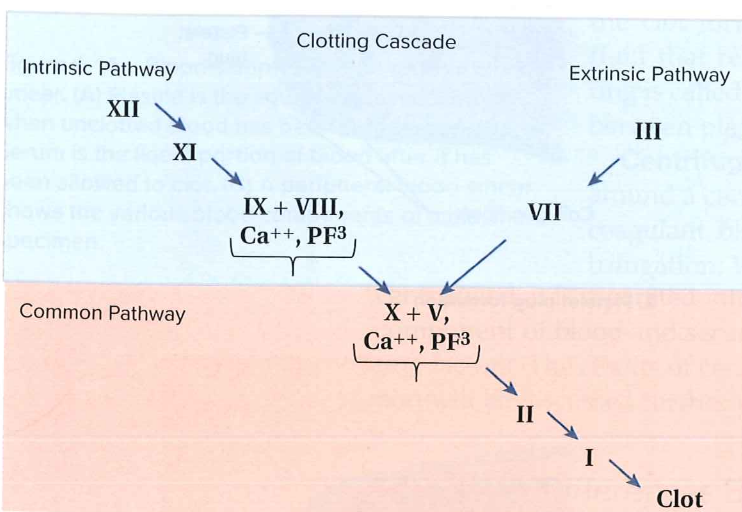


Figure 6-17 Simplified schematic of the clotting cascade, a sequence of events that result in the formation of a clot.

Blood Clotting

Extensive injury to larger blood vessels generally requires all steps in the hemostasis process. The third step is coagulation, or blood clotting, which requires the presence of specific clotting factors (Factors I, II, V, VII, VIII, IX, and X) to form a blood clot. At the time of injury to the blood vessel, certain clotting factors are called into action. These clotting factors, along with calcium ions and platelet factors, come together through a complex series of chemical reactions to produce **thrombin.** Thrombin is an enzyme used to convert the plasma protein fibrinogen into **fibrin,** which is a very strong and elastic protein. Once fibrin has been produced, the threadlike composition of fibrin forms a meshlike sac that adheres to the injury site, trapping platelets, blood cells, and other particles to form a clot. These events occur in a fashion similar to falling dominoes, where one domino falling touches off a chain reaction. The clotting proteins involved in several pathways (intrinsic, extrinsic, and common) of clotting are shown in Figure 6-17. The clot often forms around platelets that have adhered to the site of tissue or vessel damage, as shown in Figure 6-16. This process takes several minutes and is known as *secondary hemostasis.*

Fibrinolysis

The clot stimulates the growth of fibroblasts and smooth muscle cells within the vessel wall. This begins the repair process, which includes the final step in hemostasis, fibrinolysis, ultimately resulting in the dissolution of the clot. The vessel finally returns to normal (see Figure 6-18).

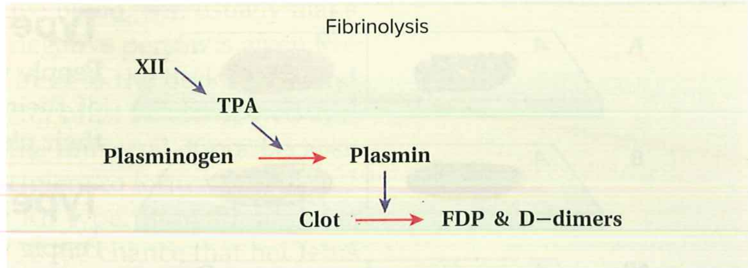


Figure 6-18 Simplified schematic of fibrinolysis. Fibrinolysis (breaking down of the clot) occurs in a "falling dominoes" fashion similar to the clotting cascade. A series of reactions occurs that results in the clot being broken down into fibrin degradation products (FDPs) and D-dimers.

Checkpoint Questions 6.5

1. What is the medical term for stopping the flow of blood?
2. Explain the purpose of thrombin in the blood coagulation process.

6.6 ABO and Rh Blood Types

If 20 tubes of blood from different patients were lined up on a counter in the laboratory, they all would look very much alike, even though they may be very different. The naked eye is not capable of detecting the inherited identifying proteins on the surface of individual red blood cells, known as **antigens.** The ABO blood group consists of four **blood types:** A, B, AB, and O. They are distinguished from each other in part by their antigens and antibodies (see Figures 6-19 and 6-20).

Medical laboratory scientists identify these blood groups by testing for **agglutination,** the clumping of red blood cells. Agglutination occurs because the antigens on the surface of red blood cells bind to antibodies in plasma.

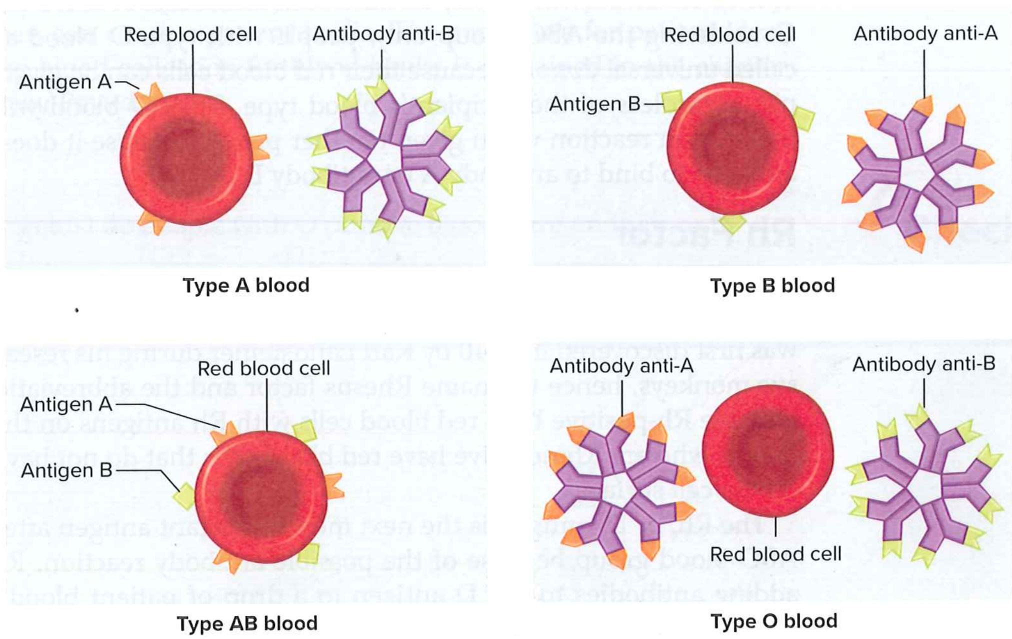


Figure 6-19 A, B, AB, and O blood types.

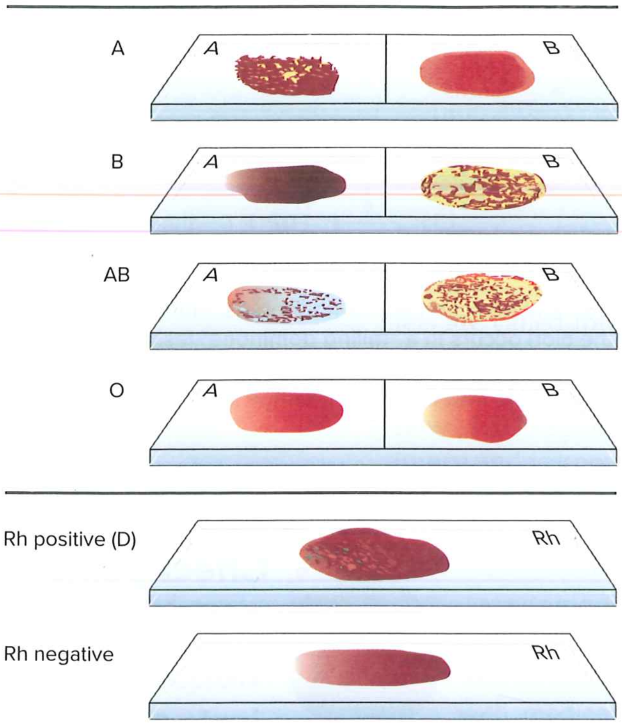


Figure 6-20 The agglutination of different ABO and Rh blood types using antisera (types of serum containing antibodies to either A, B, or D). A grainy appearance indicates agglutination. A smooth appearance indicates a lack of agglutination.

Type A

People with type A blood have antigen A on the surface of their red blood cells. They also have antibody B in their plasma.

Type B

People with type B blood have antigen B on the surface of their red blood cells. They also have antibody A in their plasma.

If a person with type A blood is given type B blood, the antibody B in the recipient's bloodstream will bind with the red blood cells of the donor blood because those cells have antigen B on their surfaces. The donated—in this case type B—red blood cells are destroyed causing severe complications for the patient. This is why a person with type A blood should *never* be given type B blood (and vice versa). It can cause complications known as transfusion reactions, which are discussed later in this chapter.

Type AB

People with type AB blood have both antigens A and B on the surface of their red blood cells. They have neither antibody A nor antibody B in their plasma. People with type AB blood are sometimes called universal blood recipients because most of them can receive all ABO blood types. They lack antibodies A and B in their plasma, so there is no reaction with antigens A and B in the donor blood. On the other hand, because AB blood has no antibodies in the plasma to react with the recipient's antigens, people who have AB blood are considered universal plasma donors.

Type O

People with type O blood have neither antigen A nor antigen B on the surface of their RBCs. However, they do have both antibodies A and B in their plasma. Considering the ABO group only, people with type O blood are sometimes called universal donors because their red blood cells can be given to most people, regardless of the recipient's blood type. Type O blood will not cause a transfusion reaction when given to other people because it does not have the antigens to bind to antibody A or antibody B.

Rh Factor

The **Rh antigen** is present on red blood cells and is classified separately from the ABO blood groups. The Rh antigen is assigned the letter *D*. The Rh antigen was first discovered in 1940 by Karl Landsteiner during his research with Rhesus monkeys, hence the name Rhesus factor and the abbreviation *Rh*. People who are Rh-positive have red blood cells with Rh antigens on the cell surface. People who are Rh-negative have red blood cells that do not have Rh antigens on the cell surface.

The Rh, or D, antigen is the next most important antigen after those in the ABO blood group because of the possible antibody reaction. Rh is tested by adding antibodies to the D antigen to a drop of patient blood. If agglutination occurs, the patient is Rh-positive. No agglutination indicates Rh-negative blood (see Figure 6-20).

A person who is Rh-negative, if given Rh-positive blood, will usually make antibodies that bind to the Rh antigens. If the Rh-negative person is given Rh-positive blood a second time, the antibodies will bind to the donor cells and agglutination will occur. Because of this, the Rh factor must be considered during blood transfusions. O negative blood is truly the universal donor because it has no A, B, or D antigens that can cause the recipient to form antibodies.

It is very important for a female to know her Rh type. If an Rh-negative female mates with an Rh-positive male, there is a 50–50 chance that her fetus will be Rh-positive. After birth, when the blood of an Rh-positive fetus mixes with the blood of a mother who is Rh-negative, the mother develops antibodies against the fetus's red blood cells. The first Rh-positive fetus usually does not suffer from these antibodies because the mother's body has not yet generated the antibodies. However, if the mother conceives another Rh-positive fetus, the fetus's blood will be attacked by the antibodies right away. The fetus then develops a condition called *erythroblastosis fetalis,* or hemolytic disease of the fetus and newborn (HDFN). The baby is born severely anemic, often needing multiple blood transfusions at birth and several times as a neonate. Without treatment, the baby may die before birth or after delivery.

Erythroblastosis fetalis is prevented by giving an Rh-negative woman drugs that suppress the production of anti-D, such as RhIg or RhoGAM®. Blood tests, such as the direct antihuman globulin test (DAT) and bilirubin, may be ordered to evaluate the newborn for any blood incompatibility between the mother and the baby.

Transfusion Reactions

A transfusion reaction occurs when a patient is transfused with blood to which they have an antibody. Initially, agglutination occurs, followed by hemolysis. Transfusion reactions can range from mild, which may produce a slight fever or hives, to severe, resulting in death. To avoid reactions, patients are given type-specific blood or blood products even in emergencies.

Phlebotomists are frequently asked to draw blood that is used to determine a patient's blood type in order to be cross-matched with appropriate blood products.

To prevent transfusion reactions, two patient identifiers must always be used. The blood and blood products must be labeled accurately. An incorrectly labeled specimen can cause a patient to die. The procedure for patient identification during blood collection for blood banks is explained in the chapter *Special Phlebotomy Procedures*.

Checkpoint Questions 6.6

1. Which antigen(s) do people with O positive blood have on their red blood cells?
2. What are the symptoms of a transfusion reaction?

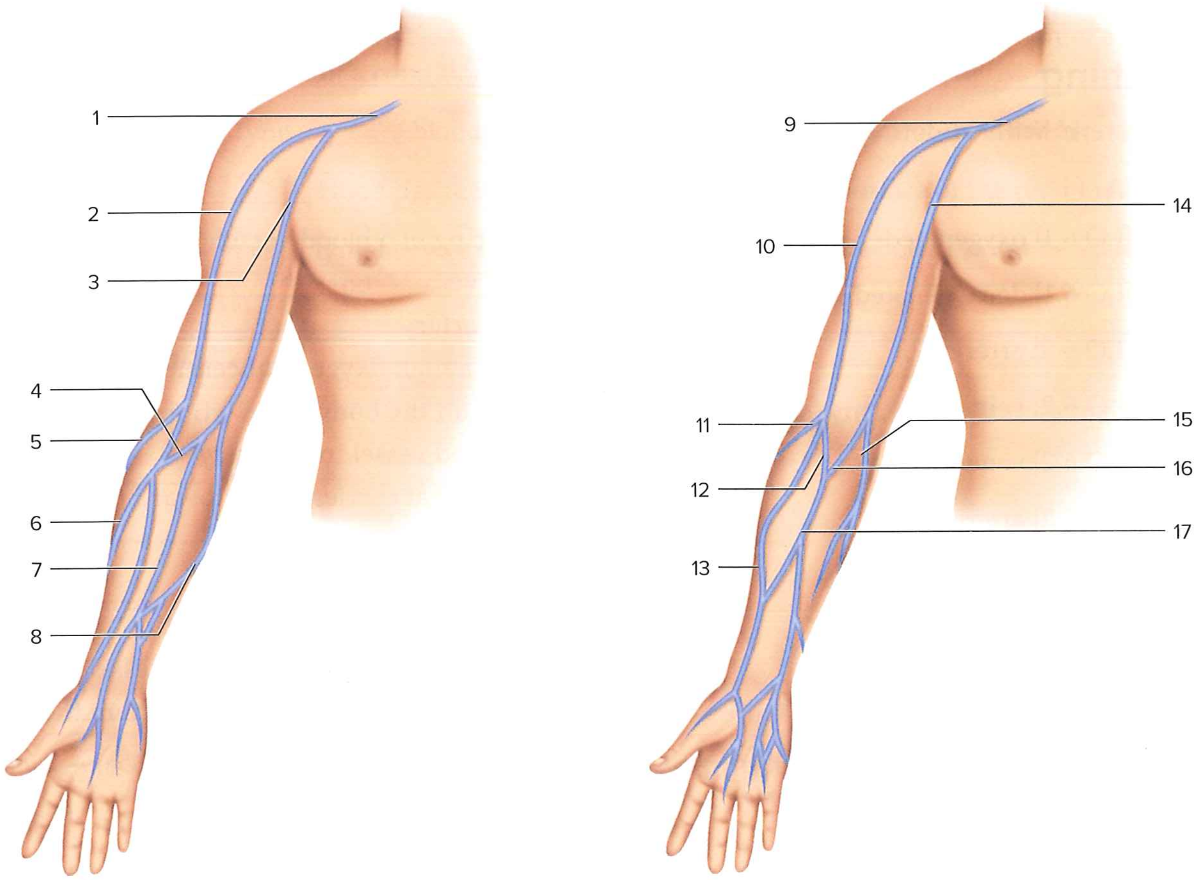
Chapter Summary

Learning Outcome	Key Concepts/Examples	Related NAACLS Competency
6.1 Describe circulation and the purpose of the vascular system.	The vascular system consists of a network of vessels that, along with the heart, provides for circulation of the blood. Coronary circulation provides blood to the heart. Systemic circulation provides oxygen and nutrients to body tissues and removes waste. Pulmonary circulation replenishes oxygen in the blood and removes carbon dioxide.	3.4
6.2 Identify and describe the structures and functions of the different types of blood vessels.	Blood vessel layers include the tunica intima (innermost), tunica media (middle), and tunica adventitia (outermost). All arteries, except the pulmonary artery, carry oxygenated blood to the body. All veins, except the pulmonary vein, carry deoxygenated blood back to the heart and lungs. Arterioles are small arteries and venules are small veins. Capillaries provide a link between arterioles and venules and allow for gas exchange.	3.4
6.3 Locate and name the veins most commonly used for phlebotomy procedures.	The three veins most commonly used for phlebotomy are located in the antecubital fossa. They include the median cubital, cephalic, and basilic veins.	3.3
6.4 Identify the major components of blood and describe the major functions of each.	The major components of blood are liquid and formed elements. Red blood cells transport oxygen and carbon dioxide. White blood cells include neutrophils for response to bacterial infections, eosinophils for response to allergies and parasitic infections, basophils for release of histamine and heparin, monocytes to fight chronic infections, and lymphocytes that assist the immune system and produce antibodies. Platelets are essential for clotting. Plasma is the liquid portion of unclotted blood. Serum is the liquid portion of clotted blood.	3.4
6.5 Define hemostasis and describe the basic coagulation process.	Hemostasis, or stopping of blood, includes four major events: blood vessel spasm, platelet plug formation, blood clotting, and fibrinolysis.	3.5, 3.6
6.6 Describe how ABO and Rh blood types are determined.	ABO and Rh blood types are determined by the type of antigen found on the red blood cells.	3.7

Chapter Review

A: Labeling

Label the arm veins commonly used for venipuncture in the following image.



1. [LO 6.3] ______________________________

2. [LO 6.3] ______________________________

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15. [LO 6.3] ______________________________

16. [LO 6.3] ______________________________

17. [LO 6.3] ______________________________

18. [LO 6.3] ______________________________

B: Matching

Match each term with its definition.

Matching A

___19. [LO 6.1] oxygenated
___20. [LO 6.1] deoxygenated
___21. [LO 6.2] artery
___22. [LO 6.2] vein
___23. [LO 6.2] venule
___24. [LO 6.2] arteriole
___25. [LO 6.1] aorta
___26. [LO 6.1] vena cava
___27. [LO 6.2] capillary
___28. [LO 6.2] tunica intima
___29. [LO 6.2] tunica media
___30. [LO 6.2] tunica adventitia

a. outer covering of a blood vessel
b. very small vein
c. very small artery
d. blood with a high oxygen concentration
e. largest vein in the body
f. smallest blood vessel in the body
g. blood vessel that carries blood toward the heart
h. largest artery in the body
i. middle layer of a blood vessel
j. blood with a low oxygen concentration
k. innermost, smooth layer of a blood vessel
l. blood vessel that carries blood away from the heart

Matching B

31. [LO 6.4] serum
32. [LO 6.4] plasma
33. [LO 6.1] pulmonary artery
34. [LO 6.1] pulmonary vein
35. [LO 6.4] lymphocytes
36. [LO 6.4] monocytes
37. [LO 6.4] diapedesis
38. [LO 6.4] eosinophils
39. [LO 6.4] erythrocytes
40. [LO 6.4] leukocytes
41. [LO 6.4] neutrophils
42. [LO 6.4] basophils
43. [LO 6.4] platelet

a. carries deoxygenated blood away from the heart
b. carries oxygenated blood to the heart
c. fluid that contains fibrinogen
d. fluid left after blood has clotted
e. perform phagocytosis to destroy pathogens
f. smallest of all the blood components and considered to be a cell fragment
g. most numerous of the WBCs
h. process by which WBCs pass through capillary walls to fight pathogens
i. least common granulocyte
j. largest of all WBCs
k. contain hemoglobin and transport oxygen and carbon dioxide
l. produce antibodies that help destroy pathogens
m. assist with inflammatory processes; level is elevated in the presence of allergies and parasites

C: Fill in the Blank

Write in the word(s) to complete the statement.

44. [LO 6.6] __________ are located on the surface of RBCs.

45. [LO 6.5] The liquid portion of the blood is referred to as _________ or plasma, depending on whether it contains fibrinogen and other clotting factors.

46. [LO 6.6] Women with Rh-negative blood may be given drugs to suppress the production of anti-D antibodies in order to prevent a condition called _________ in the fetus.

47. [LO 6.6] People with type ________ blood have the A antigen on the surface of their red blood cells.

48. [LO 6.6] Type ____________ blood has neither A nor B antigens on the surface of the red blood cells.

49. [LO 6.4] The three types of lymphocytes that play an effective role in the body's immune system are ___________, _____________, and _________.

D: Sequencing

As blood flows from the heart, it enters the following blood vessels in what order (from 1 to 5)?

50. [LO 6.2] __________ arterioles

51. [LO 6.2] __________ arteries

52. [LO 6.2] __________ capillaries

53. [LO 6.2] __________ veins

54. [LO 6.2] __________ venules

Place the events of hemostasis (coagulation) in the correct order (from 1 to 4).

55. [LO 6.5] __________ formation of the platelet plug

56. [LO 6.5] __________ blood vessel spasm

57. [LO 6.5] __________ blood clotting

58. [LO 6.5] __________ fibrinolysis

E: Case Studies/Critical Thinking

59. [LO 6.2] A phlebotomist is attempting to obtain blood from an unconscious patient. When the needle is inserted into the arm, the phlebotomist observes a bright red, pulsating flow of blood entering the syringe. What may have occurred, and what should the phlebotomist do next?

60. [LO 6.4] An immunocompromised patient requires blood to be drawn routinely, and the phlebotomist has just received a page for a STAT collection on another patient. Should the phlebotomist proceed to the isolation room quickly and just draw this patient's blood, or should the phlebotomist go back at a later time? Give an explanation for your response.

61. [LO 6.4] A patient exposed to a parasitic infection may experience elevated WBCs. What type of WBC will increase in number during an infection of this type? Why?

62. [LO 6.4] A patient complains of fatigue and noticed that the whites of his eyes have turned a bit yellow. What do you think might be wrong with the patient? What laboratory test would need to be drawn to determine the cause of the yellowing eyes?

63. [LO 6.5] You have been asked to draw blood from a patient who is known to have a low platelet count. What might happen to this patient when you perform the blood draw? How would you collect blood from this patient?

F: Exam Prep

Choose the best answer for each question.

64. [LO 6.1] Which types of circulation are included in the cardiovascular system? *(Choose all that apply.)*
   a. Coronary
   b. Pulmonary
   c. Systemic
   d. Lymphatic

65. [LO 6.1] The heart has
   a. two chambers functioning as a single pump.
   b. two chambers functioning as a dual pump.
   c. four chambers functioning as a single pump.
   d. four chambers functioning as a dual pump.

66. [LO 6.1] Which side of the heart carries deoxygenated blood?
   a. Left
   b. Right
   c. Both
   d. Neither

67. [LO 6.1] Blood vessels are lined with the same cells as the heart's
   a. endocardium.
   b. epicardium.
   c. myocardium.
   d. pericardium.

68. [LO 6.1] The structures that keep blood flowing in the correct direction are
   a. chambers.
   b. septa.
   c. valves.
   d. vessels.

69. [LO 6.1] Blood must pass through this valve when entering the left ventricle.
   a. Aortic semilunar
   b. Bicuspid
   c. Pulmonary semilunar
   d. Tricuspid

70. [LO 6.1] The mitral valve is the same as the
   a. aortic semilunar valve.
   b. bicuspid valve.
   c. pulmonary semilunar valve.
   d. tricuspid valve.

71. [LO 6.1] Blood is kept from flowing from the aorta backward into the heart by the
   a. bicuspid valve.
   b. aortic semilunar valve.
   c. tricuspid valve.
   d. venous valve.

72. [LO 6.2] The structures that carry blood to all parts of the body are the
   a. chambers.
   b. endocardium.
   c. ventricles.
   d. vessels.

73. [LO 6.3] The vein on the back of the hand that may be used for phlebotomy procedures is the
   a. basilic.
   b. cephalic.
   c. dorsal arch.
   d. median cubital.

74. [LO 6.4] Which of the following white blood cells has *no* phagocytic function?
   a. Eosinophil
   b. Lymphocyte
   c. Monocyte
   d. Neutrophil

75. [LO 6.4] The ability of red blood cells to pass through capillaries is due to their shape, which is
   a. biconcave.
   b. a flat disk.
   c. spheroid.
   d. uniconcave.

76. [LO 6.4] What type of blood cells have hemoglobin?

a. Erythrocytes
b. Leukocytes
c. Thrombocytes
d. All of these

77. [LO 6.4] Mononuclear leukocytes include all of these *except*

a. B lymphocytes (B-cells).
b. monocytes.
c. neutrophils.
d. T lymphocytes (T-cells).

78. [LO 6.4] Various types of granulocytes exhibit these colors when stained *except*

a. blue-black.
b. red-orange.
c. tan-pink.
d. yellow-green.

79. [LO 6.4] What type of blood cells may be elevated when a person is exposed to the cause of an allergy?

a. Basophils
b. Eosinophils
c. Macrophages
d. Plasma cells

80. [LO 6.4] While on vacation, a person acquires a parasitic infection. What blood cells may be elevated as a result of this infection?

a. Basophils
b. Eosinophils
c. Monocytes
d. Neutrophils

81. [LO 6.4] A function of T lymphocytes (T-cells) is to

a. fight bacterial infections.
b. mediate cellular interactions.
c. phagocytize microorganisms.
d. produce antibodies.

82. [LO 6.4] Serum differs from plasma mainly because it contains *no*

a. electrolytes.
b. fibrinogen.
c. nutrients.
d. water.

83. [LO 6.6] A woman who is pregnant is concerned that her blood type may not match that of her baby's and might harm either her or her baby. Which red blood cell antigen should be of most concern to her and her physician?

a. A
b. B
c. O
d. Rh

84. [LO 6.5] When platelets clump together to form a platelet plug, this is known as

a. thrombinolysis.
b. fibrinolysis.
c. hemolysis.
d. hemostasis.

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