Basic Human Anatomy

Lesson 9: Cardiovascular and Lymphatic System

Welcome to Lesson 9 of the Basic Human Anatomy Course. Today, we'll be studying the Human Cardiovascular and Lymphatic Systems.

I have 10 goals for you in this lesson:

1. Name and briefly explain the four basic components of any circulatory system.
2. Define the human cardiovascular system, name its four major components, and match its components with the four basic components of any circulatory system.
3. Briefly describe plasma and the formed elements of the blood and state four general functions of blood.
4. Describe the general construction of a blood vessel; name three types of blood vessels; state the basic function of each type.
5. Describe the general construction of the human heart, including its auricles, atria, ventricles, septa, wall layers, variations of wall thickness, and the names, structures, and position of the cardiac valves.
6. Describe three different control systems regulating the heart beat.
7. Describe the coronary arteries and cardiac veins and their function.
8. Briefly describe the pericardium.
9. Describe cardiovascular circulatory patterns, including the terms collateral circulation, end artery, pulmonary cycle, and systemic cycle. Name the major arteries and veins of the human body and the areas serviced or supplies.
10. Briefly describe lymphatic capillaries, lymph vessels (including the thoracic duct), lymph nodes, and tonsils.

INTRODUCTION

NEED FOR CIRCULATORY SYSTEMS

a. The need for circulatory systems is based on two criteria:

(1) Number of cells. Multicellular animals are animals with a great number of cells.

(2) Size. In larger animals, most cells are too far away from sources of food and oxygen for simple diffusion to provide sufficient amounts. Also, distances are too great for simple removal of wastes.

b. Because of these criteria, we need a system (or systems) to carry materials to all cells. To get food and oxygen to the cells and to remove waste products, we need a transport system or circulatory system. Human circulatory systems are so effective that no cell is more than two cells away from a blood capillary.

BASIC COMPONENTS OF ANY CIRCULATORY SYSTEM

The four basic components of any circulatory system are a vehicle, conduits, a motive force, and exchange areas.

a. **Vehicle**. The vehicle is the substance which actually carries the materials being transported.

b. **Conduits**. A conduit is a channel, pipe, or tube through which a vehicle travels.

c. **Motive Force**. If we say that a force is motive, we mean that it produces movement. Systems providing a motive force are often known as pumps.

d. **Exchange Areas**. Since the materials being transported must eventually be exchanged with a part of the body, special areas are developed for this purpose. They are called exchange areas.

CIRCULATORY SYSTEMS IN THE HUMAN BODY

a. The cardiovascular system is the circulatory system involving the heart and blood vessels.

b. The lymphatic system is a drainage-type circulatory system involved with the clear fluid known as lymph.

c. There are other minor circulatory systems in the human body, such as the one involved with cerebrospinal fluid.

THE HUMAN CARDIOVASCULAR SYSTEM

GENERAL

The human cardiovascular system is a collection of interacting structures designed to supply oxygen and nutrients to living cells and to remove carbon dioxide and other wastes. Its major components are the:

a. **Blood**. Blood is the vehicle for oxygen, nutrients, and wastes.

b. **Blood Vessels**. Blood vessels are the conduits, or channels, through which the blood is moved.

c. **Heart**. The heart is the pump which provides the primary motive force.

d. **Capillaries**. The capillaries, minute (very small) vessels, provide exchange areas. For example, in the capillaries of the lungs, oxygen is added and carbon dioxide is removed from the blood.

BLOOD

Blood is the vehicle for the human cardiovascular system. Its major subdivisions are the plasma, a fluid containing proteins, and the formed elements, including red blood cells, white blood cells, and platelets.

a. **Plasma**.

(1) Plasma makes up about 55 percent of the total blood volume. It is mainly composed of water. A variety of materials are dissolved in plasma. Among the most important of these are proteins.

(2) After the blood clots, the clear fluid remaining is called serum. Serum does not contain the proteins used for clotting. Otherwise, it is very similar to plasma.

b. **Formed Elements**. The formed elements make up about 45 percent of the total blood volume. The formed elements are cellular in nature. While the red blood cells (RBCs) and white blood cells (WBCs) are cells, the platelets are only fragments of cells.

(1) Red blood cells (erythrocytes). RBCs are biconcave discs. That is, they are shaped something like an inner tube from an automobile tire, but with a thin middle portion instead of a hole. There are approximately 5,000,000 RBCs in a cubic millimeter of normal adult blood. RBCs contain hemoglobin, a protein which carries most of the oxygen transported by the blood.

(2) White blood cells (leukocytes). There are various types of WBCs, but the most common are neutrophils and lymphocytes. Neutrophils phagocytize (swallow up) foreign particles and organisms and digest them. Lymphocytes produce antibodies and serve other functions in immunity. In normal adults, there are about 5,000 to 11,000 WBCs per cubic millimeter of blood.

(3) Platelets. Platelets are about half the size of erythrocytes. They are fragments of cells. Since they are fragile, they last only about three to five days. Their main function is to aid in clotting by clumping together and by releasing chemical factors related to clotting. There are 150,000 - 350,000 platelets in a cubic millimeter of normal blood.

c. **Some General Functions of the Blood**.

(1) Blood serves as a vehicle for oxygen, nutrients, carbon dioxide and other wastes, hormones, antibodies, heat, etc.

(2) Blood aids in temperature control. Beneath the skin, there is a network of vessels that functions much like a radiator. To avoid accumulation of excess heat in the body, the flow of blood to these vessels can be increased greatly. Here, aided by the evaporative cooling provided by the sweat glands, large amounts of heat can be rapidly given off. The flow of blood also helps keep the outer parts of the body from becoming too cold.

(3) The blood aids in protecting our bodies by providing immunity. Some WBCs phagocytize (swallow up) foreign particles and microorganisms. Other WBCs produce antibodies. The blood transports antibodies throughout the body.

(4) Blood clotting is another function of blood. Not only does this prevent continued blood loss, it also helps prevent invasion of the body by microorganisms and viruses by sealing the wound opening.

BLOOD VESSELS

The blood is conducted or carried through the body by tubular structures known as blood vessels. Since at no time does the whole blood ever leave a blood vessel of some sort, we refer to this system as a closed system.

a. **General Construction**. The blood vessels in general are tubular and have a three-layered wall.

(1) Intima. The lumen (hollow central cavity) is lined by a layer of smooth epithelium known as the intima.

(2) Media. A middle layer of smooth muscle tissue is called the media.

(3) Adventitia. The adventitia is the outer layer of fibrous connective tissue that holds everything together.

b. **Types of Blood Vessels**. See figure 9-1 for a diagram of the human circulatory system. We recognize three types of blood vessels: ib

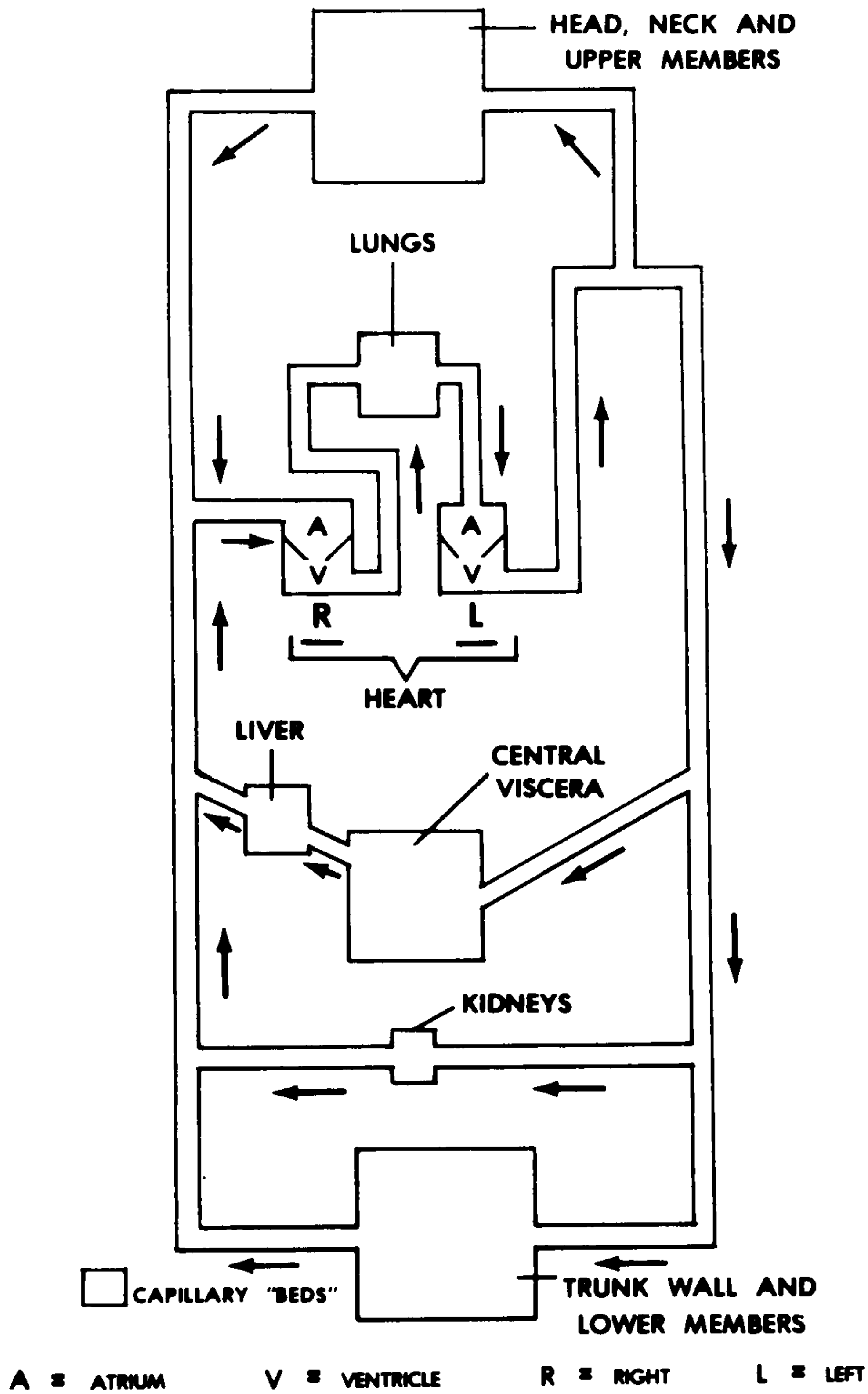

Figure 9-1. Scheme of blood vessels.

(1) The arteries carry blood away from the chambers of the heart.

(2) The veins carry blood to the chambers of the heart.

(3) Capillaries are extremely thin-walled vessels having only the intimal layer through which exchanges can take place between the blood and the tissue cells.

c. **Relationships**. Arteries and veins are largest where they are closest to the heart. Away from the heart, they branch into smaller and smaller and more numerous vessels. The branching continues until the smallest arteries (arterioles) empty into the capillaries. The capillaries in turn are drained by the venules of the venous system.

d. **Valves**. Within the heart and the veins are structures known as valves. Valves function to insure that the blood flows in only one direction.

THE HEART

Through the action of its very muscular walls, the heart produces the primary motive force to drive the blood through the arterial system. In humans, the heart is located just above the diaphragm, in the middle of the thorax, and extending slightly to the left. It is said that the heart of an average individual is about the size of that individual's clenched fist.

a. **General Construction of the Human Heart**. See figure 9-2 for an illustration of the human heart.

(1) Chambers. The heart is divided into four cavities known as the chambers. The upper two chambers are known as the atria, right and left. Each atrium has an ear-like projection known as an auricle. The lower two

chambers are known as ventricles, right and left. Between the two atria is a common wall known as the interatrial septum. Between the two ventricles is a common wall known as the interventricular septum.

ATRIUM = hall

AURICLE = ear-like flap

VENTER = belly

SEPTUM = fence

(2) Wall layers. The walls of the chambers are in three general layers. Lining the cavity of each chamber is a smooth epithelium known as the endocardium. (Endocarditis is an inflammation of the endocardium.) The middle layer is made up of cardiac muscle tissue and is known as the myocardium. The outer layer of the heart is another epithelium known as the epicardium.

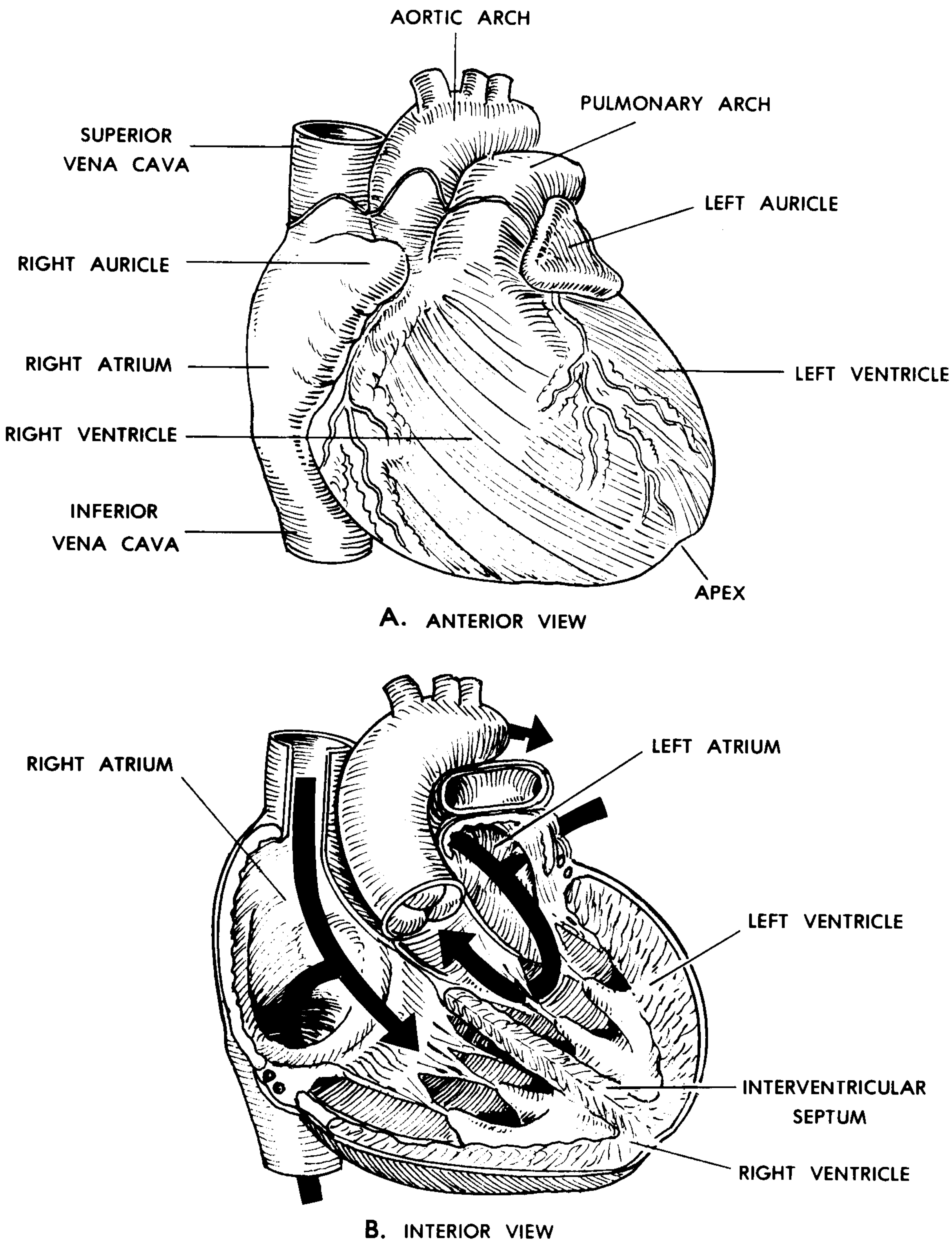

Figure 9-2. The human heart.

(3) Relationship of wall thickness to required pressure levels. A cross-section of the chambers shows that the atrial walls are relatively thin. The right ventricular wall is much thicker. The left ventricular wall is three to five times thicker than that of the right. These differences in wall thickness reflect the amount of muscle tissue needed to produce the amount of pressure required of each chamber.

(4) Cardiac valves (figure 9-3).

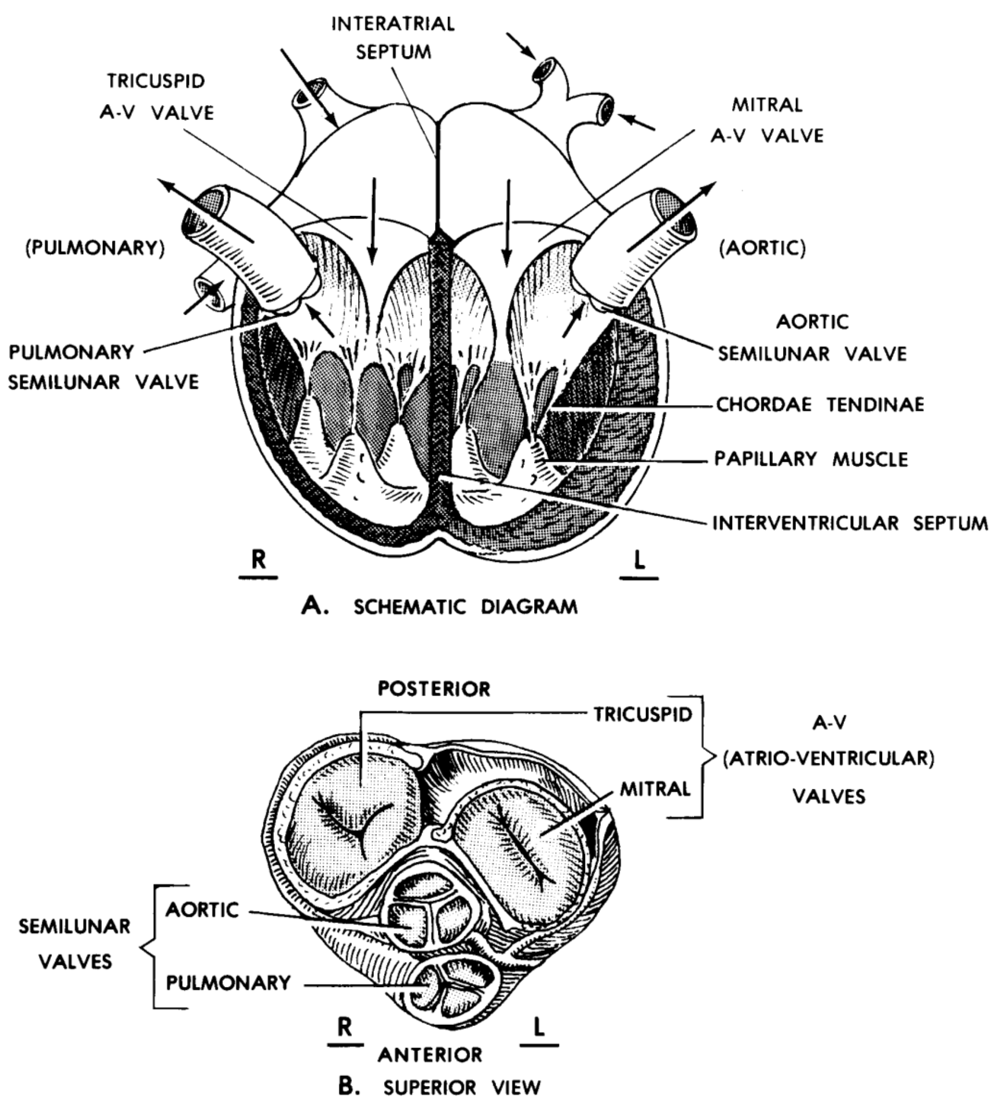

Figure 9-3. Scheme of heart valves.

(a) Between the atrium and ventricle of each side is the atrioventricular (A-V) valve. Each A-V valve prevents the blood from going back into the atrium from the ventricle of the same side. The right A-V valve is known as the tricuspid valve. The left A-V valve is known as the mitral valve. ("Might is never right.") The leaflets (flaps) of the A-V valves are prevented from being pushed back into the atria by fibrous cords. These fibrous cords are attached to the underside (the ventricular side) of the leaflets and are called chordae tendineae. At their other ends, the chordae tendineae are attached to the inner walls of the ventricles by papillary muscles.

(b) A major artery leads away from each ventricle--the pulmonary trunk from the right ventricle and the aortic arch from the left ventricle. A semilunar valve is found at the base of each of the pulmonary trunk and the aortic arch. These semilunar valves prevent blood from flowing back into the ventricles. The pulmonary (semilunar) valve and the aortic (semilunar) valve are each made up of three semilunar ("pocket-like") cusps.

b. **Control of the Heart Beat**. The heart is under several different control systems--extrinsic nervous control, intrinsic nervous control, and humoral control.

(1) Extrinsic nervous control. Extrinsic nervous control is control from outside of the heart. Extrinsic control is exerted by nerves of the autonomic nervous system. The sympathetic cardiac nerves accelerate (speed up) the heart. The vagus parasympathetic nerve decelerates (slows down) the heart.

(2) Intrinsic "nervous" control. Intrinsic "nervous" control is control built within the heart. The intrinsic "nervous" system consists of the sinoatrial (S-A) node (often referred to as the "pacemaker"), the atrioventricular (A-V) node, and the septal bundles. The septal bundles spread through the walls of the ventricles, just beneath the endocardium. This combination of nodes

and bundles initiates the heart beat automatically and transmits the impulse through the atria and the ventricles.

(3) Humoral control. In addition to the "nervous" control of heart action, it appears that there are substances in the blood itself which have varying effects on the functioning of the heart. Although these substances are not as yet well understood, they appear to have some importance. The transplanted heart seems to depend to a degree on this control mechanism, since much of its "nervous controls" have been lost for the initial period in the recipient's body.

c. **Coronary Arteries and Cardiac Veins**. We may say that the heart deals with two different kinds of blood flow--"functional" blood and "nutritive" blood. "Functional" blood is the blood that the heart works on or pushes with its motive force. However, the walls of the heart require nutrition that they cannot get directly from the blood within the chambers. "Nutritive" blood is supplied to these walls by the coronary arteries, right and left. The coronary arteries arise from the base of the aortic arch and are distributed over the surface of the heart. This blood is collected by the cardiac veins and empties into the right atrium of the heart. Should a coronary artery, or one of its branches, become closed for whatever reason, that part of the heart wall formerly supplied nutrient blood by the closed vessel will very likely die.

d. **Pericardial Sac**. The average heart contracts in what is known as a heart beat, about 70-80 times a minute. To reduce the frictional forces that would be applied to its moving surfaces, the heart is enclosed in a special serous sac known as the pericardium ("around the heart").

CARDIOVASCULAR CIRCULATORY PATTERNS

See figure 9-4 for an illustration depicting cardiovascular circulatory patterns.

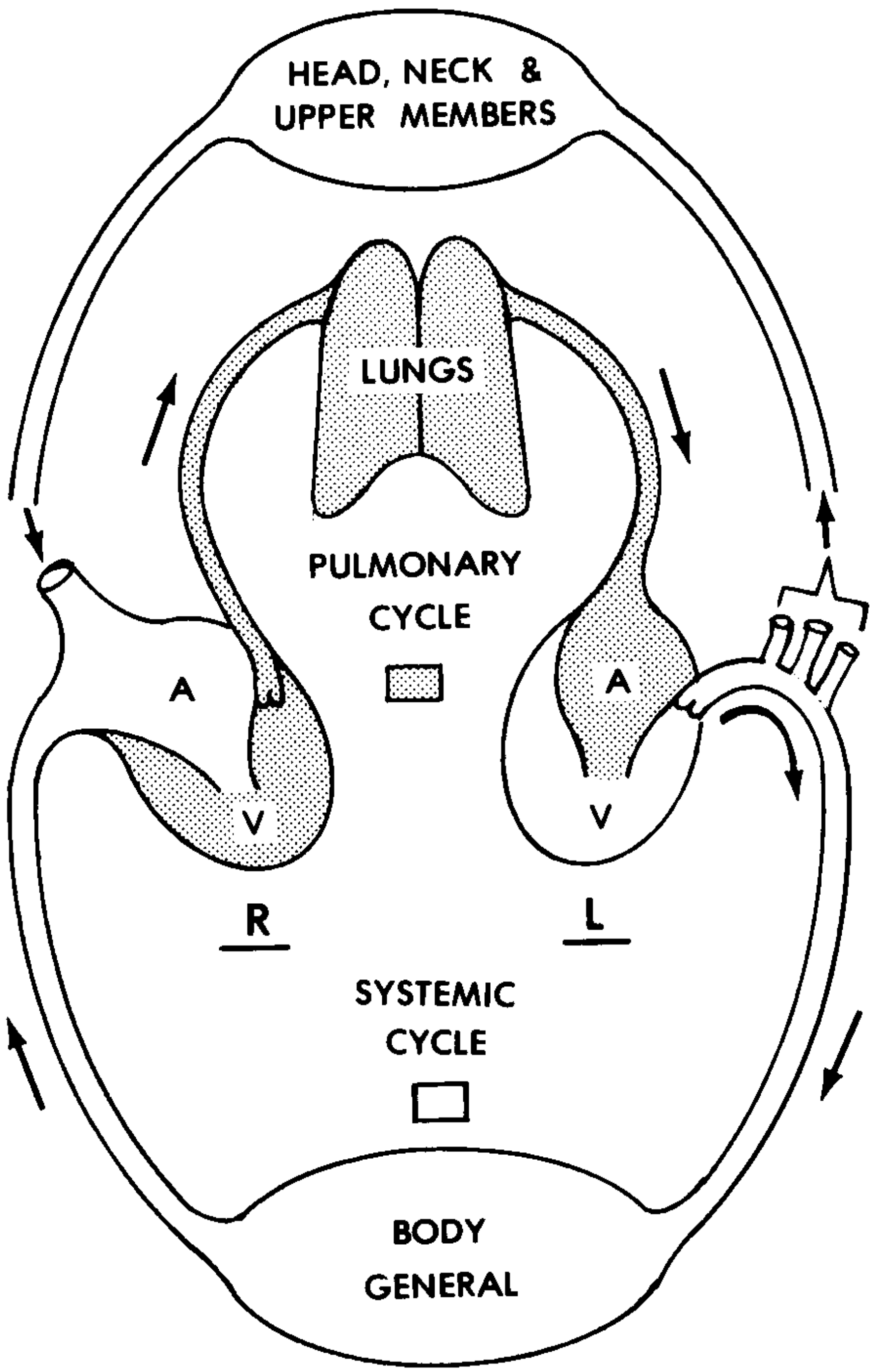

Figure 9-4. Cardiovascular circulatory patterns.

a. **General**. The human cardiovascular circulatory system is described as a closed, two-cycle system.

(1) It is closed because at no place is the blood as whole blood ever outside the system.

(2) It is two-cycle because the blood passes through the heart twice with each complete circuit of the body. In the pulmonary cycle, the blood passes from the right heart, through the lungs, and to the left heart. In the systemic cycle, the blood passes from the left heart, through the body in general, and returns to the right heart.

(3) It is common for an area of the body to be supplied by more than one blood vessel so that if one is damaged, the others will continue the supply. This is known as collateral circulation. However, there are situations, such as in the heart and the brain, where a single artery supplies a specific part of a structure. Such an artery is called an end artery. When an end artery is damaged, that area supplied by it will usually die, as in the case of the coronary artery (para 9-7c) above or in the case of a "stroke" in the brain.

b. **Pulmonary Cycle**. The pulmonary cycle begins in the right ventricle of the heart. Contraction of the right ventricular wall applies pressure to the blood. This forces the tricuspid valve closed and the closed valve prevents blood from going back into the right atrium. The pressure forces blood past the semilunar valve into the pulmonary trunk. Upon relaxation of the right ventricle, back pressure of the blood in the pulmonary trunk closes the pulmonary semilunar valve. The blood then passes into the lungs through the pulmonary arterial system. Gases are exchanged between the alveoli of the lungs and the blood in the capillaries next to the alveoli. This blood, now saturated with oxygen, is collected by the pulmonary veins and carried to the left atrium of the heart. This completes the pulmonary cycle.

c. **Systemic Cycle**.

(1) Left ventricle of the heart. The oxygen-saturated blood is moved from the left atrium into the left ventricle. When the left ventricular wall contracts, the pressure closes the mitral valve, which prevents blood from returning to the left atrium. The contraction of the left ventricular wall therefore forces the blood through the aortic semilunar valve into the aortic arch. Upon relaxation of the left ventricular wall, the back pressure of the aortic arch forces the aortic semilunar valve closed.

(2) Arterial distributions. The blood then passes through the various arteries to the tissues of the body. See figure 9-5 for an illustration of the main arteries of the human body.

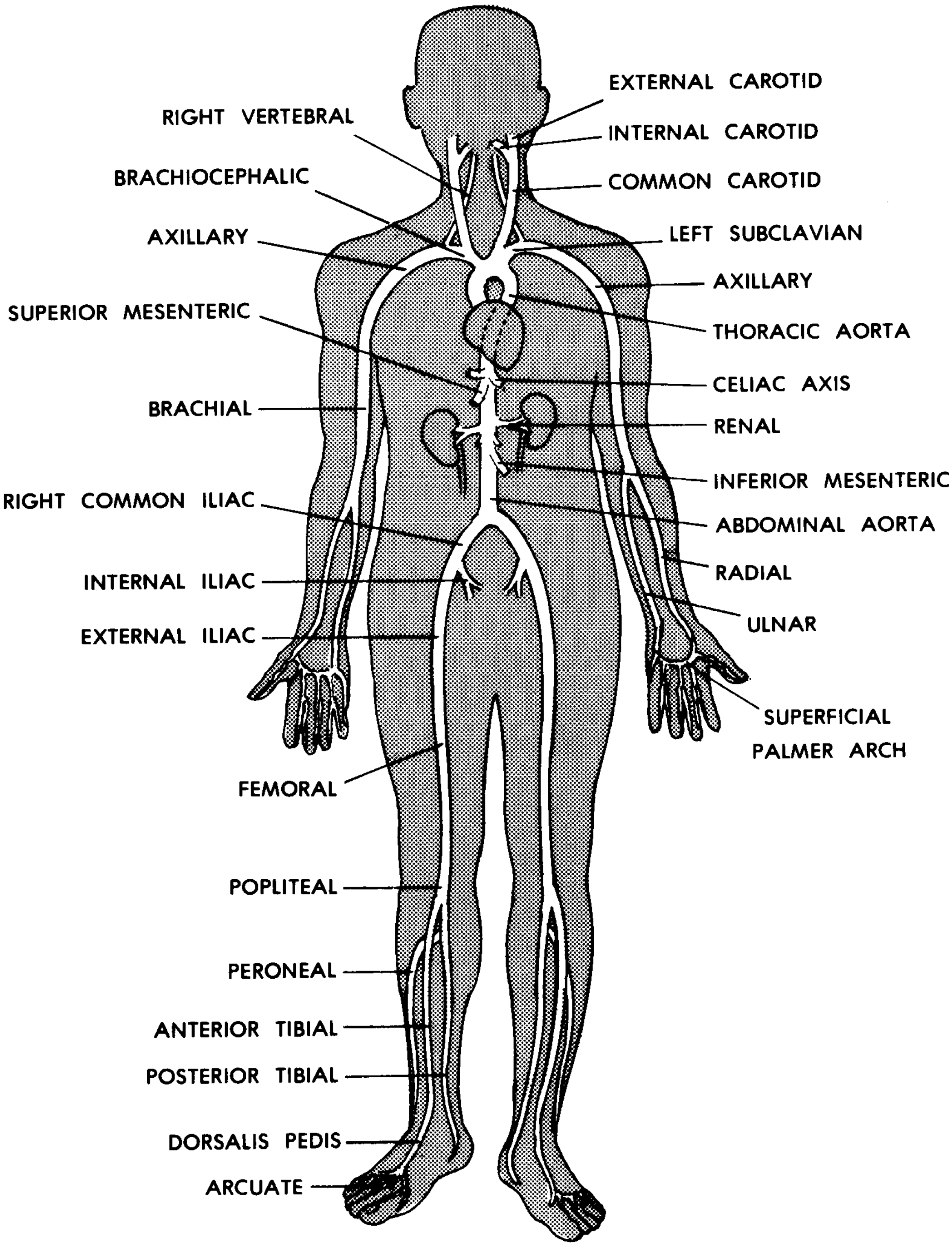

Figure 9-5. Main arteries of the human body.

(a) The carotid arteries supply the head. The neck and upper members are supplied by the subclavian arteries.

(b) The aortic arch continues as a large single vessel known as the aorta passing down through the trunk of the body in front of the vertebral column. It gives off branches to the trunk wall and to the contents of the trunk.

(c) At the lower end of the trunk, the aorta divides into right and left iliac arteries, supplying the pelvic region and lower members.

(3) Capillary beds of the body tissues. In the capillary beds of the tissues of the body, materials (such as food, oxygen, and waste products) are exchanged between the blood and the cells of the body.

(4) Venous tributaries. See figure 9-6 for an illustration of the main veins of the human body.

(a) The blood from the capillaries among the tissues is collected by a venous system parallel to the arteries. This system of deep veins returns the blood back to the right atrium of the heart.

(b) In the subcutaneous layer, immediately beneath the skin, is a network of superficial veins draining the skin areas. These superficial veins collect and then join the deep veins in the axillae (armpits) and the inguinal region (groin).

(c) The superior vena cava collects the blood from the head, neck, and upper members. The inferior vena cava collects the blood from the rest of the body. As the final major veins, the venae cavae empty the returned blood into the right atrium of heart.

(d) The veins are generally supplied with valves to assist in making the blood flow toward the heart. It is of some interest to note that the veins from the head do not contain valves.

(e) From that portion of the gut where materials are absorbed through the walls into the capillaries, the blood receives a great variety of substances. While most of these substances are useful, some may be harmful to the body. The blood carrying these substances is carried directly to the liver by the hepatic portal venous system. This blood is specially treated and conditioned in the liver before it is returned to the general circulation by way of the hepatic veins.

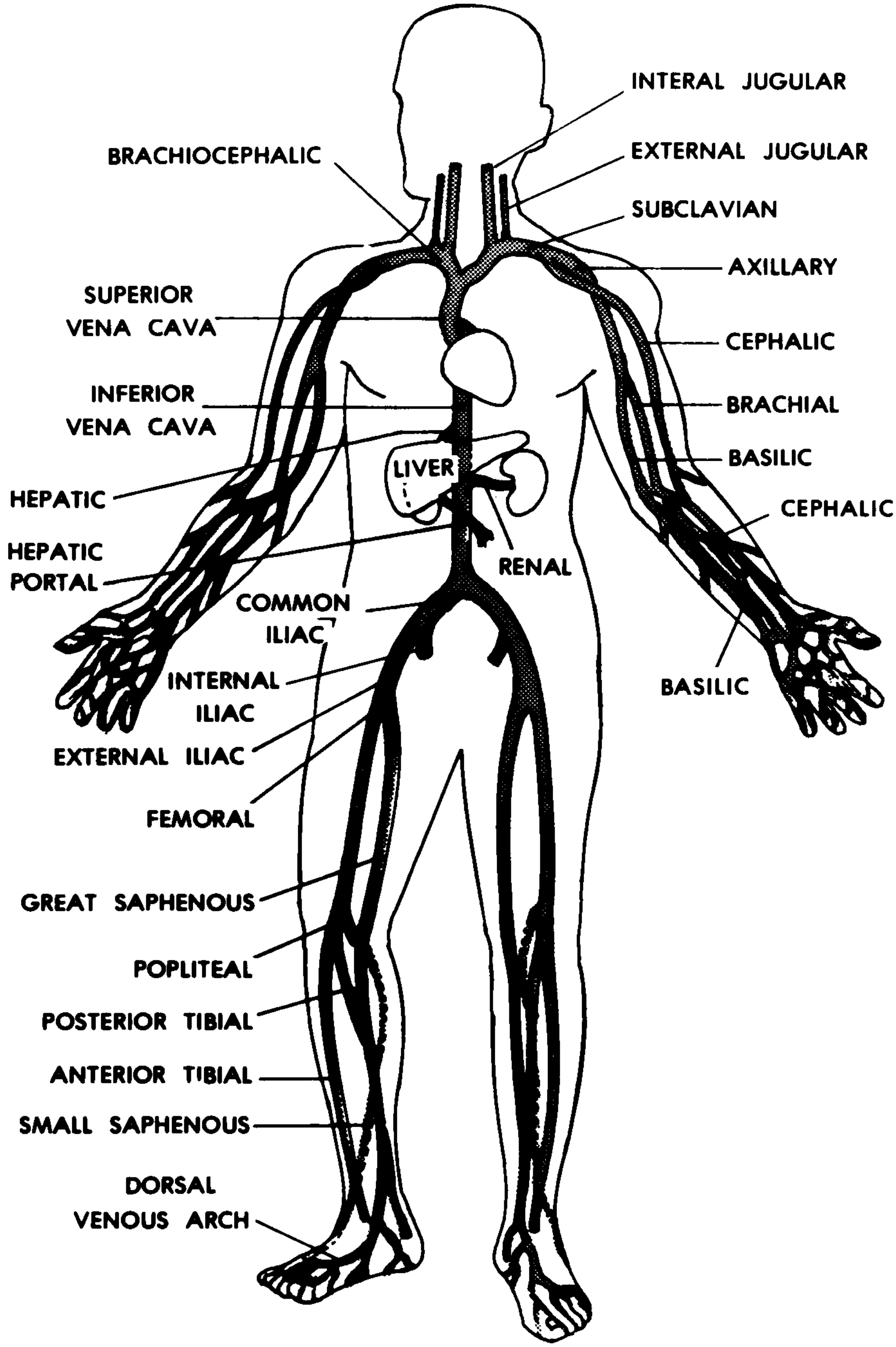

Figure 9-6. Main veins of the human body.

THE HUMAN LYMPHATIC SYSTEM

GENERAL

Between the cells of the body are spaces filled with fluid. This is the interstitial (or tissue) fluid, often referred to as intercellular fluid. There are continuous exchanges between the intracellular fluid, the interstitial fluid, and the plasma of the blood. The lymphatic system returns to the bloodstream the excess interstitial fluid, which includes proteins and fluid derived from the blood.

STRUCTURES OF THE HUMAN LYMPHATIC SYSTEM

See figure 9-7 for an illustration of the human lymphatic system.

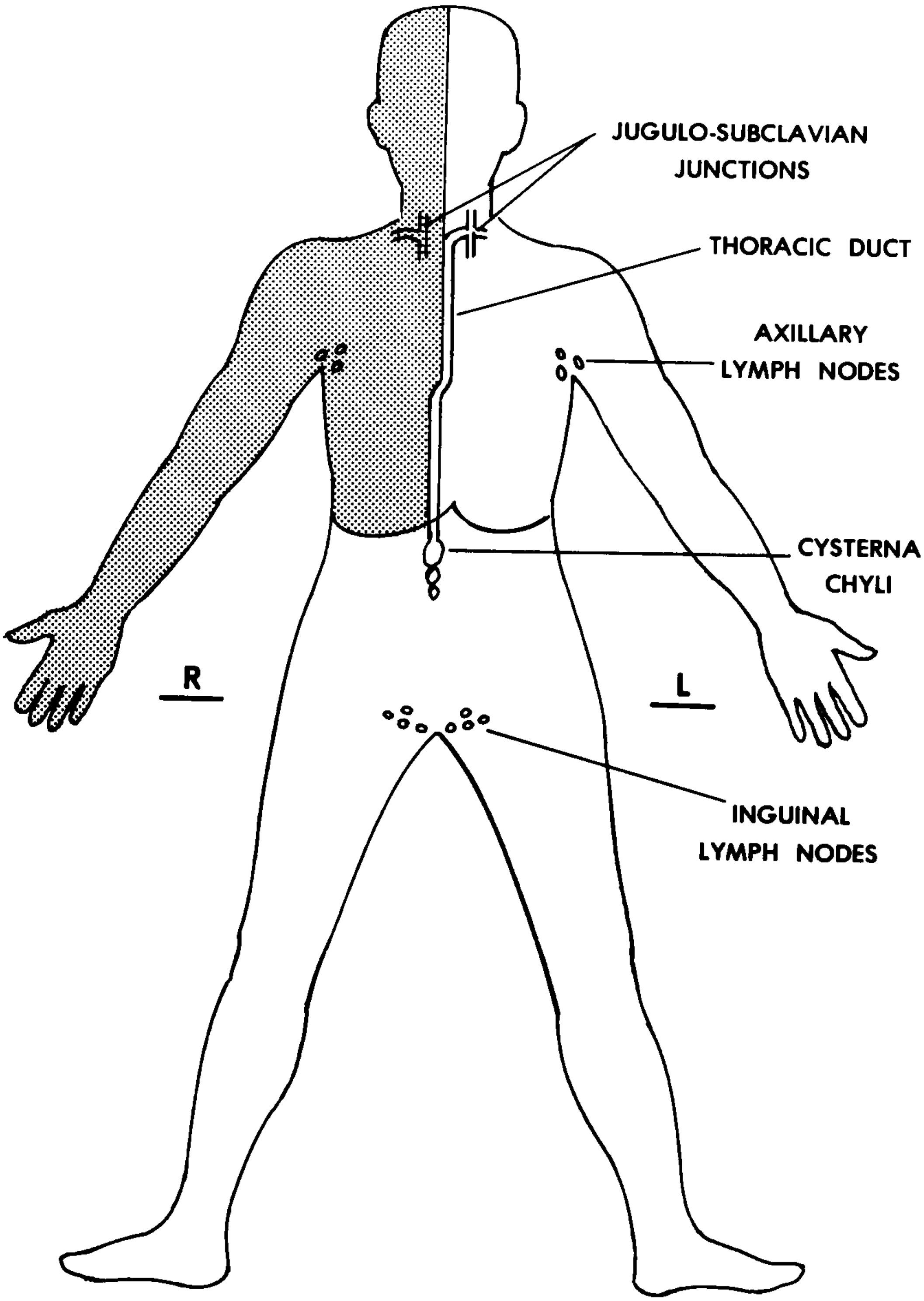

Figure 9-7. The human lymphatic system.

a. **Lymphatic Capillaries**. Lymphatic capillaries are located in the interstitial spaces. Here, they absorb the excess fluids.

b. **Lymph Vessels**. A tributary system of vessels collects these excess fluids, now called lymph. Like veins, lymphatic vessels are supplied with valves to help maintain a flow of lymph in one direction only. The lymphatic vessels, to a greater or lesser extent, parallel the venous vessels along the way. The major lymph vessel in the human body is called the thoracic duct. The thoracic duct passes from the abdomen up through the thorax and into the root of the neck in front of the vertebral column. The thoracic duct there empties into the junction of the left subclavian and jugular veins.

c. **Lymph Nodes**. Along the way, lymphatic vessels are interrupted by special structures known as lymph nodes. These lymph nodes serve as special filters for the lymph fluid passing through.

d. **Tonsils**. Tonsils are special collections of lymphoid tissue, very similar to a group of lymph nodes. These are protective structures and are located primarily at the entrances of the respiratory and digestive systems.
