

CHAPTER 5

THE CIRCULATORY SYSTEM**5-1. General**

The circulatory system has two major fluid transportation systems: the cardiovascular and the lymphatic.

a. Cardiovascular System. This system, which contains the heart and blood vessels, is a closed system, transporting blood to all parts of the body. Blood flowing through the circuit formed by the heart and blood vessels (Figure 5-1) brings oxygen, food, and other chemical elements to tissue cells and removes carbon dioxide and other waste products from the cell.

b. Lymphatic System. This system, which provides drainage for tissue fluid, is an auxiliary part of the circulatory system, returning an important amount of tissue fluid to the bloodstream through its own system of lymphatic vessels.

5-2. The Heart

The heart, a highly efficient pump, is a four-chambered muscular organ, lying within the chest, with about 2/3 of its mass to the left of the midline (Figure 5-2). It lies in the pericardial space in the thoracic cavity between the two lungs. In size and shape, it resembles a man's closed fist. Its lower point, the apex, lies just above the left diaphragm.

a. Heart Covering. The pericardium is a double-walled sac inclosing the heart. The outer fibrous surface gives support, and the inner lining prevents friction as the heart moves within its protective jacket. The inner surface of the pericardial sac produces a small amount of pericardial lubricating fluid that aids in the normal movements of the heart.

b. Heart Wall. This muscular wall is made up of cardiac muscle called myocardium.

c. Heart Chambers. There are four chambers in the heart. These chambers are essentially the same size. The upper chambers, the atria, are seemingly smaller than the lower chambers, the ventricles. The apparent difference in total size is due to the thickness of the myocardial (muscle) layer. The right atrium communicates with the right ventricle; the left atrium communicates with the left ventricle. The septum (partition), dividing the interior of the heart into right and left sides, prevents direct blood flow from right to left chambers or left to right chambers. This is important, because the right side of the heart receives unoxygenated blood returning from the systemic (body) circulation. The left side of the heart receives oxygenated blood returning from the pulmonary (lung) circulation. The special structure of the heart keeps the blood flowing in its proper direction to and from the heart chambers.

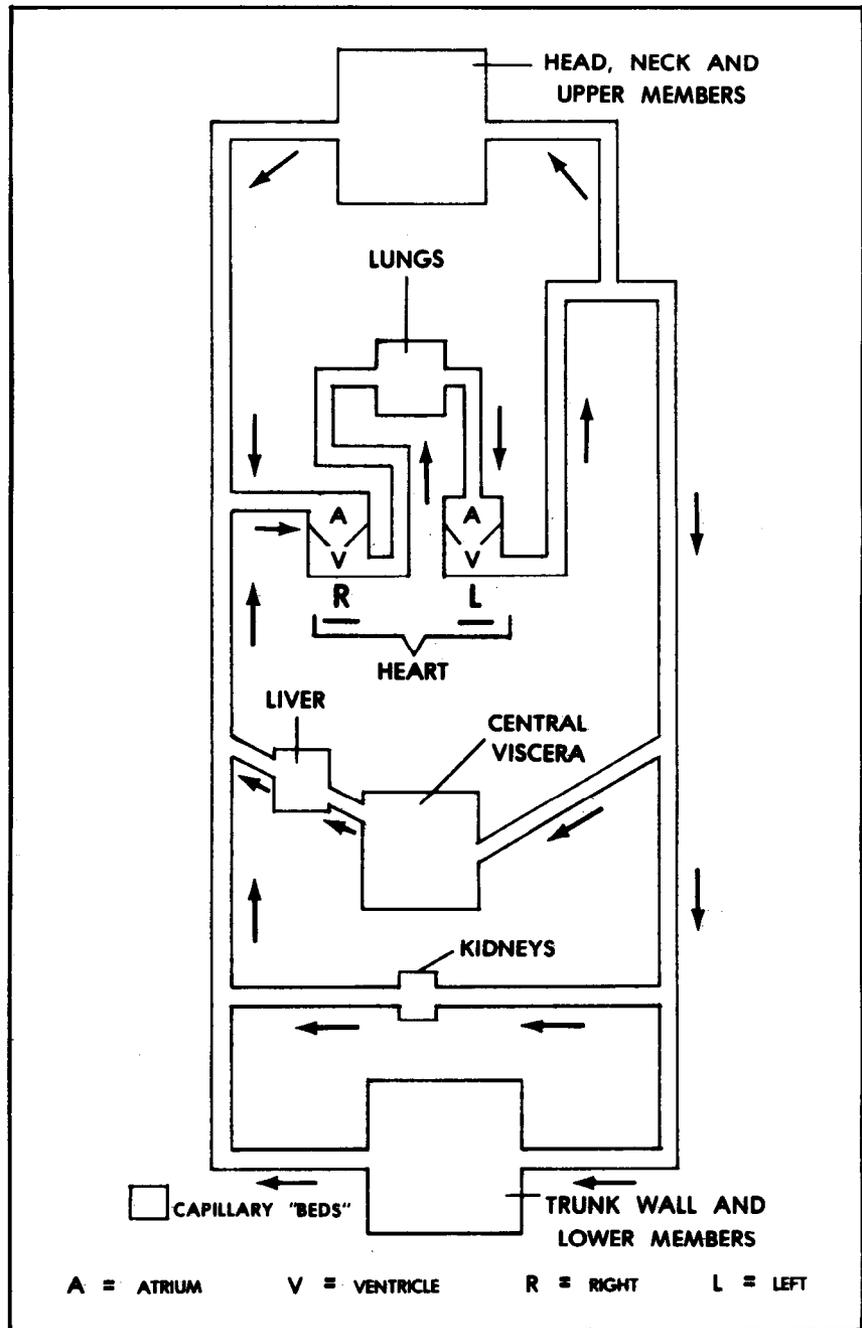


Figure 5-1. Circulation of the blood (diagrammatic).

d. Heart Valves. The four chambers of the heart are lined with endocardium (membrane tissue). This lining folds on itself and extends into the chamber opening to form valves. These valves allow the blood to pass from a chamber but prevents backflow. The atrioventricular valves, between the upper and lower chambers, are within the heart itself. The semilunar valves are within arteries attached to the right and left ventricles.

(1) *Atrioventricular valves.* The tricuspid valve is located between the right atrium and right ventricle. It has three flaps or cusps. The bicuspid (mitral) valve is located between the left atrium and left ventricle. It has two flaps or cusps.

(2) *Semilunar valves.* The pulmonary semilunar (half-moon shaped) valve is located at the opening into the pulmonary artery that is attached to the right ventricle. The aortic semilunar valve is located at the opening into the aorta that is attached to the left ventricle.

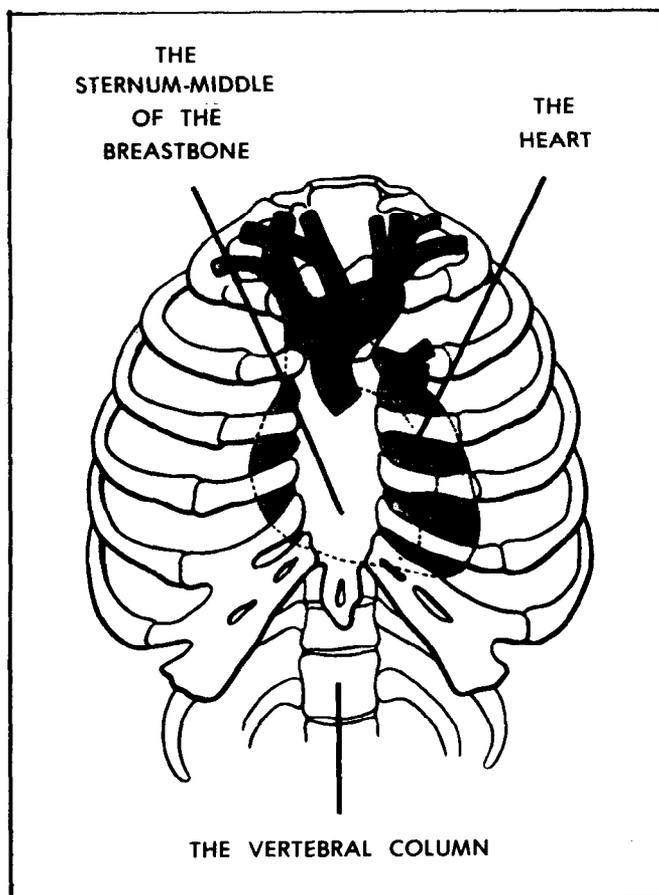


Figure 5-2. Heart and thoracic cage.

5-3. Flow of Blood Through the Heart

It is helpful to follow the flow of blood through the heart, to understand the relationship of the heart structures. Remember, the heart is the pump and is also the connection between the systemic circulation and pulmonary circulation. Blood returning from the systemic circulation must flow through the pulmonary circulation for the exchange of carbon dioxide and oxygen to take place. Blood from the upper part of the body enters the heart through the superior vena cava, and from the lower part of the body through the inferior vena cava (Figure 5-3).

- a. Blood from the superior vena cava and inferior vena cava enters the heart at the right atrium. The right atrium contracts, and blood is forced through the open tricuspid valve into the relaxed right ventricle.
- b. As the right ventricle contracts, the tricuspid valve is closed, preventing back flow into the atrium. The pulmonary semilunar valve opens as the blood is forced through it and is pumped into the pulmonary artery.
- c. The blood is carried through the lung tissues, exchanging its carbon dioxide for oxygen in the alveoli. This oxygenated blood is collected from the main pulmonary veins and delivered to the left atrium.
- d. As the left atrium contracts, the oxygenated blood flows through the open bicuspid (mitral) valve into the left ventricle.
- e. As the left ventricle contracts, the bicuspid valve is closed. The aortic semilunar valve opens as the oxygenated blood is forced through it into the aorta, the main artery of the body. The oxygenated blood now starts its flow to all body cells and tissues. The systemic circulation starts from the left ventricle, the pulmonary circulation from the right ventricle.

NOTE

Veins carry unoxygenated blood and arteries carry oxygenated blood. The only exception to this is the pulmonary vein which carries oxygenated blood from the lungs to the heart and the pulmonary artery which carries unoxygenated blood from the heart to the lungs.

5-4. Blood and Nerve Supply of the Heart

- a. *Coronary Arteries.* The heart gets its blood supply from the right and left coronary arteries. These arteries branch off the aorta just above the heart, then subdivide into many smaller branches within the heart muscle. If any part of the heart muscle is deprived of its blood supply, the muscle tissue cannot function properly and will die. This is called a myocardial infarction. Blood from the heart tissue is returned by coronary veins to the right atrium.

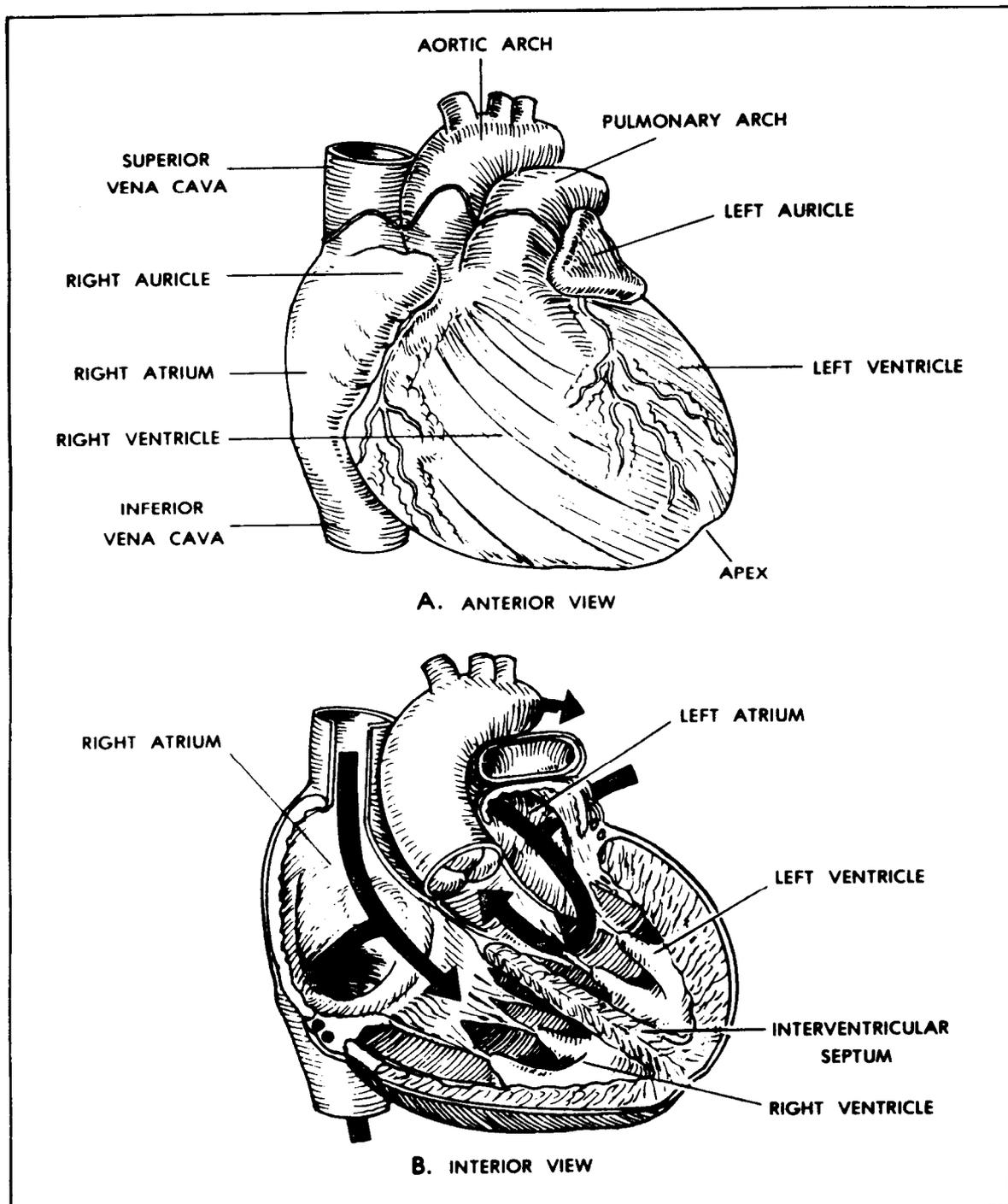


Figure 5-3. The heart chambers and flow of blood.

b. Nerve Supply. The nerve supply to the heart is from two sets of nerves originating in the medulla of the brain. The nerves are part of the involuntary (autonomic) nervous system. One set branches from the vagus nerve and keeps the heart beating at a slow, regular rate. The other set, the cardiac accelerator nerves, speeds up the heart. The heart muscle has a special ability; it contracts automatically, but the nerve supply is needed to control the contractions for blood circulation. Within the heart muscle itself are special groups of nerve fibers that conduct impulses. These groups make up the conduction system of the heart. When the conduction system does not operate properly, the heart muscle contractions are uncoordinated and ineffective. The impulses within the heart muscle are minute electric currents, which can be picked up and recorded by the electrocardiogram (ECG).

5-5. The Heartbeat and Heart Sounds

a. Heartbeat. This is a complete cycle of heart action—contraction (systole) and relaxation (diastole). During systole, blood is forced from the chambers. During diastole, blood refills the chambers. The term *cardiac cycle* means the complete heartbeat. The cardiac cycle, repeated continuously at a regular rhythm, usually 70-80 times per minute. Each complete cycle takes less than one second—in this brief time, all of the heart action needed to move blood must take place, and the heart must be ready to repeat its cycle.

b. Heart Sounds. When heard through a stethoscope, heart sounds are described as “lubb-dup.” The first sound, “lubb,” is interpreted as the sound, or vibration, of the ventricles contracting and atrioventricular valves closing. The second, higher-pitched sound, “dup,” is interpreted as the sound of the semilunar valves closing. The doctor listening to the heart sounds can detect alterations of normal sounds; the interpretation of these heart sounds is part of the diagnosis of heart disease.

5-6. Blood Vessels

The blood vessels are the closed system of tubes through which the blood flows. The arteries and arterioles are distributors. The capillaries are the vessels through which the exchange of fluid, oxygen, and carbon dioxide takes place between the blood and tissue cells. The venules and veins are collectors, carrying blood back to the heart. The capillaries are the smallest of these vessels but are of the greatest importance in the circulatory system.

a. The Arteries and Arterioles. The system of arteries (Figure 5-4) and arterioles is like a tree, with the large trunk, the aorta, giving off branches which repeatedly divide and subdivide. Arterioles are very small arteries, about the diameter of a hair. In comparison, the aorta is more than 1 inch (2.5 cm) in diameter. An artery wall has a layer of elastic, muscular tissue which allows it to expand and recoil. When an artery is cut, the artery wall does not collapse; bright red blood escapes from the artery in spurts. Arterial bleeding must often be controlled by clamping and tying off (ligating) the vessel. Some of the principal arteries and the area they supply with blood are—

- (1) Carotid arteries, external and internal, supply the neck, head, and brain through their branches.
- (2) Subclavian arteries supply the upper extremities.
- (3) Femoral arteries supply the lower extremities.

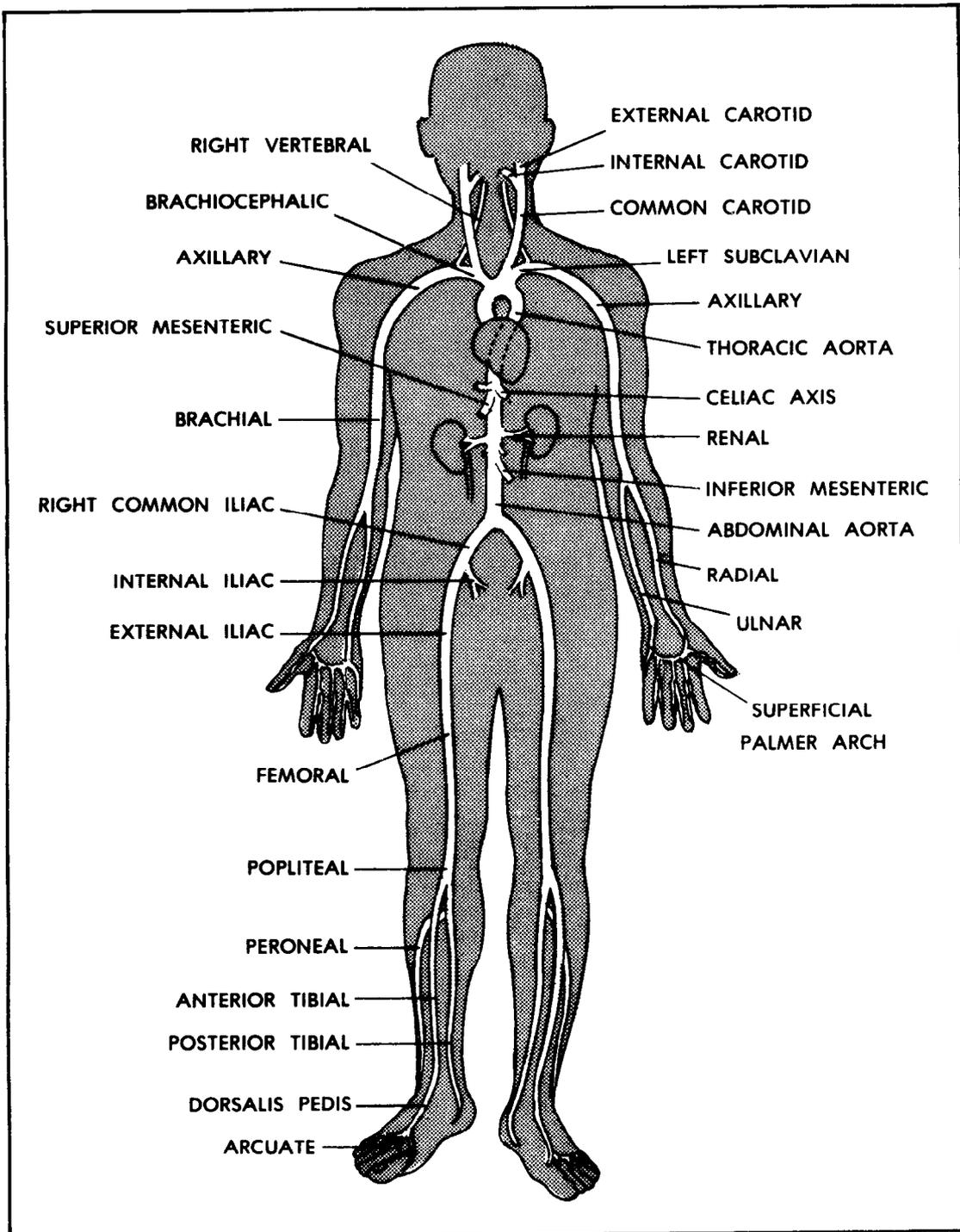


Figure 5-4. Arterial system (diagrammatic).

b. Capillaries. Microscopic in size, capillaries are so numerous that there is at least one or more near every living cell. A single layer of endothelial cells forms the walls of a capillary. Capillaries are the essential link between arterial and venous circulation. The vital exchange of substances from the blood in the capillary with tissue cells takes place through the capillary wall. Blood starts its route back to the heart as it leaves the capillaries.

c. Veins. Veins (Figure 5-5) have thin walls and valves. Formed from the inner vein lining, these valves prevent blood from flowing back toward the capillaries. Venules, the smallest veins, unite into veins of larger and larger size as the blood is collected in its return to the heart. The superior vena cava, collecting blood from all regions above the diaphragm, and the inferior vena cava, collecting blood from all regions below the diaphragm, return the venous blood to the right atrium of the heart. Superficial veins lie close to the surface of the body and can be seen through the skin.

(1) The median basilic vein at the antecubital fossa (in the bend of the elbow) is commonly used for venipuncture to obtain blood specimens or to inject solutions of drugs or fluid intravenously.

(2) The great saphenous vein is the longest vein in the body, extending from the foot to the groin. The saphenous vein has a long distance to lift blood against the force of gravity when an individual is in a standing position. It is therefore very susceptible to becoming dilated and stretched with the valves no longer functioning properly. When this occurs, the vein is said to be varicosed.

5-7. Pulse and Blood Pressure

a. Pulse. Pulse is the alternate expansion and recoil of an artery. With each heartbeat, blood is forced into the arteries causing them to dilate (expand). Then the arteries contract (recoil) as the blood moves further along in the circulatory system. The pulse can be felt at certain points in the body where an artery lies close to the surface. The most common location for feeling the pulse is at the wrist, proximal to the thumb (radial artery), on the palm side of the hand. Alternate locations are in front of the ear (temporal artery), at the side of the neck (carotid artery), and on the top (dorsum) of the foot (dorsalis pedis).

b. Blood Pressure. The force that blood exerts on the walls of vessels through which it flows is called blood pressure. All parts of the vascular system are under pressure, but the term blood pressure usually refers to arterial pressure. Pressure in the arteries is highest when the ventricles contract during systole. Pressure is lowest when the ventricles relax during diastole. The brachial artery, in the upper arm, is the artery usually used for blood pressure measurement.

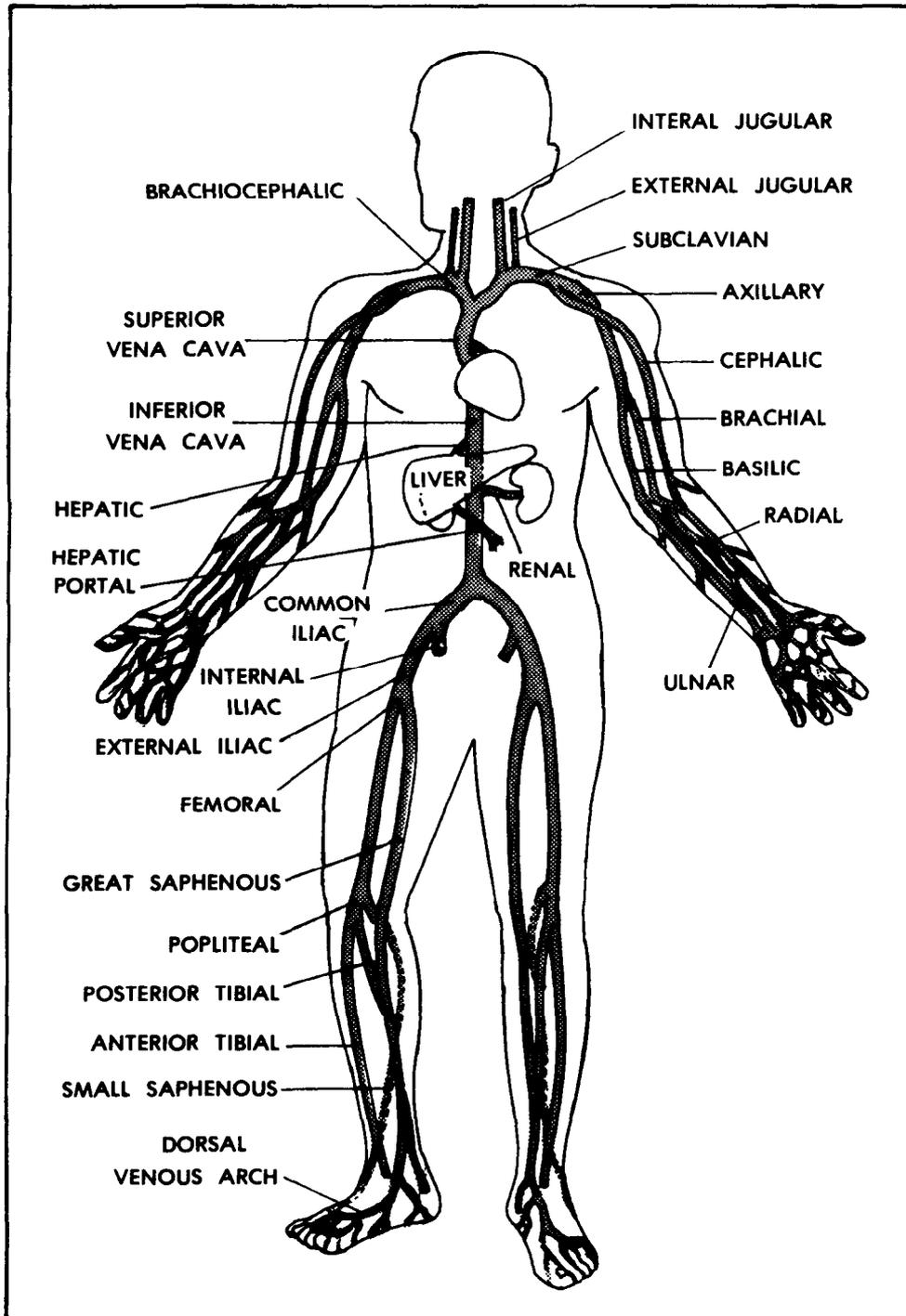


Figure 5-5. Venous system (diagrammatic).

5-8. Lymphatic System

The lymphatic system consists of lymph, lymph vessels, and lymph nodes (Figure 5-6). The spleen belongs, in part, to the lymphatic system. Unlike the cardiovascular system, the lymphatic system has no pump to move the fluid which it collects, but muscular contractions and breathing movements aid in the movement of lymph through its channels and its return to the bloodstream.

a. Lymph and Tissue Fluid. Lymph, fluid found in the lymph vessels, is clear and watery and is similar to tissue fluid, which is the colorless fluid that fills the spaces between tissues, between the cells of organs, and between cells and connective tissues. Tissue fluid serves as the "middleman" for the exchange between blood and body cells. Formed from plasma, it seeps out of capillary walls. The lymphatic system collects tissue fluid, and as lymph, it is started on its way back into the circulating blood.

b. Lymph Vessels. Starting as small ducts within the tissues, the lymphatic vessels enlarge to form lymphatic capillaries. These capillaries unite to form larger lymphatic vessels, which resemble veins in structure and arrangement. Valves in lymph vessels prevent backflow. Superficial lymph vessels collect lymph from the skin and subcutaneous tissue; deep vessels collect lymph from all other parts of the body.

c. Lymph Nodes. Occurring in groups of up to a dozen or more, lymph nodes lie along the course of the lymph vessels. Although variable in size, they are usually small oval bodies which are composed of lymphoid tissue. Lymph nodes act as filters for removal of infectious organisms from the lymph stream. Important groups of these nodes are located in the axilla (armpit), the cervical region, the submaxillary region, the inguinal (groin) region, and the mesenteric (abdominal) region.

d. Infection and the Lymphatic System. Lymph vessels and lymph nodes often become inflamed as the result of infection. An infection in the hand may cause inflammation of the lymph vessels as high as the axilla. Sore throat may cause inflammation and swelling of lymph nodes in the neck (submandibular nodes below the jaw and cervical nodes).

e. Spleen. The largest collection of lymphoid tissue in the body, the spleen is located high in the abdominal cavity on the left side (LUQ), below the diaphragm and behind the stomach. It is somewhat long and ovoid (egg-shaped). Although it can be removed (splenectomy) without noticeable harmful effects, the spleen has useful functions, such as serving as a reservoir for blood and red blood cells.

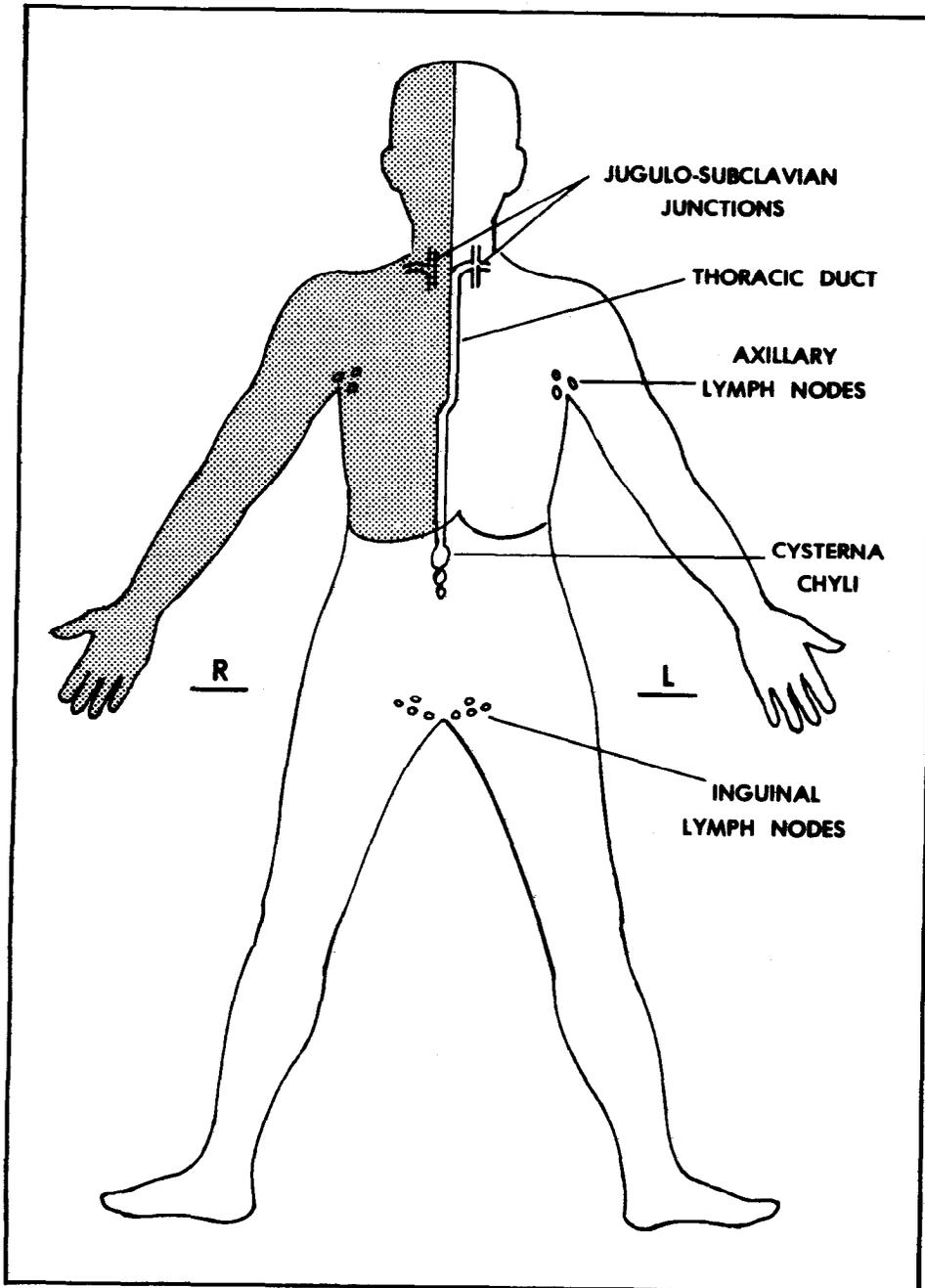


Figure 5-6. Lymphatic system.

5-9. The Blood

Blood is the red body fluid flowing through the arteries, capillaries, and veins. It varies in color from bright red (oxygenated blood) when it flows from arteries, to dark red (deoxygenated blood) when it flows from veins. The average man has about 6000 ml of blood.

a. Functions of Blood. The six major functions of blood are all carried out as the blood circulates through the vessels. These functions are—

- (1) To carry oxygen from the lungs to tissue cells and carbon dioxide from the cells to the lungs.
- (2) To carry food materials absorbed from the digestive tract to the tissue cells and to remove waste products for elimination by excretory organs (the kidneys, intestines, and skin).
- (3) To carry hormones, which help regulate body functions, from ductless (endocrine) glands to the tissues of the body.
- (4) To help regulate and equalize body temperature. Body cells generate large amounts of heat, and the circulating blood absorbs this heat.
- (5) To protect the body against infection.
- (6) To maintain the fluid balance in the body.

b. Composition of Blood. Blood is made up of a liquid portion (plasma) and formed elements (blood cells) suspended in the plasma.

(1) *Plasma.* Making up more than one-half of the total volume of blood, plasma is the carrier for blood cells, carbon dioxide, and other dissolved wastes. It brings hormones and antibodies (protective substances) to the tissues. Other components of plasma are water, oxygen, nitrogen, fat, carbohydrates, and proteins. Fibrinogen, one of the plasma proteins, helps blood clotting. When blood clots, the liquid portion that remains is serum. Blood serum contains no blood cells.

(2) *Blood cells.* The cellular elements in the blood are red cells (erythrocytes, or rbc), white cells (leukocytes, or wbc) and blood platelets (thrombocytes).

5-10. Red Blood Cells (Erythrocytes)

There are about 5,000,000 red blood cells in 1 cubic millimeter (cmm) of blood. Individual red blood cells are disc-shaped. Red cells are formed in the red bone marrow. Millions of red cells are destroyed daily, in the liver, the spleen, the lymph nodes, or in the vascular system itself. In a healthy person, the destruction rate is equaled by the production rate, maintaining a count of about 5,000,000 per cubic millimeter. Red blood cells have an average life span of about 90 to 120 days before becoming worn out.

a. Hemoglobin. Hemoglobin (Hgb) gives red cells their color. Hemoglobin has the power to combine with oxygen, carrying it from the lungs to the tissue cells. Hemoglobin assists in transporting carbon dioxide from the cells to the lungs. This transportation of gases is the principal function of the

red cells. In order to carry oxygen, hemoglobin needs iron which is ordinarily available in a nutritionally adequate diet.

b. Anemia. Anemia is due to a reduction in the number of red cells or a reduction in the hemoglobin content of red cells.

5-11. White Blood Cells (Leukocytes)

White blood cells vary in size and shape, and are larger and much fewer in number than red cells. The average number in an adult is 5,000 to 10,000 in 1 cmm of blood. Their function is primarily one of protection. They can ingest and destroy foreign particles, such as bacteria, in the blood and tissues. White cells can pass through the walls of capillaries into surrounding tissues. This ability to enter tissue makes them very useful in fighting infection—an area of infection is characterized by a great increase of white cells which gather about the site to destroy bacteria. An example of this is seen in an ordinary boil (furuncle). The pus contained in the boil is made up largely of white cells plus bacteria and dissolved tissue. Many of the white cells are killed in their struggle with invading bacteria.

5-12. Blood Platelets (Thrombocytes)

Blood platelets, which are smaller than red blood cells, are thought to be fragments of cells formed in the bone marrow. Platelets number about 300,000 per cmm of blood. Their main function is to aid in the coagulation of blood at the site of a wound. Platelets release a substance to hasten formation of a blood clot.

5-13. Coagulation of Blood

a. Blood coagulation (clotting) is the body's major method of preventing excessive loss of blood when the walls of a blood vessel are broken or cut open. When undisturbed, blood circulates in its vascular system without showing a tendency to clot. Physical and chemical factors are changed when blood leaves its natural environment and it begins to clot almost at once. At first the clot is soft and jellylike, but soon becomes firm and acts as a plug, preventing further escape of blood.

b. It takes 3 to 5 minutes for blood to clot, but sometimes it is necessary to hold back the clotting process. This is done with anticoagulant drugs.

5-14. Blood Types

All human blood is divided into four main types or groups—O, A, B, AB. This system of typing is used to prevent incompatible blood transfusion, which causes serious reactions and sometimes death. Certain types of blood are incompatible (not suited) to each other if combined. Two bloods are said to be incompatible when the plasma or serum of one blood causes clumping of the cells of the other. Two bloods are said to be compatible and safe for transfusion if the cells of each can be suspended in the plasma or serum of the other without clumping. Blood typing and cross-matching is done by highly trained laboratory technicians.

a. *Importance of Blood Types.* Table 5-1 shows that if the donor's blood is type "O" it is compatible with all types of recipient blood; or, in other words, type "O" is the universal donor. If the recipient's blood is type "AB," it is compatible with all types of donor blood, or, in other words, type "AB" is the universal recipient. When a blood transfusion is given, the blood type of both donor and recipient should be identical, and their compatibility must be proven by a cross-matching test. However, when blood of the same type is not available and death may result if transfusion is delayed, a type "O" donor (universal donor) may be used if the cross-matching is satisfactory.

b. *Rh Factor.* In addition to blood grouping and cross-matching for compatibility, the Rh factor must be considered. The Rh factor is carried in red cells, and about 85 percent of all individuals have this factor and are, therefore, Rh positive. Individuals who do not have the Rh factor are Rh negative. As a general rule, Rh negative blood can be given to anyone, provided it is compatible in the ABO typing system, but Rh positive blood should not be given to an Rh negative individual.

Table 5-1. Blood Types

Donor	Recipient			
	O	A	B	AB
O -----	Compatible	Compatible	Compatible	Compatible
A -----	Incompatible	Compatible	Incompatible	Compatible
B -----	Incompatible	Incompatible	Compatible	Compatible
AB -----	Incompatible	Incompatible	Incompatible	Compatible

5-15. Coronary Artery Disease and Angina Pectoris

a. As mentioned before, coronary arteries are blood vessels whose primary function is to transport blood to the heart muscles and at the same time remove carbon dioxide and waste products. Sometimes the coronary arteries become blocked depriving the heart muscles of oxygen and nutrients and slowing down or stopping the removal of waste products. If this condition continues without proper treatment, the artery will eventually close off, resulting in death of the affected tissue.

b. Certain factors contribute to coronary artery disease. Some of these factors are controllable while others are not. These factors are—

- Hypertension (high blood pressure)
- Cigarette smoking.
- Diabetes.
- Elevated serum cholesterol.

- Dietary habits (excessive intake of calories, carbohydrates, and/or saturated fats).

- Obesity.
- Sex (male).
- Hereditary (family history).
- Stress.

c. Early stages of coronary artery disease are asymptomatic. In the late stages of the disease, the blood flow no longer meets the demands of the myocardium for oxygen and the patient begins to experience chest pain. This pain is referred to as *angina pectoris* (choking of the heart). The patient with advanced coronary artery disease may have adequate oxygen at rest, however, during any form of stress or exercise, blood flow to the heart is inadequate. This results in *angina pectoris*. A patient can also experience *angina pectoris* while at rest. If this occurs, that patient has much more severe coronary artery disease than the one who only experiences pain with exercise and stress. The pain (*angina*) is characterized as a crushing chest pain which usually radiates to the neck, jaw, shoulders, and upper extremities. The duration of the pain is usually 2 to 3 minutes. Treatment for this condition is either stopping the stress or administering nitroglycerin. The drug, nitroglycerin, is a vasodilator. It causes the coronary arteries to dilate and provides improved blood flow to the myocardium.

5-16. Myocardial Infarction

a. Myocardial infarction (MI) (heart attack) is a blockage in a coronary artery with resulting death to the affected tissue.

b. Signs and symptoms of an MI.

(1) Chest pain similar to *angina*, however, more severe and longer lasting. The pain may not be relieved with nitroglycerin. The patient usually complains of severe crushing pain or tightness in the chest. A clenched fist is usually used to describe the pain. In approximately 25 percent of the patients, the pain will radiate down the left arm and into the fingers. Usually the pain radiates to the jaw, neck, upper back, and epigastrium. An MI is sometimes mistaken for indigestion.

- (2) Along with chest pain, the patient complains of nausea.
- (3) Diaphoresis (profuse perspiration) usually accompanies an MI.
- (4) The patient may also experience a fear of impending doom.
- (5) Shortness of breath.
- (6) Hypotension or hypertension.
- (7) Cyanosis.

c. Treating an MI. The physical findings of an MI may not always be obvious. They vary with the site and extent of cardiac muscle damage. Therefore, diagnosis in the field will depend primarily on the history of the current complaint. Treatment and stabilization should be started immediately with a detailed history. Early treatment can mean the difference between life and death. The patient should be immediately transported to a medical facility where definitive treatment can be initiated. Early treatment should include—

- (1) Attaching a cardiac monitor (if available).
- (2) Administering oxygen by mask or nasal prongs at a flow rate of 4 to 6 liters per minute.
- (3) Starting an IV infusion (D₅W at Tko rate).
- (4) Monitoring vital signs.
- (5) Positioning the patient in a semi-Fowlers or high-Fowlers (sitting) position to reduce respiratory distress.

5-17. Congestive Heart Failure

a. Congestive heart failure (CHF) is the inability of the heart to pump blood efficiently. There are several contributing factors to CHF. Some of these include—

- (1) Secondary to an MI.
- (2) Pulmonary embolism.
- (3) Administration of too much IV fluids.
- (4) Excessive sodium intake.

b. There are two types of heart failure: acute pulmonary edema and chronic congestive heart failure.

c. Signs and symptoms of pulmonary edema.

- (1) Congestion of the lungs.
- (2) Fatigue.
- (3) Dyspnea.
- (4) Cough.
- (5) Insomnia—often due to increased respiratory effort.
- (6) Hemoptysis.
- (7) Restlessness.

d. Signs and symptoms of congestive heart failure.

- (1) Unexplained weight gain.
- (2) Abdominal pain—usually in the upper region of the abdomen.
- (3) Mild to moderate respiratory distress.
- (4) Diaphoresis.
- (5) Weakness.
- (6) Anorexia.
- (7) Pitting edema.

e. Treatment of heart failure is aimed at improving oxygenation, increasing myocardial contractability, and reducing venous return. Certain specific treatments are recommended for the medical specialist and include:

- (1) Placing the patient in a sitting position, with the feet dangling. This position decreases venous return, making breathing easier.
- (2) Administering oxygen by mask at a flow rate of 4-6 liters per minute.
- (3) Starting an IV of D₅W at 10 drops per minute (Tko) rate.
- (4) Attaching a cardiac monitor, if available.
- (5) Using several types of drugs to improve cardiac function and assist respiration (if ordered by a physician).
- (6) Using rotating tourniquets to slow the venous blood flow.
- (7) Monitoring the patient's vital signs.

The primary aim when treating a patient who has CHF is to improve the cardiac function and correct hypoxia. This is accomplished to some extent by placing the patient in a sitting position and administering oxygen.

CHAPTER 6

THE RESPIRATORY SYSTEM**6-1. General**

a. The cells of the body require a constant supply of oxygen to carry on the chemical processes necessary to life. As a result of these processes, carbon dioxide (a waste product) is formed and must be removed from the body. Oxygen and carbon dioxide are continuously being exchanged, both within the body and between the body and the atmosphere, by the process known as respiration.

b. Respiration is the exchange of gases between the atmosphere and the cells of the body. It is a physiological process. There are two types of respiration: external and internal. External respiration is the exchange of gases between the air in the lungs and blood. Internal respiration is the exchange of gases between the blood and the individual cells of the body.

c. Breathing is the process that moves air into and out of the lungs. It is a mechanical process. There are two types of breathing: costal (thoracic) and diaphragmatic (abdominal). In costal breathing, the major structure causing movement of the air is the rib cage. In diaphragmatic breathing, interaction between the diaphragm and the abdominal wall causes the air to move into and out of the lungs.

6-2. Components and Subdivisions of the Respiratory System

See Figure 6-1 for an illustration of the respiratory system.

a. Components. The components of the respiratory system consist of air passageways and two lungs. Air moves from the outside of the body into tiny sacs in the lungs called alveoli.

b. Main Subdivisions. The main subdivisions of the respiratory system may be identified by their relationship to the voice box (larynx).

SUBDIVISIONS	FUNCTION
(1) <i>Supralaryngeal Structures</i> (above the larynx) (external nose, nasal chambers, and pharynx)	Cleanse, warm, moisten, and test inflowing air.
(2) <i>Larynx</i> (voice box)	Controls the volume of inflowing air; produces selected pitch (vibration frequency) in the moving column of air.
(3) <i>Infralaryngeal Structures</i> (below the larynx) (trachea and bronchi, alveoli, lungs, and pleural cavities)	Distribute air to the alveoli of the lung where the actual external respiration takes place.

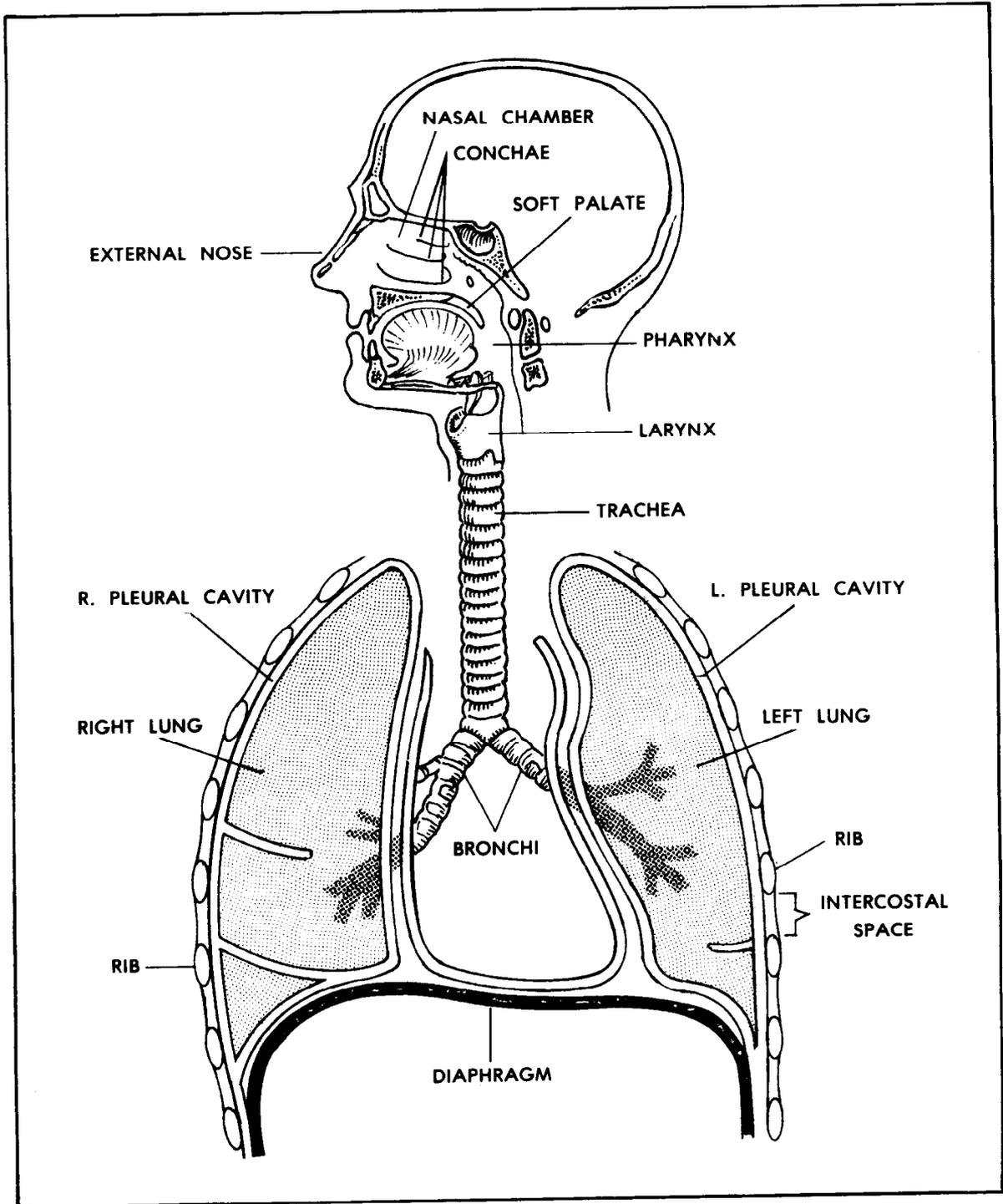


Figure 6-1. The respiratory system.

6-3. Supralaryngeal Structures

Figure 6-2 (cross-section) indicates the supralaryngeal structures.

a. External Nose. The external nose is the portion projecting from the face. It is supported primarily by nasal cartilages. It has a midline divider called the nasal septum, which extends from the internal nose. Paired openings (nostrils) lead to paired spaces (vestibules). Guard hairs in the nostrils filter incoming air.

b. Nasal Chambers (Internal Nose). Behind each vestibule of the external nose is a nasal chamber. Together the two nasal chambers form the internal nose. These chambers also are separated by the nasal septum.

(1) The walls of the nasal chambers are lined with a thick mucous-type membrane known as the mucoperiosteum. They have a ciliated (provided with hairlike projections that move fluids to the rear) epithelial surface. They also have a rich blood supply, which provides warmth and moisture. At times, they may become quite swollen.

(2) The sense of smell is the result of special nerve endings located in the upper areas of the nasal chambers.

(3) There are air "cells" or cavities in the skull known as paranasal sinuses. The paranasal sinuses are connected with the nasal chambers and are lined with the same ciliated mucoperiosteum. These sinuses are extensions of the nasal chambers into the skull bones. For this reason, they are known as paranasal sinuses.

c. Pharynx. The pharynx is the common space in the back of the throat for the respiratory and digestive systems.

(1) The portion of the pharynx specifically related to the respiratory system is the nasopharynx located above the soft palate. The two posterior openings (nares) of the nasal chambers lead into the single space of the nasopharynx. The auditory (eustachian) tubes also open into the nasopharynx. The auditory tubes connect the nasopharynx with the middle ears (to equalize the pressure between the outside and inside of the eardrum). Lying in the upper posterior wall of the nasopharynx are the pharyngeal tonsils (adenoids). The soft palate floor of the nasopharynx is a trapdoor that closes off the upper respiratory passageways during swallowing.

(2) The portion of the pharynx closely related to the digestive system is the oropharynx. It is the portion of the pharynx below the soft palate and above the upper edge of the epiglottis. (The epiglottis is the flap that prevents food from entering the larynx during swallowing.)

(3) The portion of the pharynx that is common to the respiratory and digestive systems is the laryngopharynx. It is the portion of the pharynx below the upper edge of the epiglottis. The digestive and respiratory systems lead into it from above and lead off from it below.

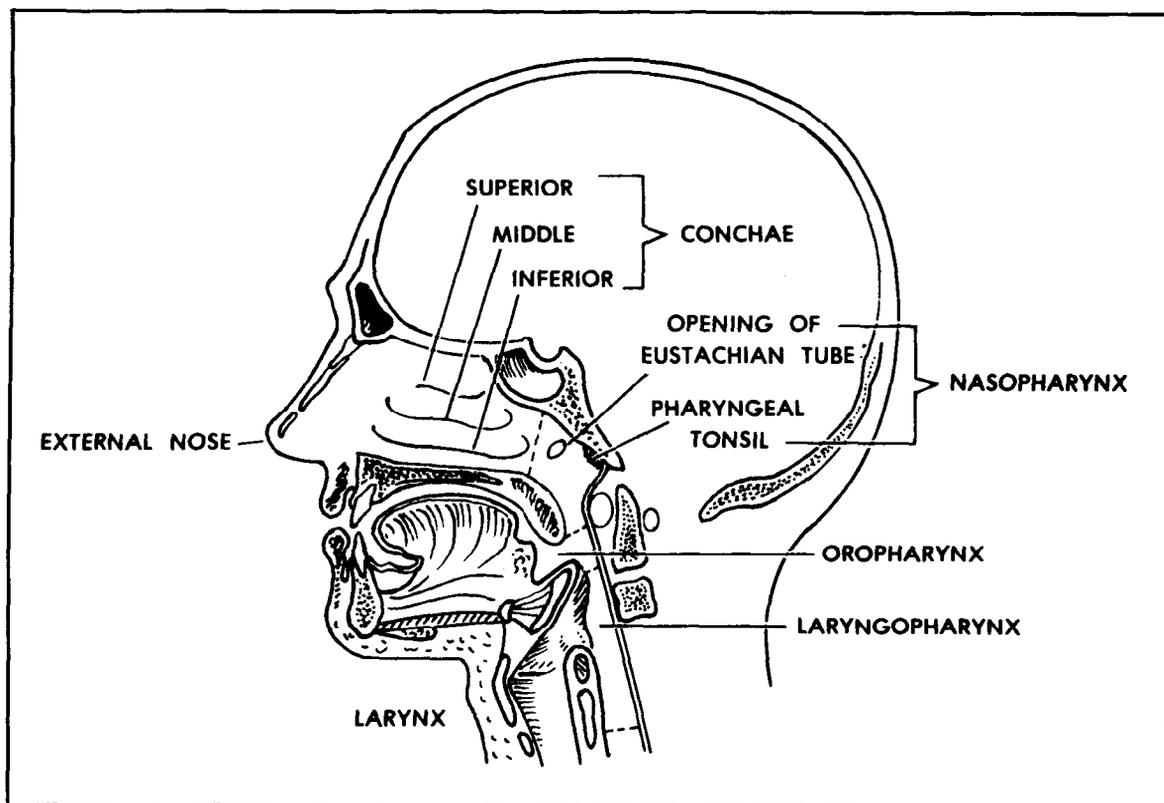


Figure 6-2. Supralaryngeal structures.

6-4. Larynx

The larynx, also called the Adam's apple or voice box, connects the pharynx with the trachea. The larynx, located in the anterior neck region, has a box-like shape (Figure 6-3). The voice box of the male becomes larger and heavier during puberty and the voice deepens. The adult male's voice box tends to be located lower in the neck; in the female, the larynx remains higher and smaller and the voice is of a higher pitch.

a. The larynx has a vestibule (entrance hallway) that can be covered over by the epiglottis. The glottis itself is the hole between the vocal cords. Through the glottis, air passes from the vestibule into the main chamber of the larynx (below the cords) and then into the trachea. The skeleton of the larynx is made up of a series of cartilages.

b. The larynx serves two functions and has two sets of muscles—one for each function.

(1) One set controls the size of the glottis. Thus, it regulates the volume of air passing through the trachea.

(2) The other set controls the tension of the vocal cords. Thus, it produces vibrations of selected frequencies (variations in pitch) of the moving air to be used in the process of speaking.

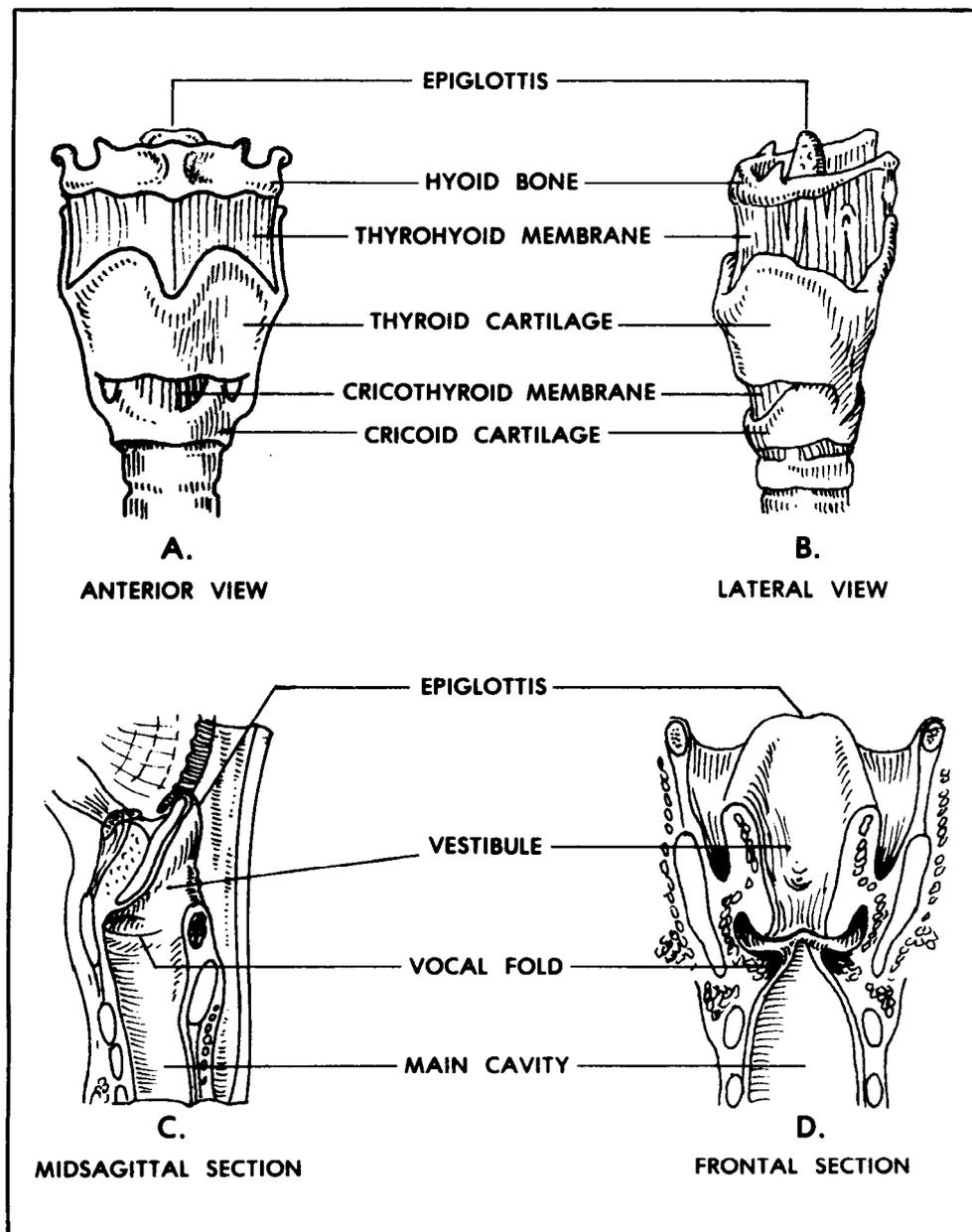


Figure 6-3. The larynx.

6-5. Infralaryngeal Structures

See Figure 6-4 for an illustration of the infralaryngeal structures.

a. Trachea and Bronchi. The respiratory tree is the set of tube-like structures that carry air from the larynx to the alveoli of the lungs. The respiratory tree is so named because it has the appearance of an inverted tree with its trunk and branches. These tubular parts are held open (made *patent*) by rings of cartilage. Their lining is ciliated to remove mucus and other materials that get into the passageway.

b. Alveoli. The alveoli (alveolus, singular) are tiny spherical (balloon-like) sacs that are connected to the larger tubes of the lungs by tiny tubes as alveolar ducts and bronchioles. The alveoli are so small that there are billions in the adult lungs. This produces a maximum surface area through which external respiration takes place. External respiration is the actual exchange of gases between the air in the alveolar spaces and the adjacent blood capillaries through their air walls.

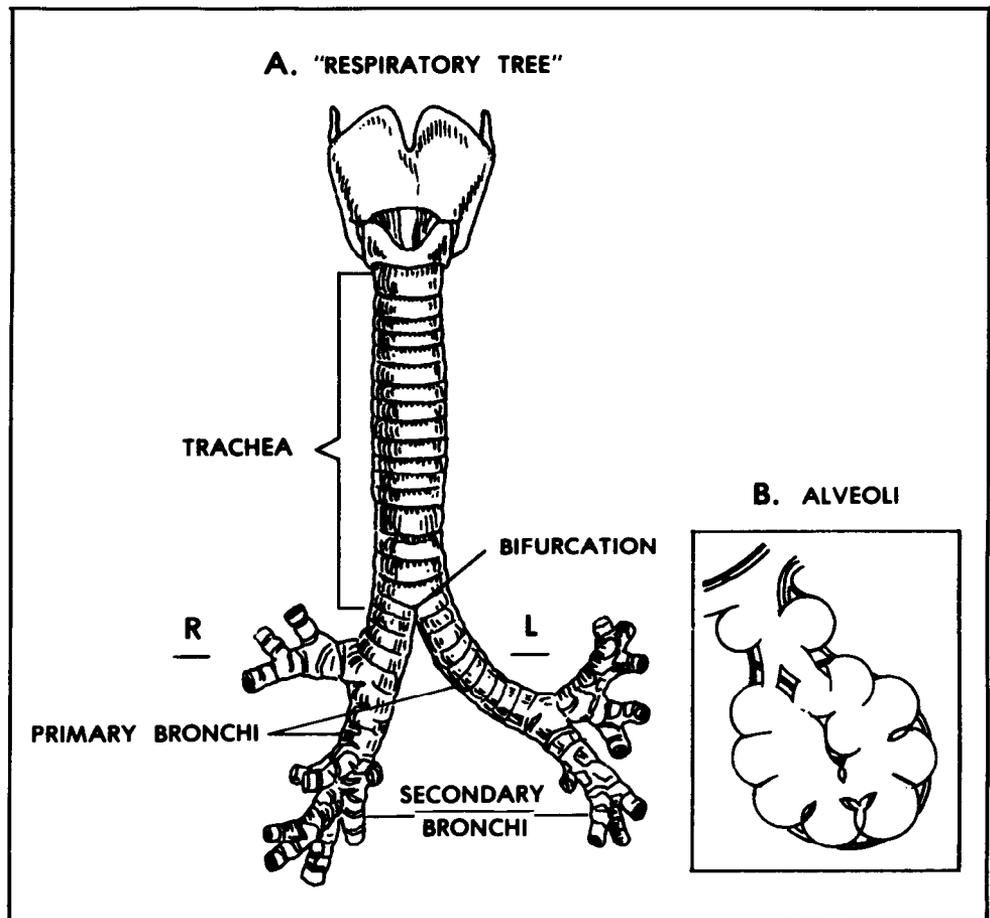


Figure 6-4. Infralaryngeal structures.

c. Lungs. A lung is an individual organ composed of tubular structures and alveoli, bound together by fibrous connective tissue. There are two lungs, right and left. Each lung is supplied by a primary or mainstream bronchus leading off of the trachea. The right lung is larger in volume than the left lung because the left lung must leave room for the heart. The right lung is divided into three pulmonary lobes (upper, middle, and lower). The left lung is divided into two pulmonary lobes (upper and lower). A pulmonary lobe is a major subdivision of the lung and is marked by deep folds.

d. Pleural Cavities. The pleural cavity is a serous cavity with inner and outer membranes. In the case of the lungs, the inner membrane is known as the visceral pleura which very closely covers the surface of the lungs. The outer membrane is known as the parietal pleura, forming the outer wall of the cavity. The pleural cavities are the potential spaces between the inner and outer membranes. The pleural cavities allow the lungs to move freely with a minimum of friction during the expansion and contraction of breathing. Located in the middle of the thorax, between the two pleural cavities, is the mediastinum (meaning "I stand between"). The mediastinum is filled with tissues and organs. Within it, the heart (of the blood circulatory system) is located at the same level as the lungs.

6-6. Breathing and Its Mechanisms

a. Boyle's law tells us that as the volume (V) of a gas-filled container increases, the pressure (P) inside decreases; as the volume of a closed container decreases, the pressure inside increases. When two connected spaces of air have different pressures, the air moves from the space with greater pressure to the one with lesser pressure. In regard to breathing, we can consider the air pressure around the body to be constant. The pressure inside the lungs may be greater or less than the pressure outside the body. Thus, a greater internal pressure causes air to flow out; a greater external pressure causes air to flow in.

b. The upper portion of the body can be compared to a cylinder. This cylinder is divided into upper and lower cavities by the diaphragm. The upper is the thoracic cavity and is essentially gas-filled. The lower is the abdominopelvic cavity and is essentially water-filled.

6-7. Costal (Thoracic) Breathing

a. Inhalation. Muscles attached to the thoracic cage raise the rib cage. A typical rib might be compared to a handle, attached at one end to the sternum (breastbone) and at the other end to the vertebral column. This handle is lifted by the overall movement upward and outward of the rib cage. These movements increase the thoracic diameters from right to left (transverse) and from front to back. Thus, the intrathoracic volume increases. Recalling Boyle's law, the increase in volume leads to a decrease in pressure. The air pressure outside the body then forces air into the lungs and inflates them.

b. Exhalation. The rib cage movements and pressure relationships are reversed for exhalation. Thus, intrathoracic volume decreases. The intrathoracic pressure increases and forces air outside the body.

6-8. Diaphragmatic (Abdominal) Breathing

The diaphragm is a thin, but strong, dome-shaped muscular membrane that separates the abdominal and thoracic cavities. The abdominal wall is elastic in nature. The abdominal cavity is filled with soft, watery tissues.

a. Inhalation. As the diaphragm contracts, the dome flattens and the diaphragm descends. This increases the depth (vertical diameter) of the thoracic cavity and increases its volume. This decreases air pressure within the thoracic cavity. The greater air pressure outside the body then forces air into the lungs.

b. Exhalation. As the diaphragm relaxes, the elastic abdominal wall forces the diaphragm back up by pushing the watery tissues of the abdomen against the underside of the relaxed diaphragm. The dome extends upward. The process of inhalation is thus reversed.

6-9. Nervous Control of Breathing

As we have seen, breathing is a combination of many factors. These factors are integrated and controlled by the nervous system.

a. Respiratory reflexes are controlled by the respiratory center found in the medullary portion of the posterior brainstem. The level of carbon dioxide (CO₂) in the circulating blood is one of the major influences upon the respiratory reflex.

b. The individual intercostal nerves innervate the intercostal muscles.

c. The muscles attached to and moving the rib cage are innervated by their appropriate nerves. (Ultimately, almost every muscle in the torso may be mobilized to assist in breathing.)

d. The diaphragm is innervated by its own individual pair of nerves.

6-10. Functional Blood Supply

There are essentially two blood supplies for the lungs—nutrient blood and functional blood. Nutrient blood is carried by the bronchial arteries from the thoracic aorta and provides nourishment and oxygen to the tissues of the lung. Functional blood is involved in the respiratory exchange of gases between the alveoli and the capillaries. It is brought to and from the lungs by the pulmonary cycle of the cardiovascular system.

a. The pulmonary cycle originates in the right ventricle of the heart. Contraction of the right ventricle forces the blood into the pulmonary arch, which divides into the right and left pulmonary arteries and paralleling the branching of the respiratory tree, the arteries divide and subdivide within the lungs. These arteries lead to capillaries in the vicinity of the alveoli. The walls of these capillaries are thin enough to accommodate the passage of gases to and from the alveoli.

b. The blood, now saturated with oxygen, is collected by the pulmonary venous system and is deposited into the left atrium of the heart.

6-11. Exchange and Transportation of Gases

Oxygen and carbon dioxide are the primary gases involved in respiration. At the alveoli, gases are exchanged between the air inside and the blood in the adjacent capillaries. Within the body, gases are exchanged between the blood of the capillaries and the individual cells of the body. The gases are transported between the alveoli and the individual cells by the cardiovascular system.

a. Some of the gases are dissolved directly in the plasma of the blood.

b. However, the greater percentages of the gases are carried within the substance of the RBCs (red blood cells/erythrocytes). The RBCs, found in large numbers in the blood, are specially constructed for transporting the gases. Hemoglobin, a substance found within RBCs, has a great affinity for oxygen. Yet, the hemoglobin can readily give up the oxygen wherever it is needed.

CHAPTER 7

THE NERVOUS SYSTEM**7-1. General**

a. The nervous system is composed of the brain, spinal cord, and branches from the spinal cord and brain called nerves. The system is divided anatomically into two parts: the central nervous system and the peripheral nervous system.

b. The central nervous system includes the brain and the spinal cord. The peripheral nervous system includes the nerves, which are either sensory or motor or a combination of both. Sensory nerves are adapted to carry sensations of touch, taste, heat, cold, and pain. Motor nerves are adapted to transmit impulses to muscles, causing them to move.

c. That part of the nervous system that regulates functions over which there is voluntary control is often called the sympathetic nervous system.

d. There is also a subdivision called the autonomic, or involuntary, nervous system. Automatic functions (such as digestion, control of vessel dilation, the ability to sweat, and all sensations and responses that cannot be controlled by a voluntary act of conscious will) are under the direction of this system.

7-2. The Central Nervous System (CNS)**a. Nerve Cells.**

(1) The nerve cell, or neuron, is the basic unit of the nervous system. Each neuron is composed of a cell body, which contains the nucleus of the nerve cell; dendrites, which carry impulses to the cell body; and axons, which carry impulses away from the cell body. Collections of cell bodies appear gray, and therefore are referred to as "gray matter."

(2) Impulses are transmitted along nerves through a process that is part chemical and part electrical. It may be helpful to think of the nerves as "wires," surrounded by myelin "insulation." Nerve cells can receive impulses (excitability), conduct them (conductivity), and transmit them to a second cell (transmission). Impulses travel from the dendrites to the cell body and then from the cell body down the axon. When an impulse reaches the end of the axon, it is transmitted to a second cell across a junction. This junction is called a synapse (Figure 7-1). The second cell may be another nerve cell or a gland cell.

(3) Unlike excitability and conductivity (which are electrical in nature), transmission of impulses from one nerve cell to another is chemical. A chemical released by the axons crosses the synapse to excite the second cell.

(4) Some drugs and poisons can block this transmission and prevent excitability of the second cell. Others can lead to a buildup of the chemical transmitter and excess excitation of the second cell.

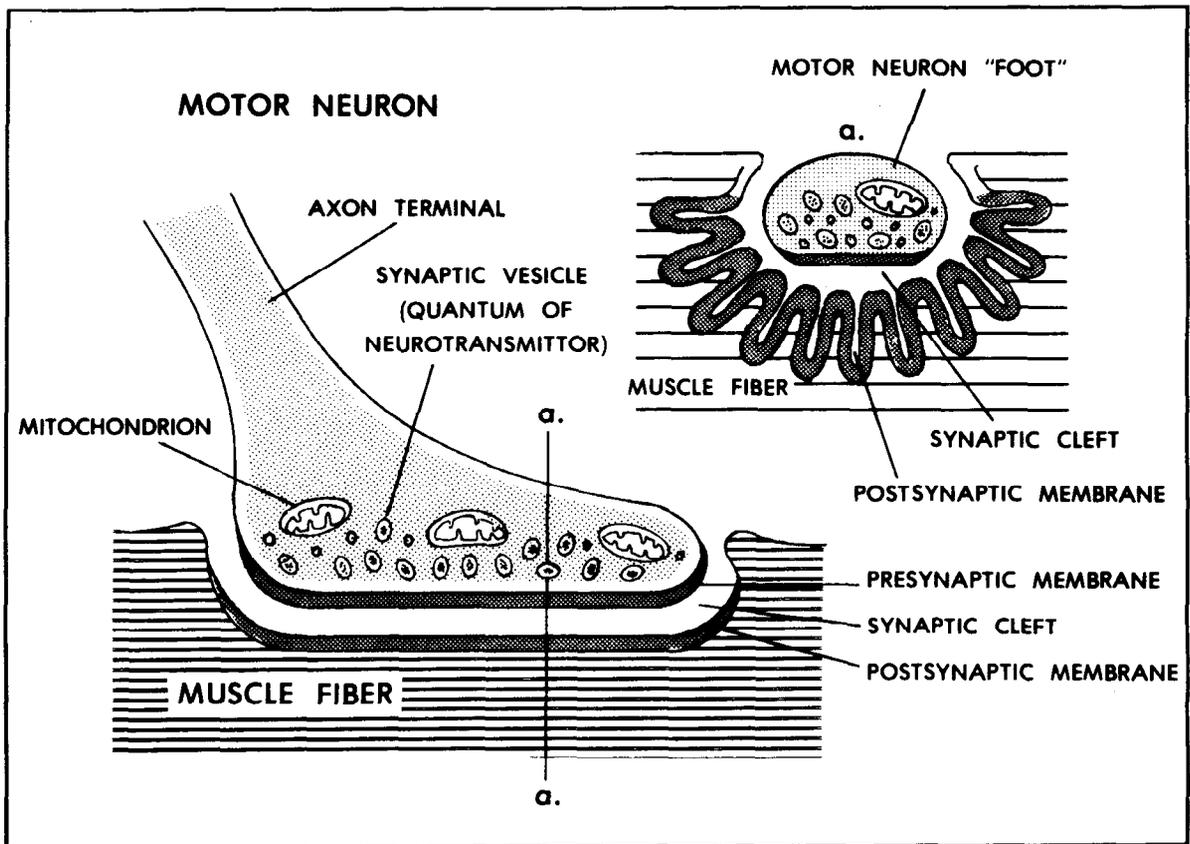


Figure 7-1. A synapse.

b. The Brain.

(1) The brain is the controlling organ of the body and occupies the entire space within the cranium (skull). It is made up of many different types of cells. Each type of cell has a specific function: some cells in the brain receive sensory impulses or messages; other cells are responsible for signaling muscles and organs to act. Still other cells are responsible for transmitting impulses to other areas of the brain and to the spinal cord.

(2) The brain is a very soft tissue organ and is richly supplied with blood vessels. This makes the brain very susceptible to injury. The skull can protect the brain from external injury because of its rigidity and hardness, but the same qualities can, in some cases, injure the brain. In some ways, the brain behaves like a sponge inside a steel case—it cannot expand inside the rigid skull. Therefore, a swelling of the brain or accumulation of blood inside the skull compresses the brain and increases the pressure inside the skull. This pressure (increased intracranial pressure) causes changes that interfere with brain functioning. Furthermore, because the skull is hard, both the brain and

the blood vessels on the brain's surface may be damaged if they strike the skull's inner surface. This condition can occur when the head is struck directly or when it is rapidly accelerated or decelerated. When struck on the back of the head, the phenomenon of "seeing stars" is due to the occipital lobe of the brain (the part that controls vision) striking against the back of the skull.

(3) The brain is divided into three main parts: the cerebrum, cerebellum, and brain stem (Figure 7-2). The first main portion, or cerebrum is the largest part of the brain, occupying the top and front of the skull. The cerebrum is divided from the front to the back of the skull into left and right cerebral hemispheres. The cerebral cortex is the gray, outer surface layer of the cerebral hemispheres. This thin layer, 2 to 5 millimeters (mm) thick, contains nerve cell bodies. Each cerebral hemisphere is further divided into four lobes: frontal, temporal, parietal, and occipital, named according to the overlying skull bones. These lobes are separated from each other by fissures, as shown in Figure 7-2.

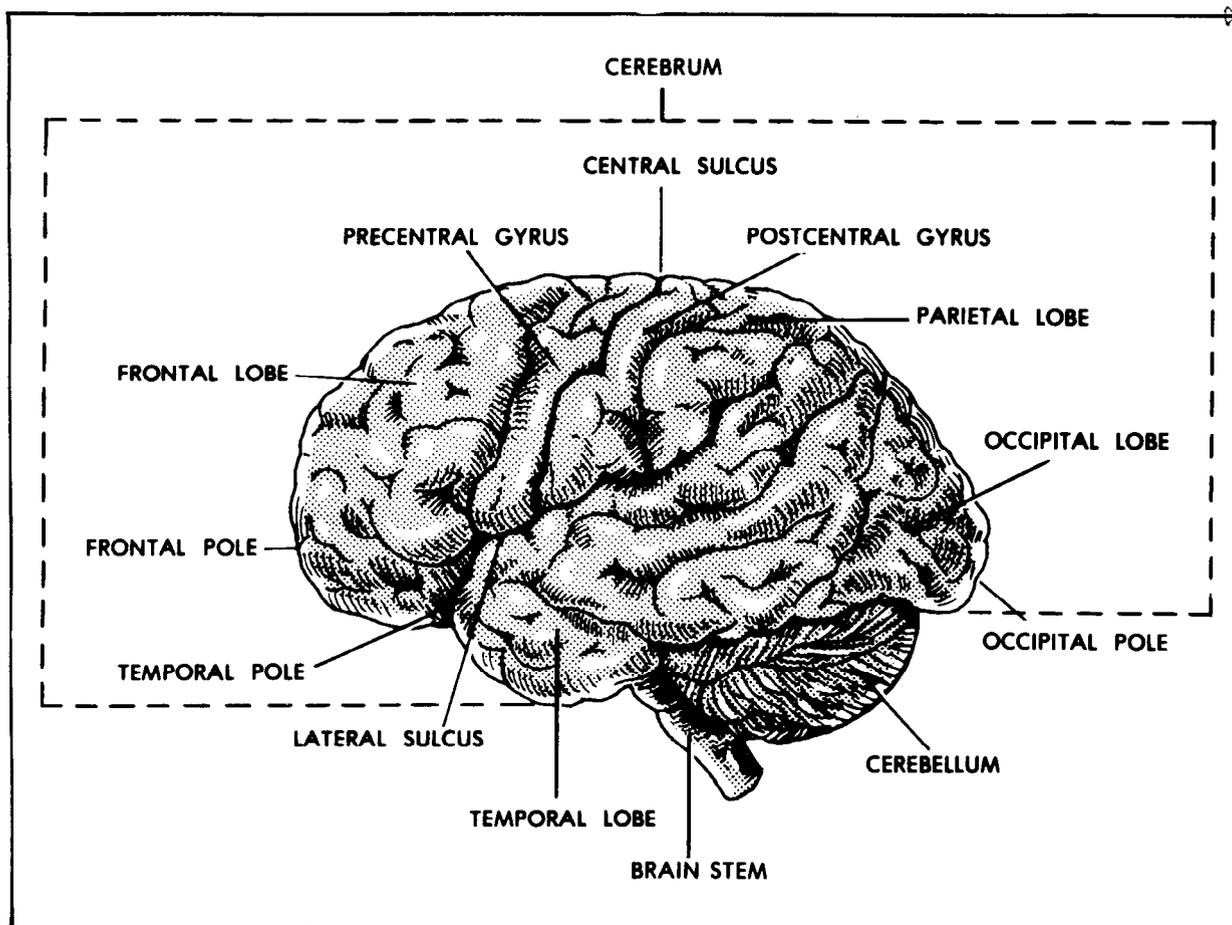


Figure 7-2. The brain.

(4) Each nerve cell in the cerebral cortex (cortical nerve cell) has a specific function, and groups of these cells that perform related functions are located in different areas of the brain. The eight major functions of the brain are:

(a) *Sensation.* The brain receives sensory input from all sense organs, including the eyes, ears, nose, and taste buds, and from all receptors of pain, pressure, and temperature. This sensory input is then interpreted by the cerebral cortex.

(b) *Voluntary movement.* The cerebral cortex directs and assists voluntary movement by coordinating muscle actions and maintaining posture and equilibrium.

(c) *Mental functions.* Mental functions include memory, foresight, personality, speech, and intelligence, and are functions of the cerebral cortex.

(d) *Emotions.* Happiness, sadness, rage, and other emotions are functions of the thalamus and the cerebral cortex.

(e) *Control of autonomic functions.* The hypothalamus directs the autonomic nervous system which innervates smooth muscle, cardiac muscle, and glands.

(f) *Control of endocrine function.* The hypothalamus triggers anterior pituitary secretion which regulates the hormone production of target endocrine glands.

(g) *Consciousness.* The reticular activating system, which originates in the brain stem and travels to the cerebral cortex, maintains wakefulness. Injuries or drugs that affect the reticular activating system produce unconsciousness.

(h) *Control of vegetative functions.* The medulla, which is part of the brain stem, controls respiration, heart rate, and blood pressure. Therefore, injury to the medulla can produce cardiorespiratory arrest.

(5) The areas are given functional names but also may be referred to by their anatomic location. It is important to be familiar with these areas because damage to each area (such as that caused by trauma (injury) and stroke) causes specific clinical signs and symptoms. The cerebrum is more subject to injury than are other parts of the central nervous system.

(6) Injury to the motor cortex, which is located in the frontal lobe, causes weakness or paralysis on the opposite side of the body because many nerve fibers from the cortex are crossed in the brain stem and spinal cord. The left side of the brain controls the right side of the body.

(7) The rest of the frontal lobe is involved in the higher mental processes of judgment, foresight, and perserverance. People with damage (injury) to this area often have difficulty making appropriate judgments.

(8) Speech is controlled by a small area of the left temporal lobe. Damage (injury) to this area causes a variety of difficulties with speech, ranging from inability to find the correct words to not being able to speak. In the superior temporal lobes, hearing is controlled by the auditory cortex. The occipital cortex, located in the posterior part of the cerebrum, is responsible for sight (visual sensation). The sensory area, located in the parietal lobe, receives and processes other types of sensory information (such as touch, temperature, vibration, position sense, and pain). The crossover relationship between the brain and the body also applies to the transmission of sensory information. For example, the sensation of a pain caused from a burn on the right hand is received by the left side of the brain. Damage to the left sensory cortex causes a loss of perception of the right side of the body.

(9) The second major area of the brain is the cerebellum. The cerebellum is located in the lower back, or inferoposterior, part of the skull (Figure 7-2). The cerebellum is divided into two hemispheres. It has a thin covering of gray matter over a core of white matter. The functions of the cerebellum are not as well localized to specific areas as the cerebral functions. Coordination of skilled voluntary muscle movement, posture, and balance are maintained by the cerebellum. Difficulties in balancing and coordination are caused by damage to the cerebellum. The difficulties are most noticeable when the injured person tries to walk. Because of its location in the back of the skull, the cerebellum rarely is injured except by direct trauma (injury) to this area.

c. The Brain Stem.

(1) The brain stem is the third major portion of the brain (Figure 7-2). It is located at the base of the brain, between the spinal cord and the cerebrum and surrounded by the cerebellum. The brain stem contains nerve tracts, which are functional units formed by groups of axons that carry impulses to and from the brain and the spinal cord. These structures also contain groups of nerve cell bodies (nuclei) that control various body functions. The medulla oblongata, the lowest area of the stem, located just above the spinal cord, has centers critical to the maintenance of vital body functions such as heart rate, respiration, and blood pressure. Damage to these centers, or interference with their functioning by certain drugs, causes various cardiorespiratory disturbances, from a slowing of the heart rate (bradycardia) to cardiopulmonary arrest.

(2) Other centers in the brain stem control the muscles of the eyes, throat, and face and receive sensory information from these areas. From these centers (nuclei), nerves run through different bony passages to the facial structures. Damage to the facial nerve (which can be caused by a skull fracture) will paralyze some of the facial muscles. Similar damage to the oculomotor (eyeball) nerve will prevent the pupil on the damaged side of the body from responding to different light levels.

d. The Spinal Cord.

(1) The second major part of the central nervous system is the spinal cord. All of the important centers of the brain are connected by long tracts of nerves directly with the organs or muscles they control. These tracts join to form the spinal cord, a continuation of the brain (Figure 7-2). Like the brain, the spinal cord is protected by a bony structure, the spine. Each section

(vertebrae) of the spine contains an anterior bony vertebral body to support the body's weight and a posterior bony ring (neural arch) to protect the spinal cord (Figure 7-3).

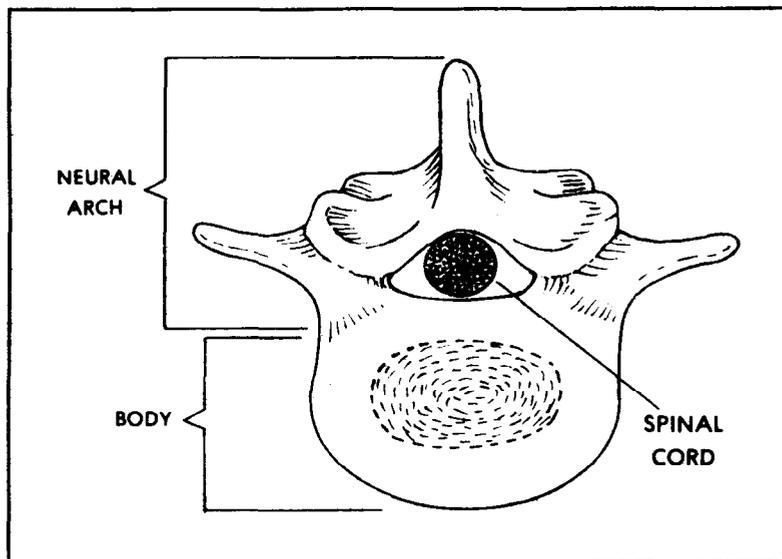


Figure 7-3. Spinal vertebra in cross-section.

(2) The spinal cord has a gray matter core surrounded by a layer of white matter. The gray matter contains cell bodies. The white matter contains nerve tracts which connect the brain with the rest of the body. There are three important nerve tracts.

(a) The posterior column, which separates position and vibratory senses.

(b) The lateral spinal thoracic tract, which separates pain and temperature sensation.

(c) The cortical spinal tract, which controls muscle movement. The spinal cord transmits messages between the brain and the peripheral nervous system. These messages are passed along a nerve as electrical impulses, much as messages are passed in a telephone cable.

(3) There are five main areas in which the spinal cord can be divided: cervical, thoracic, lumbar, sacral, and coccygeal (tailbone) (Figure 7-4). In each section of the spinal cord, nerve cells control motor function and sensation for specific parts of the body. At each level of the cord, bundles of nerve fibers join to form nerve roots that leave the front and back sides of the spinal cord and then join to form peripheral nerves (Figure 7-5). Nerve roots in different areas control specific functions. For example, inability to move the shoulder indicates injury to the fifth cervical nerve root (C5). The following list gives other important relationships between nerve roots and the function of various body structures.

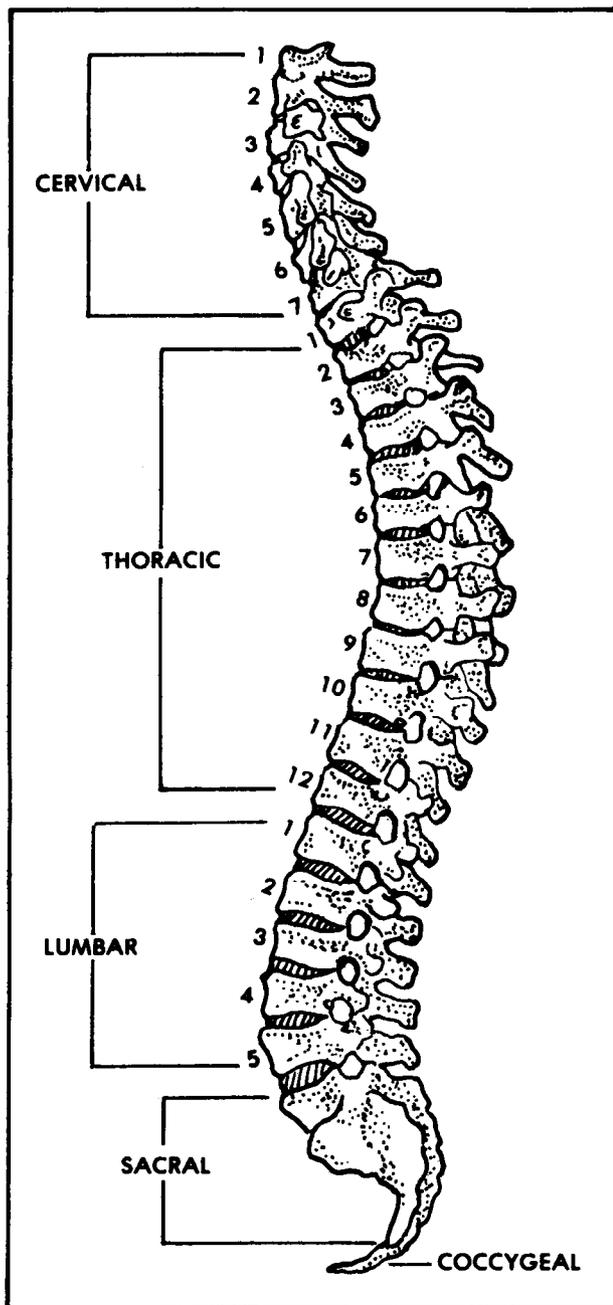


Figure 7-4. The five divisions of the spine.

- *Cervical.*
 - Shoulder girdle (C5).
 - Elbow flexion (C5, C6).
 - Elbow extension (C6, C8).
 - Wrist movement (C6, C7).
- *Thoracic.*
 - Thoracic region movement and sensation (T4 through T10).
 - Sensation at the nipple level (T4).
 - Sensation at the umbilicus (navel) level (T10).
- *Lumbar.*
 - Hip flexion (L2, L3).
 - Hip extension (L4, L5).
 - Knee extension (L3, L4).
- *Sacral.*
 - Knee flexion (L5, S1).
 - Ankle movement (S1, S2).
 - Toe movement (L5, S1, S2).

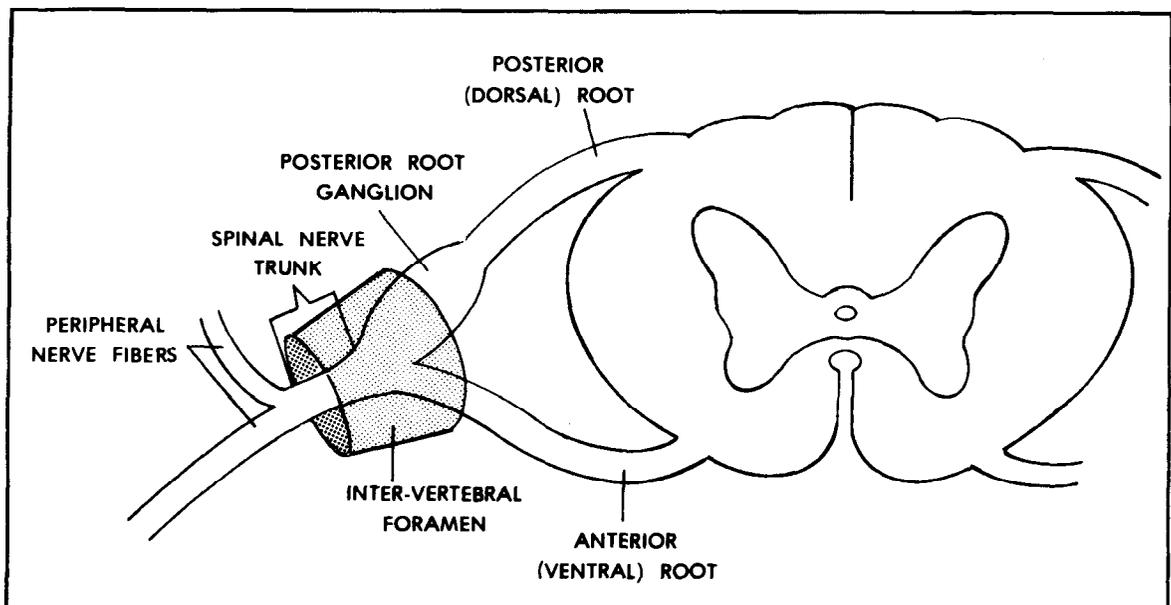


Figure 7-5. Bundles of nerve fibers joining nerve roots.

Another way of assessing possible damage to specific nerve roots is to test skin sensation in different areas. Each nerve root has cutaneous (skin) nerves which supply a given area. The area supplied by cutaneous nerves from a single nerve root is called a dermatome (Figure 7-6). These cutaneous nerves are part of the peripheral nervous system (paragraph 7-3).

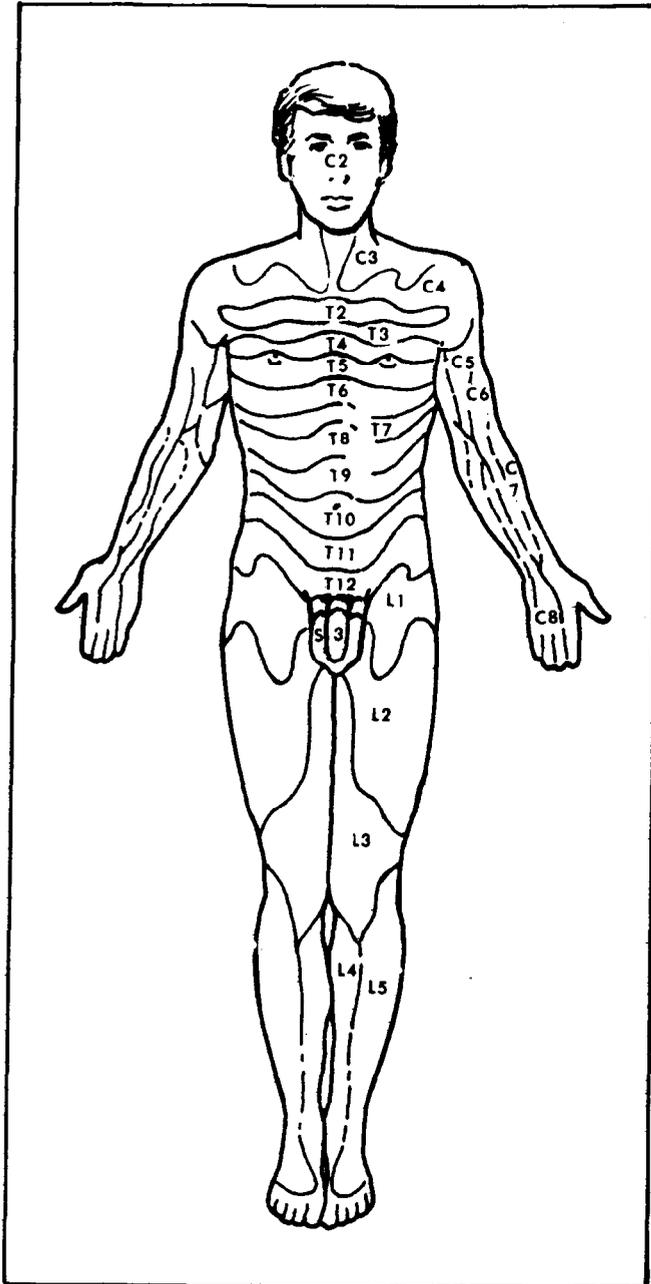


Figure 7-6. Dermatome in cross-section.

7-3. Peripheral Nervous System

a. The peripheral nervous system is complex. Branches from the spinal nerves join together with branches from other spinal cord segments to form large bundles or plexuses. These plexuses divide further to form the peripheral nerves that run to the muscles, skin, and other structures in the extremities. The peripheral nerves may be injured by fractures or lacerations of the extremities, which may cause local muscular paralysis and loss of sensation.

b. A group of large nerves in the base of the neck and armpit is the brachial plexus. Branches of the brachial plexus innervate the arm and the shoulder. Six major nerves branch from the brachial plexus:

(1) *Axillary nerve.* The axillary nerve supplies the deltoid muscle and skin of the shoulder.

(2) *Musculocutaneous nerve.* The musculocutaneous nerve descends laterally to supply the biceps muscle and ends in a cutaneous sensory nerve in the forearm.

(3) *Radial nerve.* The radial nerve branches off to the arm and forearm muscles, to the skin of the posterior arm, and to the posterior forearm. When the radial nerve is damaged, motion of and sensation in the thumb are lost.

(4) *Superficial radial nerve.* The superficial radial nerve is a cutaneous nerve that innervates the skin of the lateral posterior forearm and lateral posterior hand.

(5) *Deep radial nerve.* The deep radial nerve innervates the skin and the muscles of the ulna (the long bone in the forearm) and the hand. Because the ulnar nerve crosses the outer part of the elbow, it can be damaged in injuries to this joint. Such injuries cause sensorimotor loss in the little finger.

(6) *Median nerve.* The median nerve innervates muscles of the forearm and hand, the skin of the thumb, the first three fingers, and the radial side of the palm.

c. The lumbosacral plexus innervates the legs. Its major branches include:

(1) *Femoral nerve.* The femoral nerve innervates the muscles in the front of the thigh, including the quadriceps group. It also gives off cutaneous branches to the skin of the anterior and medial distal thigh and the medial leg and foot.

(2) *Obturator nerve.* The obturator nerve innervates muscles of the medial thigh and the skin of the distal medial thigh.

(3) *Sciatic nerve.* The sciatic nerve is the largest nerve in the body and is found in the posterior thigh. It innervates the muscles of the calf and the back of the thigh and the skin of the lower calf and the upper surface of the foot.

(4) *Superficial peroneal nerve.* The superficial peroneal nerve innervates the lateral leg muscles and the skin on the back (dorsum) of the foot.

(5) *Deep peroneal nerve.* The deep peroneal nerve innervates the anterior and lateral leg muscles and the muscles that move the toes.

(6) *Tibial nerve.* The tibial nerve innervates the skin and muscles of the posterior leg and the sole of the foot. Damage to the tibial nerve results in "footdrop," the inability to dorsiflex the foot (to bend it backward by flexing the ankle).

7-4. Autonomic Nervous System

a. The autonomic nervous system stimulates the smooth muscle of the blood vessels and the bowel, the heart muscle, and some endocrine glands. This system maintains the various bodily functions over which the individual has no conscious control, including blood pressure, temperature regulation, sweating, and peristaltic activity of the bowel. In stressful situations, the autonomic nervous system also helps the body produce the appropriate "fight or flight" response, characterized by changes in blood flow and metabolism.

b. The autonomic nervous system is divided into the parasympathetic nervous system (which controls the involuntary functions mentioned above) and the sympathetic nervous system (which prepares the body for stress). The parasympathetic nerves release acetylcholine when stimulated. This chemical transmitter crosses the synapse (neuromuscular junction) to stimulate the end organ, or muscle. Effects of acetylcholine (cholinergic effects) include salivation, pupillary constriction in the eye, slowing of the heart, constriction of bronchial smooth muscle, and increased intestinal motility.

c. Because atropine inhibits the breakdown of acetylcholine at the neuromuscular junction (increasing cholinergic activity), it is used clinically to increase the heart rate. Some insecticides, notably those of the organophosphate type, block cholinergic activity and can lead to fatal paralysis and cardiac arrest unless their effects are countered by treatment with atropine.

d. The sympathetic nervous system has more widespread effects than the parasympathetic system. Chemical transmitters in the sympathetic nervous system include norepinephrine, which is released from sympathetic nerve endings, and epinephrine (Adrenalin), which is released from the adrenal gland when it is stimulated by the sympathetic nerves. Sympathetic nervous stimulation increases the heart rate (pulse) and the force of cardiac contraction. In the blood vessels, sympathetic stimulation of specialized receptors (called beta-1 and beta-2 adrenergic receptors) can both increase and decrease the muscular tone of the vessel wall and influences blood pressure and blood flow to different parts of the body.

e. Damage to the thoracic and lumbar segments of the spinal cord can cause derangement of the sympathetic nervous system, which originates in those areas. Such damage can lead to heat loss and shock; as vascular tone diminishes, blood collects in the extremities.

7-5. Protective Mechanisms for the Central Nervous System

a. The brain and the spinal cord do not have the ability to regenerate if cells are permanently damaged. Although some brain cells can take over the functions of other damaged cells, the amount of function regained cannot be predicted and is usually limited. To prevent additional damage, any patient with possible neurological injury must be handled very carefully in the emergency treatment situation.

b. There are several protective mechanisms for the structures of the central nervous system (Figure 7-7). The skull provides a rigid container for the brain, and the spine protects the spinal cord. Within these bony structures, three layers of tissue (called meninges) provide additional protection.

(1) The first of these layers is the dura mater, the thick fibrous outer covering of the brain. It is attached to the skull except at the falx cerebri, which separates the two halves of the cerebrum, and the tentorium cerebelli, which separates the occipital lobe of the cerebrum from the cerebellum. These dural infoldings provide a suspension system for the brain and help prevent excessive motion within the skull. The dura mater also forms the outer covering of the spinal cord.

(2) The second layer of tissue is called the arachnoid membrane. Between the arachnoid membrane and the dura mater is the subdural space in which blood vessels and nerves pass to and from the brain.

(3) The third layer is the pia mater, which is closely attached to the surface of the brain and spinal cord and dips into every fold of their surfaces. Between the arachnoid membrane and the pia mater is the subarachnoid space, which is filled with cerebrospinal fluid (CSF). The cerebrospinal fluid protects the brain and spinal cord by providing a cushion between them and their adjacent bony structures. Clear and colorless, this fluid circulates through and around the brain and spinal cord before being resorbed. When tears in the dura mater occur (usually after skull fractures), the cerebrospinal fluid may leak out through the nose or the ears. Leakage of this fluid indicates a critical situation because it signals serious injury to the central nervous system and possible infection (meningitis).

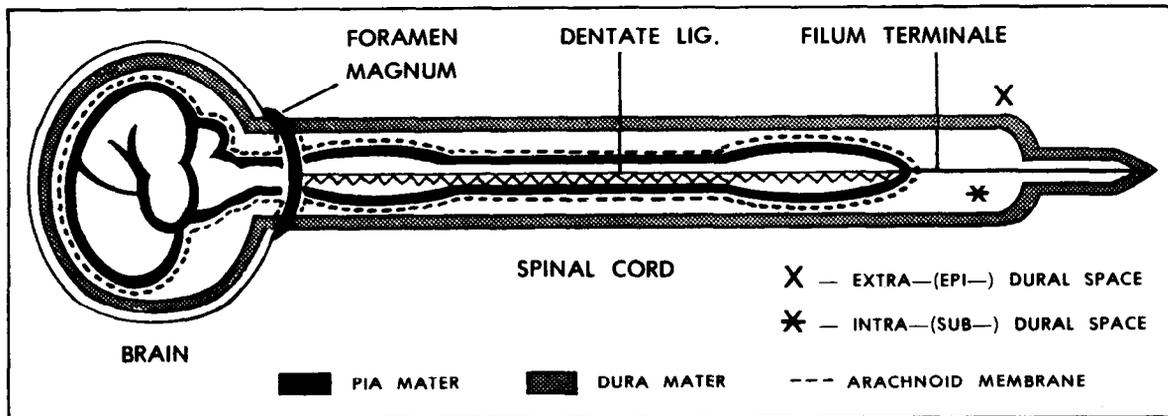


Figure 7-7. The covering membranes (meninges) suspend and protect the skull and spinal canal.

CHAPTER 8

THE DIGESTIVE SYSTEM**8-1. General**

a. The digestive system is made up of the alimentary tract (food passage) and the accessory organs of digestion. Part of this system is also known as the gastrointestinal (GI) tract. Its main functions are to take in foods, initially process foods, digest the foods, and eliminate waste material. The products of the accessory organs help to prepare food for digestion and its absorption.

b. Digestion consists of two processes: one mechanical and the other chemical. The mechanical part of digestion includes chewing, swallowing, peristalsis (movement for propelling the stomach contents), and defecation. The chemical part of digestion consists of breaking food into simple components that can be absorbed and used by the body cells. In this process, foods are broken down by enzymes in the digestive juices formed by the digestive glands. Carbohydrates are changed into glucose (simple sugar), while fats are changed into fatty acids and proteins are converted into amino acids. These materials are used by the cells—

- As energy for life processes.
- For growth and repair of body tissues.

8-2. Structure of the Digestive System

The digestive system (Figure 8-1) consists of the following:

a. The alimentary canal is about 28 feet long (8.52 m), extending from the mouth (where food is taken in) to the anus (where solid waste products of digestion are expelled from the body). This passageway is divided into: the mouth, pharynx, esophagus, stomach, small intestine and associated glands, large intestine (colon), rectum, and anal canal and anus.

b. The accessory organs that aid the process of digestion are the salivary glands, pancreas, liver, gallbladder, and other intestinal glands.

8-3. Oral Complex

The oral cavity contains structures which together are commonly known as the mouth. The cavity takes in and initially prepares foods prior to the digestive process. See Figure 8-2.

a. Lips and Cheeks. The structure of the oral cavity is covered with fleshy tissues known as cheeks. The margins of the cheeks around the oral opening are the lips. Muscles in the lips control the opening and closing of the mouth.

b. Jaws. There are two jaws: the upper jaw, which is called the maxilla and the lower jaw, which is called the mandible.

(1) In each jaw, there are sockets for the teeth. These sockets are known as alveoli. The bony parts of the jaws holding the teeth are known as alveolar ridges.

(2) The upper jaw is fixed to the base of the cranium while the lower jaw is movable. There is a special articulation (temporomandibular joint) with muscles to bring the upper and the lower teeth together to perform their functions.

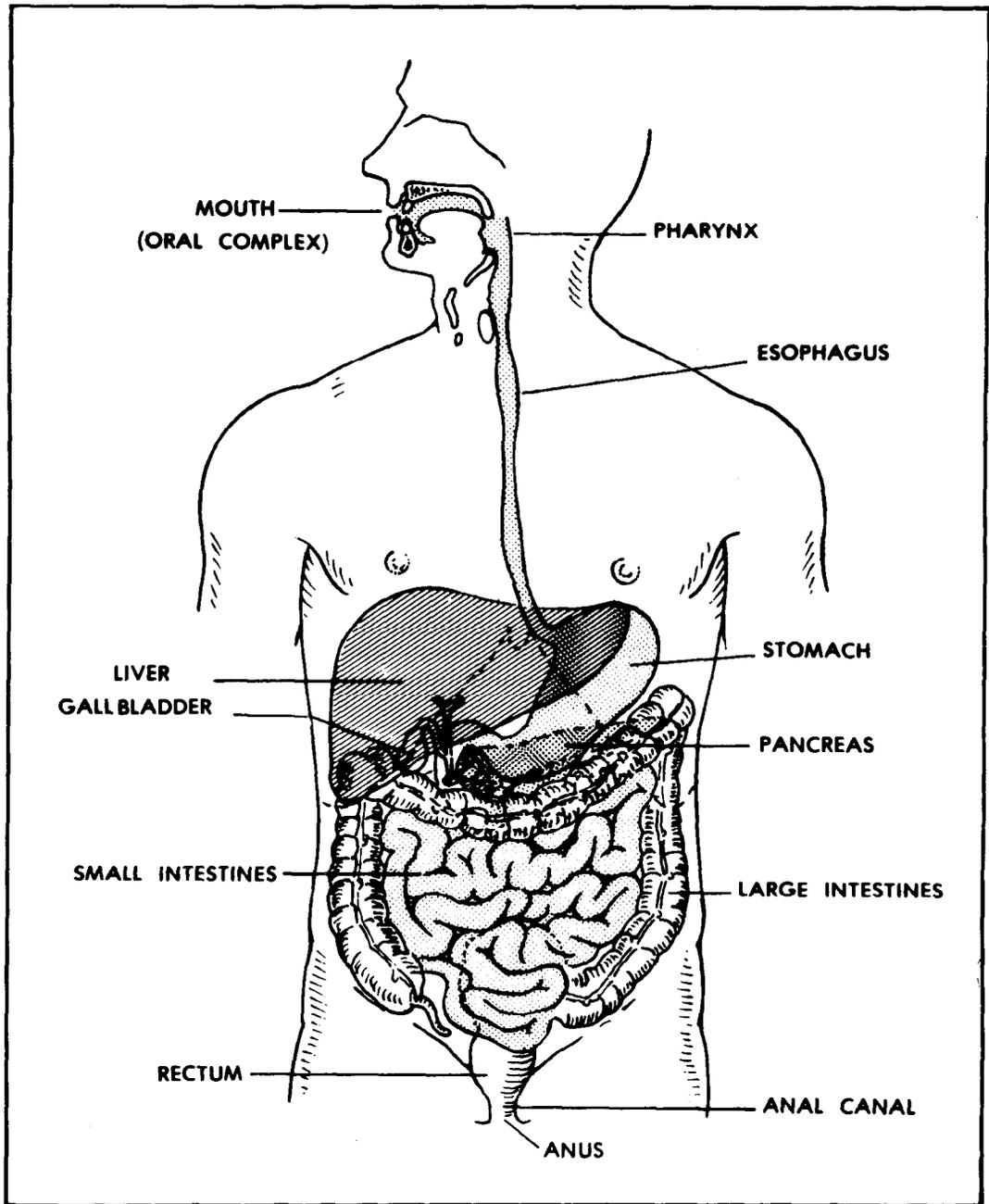


Figure 8-1. The digestive system.

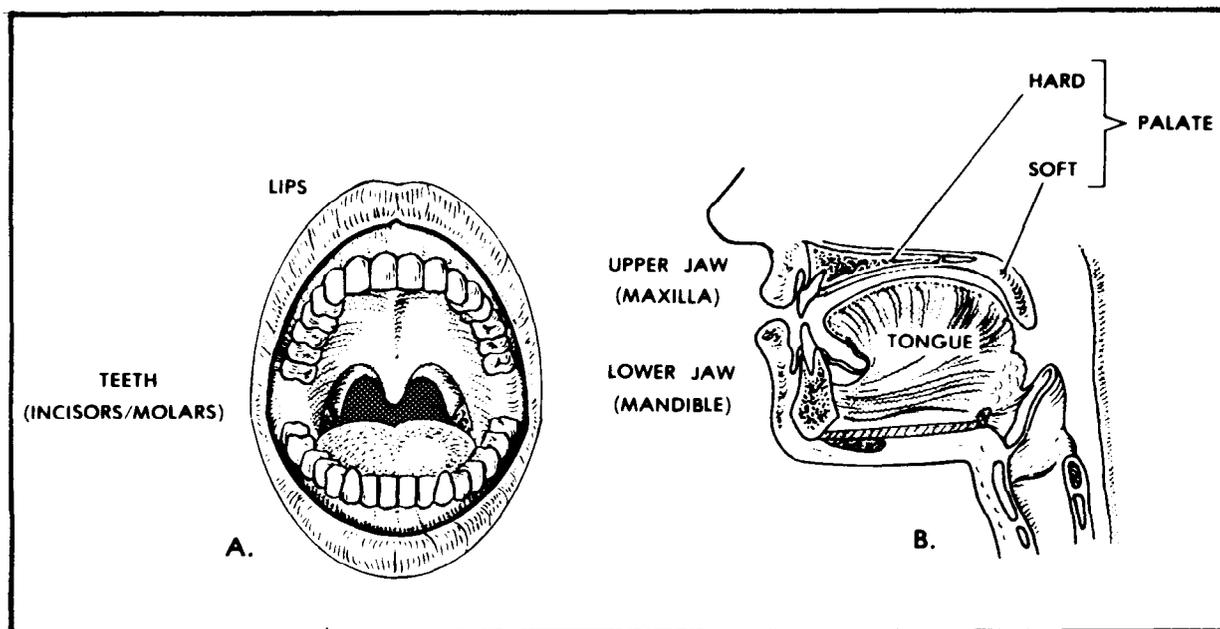


Figure 8-2. Anatomy of the oral cavity.

c. Teeth.

(1) A tooth (Figure 8-3) has two main parts: the crown and the root. A root canal passes up through the central part of the tooth. The root is suspended within a socket (called the alveolus) of one of the jaws of the mouth. The crown extends up above the surface of the jaw. The root and inner part of the crown are made of a substance called dentin. The outer portion of the crown is covered with a substance known as enamel. Enamel is the hardest substance of the body. The nerves and blood vessels of the tooth pass up into the root canal from the jaw substance.

(2) There are two kinds of teeth: anterior and posterior. The anterior teeth are also known as incisors and canine teeth and serve as choppers. They chop off mouth-sized bites of food items. The posterior teeth are called molars and are grinders. They increase the surface area of food materials by breaking them into smaller and smaller particles.

(3) There are two sets of teeth: deciduous and permanent. Initially, the deciduous set includes 20 baby teeth. These are eventually replaced by a permanent set of 32 teeth.

d. Palate. The palate serves as the roof of the mouth and the floor of the nasal chamber above. Since the anterior two-thirds is bony, it is called the hard palate. The posterior one-third is musculomembranous and is called the soft palate. The soft palate serves as a trap door to close off the upper respiratory passageway during swallowing.

e. *Tongue.* The tongue is a muscular organ that is capable of internal movement to shape its body. The tongue is moved as a whole by muscles outside of it. Interaction between the tongue and the cheeks keeps food between the molar teeth during the chewing process. When the food is properly processed, the tongue also initiates the swallowing process.

f. *Taste Buds.* Associated with the tongue and the back of the mouth are special clumps of cells known as taste buds. These taste buds literally taste the food; that is, they check its quality and acceptability.

g. *Salivary Glands.* Digestion is the process that converts food into chemical substances that can be absorbed and assimilated by the body. The chewing process greatly increases the surface area available. The surfaces are wetted by saliva produced by the salivary glands in the oral complex.

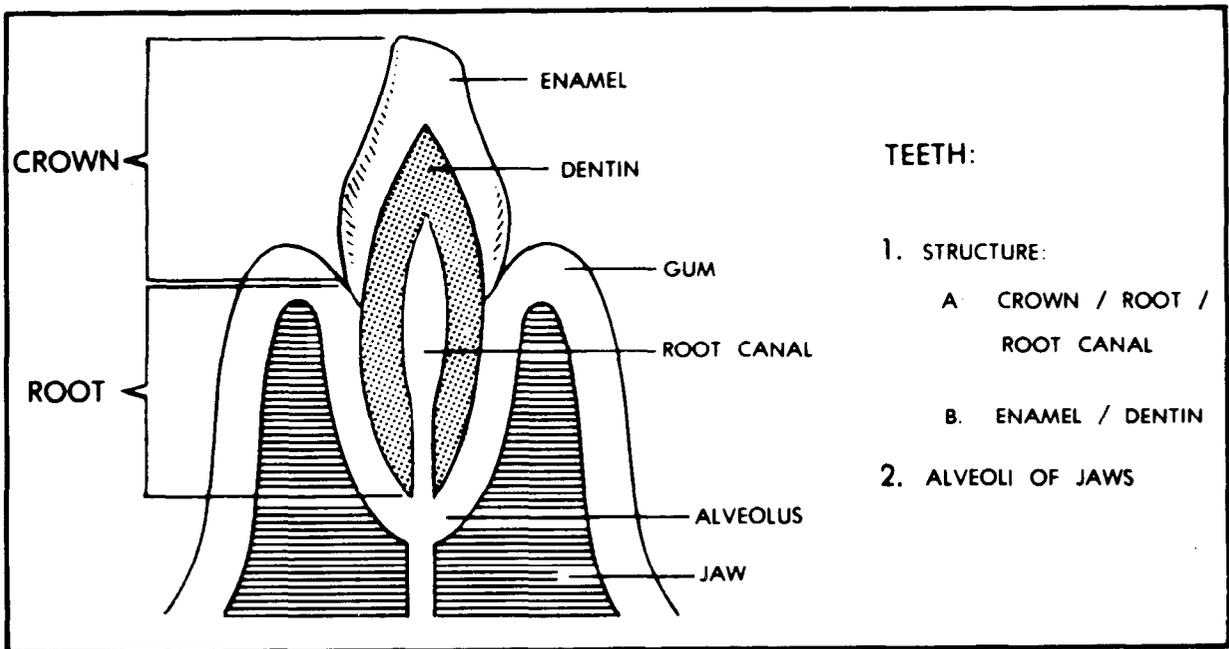


Figure 8-3. Section of a tooth and jaw.

8-4. Pharynx

The pharynx is a continuation of the back of the mouth region, just in front of the vertebral column (spine). It is a common passageway for both the respiratory and digestive systems.

8-5. Esophagus

The esophagus is a tube with muscular walls. It extends from the pharynx, down through the neck and the thorax (chest), to the stomach. During swallowing, the esophagus serves as a passageway for the food from the pharynx to the stomach.

8-6. Stomach

a. The stomach is a sac-like enlargement of the digestive tract specialized for the storage of food. The presence of valves at each end prevents the stored food from leaving the stomach before it is ready. The pyloric valve prevents the food from going further. The inner lining of the stomach is in folds to allow expansion.

b. While the food is in the stomach, the digestive processes are initiated by juices from the wall of the stomach. The musculature of the walls thoroughly mixes the food and juices while the food is being held in the stomach. The stomach has an extra layer of muscle fibers for this purpose.

c. When the pyloric valve of the stomach opens, a portion of the stomach contents moves into the small intestine.

8-7. Small Intestine and Associated Glands

The chemical process of digestion is facilitated by special chemicals called digestive enzymes. The end products of digestion are absorbed through the wall of the intestine into the blood vessels. These end products are then distributed to body parts that need them for growth, repair, or energy. There are associated glands—the liver and the pancreas—which produce additional enzymes to further the process. Most digestion and absorption takes place in the small intestine.

a. *Anatomy of the Small Intestine.*

(1) The small intestine is divided into three areas: the duodenum, jejunum and ileum. The duodenum is C-shaped, about 10 inches (25.40 cm) long in the adult. It is looped around the pancreas. The jejunum is approximately 8 feet (2.4 m) long and connects the duodenum and the ileum. The ileum is about 12 feet (3.6 m) long. The jejunum and the ileum are attached to the posterior wall of the abdomen with a membrane called the mesentery. This membrane allows mobility and serves as a passageway for nerves and vessels to the small intestine.

(2) The small intestine is tubular. It has muscular walls that produce a wave-like motion (called peristalsis) which moves the contents along. The small intestine is just the right length to allow the processes of digestion and absorption to take place completely.

(3) The inner surface of the small intestine is NOT smooth; it has folds known as plicae. On the surface of these plicae are fingerlike projections called villi. These folds and the presence of villi increase the surface area available for absorption.

b. *Liver.* The liver is a large and complex organ. Most of its mass is on the right side of the body and within the lower portion of the rib cage. Its upper surface is in contact with the diaphragm. The liver is a complex chemical factory with many functions. These include aspects of carbohydrate, protein, lipid, and vitamin metabolism and processes related to blood clotting and red blood cell destruction. Its digestive function is to produce a fluid called bile or gall.

c. *Gallbladder.* Until needed, the bile is stored and concentrated in the gallbladder, a sac on the inferior surface of the liver. Fluid from the gallbladder flows through the cystic duct, which joins the common hepatic duct from the liver to form the common bile duct. The common bile duct then usually joins with the duct of the pancreas as the fluid enters the duodenum.

d. *Pancreas.* The pancreas is a soft, pliable organ stretched across the posterior wall of the abdomen. When needed, it secretes its powerful digestive fluid, known as pancreatic juice, into the duodenum. The pancreatic duct joins the common bile duct.

8-8. Large Intestine

a. The primary function of the large intestine is salvaging water and electrolytes (salts). (Most of the end products of digestion have already been absorbed in the small intestine by the time they reach the large intestine.) Within the large intestine, the contents are first a watery fluid. Thus, the large intestine is important in the conservation of water for use by the body. The large intestine removes water until a nearly solid mass is formed before defecation (the evacuation of feces). Vitamin K, which is very important in blood clotting, is produced by microorganisms located in the large intestine. Antibiotics potentially may decrease production of vitamin K, but this is rarely of any practical significance.

b. The major subdivisions of the large intestine are the cecum (with the vermiform or "worm-shaped" appendix), ascending colon, transverse colon, descending colon, and sigmoid colon. The colon extends along the right side of the abdomen from the cecum up to the region of the liver (ascending colon). There the colon bends (hepatic flexure) and continues across the upper portion of the abdomen (transverse colon) to the spleen. The colon bends again (splenic flexure) and goes down the left side of the abdomen (descending colon). The last portion makes an S curve (sigmoid colon) toward the center and posterior of the abdomen and ends in the rectum of the pelvic cavity. The fecal mass is stored in the sigmoid colon until it is passed into the rectum.

8-9. Rectum, Anal Canal, and Anus

The rectum is a tubular structure about 6 inches (15.24 cm) long and follows the curve of the sacrum and coccyx until it bends back into the short anal canal. The anal canal is the last 1 1/2 inches (3.81 cm) beyond the rectum. It has an external opening (anus) to the exterior at the lower end of the digestive system. The anus is kept closed by strong sphincter muscles. By the action of peristalsis, the rectum receives feces and periodically expels this material through the anus. This elimination of waste is called defecation.

8-10. Time Required for Digestion

The time required for digestion varies greatly depending (among other things) on the type of meal consumed. In general, though, within a few minutes after a meal reaches the stomach, it begins to pass through the lower valve of the stomach. After the first hour the stomach is half empty, and at the end of the sixth hour none of the meal is present in the stomach. The meal goes through the small intestine, and the first part of it reaches the cecum in 20 minutes to 2 hours. At the end of the sixth hour, most of it should have passed into the

colon; in 12 hours all should be in the colon. Within 24 hours from the time food is eaten, the meal should reach the rectum. However, part of a meal may be defecated (eliminated) at one time and the rest at another time.

8-11. Special Protective Mechanisms

a. The digestive system is essentially a continuous tube open at both ends. Therefore, the cavity connects directly with the surrounding environment. Along with the ingested food, toxic materials, microorganisms, and even foreign bodies can pass through the mouth into the digestive system.

b. Within the body, there are many substances that aid in protection from bacteria, viruses, and other foreign substances. These structures include cells that can phagocytize (engulf) foreign particles or manufacture antibodies (which help to inactivate foreign substances). Collectively, such cells make up the reticuloendothelial system (RES). Such cells are found in bone marrow, the spleen, the liver, and the lymph nodes.

c. Lymphoid structures make up the largest part of the reticuloendothelial system. Lymphoid structures are collections of cells associated with the circulatory system.

(1) Tonsils are masses of lymphoid tissue. Tonsils are found in the region of the pharynx. Three pairs of tonsils (lingual, pharyngeal, and faucial) are found at the beginning of the pharynx. Together they form a ring of lymphoid tissue. This ring, called Waldeyer's ring, completely surrounds the entrance to the pharynx from both the mouth (digestive entrance) and the nose and nasal chambers (respiratory entrance).

(a) In the upper recess of the pharynx is the pair of pharyngeal tonsils (commonly known as adenoids).

(b) On either side, below the soft palate, are the palatine (faucial) tonsils. These are the tonsils that one sees most frequently in small children.

(c) On the back of the root of the tongue are the lingual tonsils.

(2) Lymphoid aggregates of varying sizes are found in the walls of the small intestine. In the ileum portion, in particular, these aggregates are large enough to be observed and are called Peyer's patches. These might be considered "tonsils" of the small intestine.

(3) At the beginning of the large intestine, at the inferior end of the cecum, is a structure known as the vermiform appendix. Since the vermiform appendix is actually a collection of lymphoid tissue, it should be considered the "tonsil" of the large intestine.

CHAPTER 9

THE UROGENITAL SYSTEM**9-1. General**

The urinary and genital systems are discussed together because their various organs and passages develop from the same embryologic beginnings, and they share many structures. The urinary system is made up of the organs which control the discharge of certain waste materials filtered from the blood. The genital system controls the reproductive processes from which life is created.

9-2. The Urinary System

The major parts of the urinary system include two kidneys, two ureters (one connecting each kidney to the urinary bladder), the urinary bladder, and the urethra (Figure 9-1). The urinary system helps the body maintain its delicate balance of water and various chemicals in the proportions needed for good health. During the process of urine formation, waste products are removed from circulating blood for elimination, and useful products are returned to the blood.

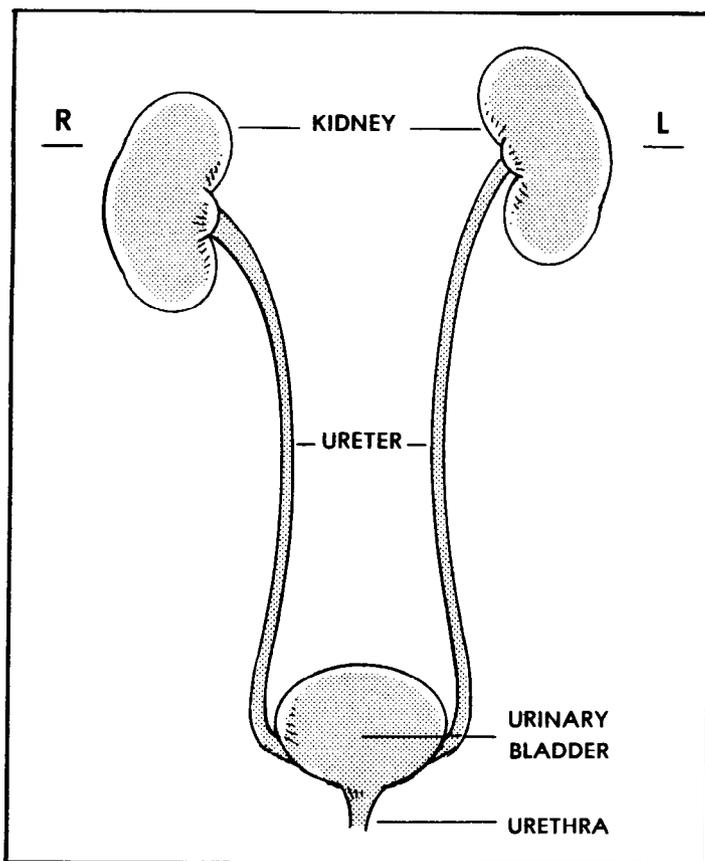


Figure 9-1. The urinary system.

9-3. Kidneys

a. The kidneys are a pair of reddish-brown organs lying against the posterior muscular wall of the abdominal cavity, near the level of the last thoracic vertebrae and the first lumbar vertebrae. The right kidney is usually slightly lower than the left. Each kidney is a bean-shaped organ 4 to 5 inches (10.2 to 12.7 cm) long.

b. The kidney (Figure 9-2) is composed of an outer shell (or cortex) and an inner layer (the medulla). The cortex is made of firm, reddish-brown tissue containing millions of microscopic filtration plants called nephrons. Nephrons are urine-forming units that receive and filter all of the body's blood approximately once every 12 minutes. During this period, they draw off and filter the liquid portion of the blood, remove liquid wastes (urine), and return the usable portion to the circulatory system to maintain the body's fluid balance.

c. Nephrons are complex structures which perform every aspect of urine formation. Each nephron has a capsule (Bowman's capsule) containing a cluster of filtering capillaries called glomerulus. Leading from the capsule is a continuous looped tubule. The water, salts, waste products, and usable products pass from the capsule to the tubules; usable products and water are then reabsorbed. The final waste product (urine) drains from the last loop of the tubule. The glomerulus, the capsule, and the loops of the tubule together form a nephron. Each part is essential for the coordination, filtration, reabsorption, and excretion processes.

d. Channels called collecting tubules form larger tubes and deliver the urine to the pelvis of the kidney.

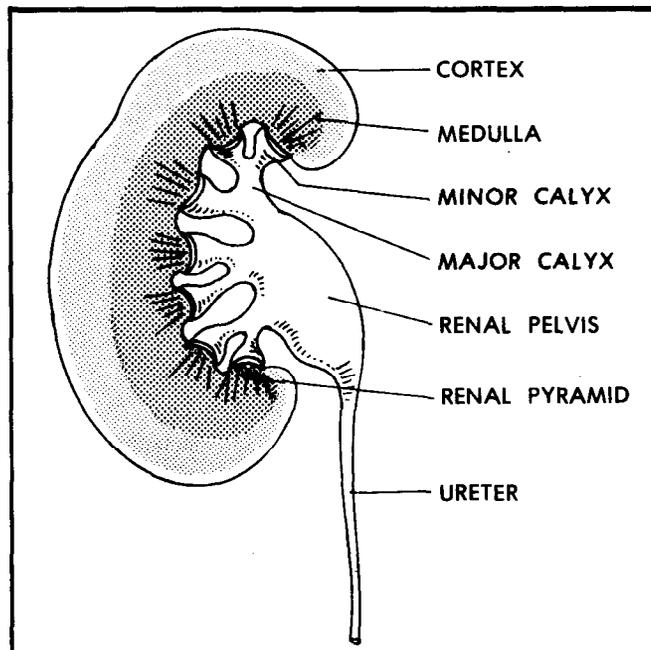


Figure 9-2. Cross section of kidney.

9-4. Ureters

The pelvis of each kidney is drained by a ureter, a muscular tube extending from the kidney to the posterior portion of the urinary bladder. Ureters are smooth muscle structures, and urine is passed through each ureter by peristalsis into the bladder. Ureters are about 15 to 18 inches (38 to 45.7 cm) in length and about 1/5 inch (.5 cm) in diameter.

9-5. Urinary Bladder

The urinary bladder is a muscle sac formed of smooth muscle with a specialized lining membrane. It is located in the lowest part of the abdominal cavity and its purpose is to store urine. Normally it holds 300 to 500 ml of urine. The bladder is emptied by contraction of muscles in its walls, which force urine out through the urethra.

9-6. Urethra

The urethra is the tube that carries urine from the urinary bladder to the external opening, the urinary meatus. In the male, the urethra varies in length. Including the portion within the body, it is about 6 to 7 1/2 inches (15 to 19 cm) long. It is divided into three areas: the prostatic, which passes through the prostate gland; the membranous area, beneath the prostate; and the penile area (anterior), which passes through the penis. The female urethra, about 1 1/2 inches (3.8 cm) long, extends from the bladder to the urinary meatus, which is located above the vaginal opening.

9-7. Urine

Normal urine is a transparent (clear) fluid varying in color from amber or pale yellow to a brownish hue. Freshly voided urine has a characteristic aromatic odor, while stale urine has a strong ammonia odor. The average quantity of urine excreted by a normal adult in 24 hours ranges from 1,500 to 2,000 ml, depending upon the fluid intake, amount of perspiration, and other factors. Urine contains protein wastes (urea), salts in solution, hormones, and pigments. (Normal urine should not contain blood, albumin, sugar, or pus cells.)

9-8. Urination

Urination (micturition) is the discharge or voiding of urine. It is accomplished by a contraction of the bladder and relaxation of the sphincters. In the adult, urination is largely an autonomic (involuntary) function, which can, however, be controlled voluntarily. Voluntary contraction of abdominal muscles can aid in urination.

9-9. The Genital System

The male and female genital (reproductive) systems have their own specialized internal and external organs, passageways, and supportive structures. The parts and functions of these systems are designed to make the process of fertilization possible. The female cell, the ovum, must be fertilized by the male cell, spermatozoa. The normal result of fertilization is reproduction.

9-10. The Male Reproductive System

The male reproductive system includes the scrotum, testicles, vas deferens (seminal duct), seminal vesicles, ejaculatory ducts, prostate gland, urethra, and penis. The penis, testicles, and scrotum are referred to as the external genitalia (see Figure 9-3).

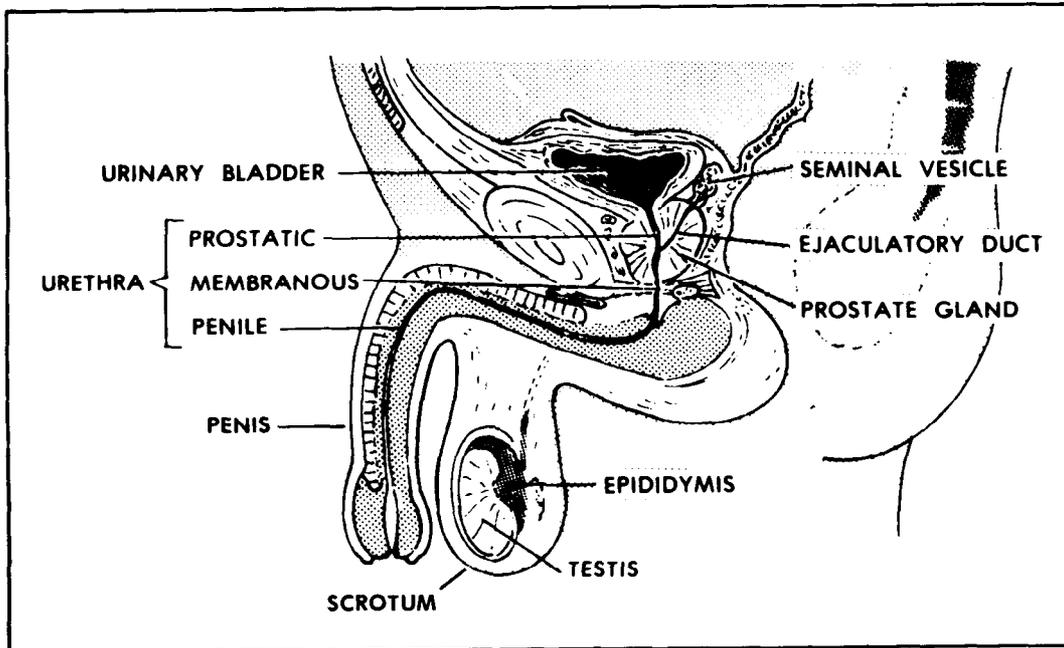


Figure 9-3. Male urogenital system.

a. The Scrotum, Testicles (Testes), and Epididymis. There are two testicles (testes), one on each side of the septum of the scrotum. A testicle (testis) is an oval-shaped gland, about 1 1/2 to 2 inches (3.8 to 5 cm) in length. Each testicle contains specialized cells that produce germ cells called spermatozoa (or sperm), and the male hormone, testosterone. The hormone is absorbed directly into the blood from the testicles. Sperm are produced in great numbers, starting at the age of puberty. Although microscopic in size, each sperm has a head, which contains a cell nucleus, and an elongated tail for movement. Sperm travels from the testicles to a tightly coiled tube, the epididymis. The vas deferens is a continuation of the epididymis.

b. The Vas Deferens. This duct carries sperm from the scrotum to the pelvic cavity. As the duct leaves the scrotum, it passes through the inguinal canal into the pelvic cavity as part of the spermatic cord. Spermatic cords, in the groin, are supporting structures. Each vas deferens curves around the bladder and delivers the sperm to one of two storage pouches, called the seminal vesicles.

c. The Seminal Vesicles and the Ejaculatory Ducts. The seminal vesicles are located behind the bladder. These vesicles constitute small storage sacs for sperm and seminal fluid. During the storage of sperm in these vesicles,

secretions are added to the sperm to keep them alive and motile. These secretions and the sperm form the seminal fluid (or semen). Ejaculatory ducts carry this seminal fluid from the seminal vesicles, through the prostate gland, and empty into the urethra.

d. The Prostate Gland. The prostate gland is a small gland that surrounds the urethra at the neck of the bladder. Prostatic secretions are added to the seminal fluid to protect it from urethral secretions and female vaginal secretions. During the act of intercourse, special mechanisms in the nervous system prevent the passage of urine into the urethra. Only seminal fluid, prostatic fluid, and sperm pass from the penis into the vagina during ejaculation. When the prostate gland becomes enlarged (hypertrophied), it can seriously constrict the urethra. The size and consistency of the prostate gland is determined by the physician by means of a rectal examination.

e. The Urethra and the Penis. The urethra, a passageway for seminal fluid and for urine, has its longest segment in the penis. Several glands add secretions to the urethra, the largest being two bulbo-urethral (or Cowper's) glands. The terminal opening of the urethra is in the glans penis, which is surrounded by a retractable fold of skin called the foreskin, or prepuce. Surgical removal of this foreskin is called a circumcision, which is performed to reduce the possibility of an abnormal constriction of the glans, called phimosis, or to reduce the possibility of irritation from secretions that accumulate under the foreskin. The penis has a special type of tissue called erectile tissue. When filled with blood, this special tissue causes the penis to distend into a state of erection. Thus, the penis becomes a rigid organ that can enter the vagina.

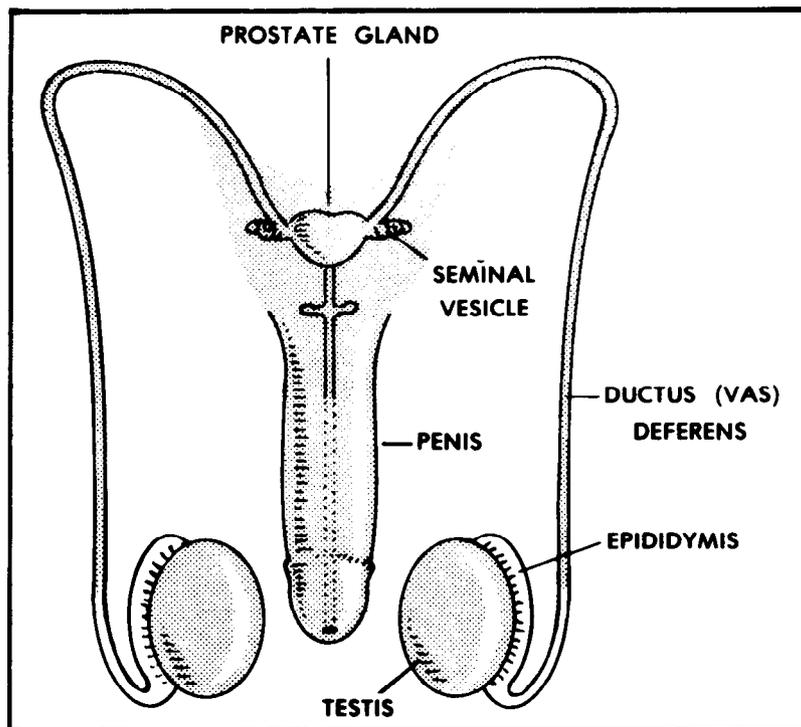


Figure 9-4. Diagram of the male reproductive system.

9-11. The Female Reproductive System

The female reproductive organs include the ovaries, fallopian tubes, uterus, vagina, and external genitalia (the vulva). The supportive structures for the internal reproductive organs are a complicated arrangement of pelvic ligaments, which are formed in part from folds of peritoneum that line the abdomino-pelvic cavity. A detailed discussion of the female reproductive system is contained in Section I, Chapter 15.

a. The Ovaries. These are two almond-shaped glands, one on either side of the abdomino-pelvic cavity. The ovaries, like the testicles, produce sex hormones (estrogen and progesterone) and specialized germ cells, ova, for reproduction. The female sex hormones are absorbed directly into the blood and aid in maintaining the normal menstrual cycle. A specialized cell, called an ovum, is expelled from the surface of an ovary in a process called ovulation, which occurs about halfway between each menstrual period. An expelled ovum is picked up by the free end of a fallopian tube for movement to the uterus.

b. Fallopian Tubes. The fallopian tubes are connected to the uterus and carry the ovum to the cavity of the uterus. There are two fallopian tubes (oviducts) each curving outward from the upper part of the uterus. Each tube is approximately 4 inches in length and has a free end which curves around, but is not attached to, an ovary. The fringed surface of the free end of the fallopian tube carries an expelled ovum into the tube, and the ovum moves slowly on its way to the uterus. If fertilization takes place, it normally occurs as the ovum moves through this tube. The male germ cell, the sperm, must therefore travel up the female reproductive tract in order to unite with the female germ cell, the ovum. Of the millions of sperm produced, only one must unite with one ovum for fertilization to occur.

c. The Uterus. The uterus, shaped somewhat like a pear, is suspended in the pelvic cavity, supported between the bladder and the rectum by its system of eight ligaments. The normal position of the body of the uterus is ante flexion (bent forward over the bladder) (Figure 9-5). The uterus is about 3 inches (7.6 cm) long and 3 inches (7.6 cm) thick at its widest part. It has a thick wall of smooth muscle and a relatively small inner cavity. During pregnancy, it can increase about 20 times in size. The upper dome-shaped portion of the uterus is the fundus, the main part is the body, and the lower neck portion is the cervix (Figure 9-6). The cervix is a canal that opens into the vagina. The inner lining of the uterus, the endometrium, undergoes periodic changes during the regular menstrual cycle, to make the uterus ready to receive a fertilized ovum. If the ovum is not fertilized, the endometrium gets a message from hormone influences and sheds its surface cells and built-up secretions. Some of the extra blood supply, the surface cells, and uterine secretions are eliminated as menstrual flow.

d. The Vagina. This muscular canal extends from the cervix portion of the uterus to the vaginal opening in the vestibule of the vulva. The vaginal canal is capable of stretching widely and serves as the birth canal. Part of the cervix protrudes into the uppermost portion of the vagina. An important part of a female pelvic examination is the physical examination of the visible surface of the cervix and vagina, plus a laboratory examination of cervical and vaginal secretions. A Pap (Papanicolaou) smear is made by obtaining these secretions for laboratory examination.

e. *The Vulva.* The several structures that make up the female external genitalia form the vulva. These are the mons pubis, the labia, the clitoris, and the vestibule. The labia, two parallel sets of liplike tissues, are the labia majora (the larger outer folds of tissue) and the labia minora (the small inner folds). The clitoris is located at the upper meeting point of the labia majora and the labia minora. Between the labia minora is the vestibule, a shallow depression into which the urethra and the vagina open. The urethral opening is above the vaginal opening. A series of glands which can become infected open into the vestibule, the largest being the Bartholin glands at the vaginal opening.

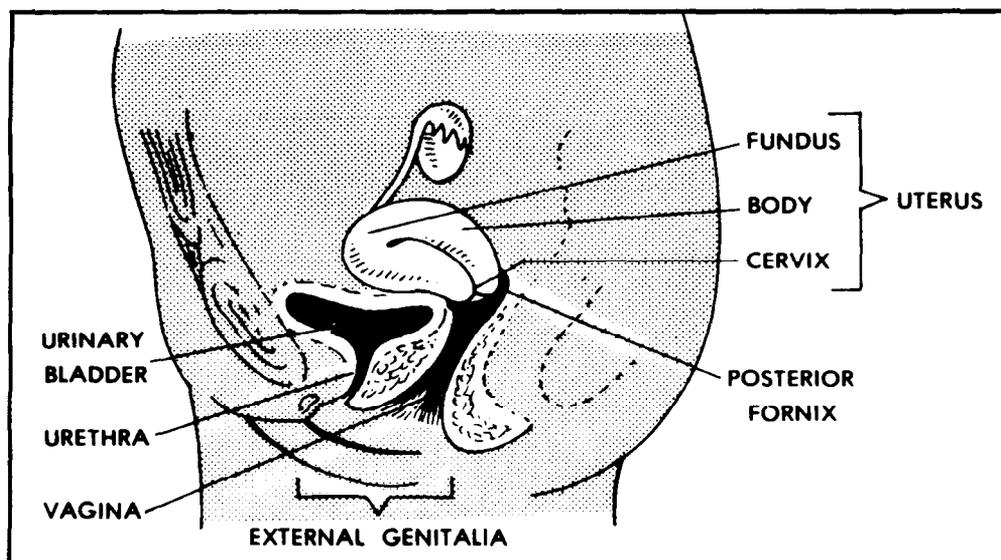


Figure 9-5. Female urogenital system.

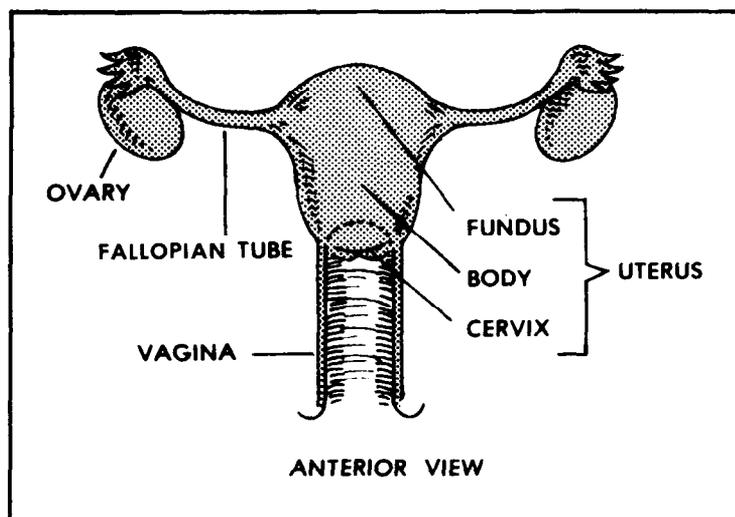


Figure 9-6. Female reproductive organs (frontal section).

9-12. Menstruation

a. The menstrual period is the end of the monthly female reproductive cycle. This process begins at puberty and is repeated, except when interrupted by disease or pregnancy, approximately every 28 days until a female passes through menopause at about 40 to 50 years of age.

b. Each month the endometrium (lining of the uterus) is stimulated by the female sex hormones to form a special bed. This bed (which is a very thin layer of cells and blood) is prepared so that if a sperm and an ovum unite, making a fertilized egg, the uterus will be able to receive it and provide a place for it to grow.

c. If the ovum is not fertilized, there will be a menstrual period. During this period, the uterus will shed its recently formed special lining. The lining, in the form of menstrual flow, will be expelled from the uterus through the vagina and out of the body. The flow will last about 5 days.

CHAPTER 10

THE ENDOCRINE SYSTEM**10-1. General**

The endocrine system is made up of glands of internal secretion (ductless glands) located in different parts of the body (Figure 10-1). Hormones produced by endocrine glands are secreted directly into the circulating blood and reach every part of the body. These hormones influence the activities of specific organs and tissues, as well as the activities of the body as a whole. Small in quantity, but powerful in action, hormones are part of the body's chemical coordinating and regulating system. There are six recognized endocrine glands:

- Pituitary body.
- Thyroid gland.
- Parathyroid gland.
- Pancreatic islets (islets of Langerhans).
- Suprarenal (adrenal) glands.
- Gonads (female—ovaries; male—testes).

10-2. The Pituitary Body

The pituitary body is a small and pea-shaped structure attached to the base of the brain in the region of the hypothalamus (Figure 10-1). It is housed within a hollow of the bony floor of the cranial cavity called the sella turcica (Turk's saddle). The pituitary body consists of two glands: the posterior pituitary gland and the anterior pituitary gland. These glands are initially separate but join together during development of the embryo.

a. Posterior Pituitary Gland. The posterior pituitary gland is the portion that comes from and retains a direct connection with the base of the brain. The hormones of the posterior pituitary gland are actually produced in the hypothalamus of the brain. From the hypothalamus, the hormones are delivered to the posterior pituitary gland where they are released into the bloodstream. There are two recognized hormones of the posterior pituitary gland:

(1) Antidiuretic hormone (ADH) is involved with the resorption or salvaging of water within the kidneys. This hormone is produced under thirst conditions.

(2) Oxytocin is involved with contractions of smooth muscle in the uterus and with milk secretion.

b. Anterior Pituitary Gland. The anterior pituitary gland originates from the roof of the embryo's mouth. It then "attaches" itself to the posterior pituitary gland. The anterior pituitary gland is indirectly connected to the hypothalamus by means of a venous portal system. Portals are the veins that carry substances from the capillaries of one point to the capillaries of another point. In the hypothalamus, certain chemicals known as releasing factors are produced. These are carried by the portal system to the anterior pituitary

gland where they stimulate the cells of that gland to secrete their specific hormones. The anterior pituitary gland produces many hormones. In general, these hormones stimulate the target organs to develop or produce their own products. This stimulating effect is referred to as trophic. Of the many hormones produced by the anterior pituitary gland, two are of particular importance:

(1) Somatotrophic hormone (growth hormone), whose target organs are the growing structures of the body. This hormone influences such structures to grow as the body matures.

(2) Adrenocorticotrophic hormone (ACTH), which stimulates the cortex of the suprarenal (adrenal) gland to produce its hormones. The hormones of the suprarenal cortex are involved with anti-inflammatory reactions of the body.

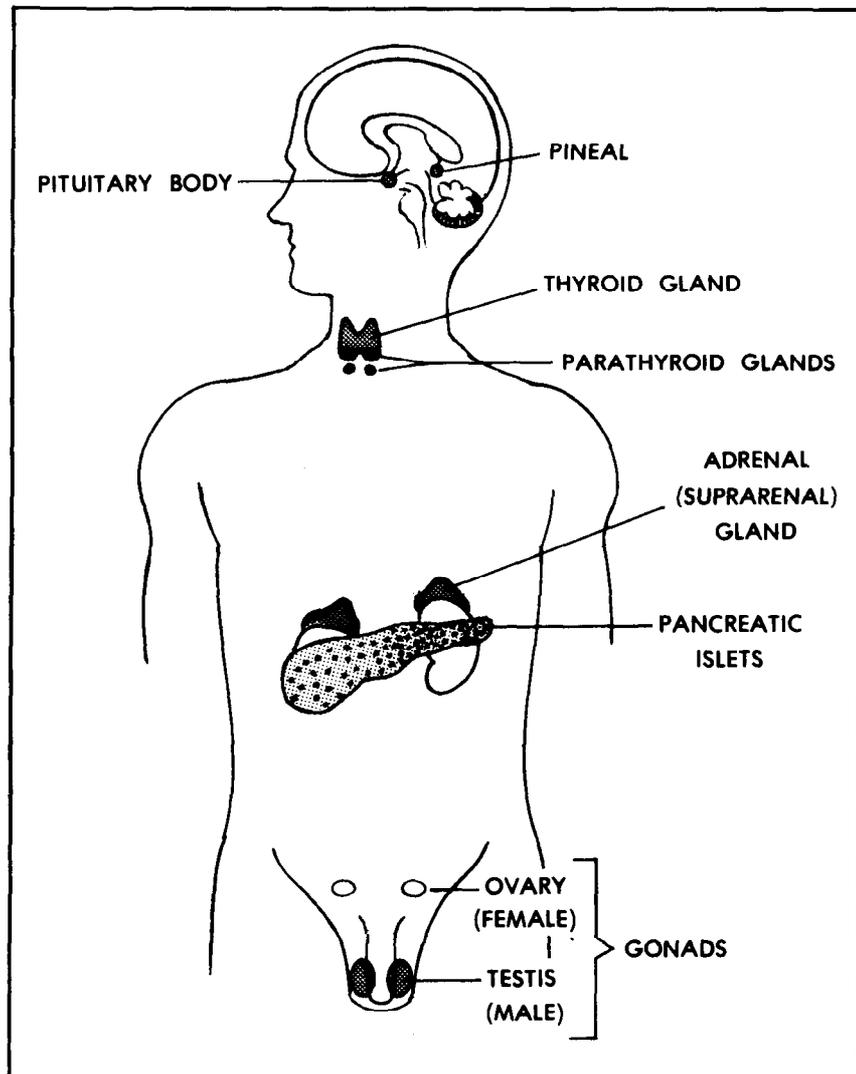


Figure 10-1. The endocrine glands and their locations.

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10-3. The Thyroid Gland

This gland is in the neck region just below the larynx and surrounds the trachea. The right and left thyroid lobes are the masses on either side of the trachea. The isthmus is found across the front of the trachea and connects the two lobes. Each lobe is supplied by arteries from above and below (superior and inferior thyroid arteries). The thyroid produces two hormones:

a. Thyroxin, which affects the basal metabolic rate (BMR), or level of activity of the body. Since iodine is a necessary element in the production of thyroxin, malformations of the thyroid gland (called goiters) can be observed where there is little or no iodine available.

b. Calcitonin, which is produced by the thyroid gland, is involved with calcium metabolism in the body.

10-4. The Parathyroid Glands

The parathyroid glands are two pairs of small, round tissue masses. These glands are located on the posterior aspects of both thyroid lobes. The hormone produced by these glands is called parathyroid hormone, or parathormone. It is involved with the body's calcium metabolism.

10-5. The Pancreatic Islets (Islets of Langerhans)

Within the pancreas are distributed small groups of cells known as islets. Although the pancreas is a ducted gland of the digestive system, these isolated islets are, in fact, ductless glands. Insulin and glucagon are the two most commonly recognized hormones of the islets. These hormones are involved with glucose metabolism.

10-6. The Suprarenal (Adrenal) Glands

Embedded in the fatty layer above each kidney is a suprarenal gland. Both suprarenal glands have an internal medulla and an external cortex.

a. Hormones of the Suprarenal Medulla. The medullary portion of each suprarenal gland produces a pair of hormones: epinephrine (adrenaline) and norepinephrine (noradrenaline). These hormones are involved in the mobilization of energy during stress reactions.

b. Hormones of the Suprarenal Cortex. Each suprarenal cortex produces a variety of hormones that can be grouped into three categories:

(1) Mineralocorticoids, which are involved with the electrolytes of the body.

(2) Glucocorticoids, which are involved with many metabolic functions and are anti-inflammatory in nature.

(3) Sex hormones.

10-7. The Gonads

The primary sex organs are known as gonads. The gonads produce sex cells (gametes) and sex hormones. These sex hormones are in addition to those produced by the suprarenal cortex (see paragraph 10-6b)

a. Female Sex Hormones. In the female, the ovaries produce two types of sex hormones during the menstrual cycle. During the first half of the cycle (days 1 to 14), the estrogens are produced. During the last half of the cycle (days 15 to 28), progesterone is produced. These hormones are involved with female sexuality and the preparation of female sex organs for reproduction.

b. Male Sex Hormones. In the male, certain cells of the testes produce the male sex hormones known as androgens (for example, testosterone). Androgens are involved with male sexuality.