

## **Chapter 13 - Cardiovascular System**

### **13.1 Introduction (Fig. 13.1)**

- A. The cardiovascular system consists of the heart, and vessels, arteries, capillaries and veins.
- B. A functional cardiovascular system is vital for supplying oxygen and nutrients to tissues and removing wastes from them.

### **13.2 Structure of the Heart (Figs. 13.2-13.3)**

- A. The heart is a hollow, cone-shaped, muscular pump within the thoracic cavity.
- B. Size and Location of the Heart
  - 1. The average adult heart is 14 cm long and 9 cm wide.
  - 2. The heart lies in the mediastinum under the sternum; its apex extends to the fifth intercostal space.
- C. Coverings of the Heart (Figs. 13.2-13.4)
  - 1. The pericardium encloses the heart.
  - 2. It is made of two layers: the outer, tough connective tissue fibrous pericardium surrounding a more delicate visceral pericardium (epicardium) that surrounds the heart.
  - 3. At the base of the heart, the visceral pericardium folds back to become the parietal pericardium that lines the fibrous pericardium.
  - 4. Between the parietal and visceral pericardia is a potential space (pericardial cavity) filled with serous fluid.
- D. Wall of the Heart (Fig. 13.4)
  - 1. The wall of the heart is composed of three distinct layers.
  - 2. The outermost layer, the epicardium, is made up of connective tissue and epithelium, and houses blood and lymph capillaries along with coronary arteries. It is the same as the visceral pericardium.
  - 3. The middle layer called myocardium consists of cardiac muscle and is the thickest layer of the heart wall.
  - 4. The inner endocardium is smooth and is made up of connective tissue and epithelium, and is continuous with the endothelium of major vessels joining the heart.
    - a. The endocardium contains the Purkinje fibers.
- E. Heart Chambers and Valves (Figs. 13.5-13.6; Table 13.1)
  - 1. The heart has four internal chambers: two atria on top and two ventricles below.
    - a. Atria receive blood returning to the heart and have thin walls and ear-like auricles projecting from their exterior.
    - b. The thick-muscled ventricles pump blood to the body.
  - 2. A septum divides the atrium and ventricle on each side. Each also has an atrioventricular (A-V) valve to ensure one way flow of blood.
    - a. The right A-V valve (tricuspid) and left A-V valve (bicuspid or mitral valve) have cusps to which chordae tendinae attach.
    - b. Chordae tendinae are, in turn, attached to papillary muscles in the inner heart wall that contract during ventricular contraction to prevent the backflow of blood through the A-V valves.
  - 3. The superior and inferior vena cavae and the coronary sinus bring blood from the body to the right atrium. This blood is low in oxygen and high in carbon dioxide.
  - 4. The blood then flows from the right atrium into the right ventricle. The right ventricle has a thinner wall than does the left ventricle because it must pump blood only as far as the lungs, compared to the left ventricle pumping to the entire body.
  - 5. At the base of the pulmonary trunk leading to the lungs is the pulmonary valve, which prevents a return flow of blood to the ventricle.

- 6. The left atrium receives blood from four pulmonary veins.
- 7. The left ventricle pumps blood into the entire body through the aorta, guarded by the aortic valve that prevents backflow of blood into the ventricle.
- F. Skeleton of the Heart (Fig. 13.6b)
  - 1. Rings of dense connective tissue surround the pulmonary trunk and aorta to provide attachments for the heart valves and fibers.
  - 2. These tough rings prevent dilating of tissue in this area.
- G. Path of Blood through the Heart (Fig. 13.7)
  - 1. Blood low in oxygen returns to the right atrium via the venae cavae and coronary sinus.
  - 2. The right atrium contracts, forcing blood through the tricuspid valve into the right ventricle.
  - 3. The right ventricle contracts, closing the tricuspid valve, and forcing blood through the pulmonary valve into the pulmonary trunk and arteries.
  - 4. The pulmonary arteries carry blood to the lungs where it can rid itself of excess carbon dioxide and pick up a new supply of oxygen.
  - 5. Freshly oxygenated blood is returned to the left atrium of the heart through the pulmonary veins.
  - 6. The left atrium contracts, forcing blood through the left bicuspid valve into the left ventricle.
  - 7. The left ventricle contracts, closing the bicuspid valve and forcing open the aortic valve as blood enters the aorta for distribution to the body.
- H. Blood Supply to the Heart (Figs. 13.8-13.9)
  - 1. The first branches off of the aorta, which carry freshly oxygenated blood, are the right and left coronary arteries that feed the heart muscle itself.
  - 2. Branches of the coronary arteries feed many capillaries of the myocardium.
  - 3. The heart muscle requires a continuous supply of freshly oxygenated blood, so smaller branches of arteries often have anastomoses as alternate pathways for blood, should one pathway become blocked.
  - 4. Cardiac veins drain blood from the heart muscle and carry it to the coronary sinus, which empties into the right atrium.

### 13.3 Heart Actions

- A. The cardiac cycle consists of the atria beating in unison (atrial systole) followed by the contraction of both ventricles, (ventricular systole) then the entire heart relaxes for a brief moment (diastole).
- B. Cardiac Cycle (Figs. 13.10)
  - 1. During the cardiac cycle, pressure within the heart chambers rises and falls with the contraction and relaxation of atria and ventricles.
  - 2. When the atria fill, pressure in the atria is greater than that of the ventricles, which forces the A-V valves open.
  - 3. Pressure inside atria rises further as they contract, forcing the remaining blood into the ventricles.
  - 4. When ventricles contract, pressure inside them increases sharply, causing A-V valves to close and the aortic and pulmonary valves to open.
    - a. As the ventricles contract, papillary muscles contract, pulling on chordae tendinae and preventing the backflow of blood through the A-V valves.
- C. Heart Sounds
  - 1. Heart sounds are due to vibrations in heart tissues as blood rapidly changes velocity within the heart.
  - 2. Heart sounds can be described as a "lubb-dupp" sound.
  - 3. The first sound (lubb) occurs as ventricles contract and A-V valves are closing.

4. The second sound (dupp) occurs as ventricles relax and aortic and pulmonary valves are closing.
- D. Cardiac Muscle Fibers
1. A mass of merging fibers that act as a unit is called a functional syncytium; one exists in the atria (atrial syncytium) and one in the ventricles (ventricular syncytium).
- E. Cardiac Conduction System (Figs. 13.11-13.13)
1. Specialized cardiac muscle tissue conducts impulses throughout the myocardium and comprises the cardiac conduction system.
  2. A self-exciting mass of specialized cardiac muscle called the sinoatrial node (S-A node or pacemaker), located on the posterior right atrium, generates the impulses for the heartbeat.
  3. Impulses spread next to the atrial syncytium, it contracts, and impulses travel to the junctional fibers leading to the atrioventricular node (A-V node) located in the septum.
    - a. Junctional fibers are small (thus they carry impulses slowly), allowing the atria to contract before the impulse spreads rapidly over the ventricles.
  4. Branches of the A-V bundle give rise to Purkinje fibers leading to papillary muscles; these fibers stimulate contraction of the papillary muscles at the same time the ventricles contract.
- F. Electrocardiogram (Figs. 13.14-13.15)
1. An electrocardiogram is a recording of the electrical changes that occur during a cardiac cycle.
  2. The first wave, the P wave, corresponds to the depolarization of the atria.
  3. The QRS complex corresponds to the depolarization of ventricles and hides the repolarization of atria.
  4. The T waves ends the ECG pattern and corresponds to ventricular repolarization.
- G. Regulation of the Cardiac Cycle (Fig. 13.16)
1. The amount of blood pumped at any one time must adjust to the current needs of the body (more is needed during strenuous exercise).
  2. The S-A node is innervated by branches of the sympathetic and parasympathetic divisions, so the CNS controls heart rate.
    - a. Sympathetic impulses speed up and parasympathetic impulses slow down heart rate.
  3. The cardiac control center of the medulla oblongata maintains a balance between the sympathetic and parasympathetic divisions of the nervous system in response to messages from baroreceptors that detect changes in blood pressure.
  4. Impulses from cerebrum or hypothalamus may also influence heart rate, as do body temperature and the concentrations of certain ions.

### 13.4 Blood Vessels (Table 13.2)

- A. The blood vessels (arteries, arterioles, capillaries, venules, and veins) form a closed tube that carries blood away from the heart, to the cells, and back again.
- B. Arteries and Arterioles (Figs. 13.17-13.18)
1. Arteries are strong, elastic vessels adapted for carrying high-pressure blood.
  2. Arteries become smaller as they divide and give rise to arterioles.
  3. The wall of an artery consists of an endothelium, tunica media (smooth muscle), and tunica externa (connective tissue).
  4. Arteries are capable of vasoconstriction as directed by the sympathetic impulses; when impulses are inhibited, vasodilation results.
- C. Capillaries (Figs. 13.18-13.20)
1. Capillaries are the smallest vessels, consisting only of a layer of endothelium

- through which substances are exchanged with tissue cells.
2. Capillary permeability varies from one tissue to the next, generally with more permeability in the liver, intestines, and certain glands, and less in muscle and considerably less in the brain (blood-brain barrier).
  3. The pattern of capillary density also varies from one body part to the next.
    - a. Areas with a great deal of metabolic activity (leg muscles, for example) have higher densities of capillaries.
  4. Precapillary sphincters can regulate the amount of blood entering a capillary bed and are controlled by oxygen concentration in the area.
    - a. If blood is needed elsewhere in the body, the capillary beds in less important areas are shut down.
  5. Exchanges in the Capillaries (Fig. 13.21)
    - a. Blood entering capillaries contains high concentrations of oxygen and nutrients that diffuse out of the capillary wall and into the tissues.
      - i. Plasma proteins remain in the blood due to their large size.
    - b. Hydrostatic pressure drives the passage of fluids and very small molecules out of the capillary at this point.
    - c. At the venule end, osmosis, due to the osmotic pressure of the blood, causes much of the tissue fluid to return to the bloodstream.
    - d. Lymphatic vessels collect excess tissue fluid and return it to circulation.
- D. Venules and Veins (Figs. 13.22-13.23)
1. Venules leading from capillaries merge to form veins that return blood to the heart.
  2. Veins have the same three layers as arteries have and have a flap-like valve inside to prevent backflow of blood.
    - a. Veins are thinner and less muscular than arteries; they do not carry high-pressure blood.
    - b. Veins also function as blood reservoirs.

### 13.5 Blood Pressure

- A. Blood pressure is the force of blood against the inner walls of blood vessels anywhere in the cardiovascular system, although the term "blood pressure" usually refers to arterial pressure.
- B. Arterial Blood Pressure (Fig. 13.24)
1. Arterial blood pressure rises and falls following a pattern established by the cardiac cycle.
    - a. During ventricular contraction, arterial pressure is at its highest (systolic pressure).
    - b. When ventricles are relaxing, arterial pressure is at its lowest (diastolic pressure).
  2. The surge of blood that occurs with ventricular contraction can be felt at certain points in the body as a pulse.
- C. Factors That Influence Arterial Blood Pressure (Fig. 13.25)
1. Arterial pressure depends on heart action, blood volume, resistance to flow, and blood viscosity.
  2. Heart Action
    - a. Heart action is dependent upon stroke volume and heart rate (together called cardiac output); if cardiac output increases, so does blood pressure.
  3. Blood Volume
    - a. Blood pressure is normally directly proportional to the volume of blood within the cardiovascular system.
    - b. Blood volume varies with age, body size, and gender.
  4. Peripheral Resistance
    - a. Friction between blood and the walls of blood vessels is a force called

- peripheral resistance.
- b. As peripheral resistance increases, such as during sympathetic constriction of blood vessels, blood pressure increases.
- 5. Blood Viscosity
  - a. The greater the viscosity (ease of flow) of blood, the greater its resistance to flowing, and the greater the blood pressure.
- D. Control of Blood Pressure (Fig . 13.26)
  - 1. Blood pressure is determined by cardiac output and peripheral resistance.
  - 2. The body maintains normal blood pressure by adjusting cardiac output and peripheral resistance.
  - 3. Cardiac output depends on stroke volume and heart rate, and a number of factors can affect these actions.
    - a. The volume of blood that enters the right atrium is normally equal to the volume leaving the left ventricle.
    - b. If arterial pressure increases, the cardiac center of the medulla oblongata sends parasympathetic impulses to slow heart rate.
    - c. If arterial pressure drops, the medulla oblongata sends sympathetic impulses to increase heart rate to adjust blood pressure.
    - d. Other factors, such as emotional upset, exercise, and a rise in temperature can result in increased cardiac output and increased blood pressure.
  - 4. The vasomotor center of the medulla oblongata can adjust the sympathetic impulses to smooth muscles in arteriole walls, adjusting blood pressure.
    - a. Certain chemicals, such as carbon dioxide, oxygen, and hydrogen ions, can also affect peripheral resistance.
- E. Venous Blood Flow (Figs. 13.23-13.24)
  - 1. Blood flow through the venous system is only partially the result of heart action and instead also depends on skeletal muscle contraction, breathing movements, and vasoconstriction of veins.
    - a. Contractions of skeletal muscle squeeze blood back up veins one valve at a time.
    - b. Differences in thoracic and abdominal pressures draw blood back up the veins.

### 13.6 Paths of Circulation

- A. The body's blood vessels can be divided into a pulmonary circuit, including vessels carrying blood to the lungs and back, and a systemic circuit made up of vessels carrying blood from the heart to the rest of the body and back.
- B. Pulmonary Circuit (Fig. 13.5)
  - 1. The pulmonary circuit is made up of vessels that convey blood from the right ventricle to the pulmonary arteries to the lungs, alveolar capillaries, and pulmonary veins leading from the lungs to the left atrium.
- C. Systemic Circuit
  - 1. The systemic circuit includes the aorta and its branches leading to all body tissues as well as the system of veins returning blood to the right atrium.

### 13.7 Arterial System (Fig. 13.27)

- A. The aorta is the body's largest artery.
- B. Principal Branches of the Aorta (Fig. 13.8, Table 13.3)
  - 1. The branches of the ascending aorta are the right and left coronary arteries that lead to heart muscle.
  - 2. Principal branches of the aortic arch include the brachiocephalic, left common carotid, and left subclavian arteries.
  - 3. The descending aorta (thoracic aorta) gives rise to many small arteries to the thoracic wall and thoracic viscera.
  - 4. The abdominal aorta gives off the following branches: celiac, superior mesenteric,

- suprarenal, renal, gonadal, inferior mesenteric, and common iliac arteries.
- C. Arteries to the Neck, Head, and Brain (Figs. 13.28-29, Table 13.4)
    - 1. Arteries to the head, neck, and brain include branches of the subclavian and common carotid arteries.
    - 2. The vertebral arteries supply the vertebrae and their associated ligaments and muscles.
    - 3. In the cranial cavity, the vertebral arteries unite to form a basilar artery that ends as two posterior cerebral arteries.
    - 4. The posterior cerebral arteries help form the circle of Willis, which provides alternate pathways through which blood can reach the brain.
    - 5. The right and left common carotid arteries diverge into the external carotid and internal carotid arteries.
    - 6. Near the base of the internal carotid arteries are the carotid sinuses that contain baroreceptors to monitor blood pressure.
  - D. Arteries to the Shoulder and Upper Limb (Fig. 13.30)
    - 1. The subclavian artery continues into the arm where it becomes the axillary artery.
    - 2. In the shoulder region, the axial artery becomes the brachial artery that, in turn, gives rise to the ulnar and radial arteries.
  - E. Arteries to the Thoracic and Abdominal Walls
    - 1. Branches of the thoracic aorta and subclavian artery supply the thoracic wall with blood.
    - 2. Branches of the abdominal aorta, as well as other arteries, supply the abdominal wall with blood.
  - F. Arteries to the Pelvis and Lower Limb (Fig. 13.31)
    - 1. At the pelvic brim, the abdominal aorta divides to form the common iliac arteries that supply the pelvic organs, gluteal area, and lower limbs.
    - 2. The common iliac arteries divide into internal and external iliac arteries.
      - a. Internal iliac arteries supply blood to pelvic muscles and visceral structures.
      - b. External iliac arteries lead into the legs, where they become femoral, popliteal, anterior tibial, and posterior tibial arteries.

### 13.8 Venous System

- A. Veins return blood to the heart after the exchange of substances has occurred in the tissues.
- B. Characteristics of Venous Pathways
  - 1. Larger veins parallel the courses of arteries and are named accordingly; smaller veins take irregular pathways and are unnamed.
  - 2. Veins from the head and upper torso drain into the superior vena cava.
  - 3. Veins from the lower body drain into the inferior vena cava.
  - 4. The vena cavae merge to join the right atrium.
- C. Veins from the Brain, Head, and Neck (Fig. 13.32)
  - 1. The jugular veins drain the head and unite with the subclavian veins to form the brachiocephalic veins.
- D. Veins from the Upper Limb and Shoulder (Fig. 13.33)
  - 1. The upper limb is drained by superficial and deep veins.
  - 2. The basilic and cephalic veins are major superficial veins.
  - 3. The major deep veins include the radial, ulnar, brachial, and axillary veins.
- E. Veins from the Abdominal and Thoracic Walls
  - 1. Tributaries of the brachiocephalic and azygous veins drain the abdominal and thoracic walls.
- F. Veins from the Abdominal Viscera (Figs. 13.34)
  - 1. Blood draining from the intestines enters the hepatic portal system and flows to the liver first rather than into general circulation.

2. The liver can process the nutrients absorbed during digestion as well as remove bacteria.
  3. Hepatic veins drain the liver, gastric veins drain the stomach, superior mesenteric veins lead from the small intestine and colon, the splenic vein leaves the spleen and pancreas, and the inferior mesenteric vein carries blood from the lower intestinal area.
- G. Veins from the Lower Limb and Pelvis (Fig. 13.35)
1. Deep and superficial veins drain the leg and pelvis.
  2. The deep veins include the anterior and posterior tibial veins, which unite into the popliteal vein and femoral vein; superficial veins include the small and great saphenous veins.
  3. These veins all merge to empty into the common iliac veins.