

# Unit II: The Cardiovascular System

## I. The Cardiovascular System

### A. A closed system of the heart and blood vessels

1. The heart pumps blood
2. Blood vessels allow blood to circulate to all parts of the body

### B. The function of the cardiovascular system is to deliver oxygen and nutrients and to remove carbon dioxide and other waste products

## II. The Heart

### A. Location

1. Thorax between the lungs in the inferior mediastinum

### B. Orientation

1. Pointed apex directed toward left hip
2. Base points toward right shoulder

### C. About the size of your fist

### D. The Heart: Coverings

#### 1. Pericardium—a double-walled sac

##### a. Fibrous pericardium is loose and superficial

##### b. Serous membrane is deep to the fibrous pericardium and composed of two layers

###### (1) Visceral pericardium

###### (a) Next to heart; also known as the epicardium

###### (2) Parietal pericardium

###### (a) Outside layer that lines the inner surface of the fibrous pericardium

###### (3) Serous fluid fills the space between the layers of pericardium

### E. The Heart: Heart Wall

#### 1. Three layers

##### a. Epicardium

###### (1) Outside layer

###### (2) This layer is the visceral pericardium

###### (3) Connective tissue layer

##### b. Myocardium

- (1) Middle layer
    - (2) Mostly *cardiac muscle*
  - c. Endocardium
    - (1) Inner layer
    - (2) Endothelium
- F. The Heart: Chambers
  - 1. Right and left side act as separate pumps
  - 2. Four chambers
    - a. Atria
      - (1) Receiving chambers
        - (a) Right atrium
        - (b) Left atrium
    - b. Ventricles
      - (1) Discharging chambers
        - (a) Right ventricle
        - (b) Left ventricle
- g. The Heart: Septa
  - 1. Interventricular septum
    - a. Separates the two ventricles
  - 2. Interatrial septum
    - a. Separates the two atria
- h. The Heart: Valves
  - 1. Allow blood to flow in only one direction to prevent backflow
  - 2. Four valves
    - a. Atrioventricular (AV) valves—between atria and ventricles
      - (1) Bicuspid (mitral) valve (left side of heart)
      - (2) Tricuspid valve (right side of heart)
      - (3) Anchored in place by chordae tendineae (“heart strings”)
      - (4) Open during heart relaxation and closed during ventricular contraction
    - b. Semilunar valves—between ventricle and artery
      - (1) Pulmonary semilunar valve
      - (2) Aortic semilunar valve
      - (3) Closed during heart relaxation but open during ventricular contraction

(4) Notice these valves operate opposite of one another to force a one-way path of blood through the heart

### I. Systemic and Pulmonary Circulations

#### 1. Systemic circulation

a. Blood flows from the left side of the heart through the body tissues and back to the right side of the heart

#### 2. Pulmonary circulation

a. Blood flows from the right side of the heart to the lungs and back to the left side of the heart

### III. The Heart: Associated Great Vessels

#### A. Arteries

##### 1. Aorta

a. Leaves left ventricle

##### 2. Pulmonary arteries

a. Leave right ventricle

#### B. Veins

##### 1. Superior and inferior venae cavae

a. Enter right atrium

##### 2. Pulmonary veins (four)

a. Enter left atrium

### IV. Blood Flow Through the Heart

A. Superior and inferior venae cavae dump blood into the right atrium

B. From right atrium, through the tricuspid valve, blood travels to the right ventricle

C. From the right ventricle, blood leaves the heart as it passes through the pulmonary semilunar valve into the pulmonary trunk

D. Pulmonary trunk splits into right and left pulmonary arteries that carry blood to the lungs

E. Oxygen is picked up and carbon dioxide is dropped off by blood in the lungs

F. Oxygen-rich blood returns to the heart through the four pulmonary veins

G. Blood enters the left atrium and travels through the bicuspid valve into the left ventricle

h. From the left ventricle, blood leaves the heart via the aortic semilunar valve and aorta

v. *Coronary Circulation*

A. Blood in the heart chambers does not nourish the myocardium

B. The heart has its own nourishing circulatory system consisting of

1. *Coronary arteries*—branch from the aorta to supply the heart muscle with oxygenated blood

2. *Cardiac veins*—drain the myocardium of blood

3. *Coronary sinus*—a large vein on the posterior of the heart, receives blood from cardiac veins

c. Blood empties into the right atrium via the coronary sinus

vi. *The Heart: Conduction System*

A. *Intrinsic conduction system (nodal system)*

1. Heart muscle cells contract, without nerve impulses, in a regular, continuous way

B. *Special tissue sets the pace*

1. *Sinoatrial node = SA node* (“pacemaker”), is in the right atrium

2. *Atrioventricular node = AV node*, is at the junction of the atria and ventricles

3. *Atrioventricular bundle = AV bundle* (bundle of His), is in the interventricular septum

4. *Bundle branches* are in the interventricular septum

5. *Purkinje fibers* spread within the ventricle wall muscles

vii. *Heart Contractions*

A. *Contraction is initiated by the sinoatrial node (SA node)*

B. *Sequential stimulation occurs at other autorhythmic cells*

C. *Force cardiac muscle depolarization in one direction— from atria to ventricles*

D. *Once SA node starts the heartbeat*

1. *Impulse spreads to the AV node*

2. *Then the atria contract*

E. *At the AV node, the impulse passes through the AV bundle, bundle branches, and Purkinje fibers*

- F. Blood is ejected from the ventricles to the aorta and pulmonary trunk as the ventricles contract
- G. Tachycardia—rapid heart rate over 100 beats per minute
- H. Bradycardia—slow heart rate less than 60 beats per minutes

#### VIII. The Heart: Cardiac Cycle

- A. Atria contract simultaneously
- B. Atria relax, then ventricles contract
- C. Systole = contraction
- D. Diastole = relaxation
- E. Cardiac cycle—events of one complete heart beat
  - 1. Mid-to-late diastole—blood flows from atria into ventricles
  - 2. Ventricular systole—blood pressure builds before ventricle contracts, pushing out blood
  - 3. Early diastole—atria finish refilling, ventricular pressure is low

#### IX. The Heart: Cardiac Output

- A. Cardiac output (*CO*)
  - 1. Amount of blood pumped by each side (ventricle) of the heart in one minute
- B. Stroke volume (*SV*)
  - 1. Volume of blood pumped by each ventricle in one contraction (each heartbeat)
  - 2. Usually remains relatively constant
  - 3. About 70 mL of blood is pumped out of the left ventricle with each heartbeat
- C. Heart rate (*HR*)
  - 1. Typically 75 beats per minute
- D.  $CO = HR \times SV$
- E.  $CO = HR (75 \text{ beats/min}) \times SV (70 \text{ mL/beat})$
- F.  $CO = 5250 \text{ mL/min}$
- G. Starling's law of the heart—the more the cardiac muscle is stretched, the stronger the contraction
- H. Changing heart rate is the most common way to change cardiac output

#### X. The Heart: Regulation of Heart Rate

- A. Increased heart rate
  - 1. Sympathetic nervous system

- a. Crisis
        - b. Low blood pressure
    - 2. Hormones
      - a. Epinephrine
      - b. Thyroxine
    - 3. Exercise
      - 4. Decreased blood volume
  - B. Decreased heart rate
    - 1. Parasympathetic nervous system
    - 2. High blood pressure or blood volume
    - 3. Decreased venous return
- XI. Blood Vessels: The Vascular System
  - A. Transport blood to the tissues and back
    - 1. Carry blood away from the heart
      - a. Arteries
      - b. Arterioles
    - 2. Exchanges between tissues and blood
      - a. Capillary beds
    - 3. Return blood toward the heart
      - a. Venules
      - b. Veins
  - B. Blood Vessels: Microscopic Anatomy
    - 1. Three layers (tunics)
      - a. Tunic intima
        - (1) Endothelium
      - b. Tunic media
        - (1) Smooth muscle
        - (2) Controlled by sympathetic nervous system
      - c. Tunic externa
        - (1) Mostly fibrous connective tissue
  - C. Differences Between Blood Vessels
    - 1. Walls of arteries are the thickest
    - 2. Lumens of veins are larger
    - 3. Larger veins have valves to prevent backflow
    - 4. Skeletal muscle "milks" blood in veins toward the heart
    - 5. Walls of capillaries are only one cell layer thick to allow for exchanges between blood and tissue

#### D. Movement of Blood Through Vessels

1. Most arterial blood is pumped by the heart
2. Veins use the milking action of muscles to help move blood

#### E. Capillary Beds

1. Capillary beds consist of two types of vessels
  - a. Vascular shunt—vessel directly connecting an arteriole to a venule
  - b. True capillaries—exchange vessels
    - (1) Oxygen and nutrients cross to cells
    - (2) Carbon dioxide and metabolic waste products cross into blood

#### F. Major Arteries of System Circulation

##### 1. Aorta

- a. Largest artery in the body
- b. Leaves from the left ventricle of the heart
- c. Regions
  - (1) Ascending aorta—leaves the left ventricle
  - (2) Aortic arch—arches to the left
  - (3) Thoracic aorta—travels downward through the thorax
  - (4) Abdominal aorta—passes through the diaphragm into the abdominopelvic cavity
  - (5) Arterial branches of the ascending aorta
    - (a) Right and left coronary arteries serve the heart

##### 2. Arterial branches of the aortic arch (BCS)

- a. Brachiocephalic trunk splits into the
  - (1) Right common carotid artery
  - (2) Right subclavian artery
- b. Left common carotid artery splits into the
  - (1) Left internal and external carotid arteries
- c. Left subclavian artery branches into the
  - (1) Vertebral artery
  - (2) In the axilla, the subclavian artery becomes the axillary artery  $\Rightarrow$  brachial artery  $\Rightarrow$  radial and ulnar arteries

##### 3. Arterial branches of the thoracic aorta

- a. Intercostal arteries supply the muscles of the thorax wall
- b. Other branches of the thoracic aorta supply the
  - (1) Lungs (bronchial arteries)
  - (2) Esophagus (esophageal arteries)
  - (3) Diaphragm (phrenic arteries)
- 4. Arterial branches of the abdominal aorta
  - a. Celiac trunk is the first branch of the abdominal aorta. Three branches are
    - (1) Left gastric artery (stomach)
    - (2) Splenic artery (spleen)
    - (3) Common hepatic artery (liver)
  - b. Superior mesenteric artery supplies most of the small intestine and first half of the large intestine
- 5. Arterial branches of the abdominal aorta
  - a. Left and right renal arteries (kidney)
  - b. Left and right gonadal arteries
    - (1) Ovarian arteries in females serve the ovaries
    - (2) Testicular arteries in males serve the testes
  - c. Lumbar arteries serve muscles of the abdomen and trunk
- 6. Arterial branches of the abdominal aorta
  - a. Inferior mesenteric artery serves the second half of the large intestine
  - b. Left and right common iliac arteries are the final branches of the aorta
    - (1) Internal iliac arteries serve the pelvic organs
    - (2) External iliac arteries enter the thigh  $\Rightarrow$  femoral artery  $\Rightarrow$  popliteal artery  $\Rightarrow$  anterior and posterior tibial arteries
- g. Major Veins of Systemic Circulation
  - 1. Superior and inferior vena cava enter the right atrium of the heart
    - a. Superior vena cava drains the head and arms
    - b. Inferior vena cava drains the lower body
  - 2. Veins draining into the superior vena cava
    - a. Radial and ulnar veins  $\Rightarrow$  brachial vein  $\Rightarrow$  axillary vein



- b. These veins drain the arms
  - c. Cephalic vein drains the lateral aspect of the arm and empties into the axillary vein
  - d. Basilic vein drains the medial aspect of the arm and empties into the brachial vein
  - e. Basilic and cephalic veins are joined at the median cubital vein (elbow area)
- f. Subclavian vein receives
  - (1) Venous blood from the arm via the axillary vein
  - (2) Venous blood from skin and muscles via external jugular vein
- g. Vertebral vein drains the posterior part of the head
  - h. Internal jugular vein drains the dural sinuses of the brain
- i. Left and right brachiocephalic veins receive venous blood from the
  - (1) Subclavian veins
  - (2) Vertebral veins
  - (3) Internal jugular veins
- j. Brachiocephalic veins join to form the superior vena cava ⇒ right atrium of heart
- k. Azygous vein drains the thorax
- 3. Veins draining into the inferior vena cava
  - a. Anterior and posterior tibial veins and fibial veins drain the legs
  - b. Posterior tibial vein ⇒ popliteal vein ⇒ femoral vein ⇒ external iliac vein
  - c. Great saphenous veins (longest veins of the body) receive superficial drainage of the legs
    - d. Each common iliac vein (left and right) is formed by the union of the internal and external iliac vein on its own side
    - e. Right gonadal vein drains the right ovary in females and right testicle in males
  - f. Left gonadal vein empties into the left renal vein
  - g. Left and right renal veins drain the kidneys
    - h. Hepatic portal vein drains the digestive organs and

travels through the liver before it enters systemic circulation

i. Left and right hepatic veins drain the liver

#### h. Arterial Supply of the Brain

1. Internal carotid arteries divide into

a. Anterior and middle cerebral arteries

b. These arteries supply most of the cerebrum

2. Vertebral arteries join once within the skull to form the basilar artery

a. Basilar artery serves the brain stem and cerebellum

3. Posterior cerebral arteries form from the division of the basilar artery

a. These arteries supply the posterior cerebrum

4. Circle of Willis

a. Anterior and posterior blood supplies are united by small communicating arterial branches

b. Result—complete circle of connecting blood vessels called cerebral arterial circle or circle of Willis

#### xii. Fetal Circulation

A. Fetus receives exchanges of gases, nutrients, and wastes through the placenta

B. Umbilical cord contains three vessels

1. Umbilical vein—carries blood rich in nutrients and oxygen to the fetus

2. Umbilical arteries (2)—carry carbon dioxide and debris-laden blood from fetus to placenta

c. Blood flow bypasses the liver through the ductus venosus and enters the inferior vena cava ⇒ right atrium of heart

d. Blood flow bypasses the lungs

1. Blood entering right atrium is shunted directly into the left atrium through the foramen ovale

2. Ductus arteriosus connects the aorta and pulmonary trunk (becomes ligamentum arteriosum at birth)

#### xiii. Hepatic Portal Circulation

A. Veins of hepatic portal circulation drain

1. Digestive organs

2. Spleen

3. Pancreas

- B. Hepatic portal vein carries this blood to the liver
- c. Liver helps maintain proper glucose, fat, and protein concentrations in blood
- D. Major vessels of hepatic portal circulation
  - 1. Inferior and superior mesenteric veins
  - 2. Splenic vein
  - 3. Left gastric vein

#### xiv. Pulse

- A. Pulse
  - 1. Pressure wave of blood
- B. Monitored at "pressure points" in arteries where pulse is easily palpated
  - c. Pulse averages 70-76 beats per minute at rest

#### xv. Blood Pressure

- A. Measurements by health professionals are made on the pressure in large arteries
  - 1. Systolic-pressure at the peak of ventricular contraction
  - 2. Diastolic-pressure when ventricles relax
  - 3. Write systolic pressure first and diastolic last (120/80 mm Hg)
- B. Pressure in blood vessels decreases as distance from the heart increases
- c. Blood Pressure: Effects of Factors
  - 1. BP is blood pressure
    - a. BP is affected by age, weight, time of day, exercise, body position, emotional state
  - 2. CO is the amount of blood pumped out of the left ventricle per minute
  - 3. PR is peripheral resistance, or the amount of friction blood encounters as it flows through vessels
    - a. Narrowing of blood vessels and increased blood volume increases PR
  - 4.  $BP = CO \times PR$
- D. Neural factors
  - 1. Autonomic nervous system adjustments (sympathetic division)
  - 2. Renal factors

- a. Regulation by altering blood volume
    - b. Renin-hormonal control
- E. Temperature
  - 1. Heat has a vasodilating effect
  - 2. Cold has a vasoconstricting effect
- F. Chemicals
  - 1. Various substances can cause increases or decreases
- G. Diet
- H. Variations in Blood Pressure
  - 1. Normal human range is variable
    - a. Normal
      - (1) 140-110 mm Hg systolic
      - (2) 80-75 mm Hg diastolic
  - 2. Hypotension
    - a. Low systolic (below 110 mm HG)
    - b. Often associated with illness
  - 3. Hypertension
    - a. High systolic (above 140 mm HG)
    - b. Can be dangerous if it is chronic
- xvi. Capillary Exchange
  - A. Substances exchanged due to concentration gradients
    - 1. Oxygen and nutrients leave the blood
    - 2. Carbon dioxide and other wastes leave the cells
  - B. Capillary Exchange: Mechanisms
    - 1. Direct diffusion across plasma membranes
    - 2. Endocytosis or exocytosis
    - 3. Some capillaries have gaps (intercellular clefts)
      - a. Plasma membrane not joined by tight junctions
    - 4. Fenestrations (pores) of some capillaries
  - C. Fluid Movements at Capillary Beds
    - 1. Blood pressure forces fluid and solutes out of capillaries
    - 2. Osmotic pressure draws fluid into capillaries
    - 3. Blood pressure is higher than osmotic pressure at the arterial end of the capillary bed
    - 4. Blood pressure is lower than osmotic pressure at the venous end of the capillary bed
- xvii. Developmental Aspects of the Cardiovascular System

- A. A simple "tube heart" develops in the embryo and pumps by the fourth week
- B. The heart becomes a four-chambered organ by the end of seven weeks
- C. Few structural changes occur after the seventh week
- D. Aging problems associated with the cardiovascular system include
  - 1. Venous valves weaken
  - 2. Varicose veins
  - 3. Progressive atherosclerosis
  - 4. Loss of elasticity of vessels leads to hypertension
  - 5. Coronary artery disease results from vessels filled with fatty, calcified deposits