The Cardiovascular System
- Heart anatomy and function
- A closed system of the heart and blood vessels
  - The heart pumps blood
  - Blood vessels allow blood to circulate to all parts of the body
  - The function of the cardiovascular system is to deliver oxygen and nutrients and to remove carbon dioxide and other waste products

The Heart
- Location
  - Thoracic between the lungs in the inferior mediastinum
- Orientation
  - Pointed apex directed toward left hip
  - Base points toward right shoulder
  - About the size of your fist

Figure 11.1a–b

Figure 11.1c
The Heart: Coverings

- Pericardium—a double-walled sac
  - Fibrous pericardium is loose and superficial
  - Serous membrane is deep to the fibrous pericardium and composed of two layers
    - Visceral pericardium
      - Next to heart, also known as the epicardium
    - Parietal pericardium
      - Outer layer that lines the inner surface of the fibrous pericardium
  - Serous fluid fills the space between the layers of pericardium

The Heart: Heart Wall

- Three layers
  - Epicardium
    - Outer layer
    - This layer is the visceral pericardium
    - Connective tissue layer
  - Myocardium
    - Middle layer
    - Mostly cardiac muscle
  - Endocardium
    - Inner layer
    - Endothelium
Slide 11: The Heart: Heart Wall

Slide 12: The Heart: Chambers
- Right and left side act as separate pumps
- Four chambers
  - Atria
    - Receiving chambers
    - Right atrium
    - Left atrium
  - Ventricles
    - Discharging chambers
    - Right ventricle
    - Left ventricle

Slide 13: The Heart: Chambers

Slide 14: Differences in Right and Left Ventricles

Slide 15: The Heart: Septa
- Interventricular septum
  - Separates the two ventricles
- Interatrial septum
  - Separates the two atria
The Heart: Chambers

Slide 17

The Heart: Valves

- Allow blood to flow in only one direction to prevent backflow
- Four valves
  - Atrioventricular (AV) valves—between atria and ventricles
    - Bicuspid (mitral) valve (left side of heart)
    - Tricuspid valve (right side of heart)
  - Semilunar valves—between ventricle and artery
    - Pulmonary semilunar valve
    - Aortic semilunar valve

Slide 18

The Heart: Valves

- AV valves
  - Anchored in place by chordae tendineae ("heart strings")
  - Open during heart relaxation and closed during ventricular contraction
- Semilunar valves
  - Closed during heart relaxation but open during ventricular contraction
  - Notice these valves operate opposite of one another to force a one-way path of blood through the heart

Slide 20

View of right A.V. valve. (tricuspid)
Blood returning to the atria, puts pressure against AV valves; the AV valves are forced open.

As the ventricles fill, AV valve flaps hang limply into ventricles.

Atria contract, forcing additional blood into ventricles.

Ventricles contract, forcing blood against AV valve flaps.

AV valves close. Chordae tendineae tighten, preventing valve flaps from everting into atria.

As ventricles contract and intraventricular pressure rises, blood is pushed up against semilunar valves, forcing them open.

Systemic and Pulmonary Circulations

- **Systemic circulation**
  - Blood flows from the left side of the heart through the body tissues and back to the right side of the heart.

- **Pulmonary circulation**
  - Blood flows from the right side of the heart to the lungs and back to the left side of the heart.

The Heart: Associated Great Vessels

- **Arteries**
  - Aorta
    - Leaves left ventricle
  - Pulmonary arteries
    - Leave right ventricle
The Heart: Associated Great Vessels

- Veins
  - Superior and inferior venae cavae
    - Enter right atrium
  - Pulmonary veins (four)
    - Enter left atrium

Blood Flow Through the Heart

- Superior and inferior venae cavae dump blood into the right atrium
- From right atrium, through the tricuspid valve, blood travels to the right ventricle
- From the right ventricle, blood leaves the heart as it passes through the pulmonary semilunar valve into the pulmonary trunk
- Pulmonary trunk splits into right and left pulmonary arteries that carry blood to the lungs

- Oxygen is picked up and carbon dioxide is dropped off by blood in the lungs
- Oxygen-rich blood returns to the heart through the four pulmonary veins
- Blood enters the left atrium and travels through the bicuspid valve into the left ventricle
- From the left ventricle, blood leaves the heart via the aortic semilunar valve and aorta

Systemic and Pulmonary Circulations
Coronary Circulation

- Blood in the heart chambers does not nourish the myocardium.
- The heart has its own nourishing circulatory system consisting of:
  - Coronary arteries—branch from the aorta to supply the heart muscle with oxygenated blood.
  - Cardiac veins—drain the myocardium of blood.
  - Coronary sinus—a large vein on the posterior of the heart, receives blood from cardiac veins.
- Blood empties into the right atrium via the coronary sinus.

The Heart: Conduction System

- Parasympathetic enervation from the vagus nerve.
- Intrinsic conduction system (nodal system).
  - Nodes have different intrinsic rhythms.
  - Fastest rhythm sets the pace for all the others.
  - Heart muscle cells contract, without nerve impulses, in a regular, continuous way.

The Heart: Conduction System

- Special tissue sets the pace.
  - Sinoatrial node = SA node ("pacemaker"), is in the right atrium.
  - Atrioventricular node = AV node, is at the junction of the atria and ventricles.
  - Atrioventricular bundle = AV bundle (bundle of His), is in the interventricular septum.
  - Bundle branches are in the interventricular septum.
  - Purkinje fibers spread within the ventricle wall muscles.

Heart Contractions

- Contraction is initiated by the sinoatrial node (SA node).
- Sequential stimulation occurs at other autorhythmic cells.
- Force cardiac muscle depolarization in one direction—from atria to ventricles.
Heart Contractions

- Once SA node starts the heartbeat
  - Impulse spreads to the AV node
  - Then the atria contract
  - At the AV node, the impulse passes through the AV bundle, bundle branches, and Purkinje fibers
  - Blood is ejected from the ventricles to the aorta and pulmonary trunk as the ventricles contract

Heart Contractions

- Tachycardia—rapid heart rate over 100 beats per minute
- Bradycardia—slow heart rate less than 60 beats per minute

The Heart: Cardiac Cycle

- Atria contract simultaneously
- Atria relax, then ventricles contract
- Systole = contraction
- Diastole = relaxation

Filling Heart Chambers: Cardiac Cycle
The Heart: Cardiac Cycle
- Cardiac cycle—events of one complete heart beat
  - Mid- to late diastole—blood flows from atria into ventricles
  - Ventricular systole—blood pressure builds before ventricle contracts, pushing out blood
  - Early diastole—atria finish refilling, ventricular pressure is low

The Heart: Cardiac Output
- Cardiac output (CO)
  - Amount of blood pumped by each side (ventricle) of the heart in one minute
- Stroke volume (SV)
  - Volume of blood pumped by each ventricle in one contraction (each heartbeat)
  - Usually remains relatively constant
  - About 70 mL of blood is pumped out of the left ventricle with each heartbeat
- Heart rate (HR)
  - Typically 75 beats per minute

\[ \text{CO} = \text{HR} \times \text{SV} \]
\[ \text{CO} = 75 \text{ beats/min} \times 70 \text{ mL/beat} = 5250 \text{ mL/min} \]

Starling’s law of the heart— the more the cardiac muscle is stretched, the stronger the contraction
- Changing heart rate is the most common way to change cardiac output

The Heart: Regulation of Heart Rate
- Increased heart rate
  - Sympathetic nervous system
    - Crisis
    - Low blood pressure
  - Hormones
    - Epinephrine
    - Thyroxine
  - Exercise
  - Decreased blood volume

- Decreased heart rate
  - Parasympathetic nervous system
  - High blood pressure or blood volume
  - Decreased venous return