Chapter 12
Lecture and Animation Outline

To run the animations you must be in Slideshow View. Use the buttons on the animation to play, pause, and turn audio/text on or off.

*Please Note:* Once you have used any of the animation functions (such as Play or Pause), you must first click on the slide’s background before you can advance to the next slide.

See separate PowerPoint slides for all figures and tables pre-inserted into PowerPoint without notes and animations.
Components of Cardiovascular System

• The Heart
• Blood Vessels
• Blood
Carotid artery
Jugular vein
Aorta
Pulmonary trunk
Heart
Brachial artery
Inferior vena cava
Femoral artery and vein
Functions

1. Regulates blood supply
2. Generates blood pressure
3. Routes blood
4. Ensures 1 way blood flow
Heart Characteristics

- **Size:**
  size of a fist and weighs less than 1 lb.

- **Location:**
  between lungs in thoracic cavity

- **Orientation:**
  apex (bottom) towards left side
Heart Coverings

- **Pericardium:** double-layered sac that anchors and protects heart
- **Parietal pericardium:** membrane around heart’s cavity
- **Visceral pericardium:** membrane on heart’s surface
- **Pericardial cavity:** space around heart

*Figure 12.4  Heart in the Pericardium*

The pericardium consists of an outer fibrous pericardium and an inner serous pericardium. The serous pericardium has two parts: The parietal pericardium lines the fibrous pericardium, and the visceral pericardium (epicardium) covers the surface of the heart. The pericardial cavity, between the parietal pericardium and visceral pericardium, is filled with a small amount of pericardial fluid.
Heart Layers

- **Epicardium**: surface of heart (outside)
- **Myocardium**: thick, middle layer composed of cardiac muscle
- **Endocardium**: smooth, inner surface
Cardiac Muscle

- 1 centrally located nucleus
- Branching cells
- Rich in mitochondria
- Striated (actin and myosin)
- \( \text{Ca}^{2+} \) and ATP used for contractions
- Intercalated disks connect cells
Chambers and Blood Vessels

• 4 Chambers:
  - left atrium (LA)
  - right atrium (RA)
  - left ventricle (LV)
  - right ventricle (RV)

• Coronary sulcus:
  separates atria from ventricles
Atria

- Upper portion
- Holding chambers
- Small, thin walled
- Contract minimally to push blood into ventricles
- **Interatrial septum:**
  separates right and left atria
Ventricles

- Lower portion
- Pumping chambers
- Thick, strong walled
- Contract forcefully to propel blood out of heart
- **Interventricular septum:**
  separates right and left ventricles
Figure 12.5 Surface of the Heart

(a) In this anterior view of the heart, the two atria (right and left) are located superiorly, and the two ventricles (right and left) are located inferiorly. The superior and inferior venae cavae enter the right atrium. The pulmonary veins enter the left atrium. The pulmonary trunk exits the right ventricle, and the aorta exits the left ventricle.
Valves

• **What are they?**
  structures that ensure 1 way blood flow

• **Atrioventricular valves (AV):**
  between atria and ventricles

  - **Tricuspid valve:**
    - AV valve between RA and RV
    - 3 cusps
- Bicuspid valve (mitral):
  - AV valve between LA and LV
  - 2 cusps

• Chordae tendineae:
  - attached to AV valve flaps
  - support valves
• **Semilunar valves:**
  - **Pulmonary:**
    base of pulmonary trunk
  - **Aortic:**
    base of aorta
Figure 12.7 Heart Valves

(a) Anterior view of the tricuspid valve, the chordae tendineae, and the papillary muscles. (b) In superior view, note that the three cusps of each semilunar valve meet to prevent the backflow of blood.
What happens when Bicuspid Valve is Open?

• Blood flows from LA into LV.

• Aortic semilunar valve is closed.

• Tension on chordae tendineae is low.
What happens when Bicuspid Valve is Closed?

• Blood flows from LV into aorta.

• Aortic semilunar valve is open.

• Tension on chordae tendineae is high.
Figure 12.8 Function of the Heart Valves

(a) As the ventricle relaxes, the pressure in the ventricle becomes lower than the pressure in the atrium. Blood flowing into the left atrium opens the bicuspid valve, and blood flows into the left ventricle. At the same time, in the aorta, blood flowing back toward the relaxed ventricle causes the aortic semilunar valve to close, and no blood can reenter the ventricle from the aorta. (b) When the ventricle contracts, blood flowing toward the atrium causes the bicuspid valve to close. The increased pressure in the left ventricle forces the aortic semilunar valve open.
Right Side of Heart

• Pulmonary circuit:
  - carries blood from heart to lungs
  - blood is $O_2$ poor, $CO_2$ rich
• **Right Atrium:**
  - receives blood from 3 places: superior and inferior vena cava and coronary sinus
  - **Superior vena cava:**
    drains blood above diaphragm (head, neck, thorax, upper limbs)
  - **Inferior vena cava:**
    drains blood below diaphragm (abdominopelvic cavity and lower limbs)
  - **coronary sinus:**
    drains blood from myocardium
• **Right Ventricle:**
  - opens into pulmonary trunk

- **Pulmonary trunk:**
  splits into right and left pulmonary arteries

- **Pulmonary arteries:**
  carry blood away from heart to lungs
Left Side of Heart

• **Systemic circuit:**
  - carries blood from heart to body
  - blood is O$_2$ rich, CO$_2$ poor
• **Left Atrium:**
  4 openings (*pulmonary veins*) that receive blood from lungs

• **Left Ventricle:**
  - opens into aorta
  - thicker, contracts more forcefully, higher blood pressure than right ventricle has to get to body

• **Aorta:**
  carries blood from LV to body
Figure 12.5  (continued)

(b) Photograph of the anterior surface of the heart. (c) In this posterior view of the heart, the two atria (right and left) are located superiorly, and the two ventricles (right and left) are located inferiorly. The superior and inferior venae cavae enter the right atrium, and the four pulmonary veins enter the left atrium.
Blood Flow through Heart

1. RA
2. Tricuspid valve
3. RV
4. Pulmonary semilunar valve
5. Pulmonary trunk
6. Pulmonary arteries
7. Lungs
8. Pulmonary veins
9. LA
10. Bicuspid valve
11. LV
12. Aortic semilunar valve
13. Aorta
14. Body
Blood Supply to Heart

• Coronary arteries:
  - supply blood to heart wall
  - originate from base of aorta (above aortic semilunar valve)

• Left coronary artery:
  - has 3 branches
  - supply blood to anterior heart wall and left ventricle
• **Right coronary artery:**
  - originates on right side of aorta
  - supply blood to right ventricle
Action Potentials in Cardiac Muscle

- Changes in membrane channels’ permeability are responsible for producing action potentials and is called **pacemaker potential**.

1. **Depolarization phase:**
   - Na⁺ channels open
   - Ca²⁺ channels open

2. **Plateau phase:**
   - Na⁺ channels close
   - Some K⁺ channels open
   - Ca²⁺ channels remain open
3. Repolarization phase:
   - $K^+$ channels are open
   - $Ca^{2+}$ channels close

• Plateau phase prolongs action potential by keeping $Ca^{2+}$ channels open.

• In skeletal muscle action potentials take 2 msec, in cardiac muscle they take 200-500 msec.
PROCESS Figure 12.14 Comparison of Action Potentials in Skeletal and Cardiac Muscle

(a) An action potential in skeletal muscle consists of depolarization and repolarization phases. (b) An action potential in cardiac muscle consists of depolarization, plateau, and repolarization phases. Cardiac muscle does not repolarize as rapidly as skeletal muscle (indicated by the break in the curve) because of the plateau phase.
Conduction System of Heart

• What is it?
  contraction of atria and ventricles by cardiac muscle cells

• Sinoatrial node (SA node):
  - in RA
  - where action potential originates
  - functions as pacemaker
  - large number of Ca^{2+} channels
Path of Action Potential through Heart

1. SA node
2. AV node (atrioventricular)
3. AV bundle
4. Right and Left Bundle branches
5. Purkinje fibers
1. Action potentials originate in the sinoatrial (SA) node and travel across the wall of the atrium (arrows) from the SA node to the atrioventricular (AV) node.

2. Action potentials pass through the AV node and along the atrioventricular (AV) bundle, which extends from the AV node, through the fibrous skeleton, into the interventricular septum.

3. The AV bundle divides into right and left bundle branches, and action potentials descend to the apex of each ventricle along the bundle branches.

4. Action potentials are carried by the Purkinje fibers from the bundle branches to the ventricular walls.

PROCESS Figure 12.15  Conduction System of the Heart
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Action potentials originate in the sinoatrial (SA) node and travel across the wall of the atrium from the sinoatrial node to the atrioventricular (AV) node.
Electrocardiogram

• **What is it?**
  - record of electrical events in heart
  - diagnoses cardiac abnormalities
  - uses electrodes
  - contains P wave, QRS complex, T wave
Components of ECG/EKG

- **P wave:**
  depolarization of atria

- **QRS complex:**
  - depolarization of ventricles
  - contains Q, R, S waves

- **T wave:**
  repolarization of ventricles
Cardiac Cycle

• Heart is 2 side by side pumps: right and left
• Atria: primers for pumps
• Ventricles: power pumps

• Cardiac Cycle:
  repetitive pumping action which includes contraction and relaxation
• Cardiac muscle contractions produce pressure changes within heart chambers.

• Pressure changes are responsible for blood movement.

• Blood moves from areas of high to low pressure.
• Atrial systole: contraction of atria

• Ventricular systole: contraction of ventricles

• Atrial diastole: relaxation of atria

• Ventricular diastole: relaxation of ventricles
1. Contraction of the ventricles causes pressure in the ventricles to increase. Almost immediately, the AV valves close (the first heart sound). The pressure in the ventricles continues to increase.

2. Continued ventricular contraction causes the pressure in the ventricles to exceed the pressure in the pulmonary trunk and aorta. As a result, the semilunar valves are forced open, and blood is ejected into the pulmonary trunk and aorta.

3. The atria contract and complete ventricular filling.

4. At the beginning of ventricular diastole, the ventricles relax, and the semilunar valves close (the second heart sound).

5. The AV valves open, and blood flows into the ventricles. The ventricles fill to approximately 70% of their volume.
Figure 12.18 Events of the Cardiac Cycle
(Top) The cardiac cycle is divided into five periods. From top to bottom, these graphs show an electrocardiogram; pressure changes for the left atrium (blue dashed line), the left ventricle (black line), and the aorta (red dashed line); left ventricular volume curve; and the sequence of the heart sounds.
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A single cardiac cycle is made up of the events associated with one heartbeat. Each cardiac cycle takes about 8 tenths of one second.
Heart Sounds

- Stethoscope is used to hear lung and heart sounds

- First sound is lubb, second is dupp

- Sounds result from opening and closing valves

- Murmurs are due to faulty valves
Figure 12.19 Location of the Heart Valves in the Thorax

Surface markings of the heart in an adult male. The positions of the four heart valves are indicated by *blue ellipses*, and the sites where the sounds of the valves are best heard with a stethoscope are indicated by *pink circles.*
Regulation of Heart Function

- **Stroke Volume:**
  - volume of blood pumped per ventricle per contraction
  - 70 ml/beat

- **Heart Rate:**
  - number of heart beats in 1 min.
  - 72 beats/min.

- **Cardiac Output:**
  - volume of blood pumped by a ventricle in 1 min.
  - 5 L/min.

  \[ CO = SV \times HR \]
Intrinsic Regulation of Heart

- **What is it?**
  - mechanisms contained within heart

- **Venous return:**
  - amt. of blood that returns to heart

- **Preload:**
  - degree ventricular walls are stretched at end of diastole
• Venous return, preload, stroke volume are related to each other

• Starlings Law of the Heart:
  - relationship between preload and stroke volume
  - influences cardiac output
  - Ex. Exercise increases venous return, preload, stroke volume, and cardiac output

• After load:
  pressure against which ventricles must pump blood
Extrinsic Regulation of Heart

• What is it?
  - mechanisms external to heart
  - nervous or chemical regulation
1. Sensory (green) neurons carry action potentials from baroreceptors to the cardioregulatory center. Baroreceptors in the medulla oblongata influence the cardioregulatory center.

2. The cardioregulatory center controls the frequency of action potentials in the parasympathetic (red) neurons extending to the heart. The parasympathetic neurons decrease the heart rate.

3. The cardioregulatory center controls the frequency of action potential in the sympathetic (blue) neurons extending to the heart. The sympathetic neurons increase the heart rate and the stroke volume.

4. The cardioregulatory center influences the frequency of action potentials in the sympathetic (blue) neurons extending to the adrenal medulla. The sympathetic neurons increase the secretion of epinephrine and some norepinephrine into the general circulation. Epinephrine and norepinephrine increase the heart rate and stroke volume.
Nervous Regulation: Baroreceptor Reflex

• What is it?
  - mechanism of nervous system which regulates heart function
  - keeps heart rate and stroke volume in normal range
  - baroreceptors monitor blood pressure in aorta and carotid arteries (carry blood to brain)
  - changes in blood pressure cause changes in frequency of action potentials
  - involves medulla oblongata
Baroreceptors in the carotid arteries and aorta detect an increase in blood pressure. The cardioregulatory center alters heart activity and decreases stimulation of the adrenal medulla.

**Blood pressure increases:** Homeostasis Disturbed

Heart rate and stroke volume decrease.

**Blood pressure decreases:** Homeostasis Restored

Baroreceptors in the carotid arteries and aorta detect a decrease in blood pressure. The cardioregulatory center alters heart activity and increases stimulation of the adrenal medulla.

**Blood pressure decreases:** Homeostasis Disturbed

Heart rate and stroke volume increase.

**Blood pressure increases:** Homeostasis Restored

**Homeostasis Figure 12.20  Baroreceptor Reflex**

The baroreceptor reflex maintains homeostasis in response to changes in blood pressure.
Chemical Regulation: Chemoreceptor Reflex

• What is it?
  - chemicals can affect heart rate and stroke volume
  - epinephrine and norepinephrine from adrenal medulla can increase heart rate and stroke volume
  - excitement, anxiety, anger an increase cardiac output
  - depression can decrease cardiac output
- medulla oblongata has chemoreceptors for changes in pH and CO₂

- K⁺, Ca²⁺, and Na⁺ affect cardiac function
Chemoreceptors in the medulla oblongata detect an increase in blood pH (often caused by a decrease in blood CO₂). Centers in the brain decrease stimulation of the heart and adrenal medulla.

Heart rate and stroke volume decrease, reducing blood flow to the lungs.

Blood pH increases: **Homeostasis Disturbed**

Blood pressure (normal range)

Blood pH decreases: **Homeostasis Disturbed**

Blood pH increases: **Homeostasis Restored**

Blood pH decreases: **Homeostasis Restored**

Heart rate and stroke volume increase, increasing blood flow to the lungs.

Chemoreceptors in the medulla oblongata detect a decrease in blood pH (often caused by an increase in blood CO₂). Centers in the brain increase stimulation of the heart and adrenal medulla.

**Homeostasis Figure 12.21 Chemoreceptor Reflex—pH**

The chemoreceptor reflex maintains homeostasis in response to changes in blood concentrations of CO₂ and H⁺ (or pH).
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Increased blood pressure stretches the carotid arteries and aorta causing the baroreceptors to increase their basal rate of action potential generation.
Heart Attack

• **Thrombus:**
  - blood clot blocks coronary blood vessel
  - causes heart attack
  - daily aspirin can prevent by thinning blood

• **Infarct:**
  - area that dies from lack of $O_2$
Heart Procedures

• **Angioplasty:**
  procedure opens blocked blood vessels

• **Stent:**
  structures inserted to keep vessels open

• **Bypass:**
  procedure reroutes blood away from blocked arteries