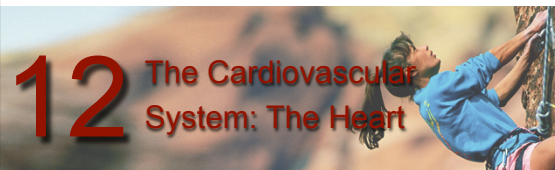


**Essentials of Anatomy & Physiology, 4th Edition**  
Martini/Bartholomew



# 12 The Cardiovascular System: The Heart

PowerPoint® Lecture Outlines  
prepared by Alan Magid, Duke University

Slides 1 to 65

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## Heart's Place in the Circulation

Heart Pumps Blood into Two Circuits in Sequence

- Pulmonary circuit
  - To and from the lungs
- Systemic circuit
  - To and from the rest of the body

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## Heart's Place in the Circulation

Three Kinds of Blood Vessels

- Arteries
  - Carry blood **away** from heart and carry it to the capillaries
- Capillaries
  - Connect arteries and veins
  - Exchange area between blood and cells
- Veins
  - Receive blood from capillaries and carry it **back** to the heart

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## Heart's Place in the Circulation

Two Sets of Pumping Chambers in Heart

- Right atrium
  - Receives systemic blood
- Right ventricle
  - Pumps blood to lungs (**pulmonary**)
- Left atrium
  - Receives blood from lungs
- Left ventricle
  - Pumps blood to organ systems (**systemic**)

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## Heart's Place in the Circulation

Overview of the Cardiovascular System

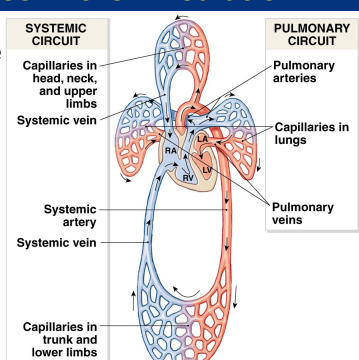


Figure 12-1

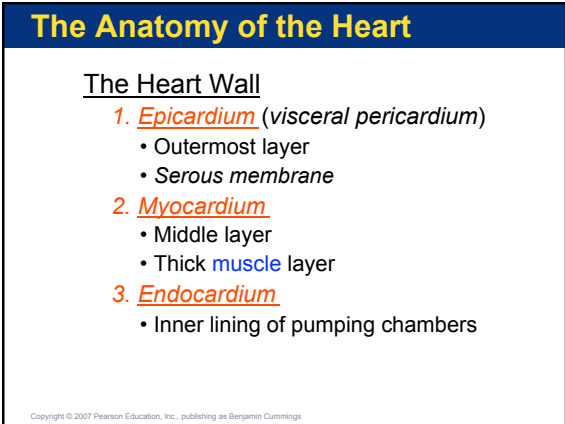
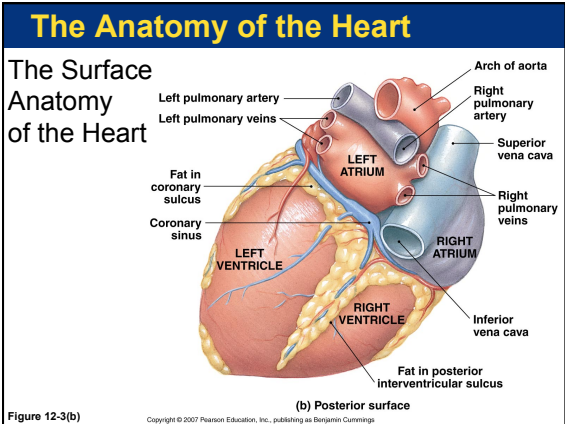
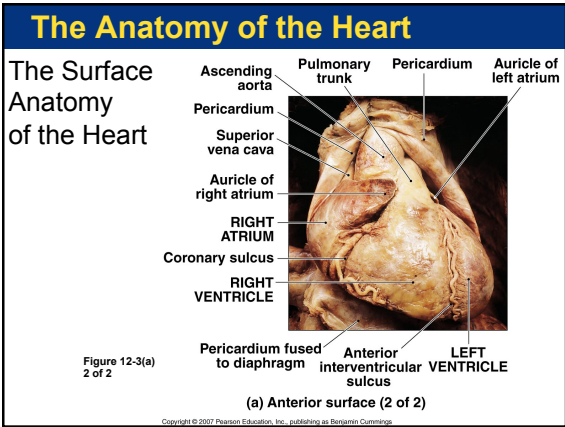
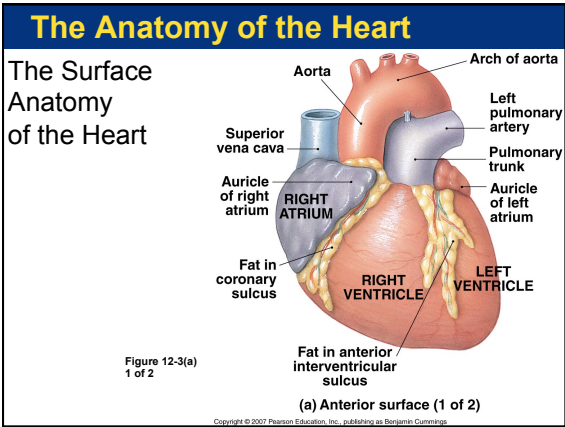
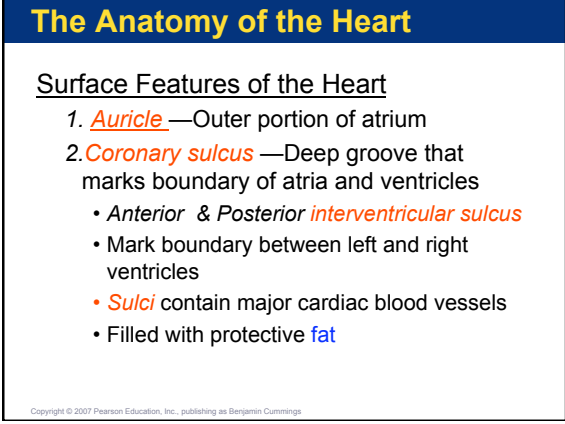
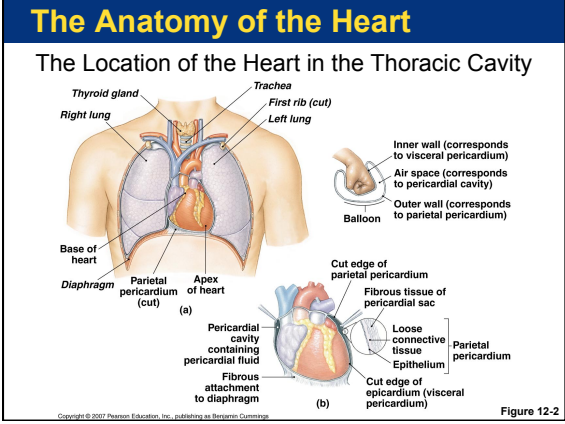
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## The Anatomy of the Heart

Pericardial Cavity

- Surrounds the heart
- Lined by pericardium
  - Two layers
    - Visceral pericardium (epicardium)
      - Covers heart surface
    - Parietal pericardium
      - Lines *pericardial sac* that surrounds heart

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## The Anatomy of the Heart

### The Heart Wall and Cardiac Muscle Tissue

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## The Anatomy of the Heart

### The Heart Wall and Cardiac Muscle Tissue

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## The Anatomy of the Heart

### The Heart Wall and Cardiac Muscle Tissue

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## The Anatomy of the Heart

### The Heart Wall and Cardiac Muscle Tissue

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## The Anatomy of the Heart

### The Heart Wall and Cardiac Muscle Tissue

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## The Anatomy of the Heart

### Cardiac Muscle Cells

- Shorter than skeletal muscle fibers
- Have single nucleus
- Have striations (sarcomere organization)
- Depend on aerobic metabolism
- Connected by *intercalated discs*
  - *Make sure all cardiac muscle cells work together so the heart beats as one unit*

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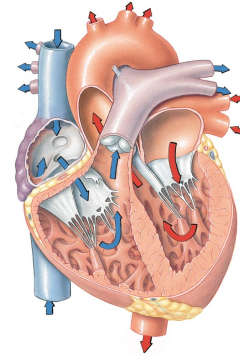
## The Anatomy of the Heart

### Internal Anatomy and Organization

1. Interatrial septum
  - Separates atria
2. Interventricular septum
  - Separates ventricles
3. Atrioventricular valves (AV valves)
  - Located between atrium and ventricle
  - Ensure one-way flow from atrium to ventricle

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## Anatomy of the Heart



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## The Anatomy of the Heart

### Blood Flow in the Heart

1. Superior and inferior venae cavae
  - Large **veins** carry systemic blood to right atrium
2. Right atrium sends blood to right ventricle
  - Flows through right AV valve
    - Bounded by three *cusps* (*tricuspid valve*)
    - Cusps anchored to heart walls by *chordae tendinae*

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## The Anatomy of the Heart

### Blood Flow in the Heart (cont' d)

3. Right ventricle pumps blood through *pulmonary semilunar valve* to **pulmonary arteries**
  - Flows to **lungs** through right, left pulmonary arteries where it picks up **oxygen**
4. **Pulmonary veins** carry blood to **left atrium**
5. Left atrium sends blood to **left ventricle**
  - Enters through left AV valve (*bicuspid or mitral*)
6. Left ventricle pumps blood to **aorta**
  - Through *aortic semilunar valve* to systems

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## The Anatomy of the Heart

### The Sectional Anatomy of the Heart

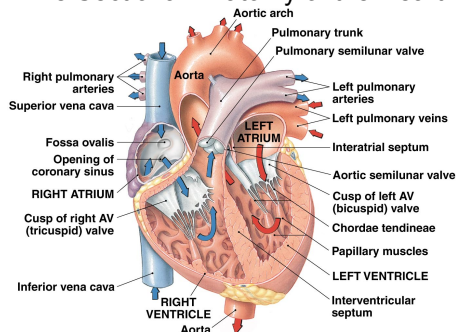


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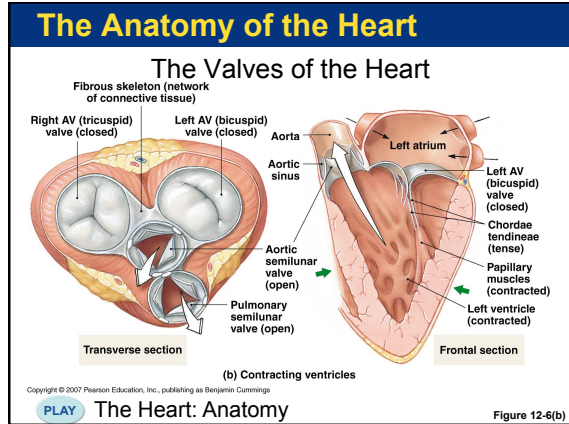
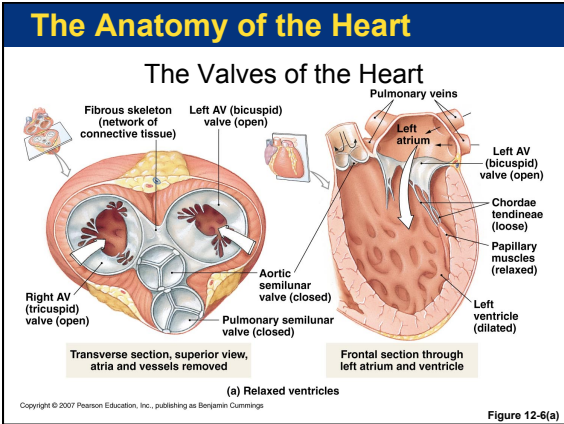
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## The Anatomy of the Heart

### Functional Anatomy of the Heart

1. Left ventricular myocardium much thicker than right
  - Why?
2. Valves ensure one-way flow of blood
  - Prevent backward flow (*regurgitation*)

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### The Anatomy of the Heart

#### Key Note

The heart has four chambers, the right atrium and ventricle with the pulmonary circuit and left atrium and ventricle with the systemic circuit. The left ventricle's greater workload makes it more massive than the right, but the two pump equal amounts of blood. AV valves prevent backflow from the ventricles into the atria, and semilunar valves prevent backflow from the outflow vessels into the ventricles.

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### The Anatomy of the Heart

#### The Blood Supply TO the Heart

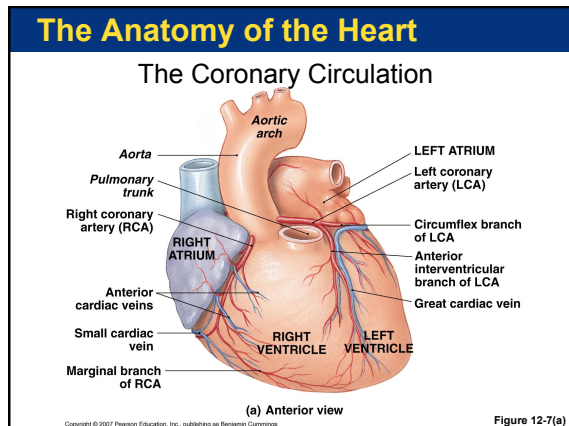
- The myocardium needs lots of oxygen and nutrients
- **Coronary arteries** (right, left) branch from **aorta** base and supply blood to the heart muscle itself
- If a coronary artery becomes blocked, a **myocardial infarction** (**heart attack**) occurs
- Blockage usually occurs because of build up of **fat** in coronary arteries

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### Anatomy of the Heart

A blocked coronary artery can be repaired by having coronary bypass surgery

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## The Anatomy of the Heart

### The Coronary Circulation

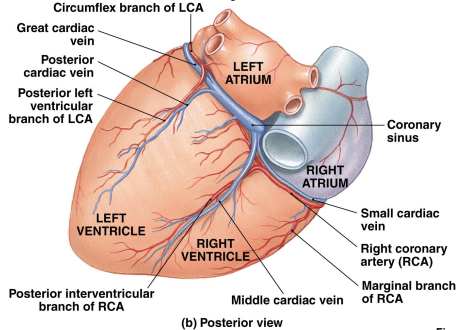


Figure 12-7(b)

## The Heartbeat

### Heartbeat Needs two Types of Cardiac Cells

1. **Contractile cells**
  - Provide the pumping action
2. **Cells of the *conducting system***
  - Generate and spread the action potential (electrical impulse)

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## The Heartbeat

### Differences between Cardiac and Skeletal Muscle Cells

- Cardiac action potential has long *plateau phase*
- Cardiac muscle has long, slow twitch
- Cardiac muscle has long *refractory period*
  - Can't be *tetanzed*

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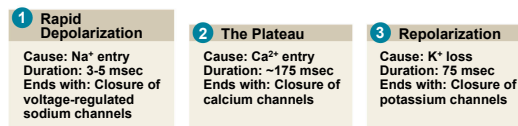


Figure 12-8(a)  
1 of 5

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### 1 Rapid Depolarization

Cause: Na<sup>+</sup> entry  
Duration: 3-5 msec  
Ends with: Closure of voltage-regulated sodium channels

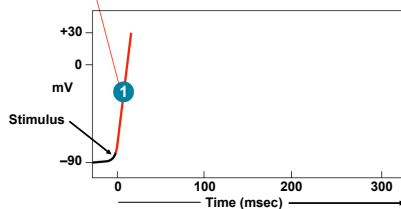


Figure 12-8(a)  
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### 1 Rapid Depolarization

Cause: Na<sup>+</sup> entry  
Duration: 3-5 msec  
Ends with: Closure of voltage-regulated sodium channels

### 2 The Plateau

Cause: Ca<sup>2+</sup> entry  
Duration: ~175 msec  
Ends with: Closure of calcium channels

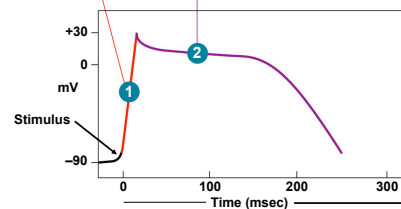
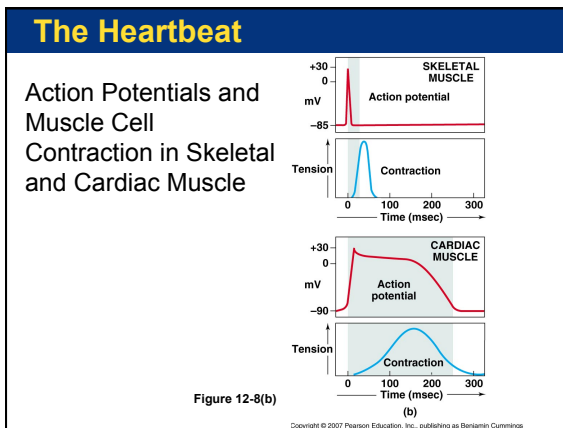
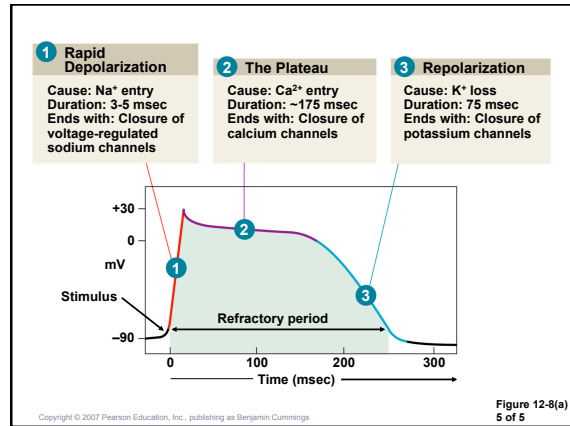
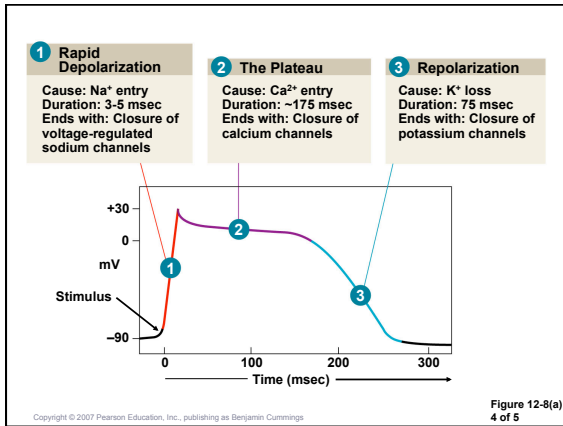


Figure 12-8(a)  
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### The Heartbeat

#### The Conducting System

- Initiates and spreads **electrical impulses** in heart
- Two types of cells
  - Pacemaker cells** (aka "nodes")
    - Reach threshold first
    - Set heart rate
  - Conducting cells**
    - Distributes stimuli to myocardium

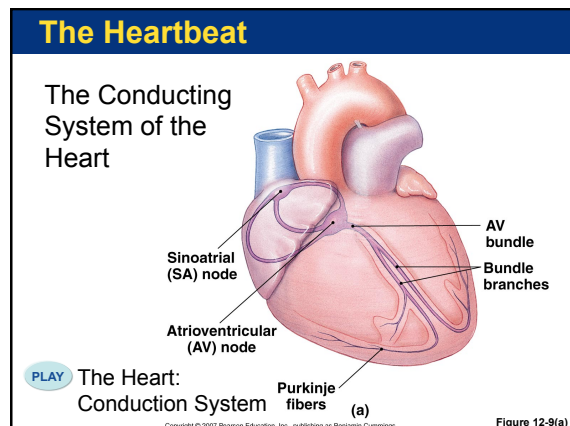
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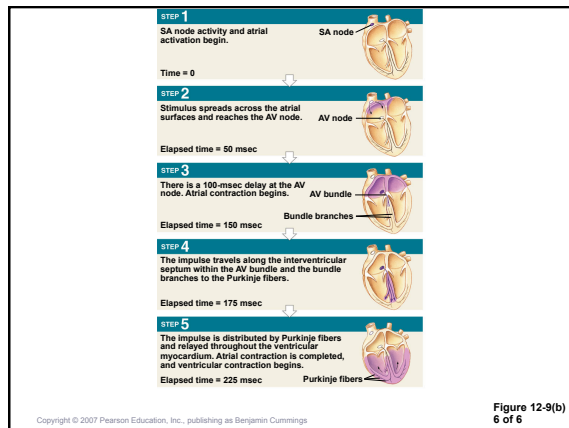
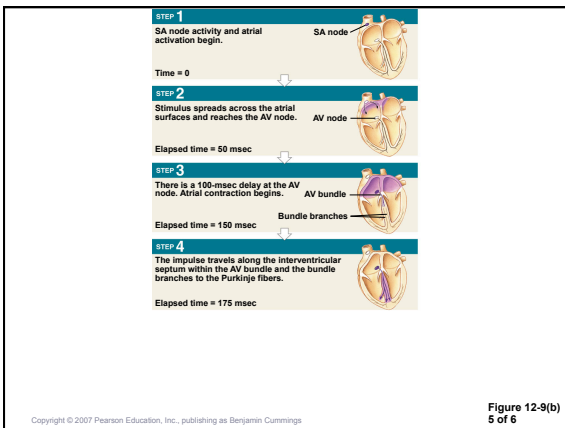
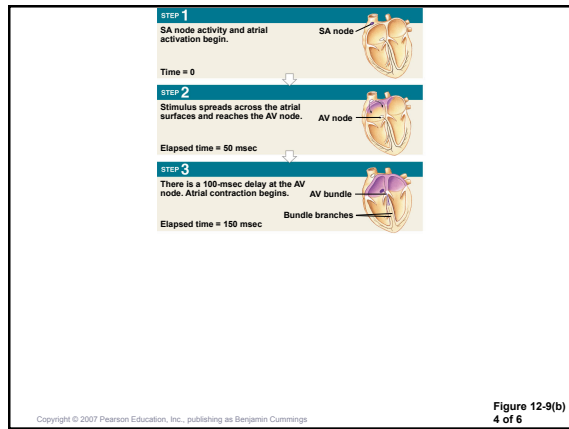
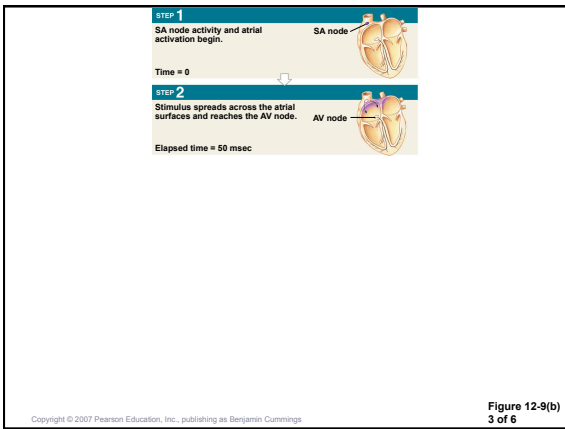
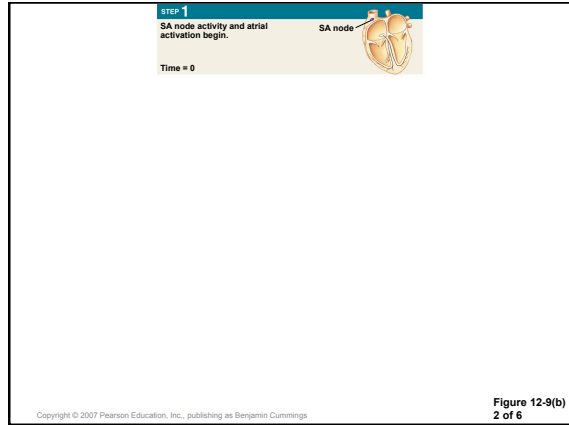
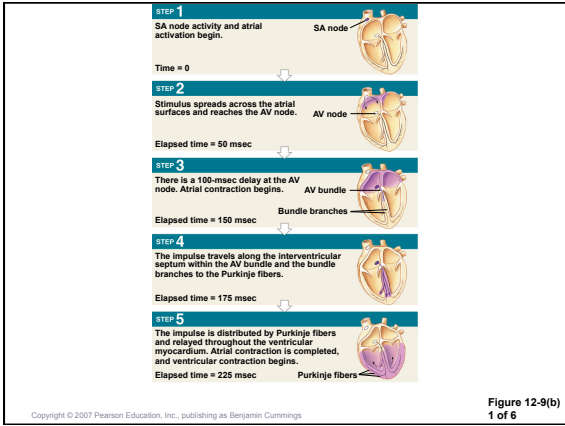
### The Heartbeat

#### The Conducting System (cont'd)

- Steps in the Conduction System:**
  - Starts in **ATRIA**. Pacemaker cells establish heart rate
    - pacemaker is also called **sinoatrial (SA) node**
  - Impulse spreads from SA node across atria
  - To **atrioventricular (AV) node**
  - To **AV bundle** and bundle branches
    - Via **Purkinje fibers** to **VENTRICLES**

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## The Heartbeat

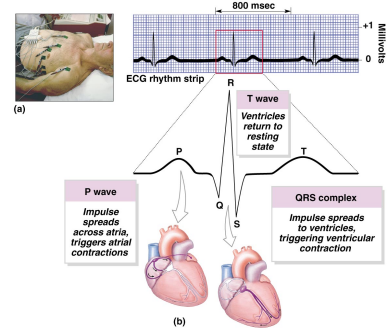
### The Electrocardiogram (ECG or EKG)

- A recording of the electrical activity of the heart
- Three main components
  1. **P wave**
    - Atrial depolarization (atria contract)
  2. **QRS complex**
    - Ventricular depolarization (ventricles contract)
  3. **T wave**
    - Ventricular repolarization (ventricles rest)

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## The Heartbeat

### An Electrocardiogram



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Figure 12-10

## The Heartbeat

### Key Note

The heart rate is established by the SA node, as modified by autonomic activity, hormones, ions, etc. From there, the stimulus is conducted through the atrium to the AV node, the AV bundle, the bundle branches, and Purkinje fibers to the ventricular myocardium. The ECG shows the electrical events associated with the heartbeat.

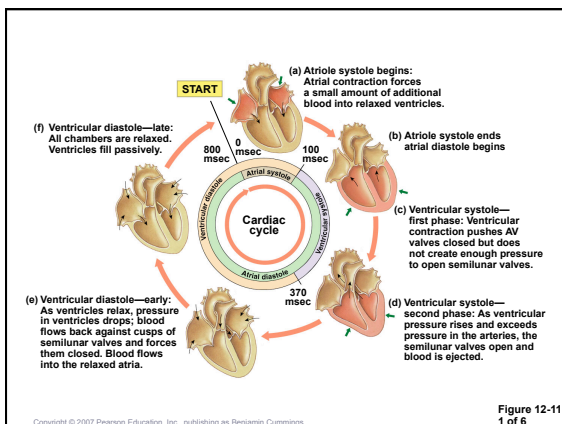
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## The Heartbeat

### The Cardiac Cycle

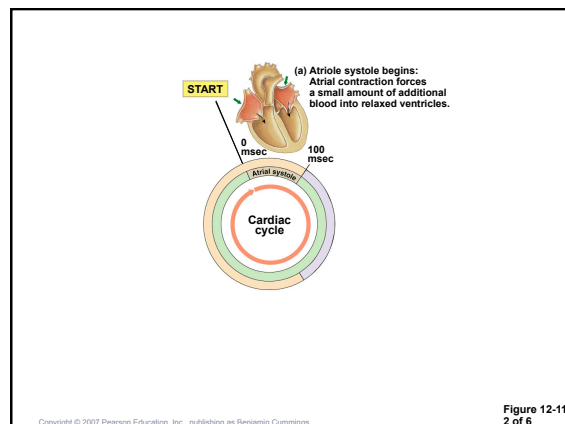
- Two phases in cardiac cycle
  1. **Systole**
    - Contraction phase
    - Both ventricles simultaneously
  2. **Diastole**
    - Relaxation phase

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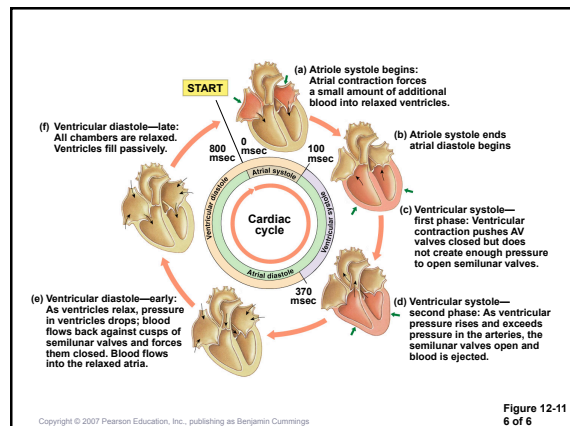
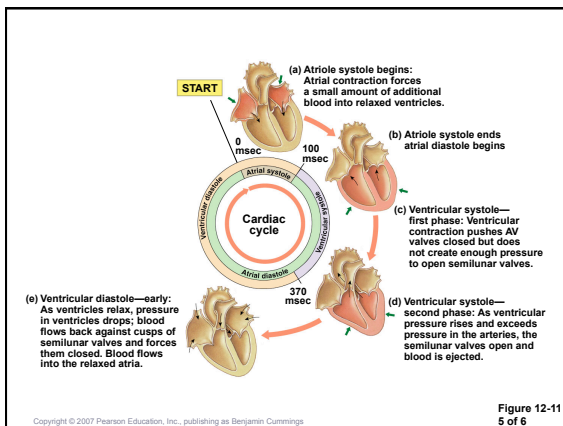
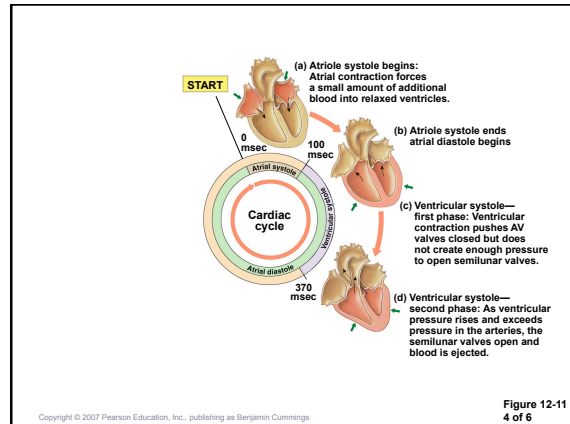
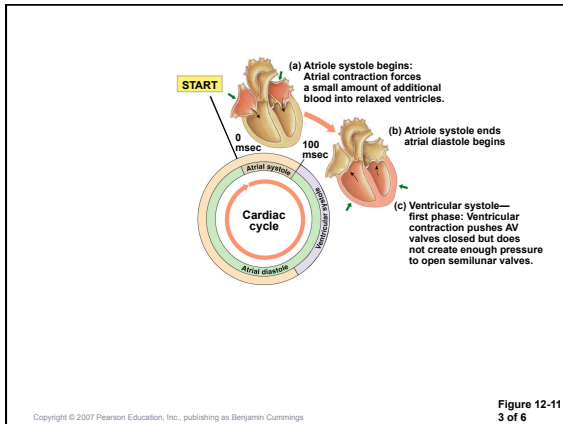
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Figure 12-11  
1 of 6



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Figure 12-11  
2 of 6



## The Heartbeat

### Heart Sounds

- Generated by *closing* of valves
- Two main heart sounds
  - First sound (*lub*)
    - Closing of bicuspid & tricuspid
  - Second sound (*dub*)
    - Closing of aortic & pulmonary valves
- Indicate start/stop of systole
- Heard with *stethoscope*

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## Heart Dynamics

### Some Essential Definitions

- Heart dynamics*—Movements and forces generated during cardiac contraction
- Stroke volume*—Amount of blood pumped in a single beat
- Cardiac output*—Amount of blood pumped each minute

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## Heart Dynamics

### Factors Controlling Cardiac Output

- Blood volume reflexes
- Autonomic innervation
  - Heart rate effects
  - Stroke volume effects
- Hormones

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## Heart Dynamics

### Blood Volume Reflexes

- Stimulated by changes in *venous return*
  - VR is amount of blood *entering* heart
- *Atrial reflex*
  - Speeds up heart rate
  - Triggered by stretching wall of right atrium
- *Frank-Starling principle*
  - Increases ventricular output
  - Triggered by stretching wall of ventricles

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## Heart Dynamics

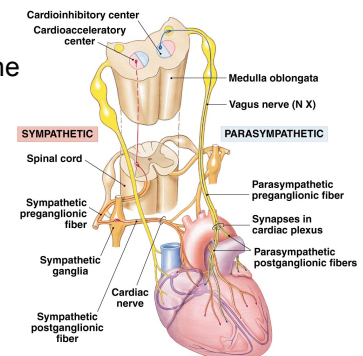
### Autonomic Control of the Heart

- Parasympathetic innervation
  - Releases acetylcholine (ACh)
  - Lowers heart rate and stroke volume
- Sympathetic innervation
  - Releases norepinephrine (NE)
  - Raises heart rate and stroke volume

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## Heart Dynamics

### Autonomic Innervation of the Heart



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Figure 12-12

## Heart Dynamics

### Hormone Effects on Cardiac Output

- Adrenal medulla hormones
  - Epinephrine, norepinephrine released
  - Heart rate and stroke volume increased
- Other hormones that increase output
  - Thyroid hormones
  - Glucagon

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## Heart Dynamics

### CNS Control of the Heart

- Basic control in *medulla oblongata*
  - *Cardioacceleratory center*
    - Activation of sympathetic neurons
  - *Cardioinhibitory center*
    - Governing of parasympathetic neurons
- Other inputs
  - Higher centers
  - Blood pressure sensors
  - Oxygen, carbon dioxide sensors

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## Heart Dynamics

### Key Note

Cardiac output is the amount of blood pumped by the left ventricle each minute. It is adjusted moment-to-moment by the ANS, and by circulating hormones, changes in blood volume and in venous return. A healthy person can increase cardiac output by three-fold to five-fold.

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