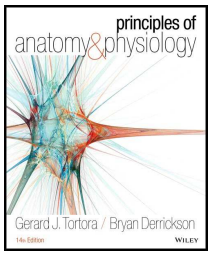


Principles of Anatomy and Physiology

14th Edition

CHAPTER 20

The Cardiovascular System: The Heart

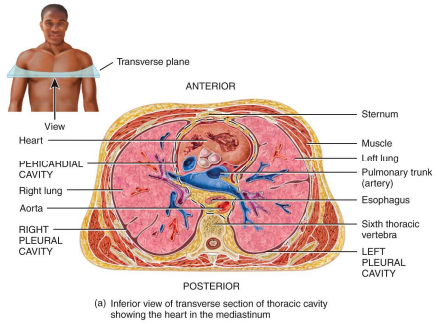
Introduction

The purpose of the chapter is to:

1. Learn about the components of the cardiovascular system
2. Focus on the anatomy and physiology of the heart
3. Learn about the cardiac cycle
4. Discuss the various factors that influence heart rate and force of contraction

Location of the Heart

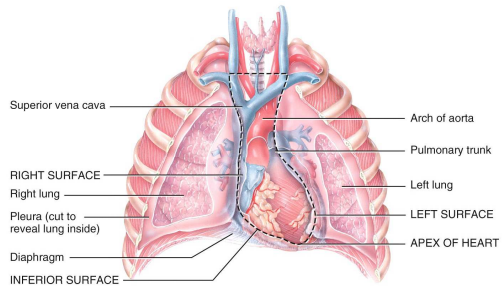
The heart is located in the mediastinum



(a) Inferior view of transverse section of thoracic cavity showing the heart in the mediastinum

Location of the Heart

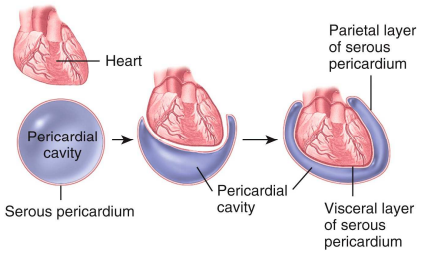
The heart is located in the mediastinum



(b) Anterior view of the heart in the thoracic cavity

Pericardium

The heart is enclosed and held in place by the pericardium



(b) Simplified relationship of serous pericardium to heart

Pericardium

- The pericardium consists of an outer fibrous pericardium and an inner serous pericardium
- The serous pericardium has 2 layers:
  1. Visceral
  2. Parietal
- The visceral and parietal layers are separated by the serous cavity, a fluid-filled space

Cardiac Muscle

Anatomy Overview:

- Cardiac Muscle

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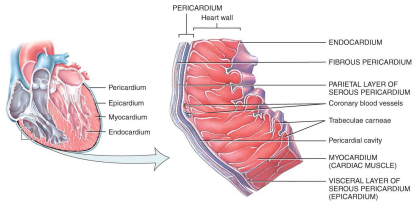
Layers of the Heart Wall

The wall of the heart has 3 layers:

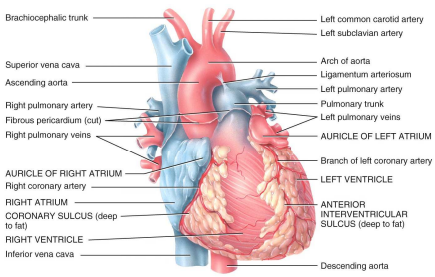
1. Epicardium
2. Myocardium
3. Endocardium



(a) Portion of pericardium and right ventricular heart wall showing divisions of pericardium and layers of heart wall

Chambers of the Heart

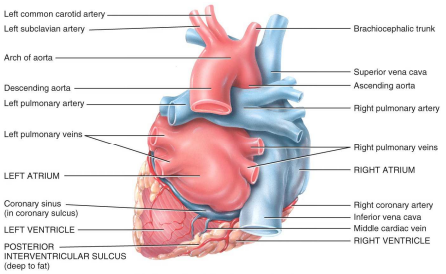
The chambers of the heart include two upper atria and two lower ventricles



(a) Anterior external view showing surface features

Chambers of the Heart

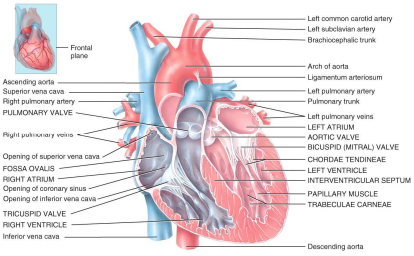
The chambers of the heart include two upper atria and two lower ventricles



(c) Posterior external view showing surface features

Right Atrium

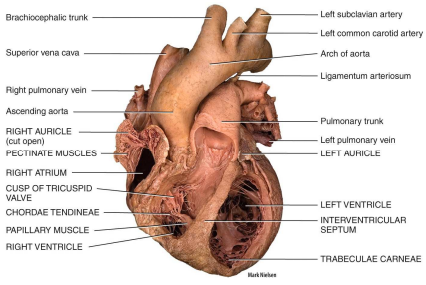
The right atrium receives blood from the superior and inferior vena cava and the coronary sinus



(a) Anterior view of frontal section showing internal anatomy

Right Ventricle

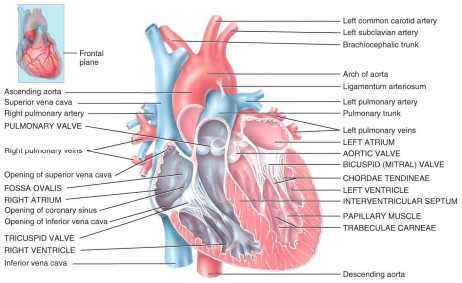
The right ventricle receives blood from the right atrium and sends blood to the lungs



(b) Anterior view of partially sectioned heart

Left Atrium

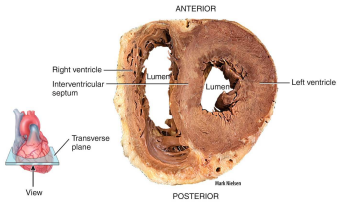
The left atrium receives blood from the pulmonary veins



(a) Anterior view of frontal section showing internal anatomy

Left Ventricle

- The left atrium receives blood from the left atrium and sends blood all over the body
- The wall of the left ventricle is much thicker than that of the right ventricle

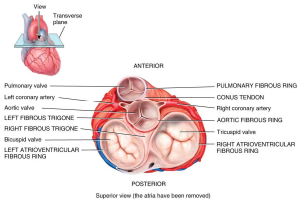


(c) Inferior view of transverse section showing differences in thickness of ventricular walls

Fibrous Skeleton

The fibrous skeleton of the heart:

- Forms the foundation for which the heart valves attach
- Serves as a point of insertion for cardiac muscle bundles
- Prevents overstretching of the heart valves
- Acts as an electrical insulator



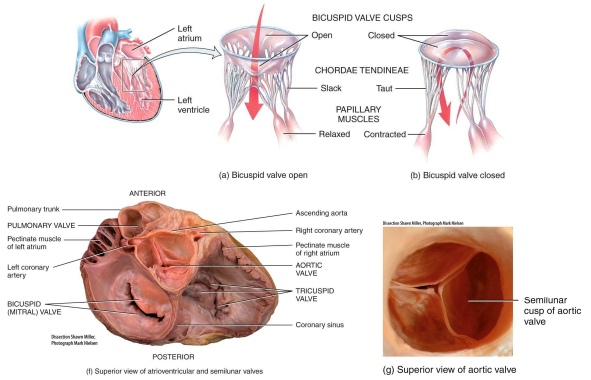
Superior view (the atria have been removed)

Heart Valves and Circulation of Blood

The valves of the heart open and close in response to pressure changes as the heart contracts and relaxes

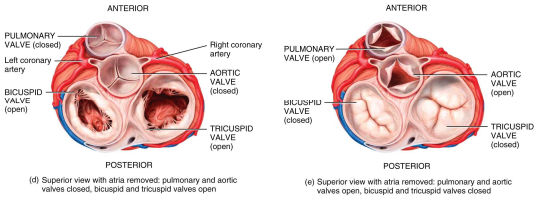
- Right and left atrioventricular valves
  - Prevent back flow from the ventricles into the atria
- Right and left semilunar valves
  - Prevent back flow from the arteries into the ventricles

Heart Valves and Circulation of Blood

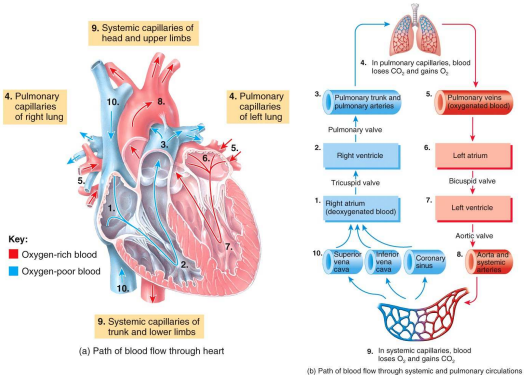


Heart Valves and Circulation of Blood

When one set of valves is open, the other set is closed



Systemic and Pulmonary Circulations



Coronary Circulation

Anatomy Overview:

- The Cardiovascular System

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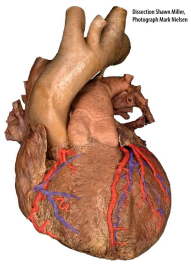
Coronary Circulation

Blood flow through coronary arteries delivers oxygenated blood and nutrients to the myocardium

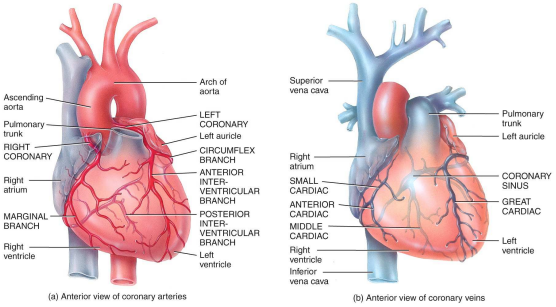
- Branches arise from the ascending aorta

Coronary veins remove carbon dioxide and wastes from the myocardium

- Branches converge at the coronary sinus



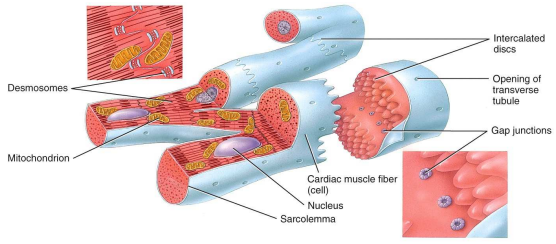
Coronary Circulation



(a) Anterior view of coronary arteries

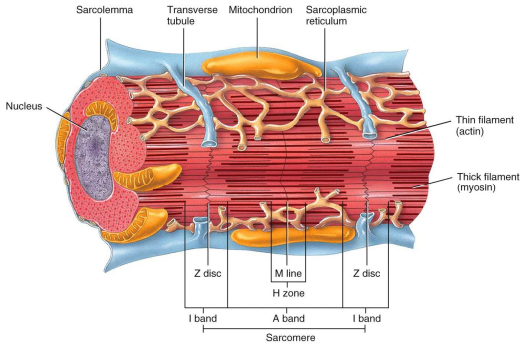
(b) Anterior view of coronary veins

Cardiac Muscle Tissue



(a) Cardiac muscle fibers

Cardiac Muscle Tissue

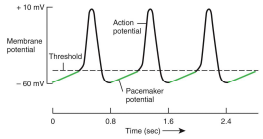


(b) Arrangement of components in a cardiac muscle fiber

The Conduction System

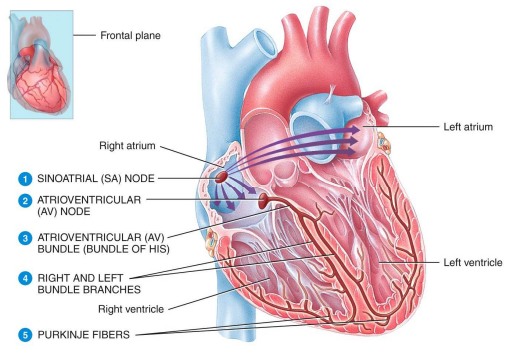
Cardiac muscle cells are self-excitable, and therefore, autorhythmic

- Cardiac muscle cells repeatedly generate spontaneous action potentials that then trigger heart contractions
  - These cells form the conduction system, which is the route for propagating action potentials through the heart muscle



(b) Pacemaker potentials (green) and action potentials (black) in autorhythmic fibers of SA node

The Conduction System



(a) Anterior view of frontal section

The Conduction System

Interactions Animation:

- Cardiac Conduction

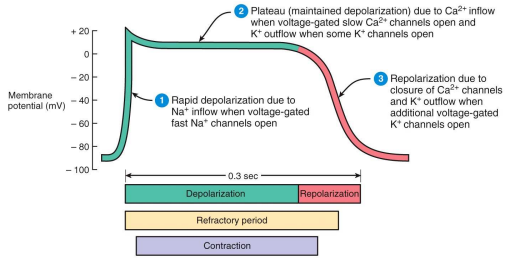
You must be connected to the Internet and in Slideshow Mode to run this animation.

Influences on the Conduction System

- The autorhythmic fibers in the SA node are the natural pacemaker of the heart because they initiate action potentials most often
- Signals from the nervous system and hormones (like epinephrine) can modify the heart rate and force of contraction but they do not set the fundamental rhythm

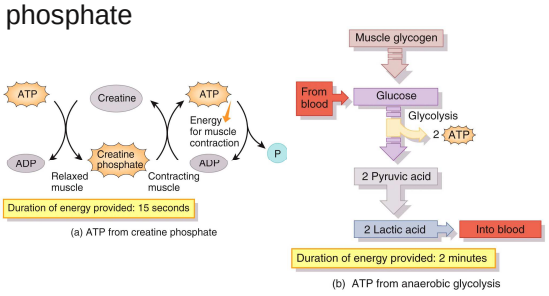
Action Potential in a Ventricular Fiber

An action potential in a ventricular contractile fiber is characterized by a rapid depolarization, plateau, and repolarization



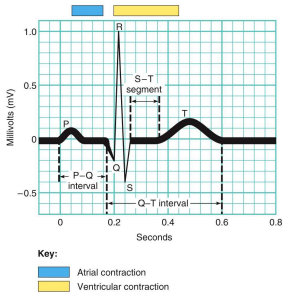
ATP Production in Cardiac Muscle

Cardiac muscle generates ATP via anaerobic cellular respiration and creatine phosphate

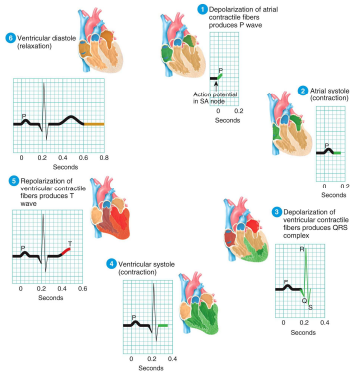


Electrocardiogram (EKG or ECG)

An EKG is a recording of the electrical changes that accompany each heart beat



Action Potential Propagation Through the Heart



The Cardiac Cycle

One cardiac cycle consists of the contraction (systole) and relaxation (diastole) of both atria, rapidly followed by the systole and diastole of both ventricles

- Electrical events
- Pressure changes
- Heart sounds
- Volume changes
- Mechanical events

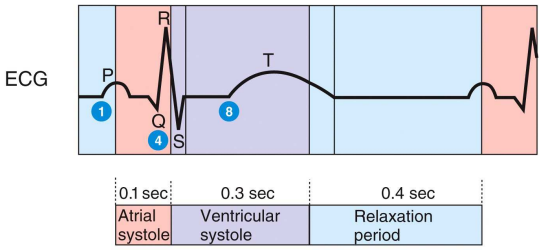
The Cardiac Cycle

Interactions Animation:

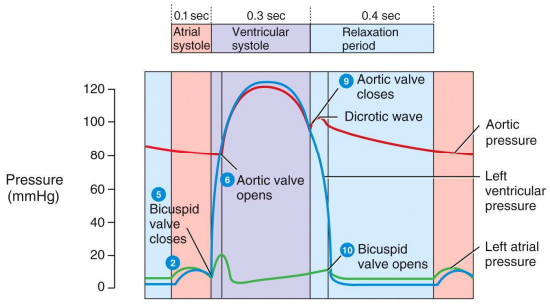
- Cardiac Cycle

You must be connected to the Internet and in Slideshow Mode to run this animation.

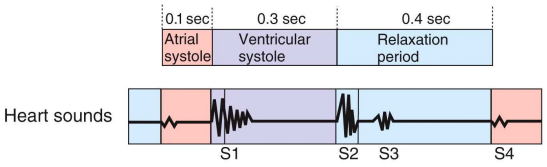
Electrical Events



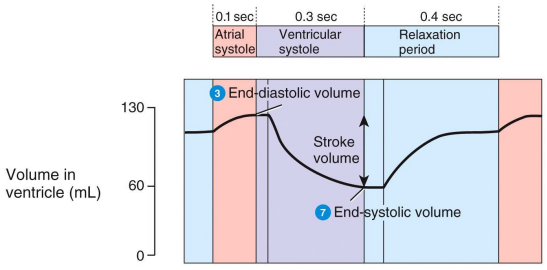
Pressure Changes



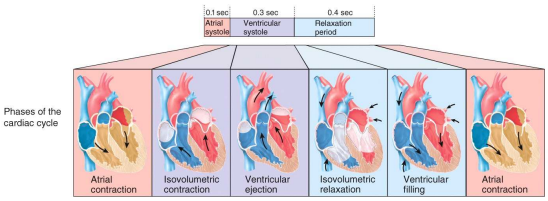
Heart Sounds

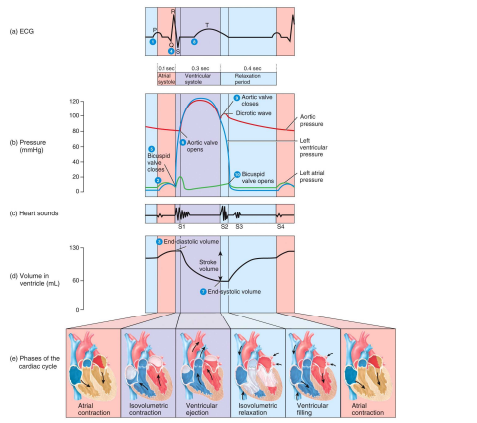


Volume Changes



Mechanical Events





Cardiac Output (CO)

- CO is the volume of blood ejected from the left or right ventricle into the aorta or pulmonary trunk each minute
- Stroke volume (SV) is the amount of blood pumped out of the ventricle in one beat
- CO (mL/min) = SV (mL/beat) x HR (beats/min)

Cardiac Output and the Factors That Influence It

Interactions Animation:

- Cardiac Output

You must be connected to the Internet and in Slideshow Mode to run this animation.

Regulation of Stroke Volume

3 factors regulate stroke volume:

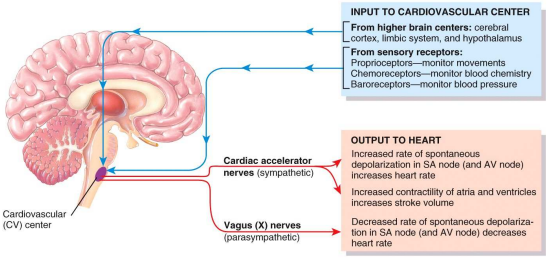
1. Preload
2. Contractility
3. Afterload

Regulation of Heart Rate

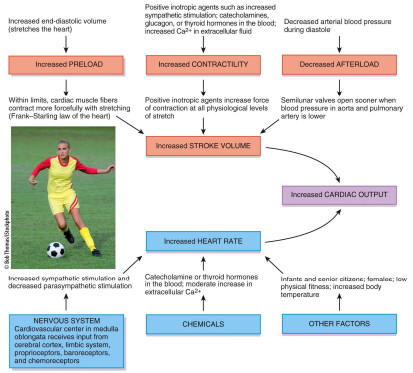
Several factors regulate heart rate:

- Autonomic nervous system
- Hormones
- Ions
- Age
- Gender
- Physical fitness
- Temperature

Nervous System Regulation of the Heart



Factors that Increase Cardiac Output



Exercise and the Heart

Regular aerobic exercise can:

- Increase cardiac output
- Increase HDL
- Decrease triglycerides
- Improve lung function
- Decrease blood pressure
- Assist in weight control

Help for Failing Hearts

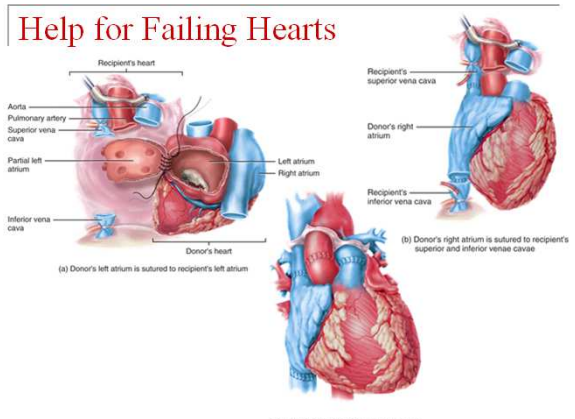
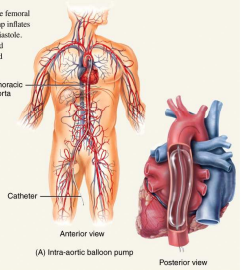


TABLE 20.1

Cardiac Assist Devices and Procedures

DEVICE	DESCRIPTION
Intra-aortic balloon pump (IABP)	A 40-mL polyurethane balloon mounted on a catheter is inserted into an artery in the groin and threaded through the femoral artery into the thoracic aorta (see Figure A). An external pump inflates the balloon with helium gas at the beginning of ventricular diastole. As the balloon inflates, it pushes blood both backward toward the heart (improves coronary blood flow) and forward toward peripheral tissues. The balloon then is rapidly deflated just before the next ventricular systole, drawing blood out of the left ventricle (making it easier for the left ventricle to eject blood). Because the balloon is inflated between heartbeats, this technique is called *intra-aortic balloon counterpulsation*.

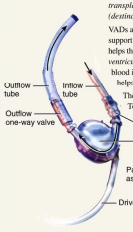


(A) Intra-aortic balloon pump

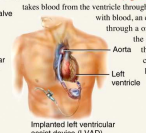
TABLE 20.1

Cardiac Assist Devices and Procedures

DEVICE	DESCRIPTION
Ventricular assist device (VAD)	A mechanical pump helps a weakened ventricle pump blood throughout the body so the heart does not have to work as hard. A VAD may be used to help a patient survive until a heart transplant can be performed *(bridge to transplant)* or provide an alternative to heart transplantation *(destination therapy)*. VADs are classified according to the ventricle that requires support. A *left ventricular assist device (LVAD)*, the most common, helps the left ventricle pump blood into the aorta (see Figure B). A *right ventricular assist device (RVAD)* helps the right ventricle pump blood into the pulmonary trunk. A *biventricular assist device (BVAD)* helps both the left and right ventricles perform. The kind of VAD used depends on the patient's specific needs. To help you understand how a VAD works, see the LVAD (Figure B). An inflow tube attached to the apex of the left ventricle takes blood from the ventricle through a one-way valve into the pump unit. Once the pump fills with blood, an external control system triggers pumping, and blood flows through a one-way valve into an outflow tube that delivers blood into the aorta. The external control system is on a belt around the waist or on a shoulder strap. Some VADs pump at a constant rate; others are coordinated with the person's heartbeat.



(B) Left ventricular assist device (LVAD)



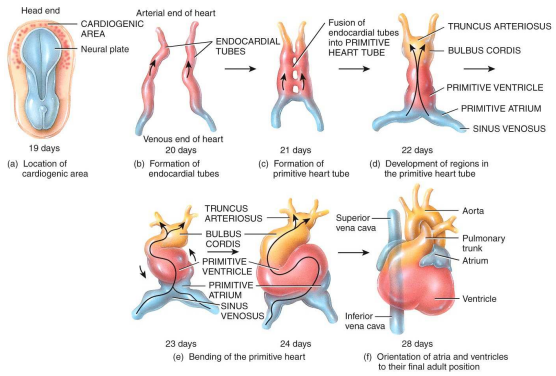
Implanted left ventricular assist device (LVAD)

TABLE 20.1

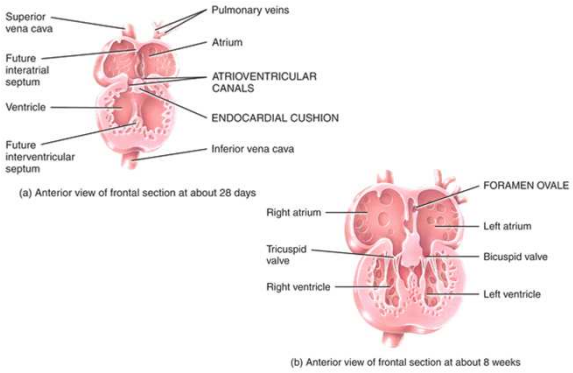
Cardiac Assist Devices and Procedures

DEVICE	DESCRIPTION
Cardiomyoplasty	A large piece of the patient's own skeletal muscle (left latissimus dorsi) is partially freed from connective tissue attachments and wrapped around the heart, leaving the blood and nerve supply intact. An implanted pacemaker stimulates the skeletal muscle's motor neurons to cause contraction 10–20 times per minute, in synchrony with some of the heartbeats.
Skeletal muscle assist device	A piece of the patient's own skeletal muscle is used to fashion a pouch inserted between the heart and aorta, functioning as a booster heart. A pacemaker stimulates the muscle's motor neurons to elicit contraction.

Development of the Heart



Development of the Heart



Disorders: Homeostatic Imbalances

- Coronary artery disease
- Atherosclerotic plaques
- Congenital heart defects
- Arrhythmia
- Congestive heart failure

End of Chapter 20