

12

The Heart

FOCUS: The heart is composed of cardiac muscle cells, which are elongated, branching cells that appear striated. Cardiac muscle cells behave as a single electrical unit, and the highly coordinated contractions of the heart depend on this characteristic. The heart, which is surrounded by pericardium, has two atria, which pump blood to the ventricles, and two ventricles, which pump blood to the body and lungs. Atrioventricular valves and semilunar

valves ensure one-way flow of blood through the heart, and the heart sounds are produced as these valves close. Specialized cardiac muscle cells originate action potentials which produce the rhythmic contraction and relaxation of the heart, which is called the cardiac cycle. Both intrinsic (i.e., Starling's law of the heart) and extrinsic (i.e., baroreceptor and chemoreceptor) mechanisms control heart function.

CONTENT LEARNING ACTIVITY

Size, Form, and Location of the Heart

“The adult heart has the shape of a blunt cone and is about the size of a closed fist.”

Match these terms with the correct statement or definition:

Apex
Base

- _____ 1. Blunt, rounded point; most inferior part of the heart.
_____ 2. Larger, flat portion of the heart opposite the point.



The right side of the heart forces blood to the lungs and back through the pulmonary circulation; the left side of the heart forces blood to all other tissues of the body and back through the systemic circulation.

Pericardium

“The pericardium is a double-layered sac that surrounds the heart and anchors it within the mediastinum.”

Match these terms with the correct statement or definition:

Fibrous pericardium
Parietal pericardium
Pericardial cavity

Pericardial fluid
Serous pericardium
Visceral pericardium

1. Tough, fibrous connective tissue outer layer of the pericardium.
2. Inner layer of the pericardium; a layer of flat epithelial cells.
3. Serous pericardium that lines the fibrous pericardium.
4. Serous pericardium that covers the heart surface.
5. Space between the visceral and parietal pericardia.
6. Fluid in the pericardial cavity that helps reduce friction as the heart moves within the pericardial sac.

External Anatomy

“Several grooves and blood vessels are visible on the surface of the heart.”

Match these blood vessels with the correct description:

Aorta
Cardiac veins
Coronary arteries
Coronary sinus

Coronary sulcus
Pulmonary trunk and arteries
Pulmonary veins
Venae cavae

1. Groove that runs around the heart, separating the atria from the ventricles.
2. Carry blood from the body to the right atrium.
3. Carry blood from the lungs to the left atrium.
4. Carry blood from the right ventricle to the lungs.
5. Carries blood from the left ventricle to the body.
6. Supply blood to the tissues of the heart.
7. Large vein that drains the cardiac veins of the heart and empties into the right atrium.

Blood Supply to the Heart

“Cardiac muscle in the wall of the heart is thick and metabolically very active.”

Match these terms with the correct statement or definition:

Cardiac veins
Left coronary artery

Right coronary artery

1. Supplies blood to much of the anterior wall of the heart and most of the left ventricle.
2. Supplies blood to most of the wall of the right ventricle.
3. Drain blood from cardiac muscle; empty into coronary sinus.



Cardiac muscle is very dependent on increased blood flow through the coronary arteries during exercise.

Heart Chambers

“The heart is a muscular pump consisting of four chambers.”

Match these terms with the correct statement or definition:

Interatrial septum

Interventricular septum

1. Wall that separates the right and left atria.
2. Wall that separates the right and left ventricles.

Heart Valves

“The heart valves allow one-way flow of blood through the heart.”

A. Match these terms with the correct statement or definition:

Bicuspid (mitral) valve
Chordae tendineae
Papillary muscles

Semilunar valves
Skeleton of the heart
Tricuspid valve

1. Atrioventricular valve between the right atrium and right ventricle.
2. Atrioventricular valve between the left atrium and left ventricle.
3. Cone-shaped muscular pillars in each ventricle.
4. Connective tissue strings connecting papillary muscles with the cusps of atrioventricular valves.
5. Valves with three cusps found in the aorta and pulmonary trunk.
6. Plate of fibrous connective tissue that provides support, electrical insulation, and rigid attachment for cardiac muscle.

B. Match these terms with the correct parts labeled in figure 12.1:

Aorta
 Aortic semilunar valve
 Bicuspid (mitral) valve
 Chordae tendineae
 Interventricular septum
 Left atrium
 Left ventricle
 Papillary muscles

Pulmonary artery
 Pulmonary semilunar valve
 Pulmonary trunk
 Pulmonary veins
 Right atrium
 Right ventricle
 Superior vena cava
 Tricuspid valve

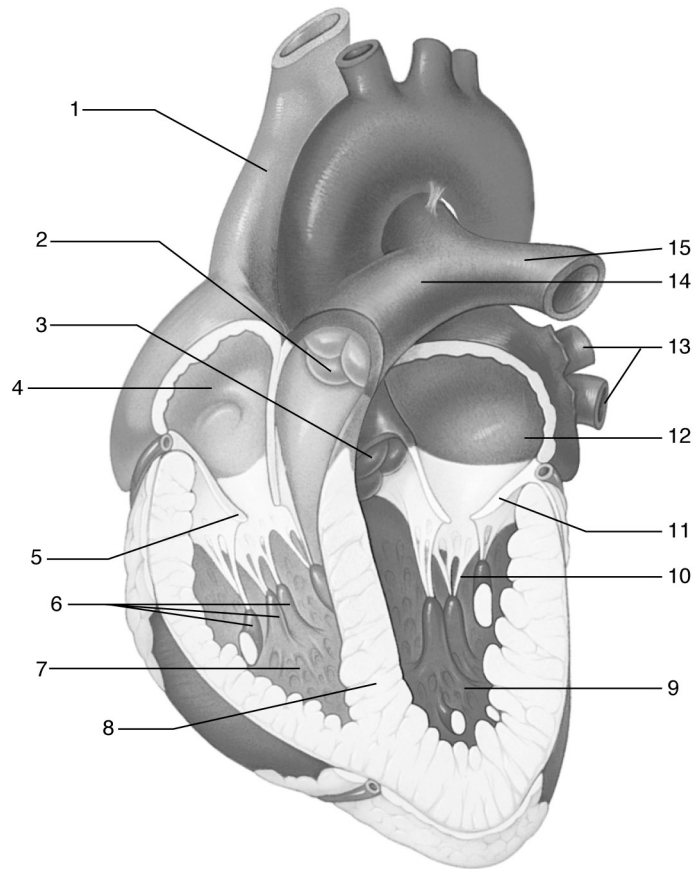


Figure 12.1

- | | | |
|----------|-----------|-----------|
| 1. _____ | 6. _____ | 11. _____ |
| 2. _____ | 7. _____ | 12. _____ |
| 3. _____ | 8. _____ | 13. _____ |
| 4. _____ | 9. _____ | 14. _____ |
| 5. _____ | 10. _____ | 15. _____ |

Route of Blood Flow Through the Heart

“It is important to understand that both atria contract at the same time, and both ventricles contract at the same time.”

Using the terms provided, complete these statements:

- | | |
|---------------------------|----------------------|
| Aortic semilunar valve | Pulmonary veins |
| Bicuspid (mitral) valve | Right atrium |
| Left atrium | Right ventricle |
| Pulmonary arteries | Systemic circulation |
| Pulmonary semilunar valve | Tricuspid valve |
| Pulmonary trunk | |

Blood flows into the right atrium from the (1), which returns blood from all the tissues of the body. Blood then flows into the (2), which completes filling as the right atrium contracts. Contraction of the right ventricle pushes blood against the (3), which closes, and the (4), which opens, allowing blood to enter the (5). The (6) carry blood to the lungs, where carbon dioxide is released, and oxygen is picked up. Blood returning from the lungs enters the (7) through the four (8). Blood passing from the left atrium to the left ventricle opens the (9), and contraction of the left atrium completes filling of the left ventricle. Contraction of the left ventricle opens the (10) allowing blood to enter the aorta.

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____

Heart Wall

“Cardiac muscle and several other types of tissue make up the structure of the heart.”

Match these terms with the correct statement or definition:

- | | | |
|-------------|--|------------|
| Endocardium | | Myocardium |
| Epicardium | | |

- _____
- _____
- _____

1. Thin serous membrane forming the smooth outer surface of the heart; also called visceral pericardium.
2. Thick middle layer of the heart composed of cardiac muscle.
3. Smooth inner surface of the heart chambers; composed of simple squamous epithelium over connective tissue.

Cardiac Muscle

“Cardiac muscle cells are elongated, branching, striated cells with one or occasionally two nuclei.”

Using the terms provided, complete these statements:

ATP
Intercalated disks

Mitochondria
Oxygen

1. _____
2. _____
3. _____
4. _____

The energy for cardiac muscle contraction is provided by (1). Cardiac muscle cells have many (2), where ATP is produced at a rapid enough rate to sustain muscle contraction. (3) must be supplied to the cells, because, unlike skeletal muscle, cardiac muscle cannot develop a significant oxygen debt. The cardiac muscle cells are bound to each other by specialized cell-to-cell contacts called (4), which reduce electrical resistance between cells, allowing action potentials to pass from cell to cell.

Electrical Activity of the Heart

“Like skeletal muscle and neurons, action potentials in cardiac muscle exhibit depolarization followed by repolarization of the resting membrane potential.”

Using the terms provided, complete these statements:

Calcium ion channels
Close
Plateau
Open
Potassium ion channels

Repolarization
Refractory period
Sodium ion channels
Threshold

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____

In cardiac muscle, a period of slow repolarization called the (1) phase greatly prolongs the action potential. The depolarization phase of the action potential occurs when voltage-gated (2) open, allowing sodium ions to diffuse into the cell. When the membrane potential reaches its maximum depolarization, voltage-gated sodium ion channels (3). Depolarization in the cardiac muscle causes voltage-gated (4) to open, however, and calcium ions move into the cell and keep it depolarized, resulting in the plateau phase. At the end of the plateau phase, voltage-gated (5) open and potassium ions move out of the cell, causing (6). Cardiac muscle cells in the SA node have a larger number of voltage-gated (7) than other areas of the heart. When their channels open spontaneously, calcium ions diffuse into cardiac muscle causing depolarization. When the depolarization reaches (8), this causes the SA node to produce action potentials. Action potentials in cardiac muscle cells exhibit a (9) that lasts about as long as the prolonged action potential, and prevents tetanic contractions from occurring.

Conduction System of the Heart

“Contraction of atria and ventricles is coordinated by specialized cardiac muscle cells in the wall of the heart.”

A. Match these terms with the correct statement or definition:

Atrioventricular bundle
AV node
Bundle branches

Purkinje fibers
SA node

1. Located in upper wall of right atrium; initiates contraction of the heart.
2. Located in the lower portion of the right atrium; slows rate of action potential conduction.
3. Conducting cells that arise from the AV node; rapid action potential conduction occurs here.
4. Right and left subdivisions of the atrioventricular bundle.
5. Numerous small branches of conducting tissue that extend around the apex of the ventricles.



When action potentials originate in an area of the heart other than the SA node, the result is an ectopic beat.

B. Match these terms with the correct parts labeled in figure 12.2:

AV bundle
AV node
Bundle branches
Purkinje fibers
SA node

1. _____
2. _____
3. _____
4. _____
5. _____

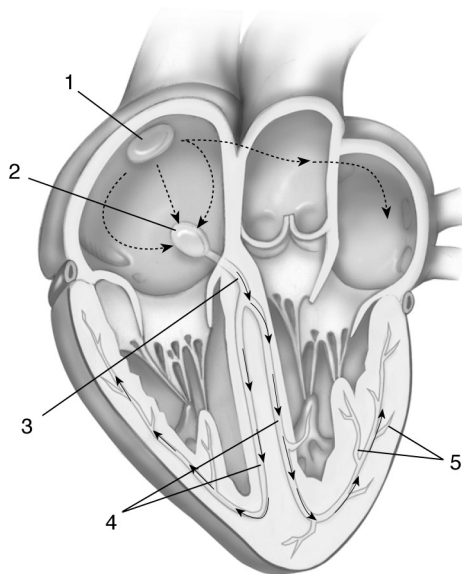


Figure 12.2

Electrocardiogram

“The record of electrical changes resulting from action potentials in cardiac muscle is an electrocardiogram.”

A. Match these terms with the correct statement or definition:

P-Q (P-R) interval
P wave
QRS complex

Q-T interval
T wave

1. Record of action potentials during depolarization of the atrial myocardium.
2. Record of action potentials from depolarization of the ventricles.
3. Record of repolarization of the ventricles.
4. Time during which the atria contract and begin to relax.
5. Length of time required for ventricular depolarization and repolarization.

B. Match these terms with the correct parts labeled in figure 12.3:

P-Q (P-R) interval
P wave
QRS complex
Q-T interval
T wave

1. _____
2. _____
3. _____
4. _____
5. _____

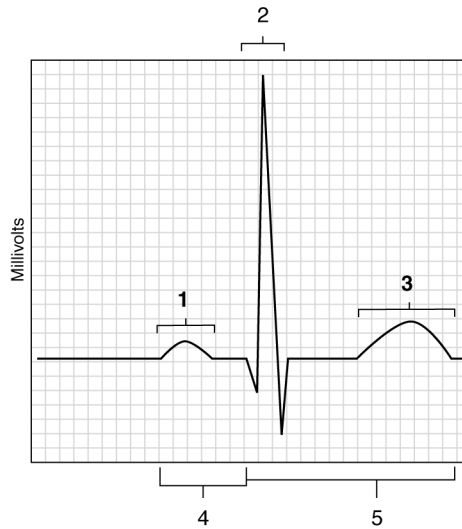


Figure 12.3

Cardiac Cycle

“Cardiac cycle refers to the repetitive pumping process that begins with the onset of cardiac muscle contraction and ends with the beginning of the next contraction.”

Match these terms with the correct statement or definition:

Atrial diastole
Atrial systole

Ventricular diastole
Ventricular systole

1. Process that causes the last 30% of ventricular volume to fill.
2. Increases ventricular pressure; bicuspid and tricuspid valves close and aortic and pulmonary semilunar valves open.
3. Decreases ventricular pressure; aortic and pulmonary semilunar valves close and bicuspid and tricuspid valves open.

Heart Sounds

“There are two main heart sounds.”

Match these terms with the correct statement or definition:

First heart sound
Second heart sound

Murmur
Stenosed valve

1. Occurs at the beginning of ventricular systole; results from the closure of tricuspid and bicuspid valves.
2. Results from the closure of semilunar valves.
3. Caused by leaky valve; swishing sound after valve closure.
4. Narrowed valve; swishing sound before valve closure.

Regulation of Heart Function

“There are a number of mechanisms that modify heart rate and stroke volume.”

Match these terms with the correct statement or definition:

Cardiac output
Heart rate

Stroke volume

1. Volume of blood pumped by either ventricle of the heart each minute (stroke volume X heart rate).
2. Volume of blood pumped per ventricle each time the heart contracts.
3. Number of times the heart contracts each minute.

Intrinsic Regulation of the Heart

“*Intrinsic regulation of the heart refers to mechanisms contained within the heart itself.*”

Using the terms provided, complete these statements:

Afterload
Decreased
Increased
Preload

Starling's law
of the heart
Venous return

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____
11. _____
12. _____

The amount of blood that returns to the heart is called (1). The degree to which ventricular walls are stretched at the end of diastole is called (2). If venous return is (3), the heart fills to a greater volume, which stretches the cardiac muscle fibers, producing increased preload. In response to increased preload, cardiac muscles contract with (4) force. Greater force causes a(n) (5) volume of blood to be ejected from the heart, resulting in (6) stroke volume. Stretch also causes a slightly (7) heart rate. Therefore, if venous return is decreased, cardiac output is (8), whereas, if venous return is increased, cardiac output is (9). This direct relationship between preload and cardiac output is called (10). (11) refers to the pressure against which the ventricles must pump blood. People suffering from hypertension have a(n) (12) afterload.

Extrinsic Regulation of the Heart

“*Extrinsic regulation of the heart refers to both nervous and hormonal regulation of the heart.*”

A. Match these terms with the correct statement or definition:

Baroreceptors
Chemoreceptors

Cardioregulatory center

- _____
- _____
- _____

1. Sensory receptors sensitive to the stretch of the walls of the aorta and internal carotid arteries.
2. Sensory receptors sensitive to changes in pH and carbon dioxide levels.
3. Part of the medulla that receives and integrates action potentials from baroreceptors.



The autonomic nervous system innervates the heart; stimulation of parasympathetic fibers to the heart decreases heart rate, whereas stimulation of sympathetic fibers increases heart rate and stroke volume.

B. Match these terms with the correct statement or definition:

Decrease(s)

Increase(s)

1. Increased blood pressure causes stretching of baroreceptors, which increases parasympathetic stimulation and _____ heart rate.
2. Excitement, anxiety, or anger increases sympathetic stimulation of the heart, which _____ cardiac output.
3. Epinephrine and norepinephrine from the adrenal medulla _____ heart rate and stroke volume.
4. Decrease in pH and an increase in carbon dioxide _____ sympathetic stimulation of the heart.
5. Excess potassium ions _____ heart rate.
6. Decreased body temperature _____ heart rate.

QUICK RECALL

1. List four functions of the heart.
2. Name the four valves that regulate blood flow in the heart, and give their location.
3. State the cause of the P wave, the QRS complex, and the T wave of the ECG. Name the contraction event associated with each wave.
4. List the two normal heart sounds, and give the reason for each.
5. List the effects of parasympathetic and sympathetic stimulation of the heart.

WORD PARTS

Give an example of a new vocabulary word that contains each word part.

WORD PART	MEANING	EXAMPLE
diastol-	stand apart; relax	1. _____
systol-	stand together; contract	2. _____
-cusp-	a point	3. _____
semi-	half	4. _____
-lun-	the moon	5. _____
cardi-	the heart	6. _____

MASTERY LEARNING ACTIVITY

Place the letter corresponding to the correct answer in the space provided.

- | | |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>_____ 1. Which of these structures carry blood to the right atrium?</p> <ul style="list-style-type: none"> a. coronary sinus b. superior vena cava c. inferior vena cava d. all of the above | <p>_____ 4. The papillary muscles</p> <ul style="list-style-type: none"> a. are attached to the chordae tendineae. b. are found in the atria. c. attach the auricles to the heart. d. are attached to the semilunar valves. |
| <p>_____ 2. The pericardial cavity</p> <ul style="list-style-type: none"> a. is located between the parietal and visceral pericardia. b. is lined with fibrous pericardium. c. is filled with air. d. all of the above | <p>_____ 5. Given these blood vessels:</p> <ul style="list-style-type: none"> 1. aorta 2. inferior vena cava 3. pulmonary trunk 4. pulmonary vein |
| <p>_____ 3. The valve located between the right atrium and the right ventricle is the</p> <ul style="list-style-type: none"> a. aortic semilunar valve. b. pulmonary semilunar valve. c. tricuspid valve. d. bicuspid (mitral) valve. | <p>Choose the arrangement that lists the vessels in the order a red blood cell encounters them as it returns to the heart.</p> <ul style="list-style-type: none"> a. 1,3,4,2 b. 2,3,4,1 c. 2,4,3,1 d. 3,2,1,4 |

- _____ 6. Most of the heart wall consists of
- epicardium
 - myocardium
 - pericardium
 - endocardium
- _____ 7. Depolarization of a cardiac muscle cell involves voltage-gated _____ channels
- calcium
 - potassium
 - sodium
 - both a and c
- _____ 8. Given these structures of the conduction system of the heart:
- atrioventricular bundle
 - AV node
 - bundle branches
 - Purkinje fibers
 - SA node
- Choose the arrangement that lists the structures in the order an action potential passes through them.
- 2,5,1,3,4
 - 2,5,3,1,4
 - 2,5,4,1,3
 - 5,2,1,3,4
 - 5,2,4,3,1
- _____ 9. A T wave represents
- depolarization of the ventricles.
 - repolarization of the ventricles.
 - depolarization of the atria.
 - repolarization of the atria.
- _____ 10. Which of these correctly describes conditions during the cardiac cycle?
- As pressure increases in the ventricles, the tricuspid and bicuspid valves open.
 - Both ventricles are 70% filled before the atria contract.
 - Atrial systole closes the aortic and pulmonary semilunar valves.
 - During ventricular diastole, pressure in the ventricles increases greatly.
 - all of the above
- _____ 11. Cardiac output is defined as
- blood pressure times peripheral resistance.
 - peripheral resistance times heart rate.
 - heart rate times stroke volume.
 - stroke volume times blood pressure
- _____ 12. The "dupp" sound (second heart sound) is caused by
- the closing of the bicuspid and tricuspid valves.
 - the closing of the semilunar valves.
 - blood rushing out of the ventricles.
 - the filling of the ventricles.
 - ventricular contraction.
- _____ 13. Increased venous return results in increased
- stroke volume.
 - heart rate.
 - cardiac output.
 - all of the above
- _____ 14. Through the baroreceptor reflex, when normal arterial blood pressure decreases, you would expect
- heart rate to decrease.
 - stroke volume to decrease.
 - increased parasympathetic stimulation of the heart.
 - blood pressure to return to normal.
 - all of the above
- _____ 15. A decrease in blood pH and an increase in blood carbon dioxide levels results in
- increased heart rate.
 - increased stroke volume.
 - increased sympathetic stimulation of the heart.
 - all of the above



FINAL CHALLENGES



Use a separate sheet of paper to complete this section.

1. The Jarvik-7 artificial heart is designed as a replacement for the ventricles. Explain why it is more important to replace the ventricles than the atria of the heart.
2. During an experiment in a physiology laboratory a student named C. Saw was placed on a table that could be tilted. The instructor asked the students to predict what would happen to C. Saw's heart rate if the table were tilted so that her head were lower than her feet. Some students predicted an increase in heart rate, and others claimed it would decrease. Can you explain why both predictions might be true?
3. After C. Saw was tilted so that her head was lower than her feet for a few minutes, the table was tilted so that her head was higher than her feet. Predict the effect this change has on C. Saw's heart rate.
4. Mary Traveler visits the Grand Canyon for the first time, and finds the view so stunning that she hyperventilates. Given that hyperventilation decreases the amount of CO_2 in the blood, how is her heart rate affected?