

PCT Blizzard Bag, Day 2: The Cardiovascular System Packet

- Read packet
- Complete questions at end



CHAPTER

2

The Cardiovascular System

Chapter Outline

- Anatomy of the Heart (pg. 18)
- Principles of Circulation (pg. 20)
- The Cardiac Cycle (pg. 21)
- Conduction System of the Heart (pg. 22)
- Electrical Stimulation and the ECG Waveform (pg. 24)

Objectives

Upon completion of this chapter, you should be able to:

- Identify the structures of the heart including valves, chambers, and vessels
- Compare and contrast the pulmonary and systemic circulation
- Trace the pathway of the blood through pulmonary and systemic circulation
- Describe coronary circulation
- Explain the cardiac cycle
- Identify what takes place during systole and diastole
- Describe the parts and function of the conduction system
- Define the unique qualities of the heart and their relationship to the cardiac conduction system
- Explain the conduction system as it relates to the ECG
- Discuss the electrical stimulation of the heart as it relates to the ECG waveform
- Identify each part of the ECG waveform
- Describe the heart activity that produces the ECG waveform

Key Terms

aorta - The largest artery of the body, which transports blood from the left ventricle of the heart to the entire body.

aortic semilunar valve - Valve located in the aorta that prevents the backflow of blood into the left ventricle.

atrioventricular (AV) node - Specialized cells that delay the electrical conduction through the heart and allow the atria time to contract.

atrium (pl. atria) - One of the upper two small chambers of the heart. The right atrium receives blood from the body through the vena cava, and the left atrium receives blood from the lungs through the pulmonary vein.

automaticity - The ability of the heart to initiate an electrical impulse without being stimulated by another source.

bundle branches - Left and right branches of the Bundle of His that conduct impulses down either side of the interventricular septum to the left and right ventricles.

Bundle of His (AV bundle) - A bundle of fibers that originate in the AV node and enter the interventricular septum conducting electrical impulses to the left and right bundle branches.

cardiac cycle - The period from the beginning of one heartbeat to the beginning of the next; the cardiac cycle is made up of systole and diastole.

Key Terms (cont.)

complex - A group of ECG waveform deflections that indicate electrical activity in the heart.

conductivity - The ability of the heart cells to receive and transmit an electrical impulse.

contractility - The ability of the heart muscle cells to shorten in response to an electrical stimulus.

coronary circulation - The circulation of blood to and from the heart muscle.

deoxygenated blood - Blood that has little or no oxygen (oxygen-poor blood).

depolarization - The electrical activation of the cells of the heart that initiates contraction of the heart muscle.

diastole - The phase of the cardiac cycle when the heart is expanding and refilling; also known as the relaxation phase.

excitability - The ability of the heart muscle cells to respond to an impulse or stimulus.

interval - The period of time between two activities within the heart.

interventricular septum - A partition or wall (septum) that divides the right and left ventricles.

ischemia - Temporary lack of blood supply to an area of tissue due to a blockage in the circulation to that area.

isoelectric - The period when the electrical tracing of the ECG is at zero or a straight line; no positive or negative deflections are seen.

left atrium - The left upper chamber of the heart, which receives blood from the lungs.

left ventricle - The left lower chamber of the heart, which pumps oxygenated blood through the body; also known as the workhorse of the heart.

mitral (bicuspid) valve - Valve with two cusps or leaflets located between the left atrium and left ventricle; it prevents backflow of blood into the left atrium.

myocardial - Pertaining to the heart (*cardi*) muscle (*myo*).

oxygenated blood - Blood having oxygen (oxygen-rich blood).

pericardium - A two-layered sac of tissue enclosing the heart.

polarization - The state of cellular rest in which the inside is negatively charged and the outside is positively charged.

pulmonary artery - Large artery that transports deoxygenated blood from the right ventricle

to the lungs; the only artery in the body that carries deoxygenated blood.

pulmonary circulation - The transportation of blood to and from the lungs; blood is oxygenated in the lungs during pulmonary circulation.

pulmonary semilunar valve - A valve found in the pulmonary artery that prevents backflow of blood into the right ventricle during pulmonary circulation.

pulmonary vein - A blood vessel that transports blood from the lungs to the left atrium. The only vein in the body to carry oxygenated blood.

Purkinje fibers - The fibers within the heart that distribute electrical impulses to cells throughout the ventricles.

Purkinje network - A network of fibers that distribute electrical impulses through the ventricles; named after a scientist with the last name of Purkinje.

repolarization - When heart muscle cells return to their resting electrical state and the heart muscle relaxes.

right atrium - The right upper chamber of the heart, which receives blood from the body.

right ventricle - The right lower chamber of the heart, which pumps blood to the lungs.

segment - A portion or part of the electrical tracing produced by the heart.

semilunar valve - A valve with half-moon-shaped cusps that open and close, allowing blood to travel only one way; located in the pulmonary artery and the aorta.

sinoatrial (SA) node - An area of specialized cells in the upper right atrium that initiates the heartbeat.

systemic circulation - The circulation between the heart and the entire body excluding the lungs.

systole - The contraction phase of the cardiac cycle, during which the heart is pumping blood out to the body.

tricuspid valve - Valve located between the right atrium and right ventricle; it prevents backflow of blood into the right atrium.

vena cava - Largest vein in the body, which provides a pathway for deoxygenated blood to return to the heart; its upper portion, the superior vena cava, transports blood from the head, arms, and upper body; and its lower portion, the inferior vena cava, transports blood from the lower body and legs.

The function of the heart is to pump blood to and from all the tissues of the body. Blood supplies the tissues with nutrients and oxygen and removes carbon dioxide and waste products. The process of transporting blood to and from the body tissues is known as circulation. The heart's powerful muscular pump performs the task of circulation. Circulation of the blood is dependent upon the heart and its ability to contract or beat. Each contraction of the heart is recorded on the ECG. Knowledge of the heart, its functions, and what produces the ECG tracing will provide you with a clear understanding of the tasks you will be performing as an ECG health care professional.

Anatomy of the Heart

The heart lies in the center of the chest, under the sternum, and in between the lungs. Two-thirds of it lies to the left of the sternum. It is approximately the size of your fist and weighs about 10.6 ounces or 300 grams (see Figure 2-1).

The heart is a powerful muscular pump that beats an average of 72 times per minute, 100,000 times per day, and 22.5 billion times in the average lifetime. The heart pumps about 140 mL of blood per beat, for a total output of 5 liters per minute. Each day the heart pumps approximately 7250 liters or 1800 gallons of blood. This is enough to fill an average size bathtub about 36 times.

The entire heart is enclosed in a sac of tissue called the **pericardium**. This sac consists of two layers: the tough, outer layer is called the parietal layer and the inner layer is called the visceral layer. The visceral pericardium adheres closely to the heart. It is also referred to as the epicardium, the outermost layer of the heart. The purpose of the pericardium is to protect the heart from infection and trauma.

The space between the two layers is called the pericardial space. It contains about 10–20 mL (about ½ ounce) of fluid. This fluid serves to cushion the heart against blows and decreases friction between the layers created by the pumping heart.

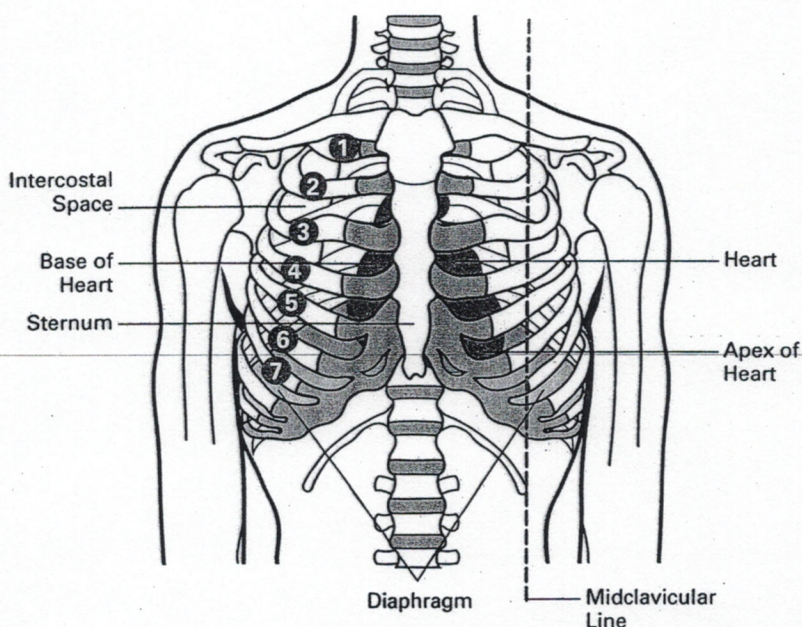


Figure 2-1: The heart is tipped to the left side of the body, and two-thirds of it is located on the left side of the chest.

The heart consists of three layers: the endocardium, the myocardium, and the epicardium or visceral pericardium. The epicardium, the outermost layer, is thin and contains the coronary arteries. The myocardium is the middle muscular layer that contracts the heart. The endocardium is the innermost layer, which lines the inner surfaces of the heart chambers and the valves. It is also where the Purkinje fibers are located (see Figure 2-2 and Table 2-1).

Chambers and valves

The heart is divided into four chambers. The top chambers are the **right atrium** and **left atrium**. The bottom chambers are the **right ventricle** and **left ventricle**. The myocardium varies in thickness between chambers. It is thin in the atria, thick in the

Table 2-1 Heart layers

Layer	Location and Function
Endocardium	Inner layer of the heart that lines the chambers and valves. The Purkinje fibers are located here.
Myocardium	Middle, thickest muscular layer, responsible for heart contraction
Epicardium (also called the visceral pericardium)	Outside, thin layer of the heart that contains the coronary arteries; also the inner layer of the pericardium
Pericardium (made up of the visceral pericardium and the parietal pericardium)	A double-layer sac that encloses the heart. The inner layer, or visceral pericardium, is also called the epicardium; the outer layer is the parietal pericardium.

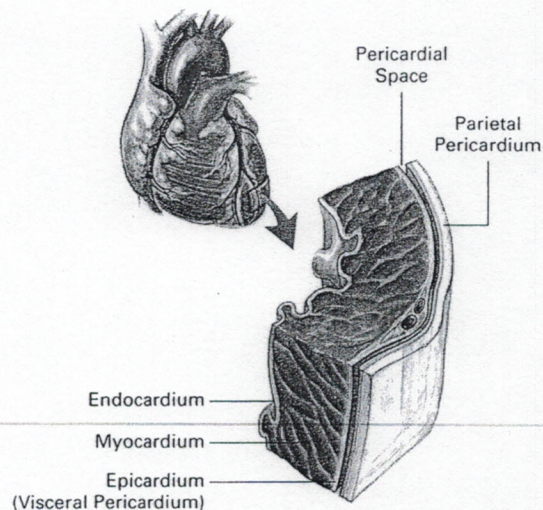


Figure 2-2: Three distinct layers can be identified on the heart. A sac called the pericardium protects it.

right ventricle, and thickest in the left ventricle. The thicker the myocardium of a chamber is, the stronger the muscular contraction of that chamber. The left ventricle is sometimes known as the “workhorse of the heart” because of its thick myocardium and powerful muscular contraction.

Between the right atrium and right ventricle is the **tricuspid valve**. Between the left atrium and left ventricle is the **mitral (bicuspid) valve**. These two valves are known as atrioventricular valves because they divide the atria from the ventricles. The **pulmonary artery** and the **aorta** each have a **semilunar valve**. They are called semilunar because the valve flaps look like a half (*semi*) moon (*lunar*). These valves are called the **aortic semilunar valve** and the **pulmonary semilunar valve** (see Figure 2-3 and Table 2-2).

The one-way valves in the heart keep the blood flow headed in the right direction. The flaps or “cusps” open to allow the blood to flow, then close to prevent the back-flow of blood. The mitral (bicuspid) and tricuspid valves separate the atria and ventricles and prevent the blood from flowing back from the ventricles to the atria.

Table 2-2 Heart valves and their locations

Name	Valve Type	Location
Aortic	Semilunar	Between left ventricle and aorta
Pulmonary	Semilunar	Between right ventricle and pulmonary artery
Tricuspid	Atrioventricular	Separates right atrium and right ventricle
Mitral (bicuspid)	Atrioventricular	Separates left atrium and left ventricle

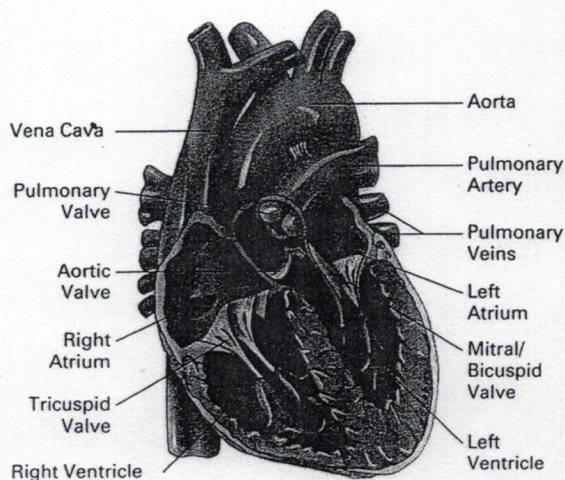


Figure 2-3: Heart chambers, valves, and vessels

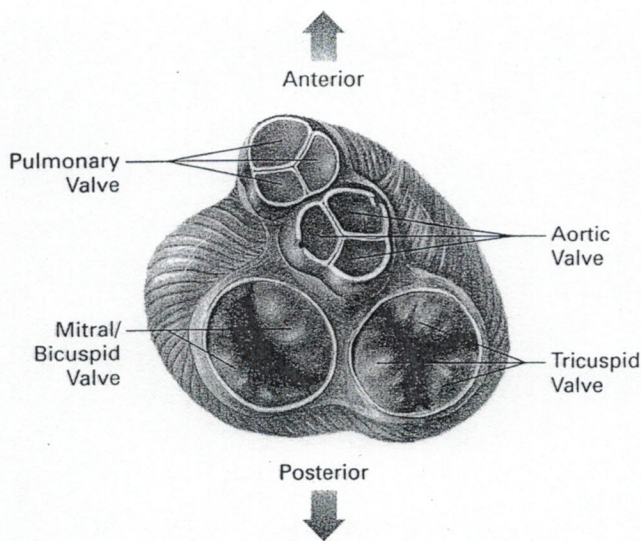


Figure 2-4: Valves viewed from a cross section of the heart

The semilunar valves in the pulmonary artery and the aorta prevent the backflow of blood into the ventricles (see Figure 2-4).

The major vessels of the heart

Blood vessels are the veins and arteries that transport blood all over the body. The major blood vessels that transport blood to and from the heart are the vena cava, pulmonary artery, pulmonary veins, and the aorta.

Blood travels from the body tissue through the veins toward the heart. The blood is returned through the largest vein of the body, the **vena cava**, to the right atrium. There are two branches to the vena cava. The superior vena cava transports blood from the head, arms, and upper body.

The inferior vena cava transports blood from the lower body and legs.

When the heart contracts, the right ventricle pumps **deoxygenated blood** (blood that has little or no oxygen) to the lungs via the pulmonary artery. The **pulmonary veins** transport **oxygenated blood** (blood containing oxygen) back to the heart into the left atrium. Transporting blood to the entire body is the function of the aorta. When the left ventricle contracts, the blood is pumped into the aorta. The first vessels to branch off the aorta are the coronary arteries. Coronary arteries are part of coronary circulation, which supplies blood to the muscular heart pump (see Figure 2-5).

Principles of Circulation

The heart is actually a two-sided pump. The left side of the heart pumps oxygenated blood to the body tissue. The right side of the heart pumps deoxygenated blood to the lungs. The pathways for pumping blood to and from the lungs are known as **pulmonary circulation**. The pathways for pumping blood throughout the body and back to the heart are known as **systemic circulation**. The circulation of

blood to and from the heart muscle is known as **coronary circulation**.

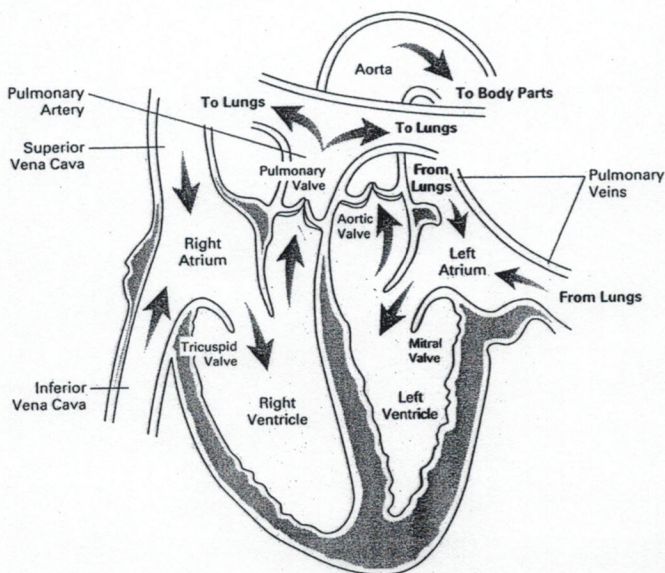


Figure 2-5: Pathways for blood through the heart

Pulmonary circulation: The heart and lung connection

Deoxygenated blood enters the right atrium through the superior and inferior vena cava. Blood travels through the tricuspid valve into the right ventricle. The right ventricle pumps the blood through the pulmonary semilunar valve into the pulmonary artery, then into the lungs. In the lungs, the blood is oxygenated. The blood returns to the heart through the pulmonary veins into the left atrium. The left atrium is the last step of pulmonary circulation.

Systemic circulation: The heart and body connection

Oxygenated blood enters the left atrium and travels through the mitral valve into the left

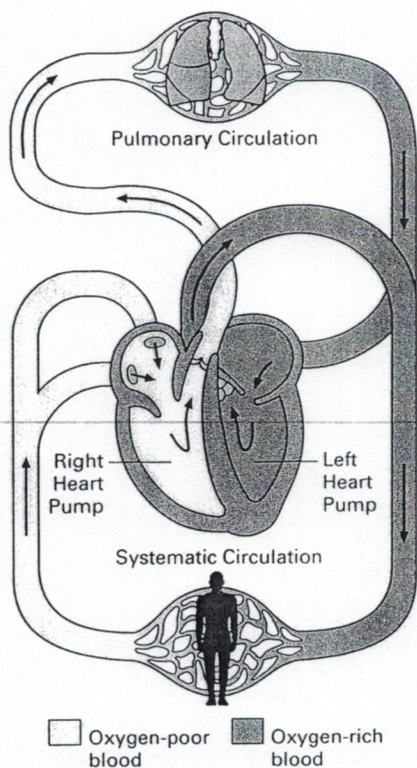


Figure 2-6: Pulmonary and systemic circulation

heart. The left main artery has more branches than the right because the left side of the heart is more muscular and requires more blood supply. The deoxygenated blood travels through the coronary veins and is collected in the coronary sinus, which empties the blood directly into the right atrium (see Figure 2-7).

The Cardiac Cycle

Each beat of the heart has two phases that indicate the contraction and the relaxation periods of the heart. The contraction and relaxation of the heart together make up the **cardiac cycle**. When the heart contracts, it is squeezing blood out to the body. As the heart relaxes, it is expanding and refilling. The relaxation phase of the heart is known as **diastole**. The contraction phase is known as **systole** (see Figure 2-8 on p. 22).

Diastole: Relaxation of the heart

During the diastolic phase, blood from the upper body returns to the heart via the superior vena cava and blood from the lower body returns via the inferior vena cava. The right atrium fills with blood and contracts, pushing open the tricuspid valve. This allows blood to flow into the right ventricle. At the same time, blood is returning from the lungs via the pulmonary veins to the left atrium. This blood fills the left atrium prior to the atrial contraction. The atrial contraction forces the mitral valve open to allow blood to flow into the left ventricle.

ventricle. The left ventricle pumps the blood through the aortic semilunar valve into the aorta. The aorta provides the pathway for the blood to circulate through the body. In the body, the oxygen in the blood is exchanged with carbon dioxide. After traveling through the body, the deoxygenated blood returns to the heart through the superior and inferior vena cava (see Figure 2-6).

Coronary circulation: The heart's blood supply

Oxygenated blood from the left ventricle travels through the aorta to the coronary arteries. There are two main coronary arteries, the left main artery and the right main coronary artery. These arteries branch to supply oxygenated blood to the entire

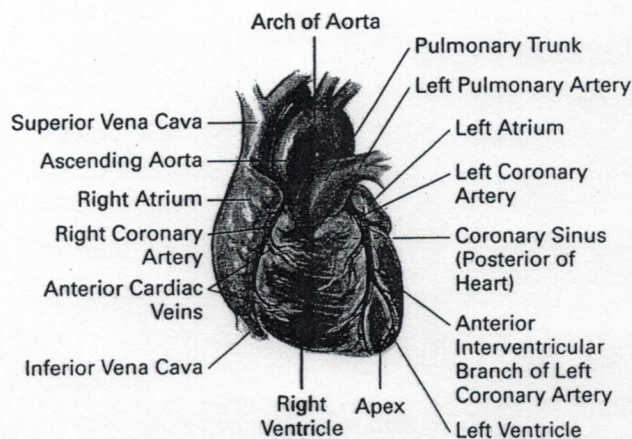


Figure 2-7: Coronary circulation

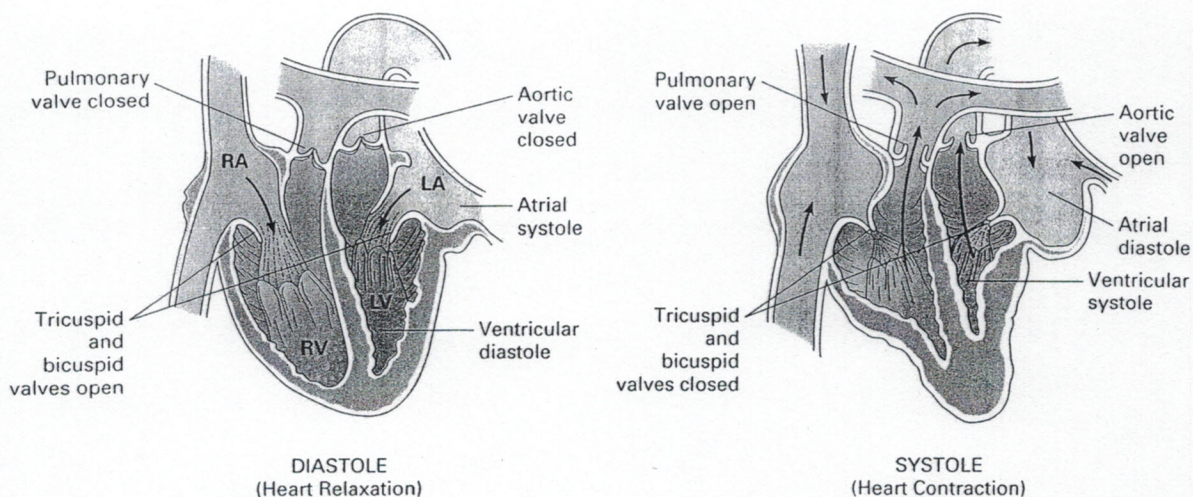


Figure 2-8: Diastole and systole

Systole: Contraction of the heart

During the systolic phase, the heart muscle contracts, creating pressure to open the pulmonary and aortic valves. Blood from the right ventricle is pushed into the lungs to exchange oxygen and carbon dioxide. Blood from the left ventricle is pushed through the aorta to be distributed throughout the body to provide oxygen for tissues and remove carbon dioxide.

In adults, the average heart beats approximately 60 to 100 times per minute. In general, women have a faster heartbeat than men. Children's heart rates are usually faster than an adult's heart rate. Children's heart rates depend upon the age and size of the child. If you listen to the heart with a stethoscope, you will hear two sounds: "lubb" and "dupp." These sounds are made by the opening and closing of the heart valves, which is caused by the contraction of the heart. The "lubb" you hear is the sound made during the systolic phase by the contraction of the ventricles and the closing of the mitral and tricuspid valves. The "dupp" sound is made during the diastolic phase. It is shorter and occurs during the beginning of ventricular relaxation. This sound is from the closure of the pulmonary and aortic valves. Each complete "lubb-dupp" you hear is actually one beat of the heart.

Conduction System of the Heart

The pumping cycle or contraction of the heart muscle is controlled by electrical impulses. These impulses are initiated and transmitted through the heart. Specialized masses of tissue in the heart produce these impulses and form the conduction system. The conduction system is necessary for the heart to pump continuously and rhythmically.

Unique qualities of the heart

The conduction system is a network of conducting tissue that creates the heartbeat and establishes a pattern for the electrical activity of the heart. The conducting tissue of the heart has several unique qualities. These qualities control the beat of the heart and produce the electrical wave. They include automaticity, conductivity, contractility, and excitability.

Automaticity is the ability of the heart to initiate an electrical impulse without being stimulated by another or independent source. Automaticity is a form of the word *automatic*, which is exactly how the heart beats—automatically. The heart tissue has its own innate ability to initiate an electrical impulse.

The heartbeat relies on the ability of the **myocardial** cells to conduct electrical impulses. (**Myocardial** means pertaining to the heart muscle.) **Conductivity** is the ability of the heart cells to receive and transmit an electrical impulse. The electrical impulse is initiated by automaticity and then travels through the rest of the heart due to the ability of the heart cells to conduct the impulse.

When the heart muscle cells are stimulated by an electrical impulse, they contract. This ability of the heart muscle cells to shorten in response to an electrical stimulus is known as **contractility**. The contraction of the heart muscle cells produces the heartbeat or pumping of the heart.

Excitability is the ability of the heart muscle cells to respond to an impulse or stimulus. Without the quality of excitability, the heart would not react to the electrical impulses that are initiated within the heart.

As you can see, the heart's unique qualities are essential to the rhythmic contraction of the heart muscle and the circulation of blood through the body. Without these qualities the heart would not beat.

In addition to automaticity, the heartbeat is controlled by the autonomic nervous system (ANS). Like the unique qualities of the heart, the ANS is involuntary. This means you have no conscious control over its functions. The sympathetic branch of the ANS increases the heart rate. This happens automatically when you are under stress or become frightened. You can think of the automaticity of the heart as the cruise control in your car. In a normal heart, automaticity sets the rate of the heart to 60 to 100 beats a minute. When the sympathetic branch of the ANS is stimulated, it speeds up the heart. When you let your foot off the accelerator (remove the stimulation to the sympathetic branch of the ANS), the heart rate coasts down to the cruise control speed of 60 to 100.

The parasympathetic branch of the ANS exerts a depressant effect on the heart. The vagus nerve is the major nerve of the parasympathetic system and exerts an effect on many of the body organs. It is widespread throughout the body. Stimulation of the vagus nerve slows the heart, acting like a brake to the heart rate. When a patient is experiencing an abnormally fast heart rate, stimulation of the vagus nerve is used to bring the heart back to its normal cruise control rate.

Pathways for conduction

The conduction system consists of the sinoatrial (SA) node, atrioventricular (AV) node, Bundle of His (AV bundle), bundle branches, and the Purkinje fibers (network). The SA and AV nodes are small, round structures that consist of Purkinje fibers. The **sinoatrial (SA) node** is located in the upper portion of the right atrium. It is the pacemaker of the heart and initiates the heartbeat. The automaticity of the fibers in the SA node produces the contraction of the right and left atria. The SA node fires at about 60 to 100 times per minute. Normal conduction of the heart begins with the SA node (see Figure 2-9 and Table 2-3 on p. 24).

On the floor of the right atrium is another mass of Purkinje fibers known as the **atrioventricular (AV) node**. Impulses travel to the AV node because of the unique quality of conductivity through a specialized

Figure 2-9: Conduction pathways

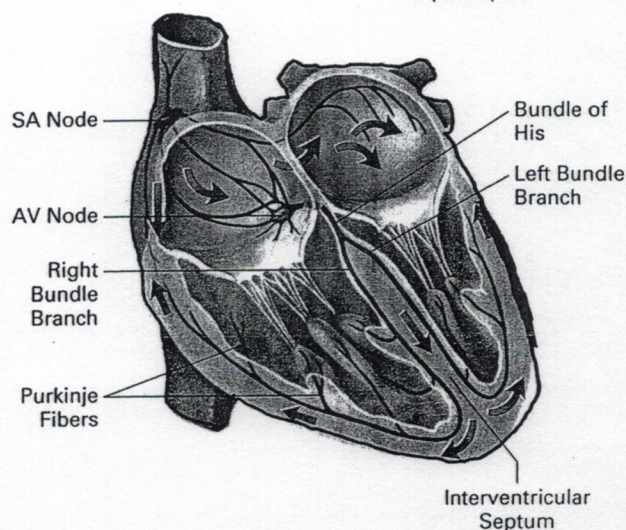


Table 2-3 Parts of the conduction system

Part	Function
Sinoatrial (SA) node (pacemaker)	Initiates heart at a rate of 60 to 100 beats per minute with electrical impulse that causes depolarization
Atrioventricular (AV) node	Delays the electrical impulse to allow for the atria to complete their contraction and ventricles to fill before the next contraction
Bundle of His (AV bundle)	Conducts electrical impulses from the atria to the ventricles
Bundle branches	Conducts impulses down both sides of the interventricular septum
Purkinje fibers (network)	Distributes the electrical impulses through the right and left ventricles

pathway through the atria. The AV node itself causes a delay (slowdown) in the electrical impulse. This process is important for two reasons. First, it provides time for additional blood to travel from the atria to the ventricles before they contract. This additional blood is known as the atrial kick. The atrial kick increases the cardiac output or the amount of blood that is pumped out of the heart into the body with each contraction. Second, the delay in the electrical impulse reduces the number of electrical impulses transmitted to the ventricles. This is important when the atria is firing too fast. It prevents an excessive rate of electrical impulses from reaching the ventricles. The AV node can also act as the pacemaker if the SA

node is not working. It will fire at a rate of 40 to 60 times per minute. This is known as the inherent rate of the AV node.

The **Bundle of His (AV bundle)**, located next to the AV node, provides the transfer of the electrical impulse from the atria to the ventricles. When the impulse reaches the ventricles, it is divided into the bundle branches. The **bundle branches** are located along the left and right side of the **interventricular septum**. The electrical impulse travels through the right and left bundle branches to the right and left ventricles. The bundle branches are like a fork in the road, and the electrical impulse splits and travels down both sides.

The right and left bundle branches are pathways down the interventricular septum, where the impulses travel to activate the myocardial tissue to contract. Impulses traveling down the left bundle branch will stimulate the interventricular septum to contract in a left-to-right pattern. The ventricles receive their electrical impulses from the bundle branches.

The **Purkinje network** spreads the impulse throughout the ventricles, which occurs through a network of fibers called the **Purkinje fibers**. These fibers provide an electrical pathway for each of the cardiac cells. The electrical impulses accelerate and activate the right and left ventricles at the same time to cause the ventricles to contract. The electrical impulse produces an electrical wave.

Electrical Stimulation and the ECG Waveform

Heart cells, in their resting state, are electrically polarized. This means their insides are negatively charged, whereas on the outside, they are positively charged. This state of cellular rest is known as **polarization** and is the ready phase of the heart.

Depolarization, on the other hand, is a state of cellular stimulation, which precedes contraction. It is the electrical activation of the cells of the heart when they lose their internal negativity. Depolarization moves from cell to cell through the electrical pathways. Depolarization is the most important electrical event in the heart—it causes the heart to contract and pump blood to the body.

Repolarization is a state of cellular recovery, which follows each contraction. The cardiac cells return to their resting phase of internal negativity. After depolarization, the cardiac cells return to this state in order to prepare for another depolarization. During repolarization the heart relaxes and allows for refilling of the chambers of the heart.

The ECG waveform is recorded from the electrical activity produced during depolarization and repolarization of the heart. The waveform on the electrocardiogram is a series of up-and-down deflections off a straight line known as an **isoelectric** line. The isoelectric line represents the period when no electrical activity is occurring in the heart and is known as a baseline. Deflections, which appear as waves on the ECG tracing, indicate electrical activity in the heart. The deflections that go up are positive; the deflections that go down are negative.

When the waveform was first discovered, Einthoven labeled the waves of the electrocardiogram as P, Q, R, S, and T. Legend holds that he chose the letters from the center of the alphabet because he did not know what the waves meant, or whether other waves preceding the P wave or following the T wave would be discovered. The U wave was added after Einthoven's discovery. Each of these waves indicates specific activity in the heart (see Table 2-4).

In addition to the waves, the ECG waveform contains **intervals**, **segments**, and **complexes**. Each of these elements indicates specific activity within the heart. The elements include the QRS complex, the ST segment, the PR interval, and the QT interval.

What each part of the waveform represents

The first deflection is positive and is known as the P wave. This P wave is seen when the atria depolarize. The P wave is small (compared to the other waves of the ECG), rounded, and is the first wave of the normal complex.

During the delay of conduction that occurs at the AV node, a small baseline segment is seen on the waveform. There is no electrical activity occurring (depolarization or repolarization), thus no wave or deflection is seen. It is during this time that atrial kick occurs.

The Q wave represents the conduction of the impulse down the interventricular septum. It is a negative deflection before the R wave. It is not unusual or abnormal for a QRS complex not to have a Q wave. A normal Q wave is less than one fourth

Table 2-4 ECG components

Component	Appearance	Heart Activity
P wave	Upward small curve	Atrial depolarization with resulting atrial contraction
QRS complex	Q, R, and S waves	Ventricular depolarization and resulting ventricular contraction (larger than the P wave) atrial repolarization occurs (not seen)
T wave	Small upward sloping curve	Ventricular repolarization
U wave	Small upward curve	Repolarization of the Bundle of His and Purkinje fibers (not always seen)
PR interval	P wave and baseline prior to QRS complex	Beginning of atrial depolarization to the beginning of ventricular depolarization; time it takes the impulse to travel from the SA node to the AV node
QT interval	QRS complex, ST segment, and T wave	Period of time from the start of ventricular depolarization to the end of ventricular repolarization
ST segment	End of QRS complex to the beginning of T wave	Time between ventricular depolarization and the beginning of ventricular repolarization

of the height of the R wave. The R wave is the first positive wave. It represents the conduction of electrical impulse to the left ventricle. It is usually the easiest wave to locate on the ECG tracing. The S wave is the first negative deflection after the R wave. It represents the conduction of the electrical impulse through both ventricles. The QRS waves together form the QRS complex. The QRS complex represents ventricular depolarization. It is reflective of the time it takes for the impulses to activate the myocardium to complete contraction from the Purkinje fibers.

The ST segment is measured from the end of the S wave to the beginning of the T wave. This segment should normally be on the isoelectric line. It indicates the end of ventricular depolarization and the beginning of ventricular repolarization. The reason this segment is studied in a 12-lead ECG recording is to determine whether or not there is any ischemia and myocardial damage. **Ischemia**, which is a lack of oxygen to the heart muscle, causes the ST segment to elevate. An elevated ST segment indicates myocardial damage in the form of injury to the heart muscle. These changes are studied when interpreting an ECG. More information about interpreting an ECG is included in Chapter 5.

The T wave represents ventricular repolarization. As repolarization occurs, the ventricular muscles relax. Normal T waves are in the same direction as the QRS complex and the P wave. A normal T wave peaks toward the end instead of the middle. Unlike the symmetrical mountain shape of the P wave, the T wave looks like a small mountain with one sloping side.

The U wave follows the T wave. The U wave represents repolarization of the Bundle of His and Purkinje fibers. The U wave does not always show up on the ECG; however, its presence can indicate an electrolyte imbalance.

The PR interval is measured from the beginning of the P wave to the beginning of the QRS complex. The normal length of time for the PR interval is 0.12 to 0.20 seconds. The PR interval on a normal ECG should be consistent.

The QT interval is the time required for ventricular depolarization and repolarization to take place. It begins at the beginning of the QRS complex and ends at the end of the T wave. It includes the QRS complex, ST segment, and the T wave.

R to R interval is the measurement of time from the start of a QRS complex in a rhythm to the start of the next adjacent QRS complex. R waves are readily seen on

the ECG and are used to calculate the heart rate in a regular rhythm. We will discuss this in Chapter 3.

The junction of the QRS interval and the ST interval is the J point. This represents the end of the QRS complex and ventricular depolarization. The J point is important when measuring the length of the QRS complex and interpreting the ECG tracing. A normal QRS complex is .06 to .10 seconds (see Figure 2-10).

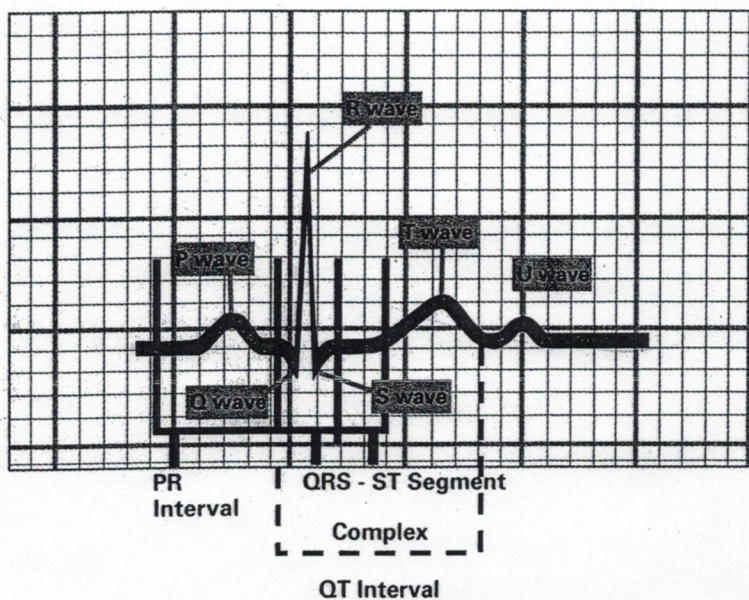


Figure 2-10: The ECG waveform and heart activity

Chapter Review

The Match Game: Match the valves, vessels, and chambers of the heart to their definitions. Place the correct letter on the line provided.

- | | |
|---------------------------|--|
| _____ 1. left ventricle | a. artery that transports blood to the entire body |
| _____ 2. tricuspid valve | b. type of valve located in the aorta and the pulmonary artery |
| _____ 3. left atrium | c. atrioventricular valve between the left atrium and left ventricle |
| _____ 4. aorta | d. heart chamber that pumps blood to the body, known as the workhorse of the heart |
| _____ 5. pulmonary artery | e. heart chamber that receives blood from the lungs |
| _____ 6. right atrium | f. chamber of the heart that receives blood from the body |
| _____ 7. right ventricle | g. chamber of the heart that pumps blood to the lungs |
| _____ 8. semilunar valve | h. blood vessels that transport blood from the lungs to the left atrium |
| _____ 9. pulmonary vein | i. valve located between the right atrium and right ventricle |
| _____ 10. mitral valve | j. blood vessel that provides a pathway for deoxygenated blood to return to the lungs |

Match the conduction system parts and unique qualities of the heart to their definitions. Place the correct letter on the line provided.

- | | |
|---------------------------|---|
| _____ 11. excitability | a. delays the electrical conduction through the heart |
| _____ 12. automaticity | b. ability of the heart to initiate an electrical impulse |
| _____ 13. bundle branches | c. branches off the Bundle of His that conduct impulses to the left and right ventricle |
| _____ 14. SA node | d. ability of the heart cells to receive and transmit an electrical impulse |
| _____ 15. contractility | e. an electrical current that initiates the contraction of the heart muscle |
| _____ 16. depolarization | f. ability of the heart muscle cells to shorten in response to an electrical stimulus |
| _____ 17. AV node | g. ability of the heart muscle cells to respond to an impulse or stimulus |
| _____ 18. Purkinje fibers | h. heart muscle cells return to their resting electrical state and the heart muscle relaxes |
| _____ 19. repolarization | i. initiates the heartbeat |
| _____ 20. conductivity | j. distributes electrical impulses from cell to cell throughout the ventricles |

It's Your Choice: Circle the correct answer.

21. The PR interval is usually:
- a. .06 to .10 seconds
 - b. .12 to .20 seconds
 - c. greater than .20 seconds
 - d. less than .06 seconds
22. What part of the ECG tracing represents the repolarization of the Bundle of His and Purkinje fibers?
- a. T wave
 - b. PR interval
 - c. U wave
 - d. P wave
23. What part of the ECG tracing represents the time it takes for the impulse to activate the myocardium to the complete contraction?
- a. QRS complex
 - b. J point
 - c. QT interval
 - d. PR interval
24. What part of the ECG tracing is measured from the end of the S wave to the beginning of the T wave and is normally on the isoelectric line?
- a. ST segment
 - b. QT segment
 - c. U wave
 - d. QRS complex
25. What wave on the ECG tracing is not always seen and sometimes when seen can indicate an electrolyte imbalance?
- a. U wave
 - b. P wave
 - c. Q wave
 - d. R wave

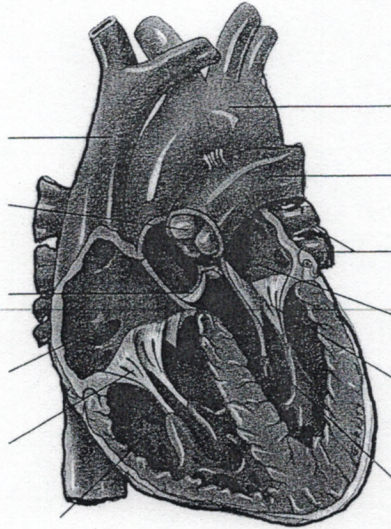
The Match Game Part Two: Match the information about circulation and the cardiac cycle to the definitions. Place the correct letter on the line provided.

- | | |
|---------------------------------|---|
| _____ 26. deoxygenated blood | a. period between the beginning of one beat of the heart to the next |
| _____ 27. cardiac cycle | b. circulation of blood through the heart and heart muscle |
| _____ 28. systole | c. blood that has little or no oxygen |
| _____ 29. coronary circulation | d. phase of the cardiac cycle when the heart is expanding and refilling; also known as the relaxation phase |
| _____ 30. systemic circulation | e. blood having oxygen |
| _____ 31. oxygenated blood | f. circulation between the heart and the entire body, excluding the lungs |
| _____ 32. diastole | g. transportation of blood to and from the lungs |
| _____ 33. pulmonary circulation | h. contraction phase of the cardiac cycle, when the heart is pumping blood out to the body |

Label the Parts

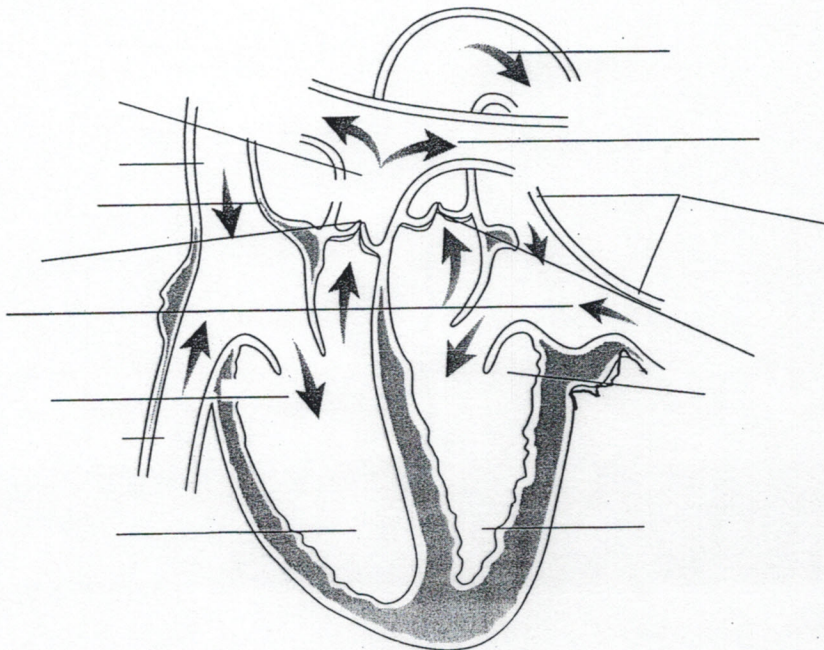
34. a.-l. Label the vessels, valves, and chambers of the heart by using the letters of the terms.

- | | |
|--------------------|----------------------------|
| a. Right atrium | g. Vena cava |
| b. Aorta | h. Pulmonary valve |
| c. Right ventricle | i. Aortic valve |
| d. Pulmonary veins | j. Tricuspid valve |
| e. Left atrium | k. Pulmonary artery |
| f. Left ventricle | l. Mitral (bicuspid valve) |



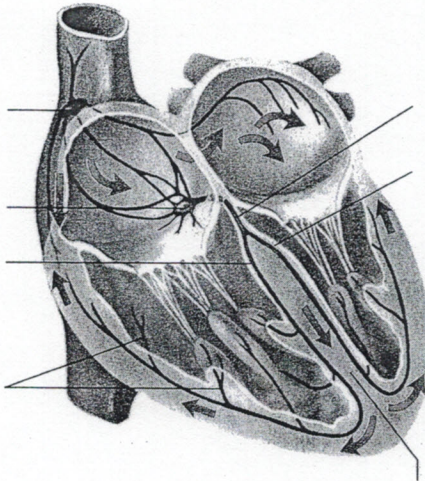
35. Label the following figure representing the flow of blood through the heart. Use the letters of the terms.

- | | |
|-----------------------|-----------------------|
| a. Superior vena cava | h. Mitral valve |
| b. Right atrium | i. Pulmonary vein |
| c. Aorta | j. Tricuspid valve |
| d. Right ventricle | k. Left ventricle |
| e. Pulmonary valve | l. Aortic valve |
| f. Left atrium | m. Pulmonary artery |
| g. Lungs | n. Inferior vena cava |



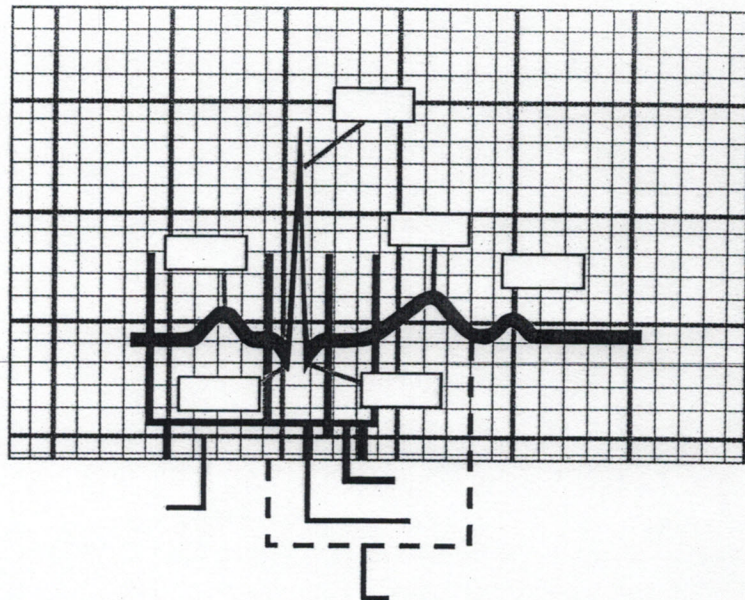
36. a.-g. Label the parts of the conduction system.

- a. Interventricular septum
- b. Left bundle branch
- c. Purkinje fibers
- d. AV node
- e. SA node
- f. Bundle of His
- g. Right bundle branch



37. a.-j. Label the waves, complexes, intervals, and segments of the ECG waveform.

- a. S wave
- b. R wave
- c. P wave
- d. U wave
- e. T wave
- f. Q wave
- g. QT interval
- h. Complex
- i. QRS-ST interval
- j. PR interval



Right or Wrong?

38. You and a friend have just finished studying this chapter. Your friend makes the following statements. Are his or her statements correct or incorrect? If the statement is incorrect, write down what you would say to correct your friend.

a. "The valves between the atria and the ventricles are semilunar." _____

b. "The atria always pump the blood." _____

c. "The heart is a two-sided pump that produces pulmonary circulation and systemic circulation."

d. "The coronary arteries carry deoxygenated blood."

e. "The pulmonary artery carries oxygenated blood."

f. "The waves on the ECG waveform are positive when they are up and negative when they are down."

g. "If you are a man you will have a faster heartbeat."

h. "The top chambers of the heart are the ventricles and the bottom chambers of the heart are the atria."

i. "The right ventricle is sometimes known as the workhorse of the heart."

j. "The waves of the ECG waveform are P, Q, R, S, T, and sometimes a U."

Voyage Through the Heart

39. For each of the following statements, identify the vessel or structure you are in. Write in the space provided. Imagine you are a drop of blood traveling through the heart. Returning from the brain, you are about ready to enter the heart.

a. What vessel are you in?

b. After you enter the right atrium, you have to go through a door in order to enter the right ventricle. What is the name of this door?

c. You have made it to the lungs successfully and are traveling back to the heart. What vessels are you in?

d. When you get to the heart where will you be? _____

e. You have finally made it to the last chamber of the heart. The left ventricle pumps you into the entire body. After entering the aorta, what are the very first vessels you will travel into?



What Would You Do?

Read the following situations and use your critical thinking skills to determine how you would handle each. Write your answer in detail in the space provided.

40. When the atria outside of the SA node stimulates the atria to beat too fast, this is known as atrial flutter or atrial fibrillation. When these heart rhythms occur, the ventricles do not beat at the same rate as the atria. What part of the conduction system prevents the ventricles from beating as fast as the atria and how does it occur?

41. You are working in the emergency room recording an ECG when the electricity goes out. There is a short period of darkness followed by a very loud noise. When you regain power, the heart of you and your patient are beating extremely fast. What part of the cardiovascular system is responsible for this increased heart rate? Should you continue recording the ECG now or later, and why?



GET CONNECTED TO THE WEB

✓ **Learn More About the Heart** For more information about the heart and some real-life pictures, go to the Web site Heart: A Virtual Exploration at <http://sln.fi.edu/biosci/heart.html>.

The site Heart Info, at <http://www.heartinfo.org/physician/ecg/norm.htm>, shows a normal 12-lead ECG and the parts of the ECG waveform along with what they represent. Go to this site to review the ECG waveform.

At the University of Utah's site <http://medstat.med.utah.edu/WebPath/CVHTML/CVIDX.html> you can view pictures of the heart and its structures. Go to this site and find the pictures of the heart valves. Describe each valve, where it is located, and how it functions.

Search the National Heart, Lung, and Blood Institute's Web site at <http://www.nhlbi.nih.gov/> for more information about coronary heart disease.

unable to find ECG

no