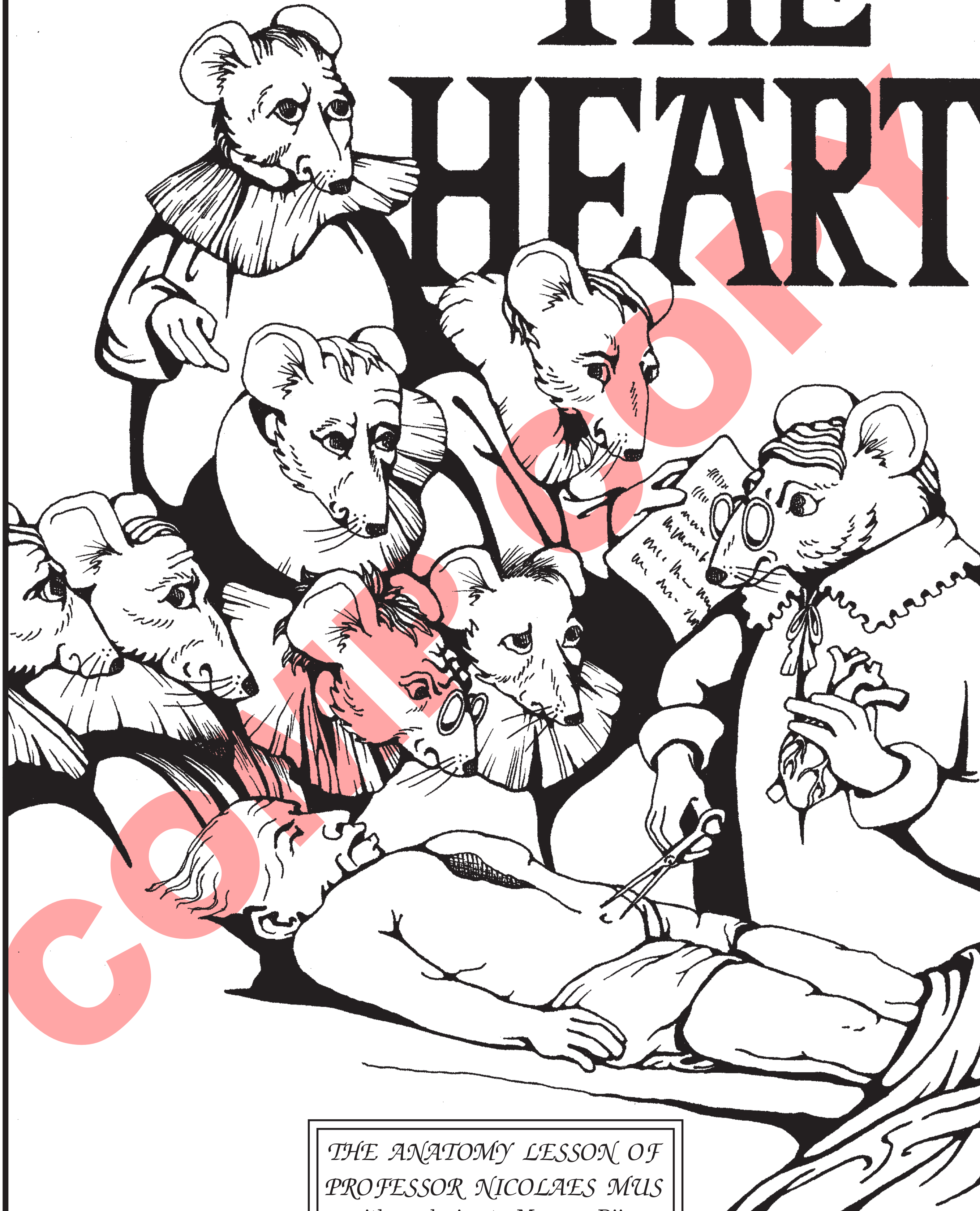
THE HEART



THE ANATOMY LESSON OF PROFESSOR NICOLAES MUS
with apologies to Mr. van Rijn

Summary Questions

1. Describe the circulation of blood through the heart including how the blood reaches the lungs and the rest of the body.

2. What structures ensure that blood flows only in one direction through the heart? Explain how they operate.

3. Heart sounds are most closely associated with . . .

4. On average, if a person has a heart rate that is elevated 20% beyond normal, about how much reduction in longevity would be expected?

5. Name and describe the two blood pressure readings measured using a stethoscope.

6. What is collateral circulation?

7. Discuss the role of cholesterol, arteriosclerosis, and clots on circulation.

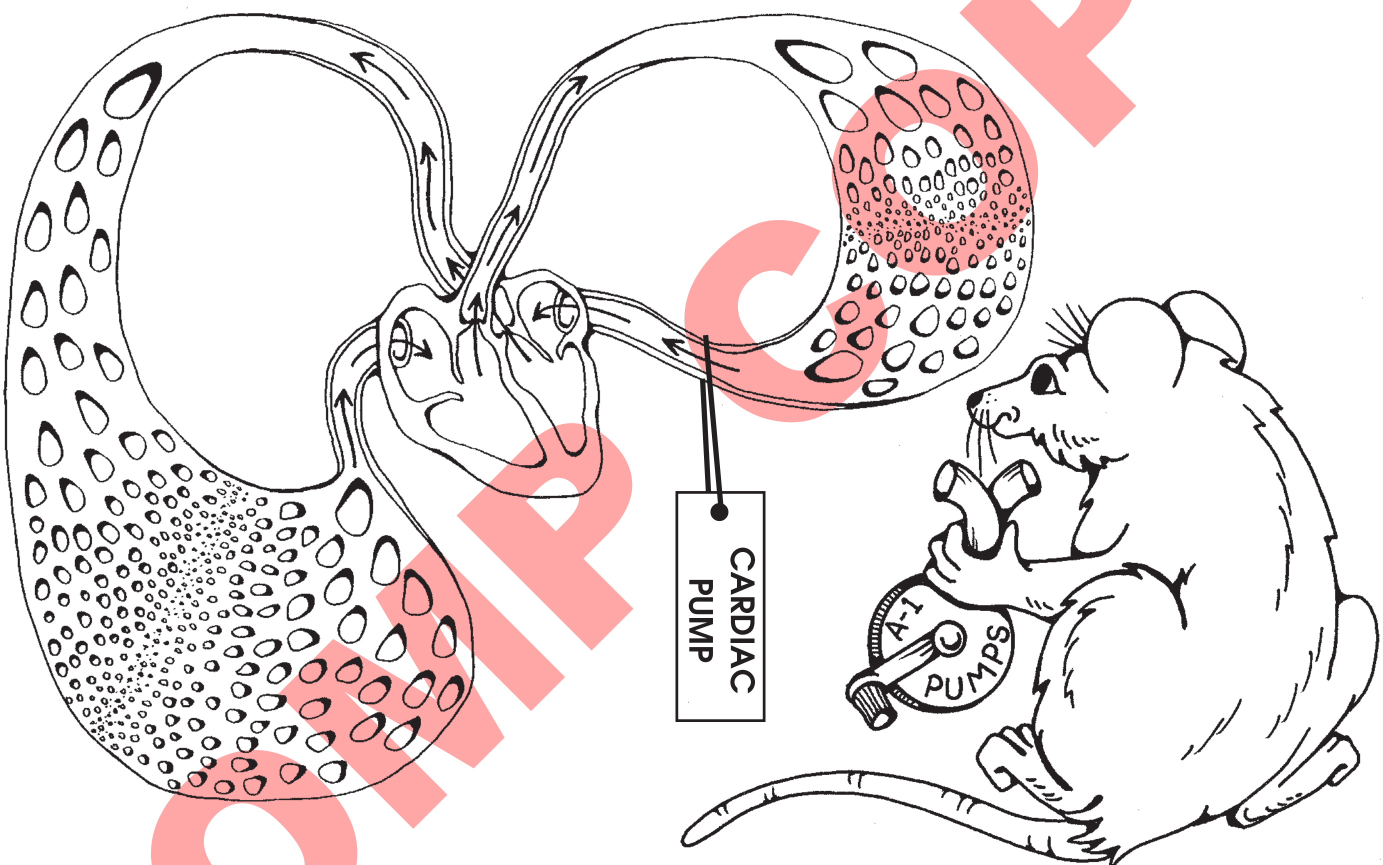
8. What function is being recorded in each part of an EKG: P wave, QRS wave, and T wave?

THE HEART

INTRODUCTION

The heart is an incredible pump. It can beat 2.5 billion times in a lifetime, pumping 35 million gallons of blood. Furthermore, the heart is capable of varying its output between 50 ml and 250 ml per stroke. It can contract at rates from 60 to 160 beats per minute. You can't buy a better pump!

This week's lab will include some aspects of heart structure and function. Also, you will learn to measure blood pressure, and discover the medical implications related to heart function.



ACTIVITIES

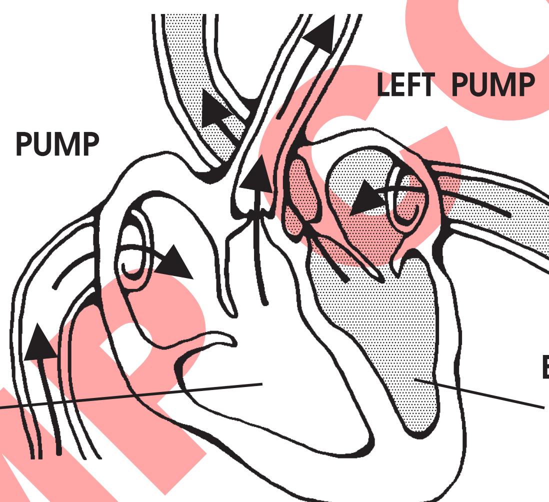
ACTIVITY #1

"THE HEART AS A PUMP"

When you are resting, your heart pumps about 5 liters of blood per minute. This is about the same rate as a slow flow of water from the bathroom faucet when you brush your teeth. During strenuous exercise your heart can pump 30 liters of blood per minute. This is about equal to the water flow when you fast-fill the bathtub. The heart is capable of this wide range of performance because of its structure.

TWO PUMPS IN ONE

The heart is actually two pumps—a ***right pump*** and a ***left pump***. The right pump delivers blood to the lungs; this route is called the ***pulmonary circuit***. The left pump pushes blood to the rest of the body; this route is called the ***systemic circuit***.



Notice that this diagram is drawn as if the heart is facing you. This means that the right side of the heart is on the *left* side of the drawing. All anatomy diagrams are drawn in this view. Remember this whenever you look at a medical picture.

TWO CHAMBERS PER PUMP

There are *two* chambers in each of the two heart pumps. The top one is a temporary storage chamber called the ***atrium***, and the bottom one is a pumping chamber called the ***ventricle***. Blood from the body tissues flows into the atrium of the right heart pump. This blood is then pushed through a valve and enters the right ventricle. The ventricle does the hard work of pumping blood out of the heart. The right ventricle pumps blood to the lungs where it is *oxygenated*. While the ventricle is pumping blood out of the heart, the atrium fills with blood entering the heart. This efficient design allows the atrium to quickly refill the emptied ventricle, resulting in a fast-pumping heart.

Oxygenated blood from the lungs enters the atrium of the left heart pump. This blood is then moved into the left ventricle, which pumps the blood to all of the body tissues.

? QUESTION

1. Which chamber has to do the most work? (circle your choice)

Atrium or Ventricle

2. Which chamber would have a thicker muscle wall? (circle your choice)

Atrium or Ventricle

3. Which pump has to do the most work? (circle your choice)

Right Ventricle or Left Ventricle

4. Which pump would have a thicker muscle wall? (circle your choice)

Right Ventricle or Left Ventricle

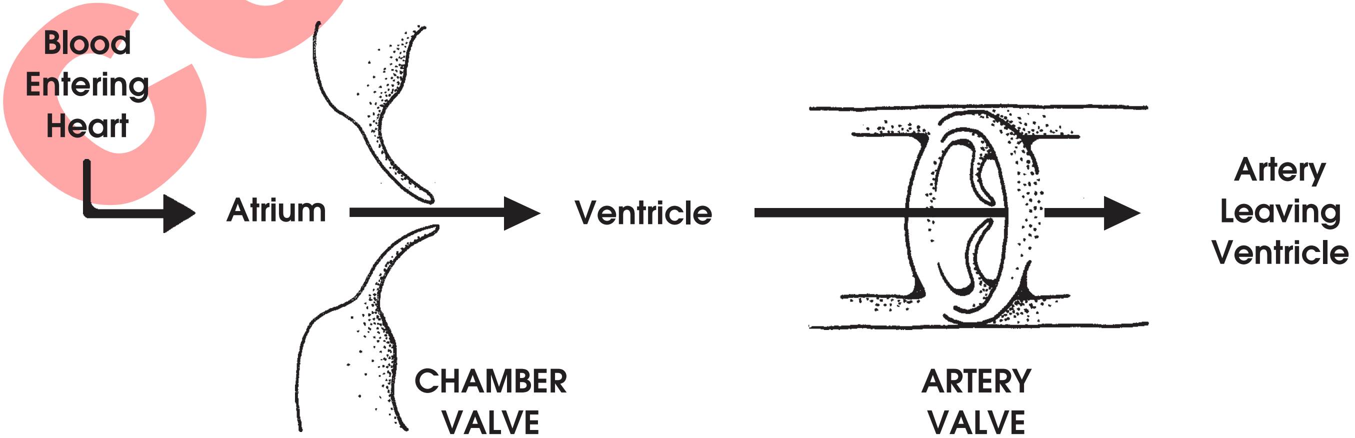
5. The right heart pump moves blood to the ____________________.

6. The left heart pump moves blood to the ______________________.

HEART VALVES

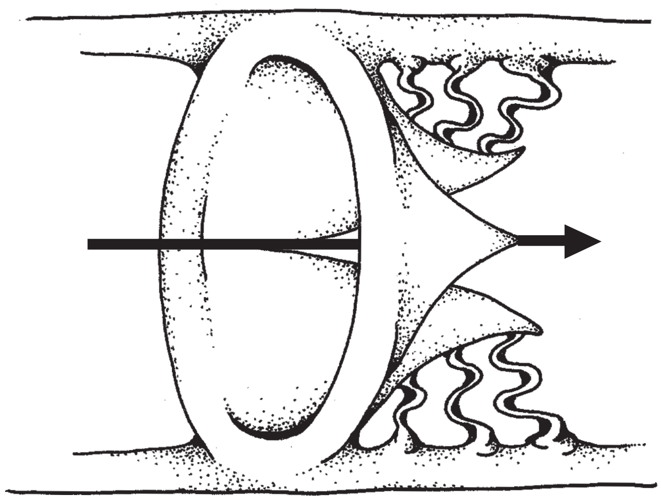
Four heart valves are strategically located to prevent backflow as blood moves through the heart. These valves are like one-way doors—they only open in one direction. There is a ***chamber valve*** between each atrium and ventricle. These two chamber valves ensure that blood will not flow back into the atria when the ventricles contract.

Blood is pushed out of the ventricles and into the two big arteries leaving the heart. There is a valve in each of these arteries. The ***artery valves*** prevent backflow into the ventricles once blood has been pumped into the arteries. The four heart valves ensure that blood moves in only one direction through the heart circuit. Each of the heart valves has its own special name, but we'll leave those details to an anatomy class.

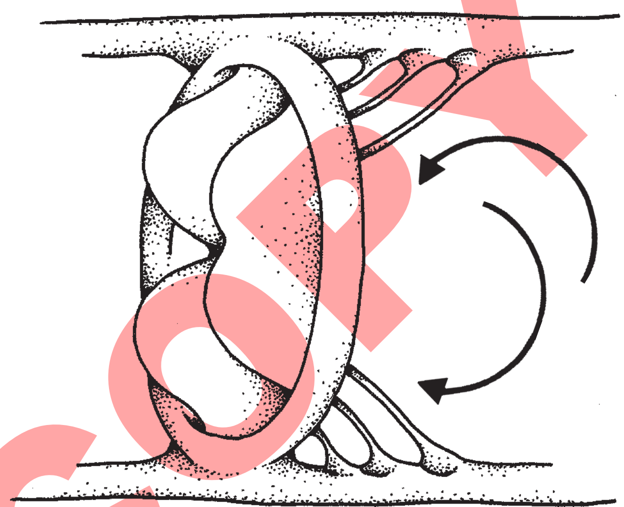


A heart valve is designed to plug an opening when blood moves in the wrong direction. Think of a valve as being something like a parachute that is attached to the heart or artery wall. If blood moves in the wrong direction, the "parachute" (valve) fills with blood and expands to plug the opening. When the blood moves in the correct direction, the valve collapses like an upside-down parachute. This allows the blood to easily pass through the valve.

EXAMPLE



Blood moving in the correct direction pushes the valve aside, and blood enters the ventricle.



Blood moving in the wrong direction fills the valve which plugs the opening so that blood cannot re-enter the atrium.

The heart valves are *flexible* so that they can fill with blood as shown above. There are *special cords* attaching the valve to the heart wall. These cords operate similar to the ropes of a parachute.

? QUESTION

1. What would happen to blood flow if one of the valve "cords" broke? Be specific.

2. What would happen to blood flow if one of the valves was scarred by disease, narrowing the opening?

3. If you had a moderate heart valve problem, what would the heart have to do to compensate?

4. On which side of the heart would a moderate heart valve problem have more consequence to your health? Explain your answer.

GO GET

A sectioned sheep heart from the display table.

NOW

1. See if you can identify the four chambers of the heart. ***Remember:*** One of the ventricles should have a thicker muscle wall.

2. Find a heart valve and feel the valve to determine its flexibility. Can you find the valve "cords"?

3. Show your instructor when you can identify all of these structures.

4. Draw a simple sketch of the dissected heart. This will remind you of what you saw in case you are tested on it later.

Dissected Heart

ACTIVITY #2

"HEART SOUNDS"

The heart sound is often described as "lub-dub." You might think that the two parts of this sound come from the separate contractions of the upper and lower chambers of the heart. That is not correct. Actually, these sounds are more closely associated with the closing of the heart valves.

The first sound, ***lub***, happens when the blood vibrates after the ***chamber valves close*** between the atria and ventricles. The second sound, ***dub***, occurs when the blood vibrates just after the heart ***artery valves close***. The sounds are created by vibration waves. With the aid of a stethoscope, a physician can hear these heart sounds and determine if there has been any damage to the valves.

GO GET

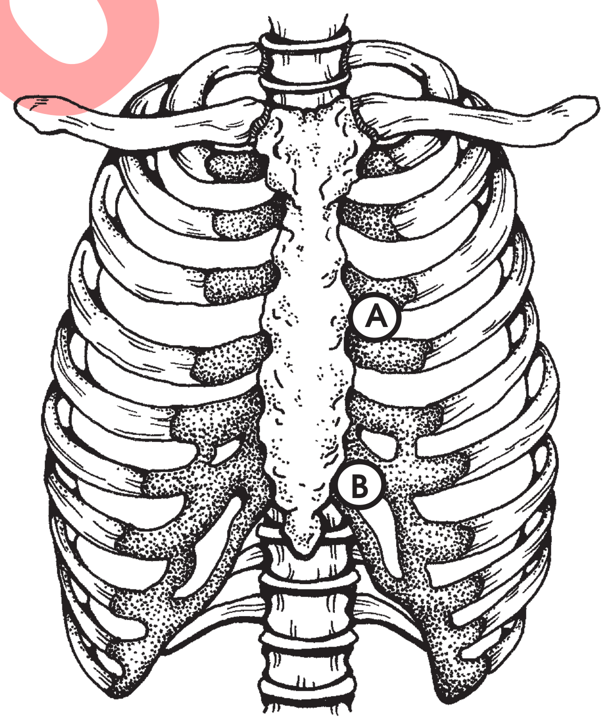
A stethoscope.

NOW

1. Clean the earpieces of the stethoscope with a cotton ball soaked in alcohol. *Always repeat this procedure whenever another person uses the stethoscope.*

2. Fit the stethoscope earpieces in your ears so that they are comfortable and point slightly forward in the ear passage. (Your ear passage points forward before it turns inwards to the ear drum.)

3. Move the bell of the stethoscope around the *left* side of your chest starting at the lower center notch of your rib cage.



As the stethoscope is moved around the heart area, you will hear the "lub" sound better at some places and the "dub" sound better at other places. An experienced physician or nurse can position the stethoscope to hear each heart valve and determine whether there is an abnormal sound. Abnormal sounds indicate possible valve damage or other circulation problems.

THEN

This part gets a little tricky, so read carefully.

Most people expect that the two big heart arteries would exit from the bottom of the ventricles, but they don't. These arteries come out of the top of the ventricles, and arch upwards above the heart. Refer to the diagram under "Two Pumps in One" in Activity #1, and notice the location of the two heart arteries. The artery valve allowing blood flow out of the ventricle is next to the chamber valve controlling flow from the atrium into the ventricle.

The **"dub"** sound of the heartbeat resonates *upward*, which is the direction that the heart arteries leave the heart. In which position of the stethoscope (A or B) do you hear mainly a "dub" sound? ________________ This would indicate that you are located near the top of the heart where the heart artery valves make their sounds.

Continue to move the stethoscope to *both sides* of this position until the heart sounds quiet. You are mapping the general location of the top of the heart. Mark the extent of this "dub" zone on the rib cage diagram. The sound zone is bigger than the heart because the sound spreads outward.

The **"lub"** sound of the heartbeat resonates *downward* from the chamber valves, so you hear it best at the bottom of the heart. In which position of the stethoscope (A or B) do you hear mainly a "lub" sound? ________________ This would indicate that you are located nearer the bottom of the heart where the sound of chamber valves is loudest.

Continue to move the stethoscope to the *left* of this position until the loud "lub" sound quiets. You are mapping the general location of the bottom of the heart. Mark the extent of this "lub" zone on the rib cage diagram.

FINALLY

Draw an arrow from the center of the "dub" zone to the center of the "lub" zone on the rib cage diagram. That arrow is the general orientation of the heart. The orientation is (circle your choice)

vertical (straight up and down).

to the left of vertical (bottom of the heart points to the left).

to the right of vertical (bottom of the heart points to the right).

This sound technique of inferring the orientation of the heart is less accurate than the EKG method used in hospitals. The EKG can reveal whether the heart has enlarged on its left or right side. Enlargement is an indication of a heart or circulation abnormality.

ACTIVITY #3

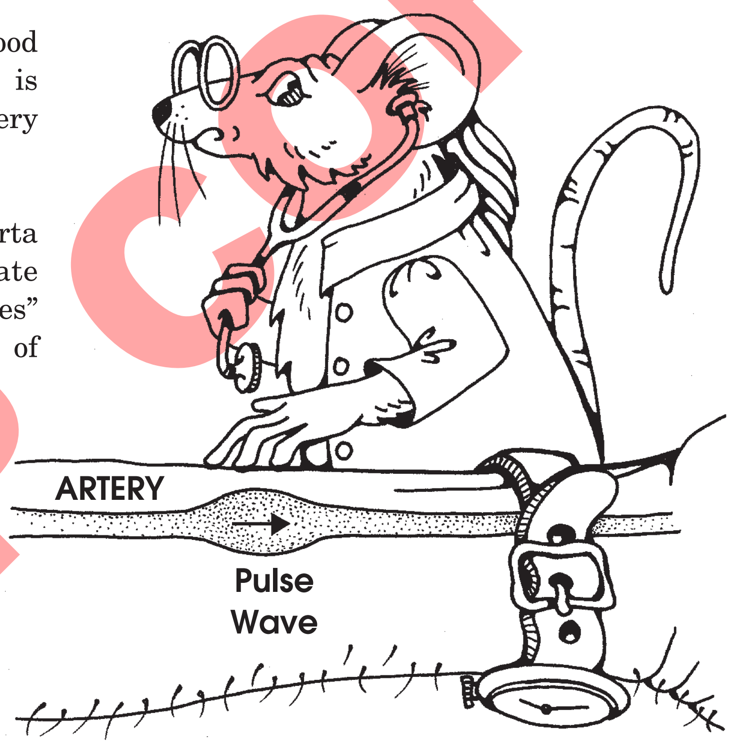
"HEART RATE AND THE PULSE"

The heart of a resting person contracts somewhere between 60 and 80 times per minute. These contractions can be counted with the aid of a stethoscope, which you will do in a few minutes. Heart rate can also be determined by counting the number of pulse waves that pass by a spot on an artery. Counting these waves by touch is how you measure the ***pulse***.

THE PULSE WAVE

The ***aorta*** is the large artery that supplies the blood to all other arteries that feed the body tissues.

Each heart contraction forces a volume of blood (50–250 ml) into the aorta. First, the aorta is "ballooned" out by blood, then the elastic artery wall snaps back an instant later.



The recoil causes the adjacent area of the aorta to balloon out and snap back. The alternate expansion and recoil of the aorta wall "pulses" outward from the heart to the other arteries of the body.

You feel these waves passing by whenever you press a finger on an artery.

The ***carotid pulse*** is felt when you press your fingers against the side of your throat. The ***radial pulse*** is felt when you press your fingers on the thumb side of your upward-turned wrist.

NOW

1. Use the stethoscope to count your heartbeats for 30 seconds.

Stethoscope Heart Rate = ________________ beats per minute

2. Count both your radial pulse waves and carotid pulse waves for 30 seconds.

Radial Pulse = ________________ waves per minute

Carotid Pulse = ________________ waves per minute

? QUESTION

1. Which had the stronger pulse waves? (circle your choice)

Carotid or Radial

2. Which is closer to the heart? (circle your choice)

Carotid or Radial

3. Which would produce a stronger pulse wave? (circle your choice)

A smaller heart or A bigger heart

4. Arteriosclerosis hardens the artery wall with scar tissue. If arteries have been partially injured by arteriosclerosis and the arterial wall is less flexible than normal, then would the pulse be stronger or weaker than normal?

5. If a person has arteriosclerosis, what happens to the blood pressure near the end of the arteries? (circle your choice) ***Hint:*** Is some of the energy of the heart contraction "used up" by the pulse wave?

a. it is the same as normal

b. it is higher than normal

c. it is lower than normal

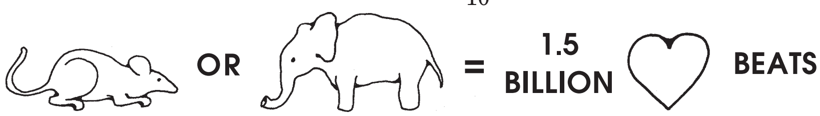
What would be the consequences?

6. Half of the people have a smaller-than-average sized heart and half have a larger-than-average sized heart. In which group would you expect the *heart rate* to be higher? Explain your answer.

7. In general, females have a higher heart rate than males. What explanation can you give for this difference?

HEART RATE AND LONGEVITY

Research in comparative physiology suggests that the average mammal heart beats about 1.5 billion times before it wears out. Although there are exceptions to this heart longevity rule, it seems to be generally true whether you're a mouse or an elephant. A mouse's heart beats about 10 times faster than an elephant's heart, and a mouse lives about $\frac{1}{10}$ as long.



Based on the mammalian average for total heart beats, the modern human species is predicted to live about 35 years. Humans score above most other species for longevity. This is probably because we are smarter and can avoid more hardships than the average mammal. However, we also have a limit—somewhere around 2.5 billion beats—if we are lucky enough to survive disaster and illness. How you spend these heartbeats is partly determined by the activities in your lifestyle.

Let's assume that the longevity rule is generally true for humans. A woman who is already doing enough daily activity to keep her heart healthy, asks the question, *"If I train in a very strenuous sport for 4 hours a day beyond my normal activity, then how much am I shortening my life by doing this sport?"* Assume that her normal heart rate of 70 is elevated to 120 during the heavy training.

? QUESTION

1. How many *extra* heartbeats does she use per day of sport training? ________________

2. Her normal heart rate of 70 per minute means that she would use 100,800 heart beats on a normal day without sport. If an extra 100,800 beats shortens her life by one day, then how many days of sport training does it take to shorten her life by one day? ________________

3. How many years of sport would shorten her life by one year? ________________

4. Let's assume that this person is considering 8 hours of strenuous sport per day. How many years of this sport activity would it take to shorten her life by one year? ________________

Before we ascribe too much importance to a higher heart rate, remember that females generally live 10% longer than males even though females have a 10% higher resting heart rate. Obviously, other important factors affect longevity.

5. Smoking elevates the heart rate about 10% above normal; so does drinking 2 to 4 cups of coffee per day. If you were a smoker or a coffee drinker for 40 years, how many years of longevity might be lost due to the increased heart rate alone (not taking into account the obvious health risks of tobacco and caffeine)? ________________

6. Negative stress can elevate the heart rate 10–20% above normal. How many lost years of longevity might result from a 20-year stress-filled job that elevated heart rate 20% above normal?

ACTIVITY #4

"HOW TO MEASURE BLOOD PRESSURE"

Knowing how to measure your blood pressure is one of the best health-maintenance tools you can have. We offer this Activity to promote your good health.

BLOOD PRESSURE

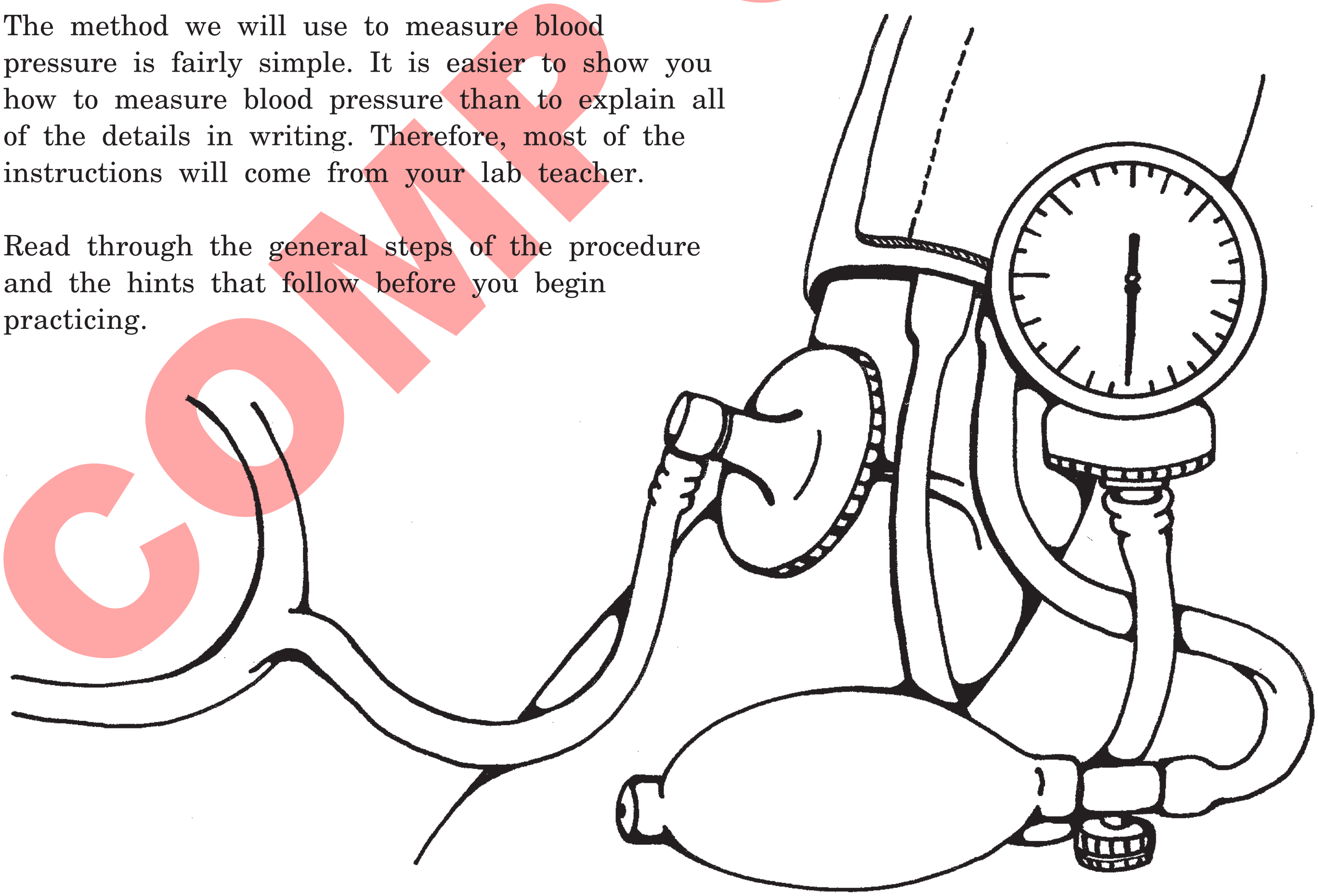
Blood pressure in body arteries is created by the contraction of the left ventricle. As you would expect, the pressure is highest when the chamber contracts. Pressure during heart contraction is called the ***systolic pressure***. When the ventricle relaxes the blood pressure drops. However, instead of dropping to zero, the blood pressure is partially maintained by the recoil of artery walls that are stretched by blood pumped out of the heart. The lower artery pressure during the relaxation of the ventricle is called the ***diastolic pressure***.

Medical books state that the typical resting blood pressure is 120 over 80. The 120 refers to the systolic pressure and the 80 refers to the diastolic pressure.

MEASURING BLOOD PRESSURE

The method we will use to measure blood pressure is fairly simple. It is easier to show you how to measure blood pressure than to explain all of the details in writing. Therefore, most of the instructions will come from your lab teacher.

Read through the general steps of the procedure and the hints that follow before you begin practicing.



GO GET

A blood pressure cuff.

STEP 1 Fasten a pressure cuff around your upper arm. Place the stethoscope diaphragm over the brachial artery (*inside bend of elbow*). Pump the cuff full of air until all blood is stopped in the brachial artery. The thumping heart sound that you hear through the stethoscope will fade and disappear as the cuff pressure is pumped above the systolic pressure.

STEP 2 Release the pressure on the cuff by slowly opening the valve. Listen to the brachial artery with the stethoscope.

STEP 3 When you first hear a "thumping" sound, read the gauge on the pressure cuff. This is the *systolic pressure*. The blood is just starting to squirt past the cuff during the contraction of the heart.

STEP 4 Continue to release the pressure on the cuff until the thumping sound disappears. Read the pressure gauge. This is the *diastolic pressure*. The blood flows past the cuff during both the contraction and relaxation of the ventricle. The sound disappears when the flow changes from a pulsating squirt to a constant flow.

HINTS

1. Don't pump the pressure cuff over 150 until you've practiced the technique several times.

2. Don't keep pressure on your arm for more than 30 seconds.

3. Let your arm rest for at least 2 minutes after each reading before taking another measurement. This is especially important while you are learning the technique.

4. Take your time. Learn this procedure well. It is important that you can measure your own blood pressure. Checking your blood pressure every few months provides you with a thorough understanding of your normal physiology. When an abnormal change occurs, you can seek medical advice.

NOW

Record your blood pressure while sitting: ________________ B.P.

With the blood pressure cuff still on your arm but not pumped up, run in place for 30 seconds. Measure your blood pressure after exercise: ________________ B.P.

COLD WATER TEST

This test is used to determine the effect of a sensory stimulus (cold) on blood pressure. The normal reflex response to a cold stimulus is a slight increase in blood pressure (both systolic and diastolic). In a normal individual, the systolic pressure will rise no more than 10 mm Hg, but the increase in a ***hyper-reactive*** individual may be 30 to 40 mm Hg. We will discuss the implications of these responses later.

PROCEDURE

1. The subject should be seated comfortably.

2. Immerse the person's free hand in ice water (approximately 5 °C) to a depth well over the wrist.

3. After waiting 30 seconds, measure the blood pressure.

Your normal resting blood pressure is ____________________.

Your blood pressure after cold water is ____________________.

Are you a normal or a hyper-reactive individual based on the cold-water test? ____________________

IMPLICATIONS

There is some evidence that people showing a hyper-reaction to a cold stimulus may have a greater chance of developing high blood pressure later in life. Perhaps there is some minor defect in the physiology of these people. Or they may have inherited a more reactive nervous system—favored in hunter-gatherer times—but more easily overstimulated by our modern chaotic life. We just don't know.

Before giving too much importance to the results of the cold water test, remember that lack of exercise, high salt intake, unhealthy diet, and stressful situations are known causes of high blood pressure, and are mostly under your control.

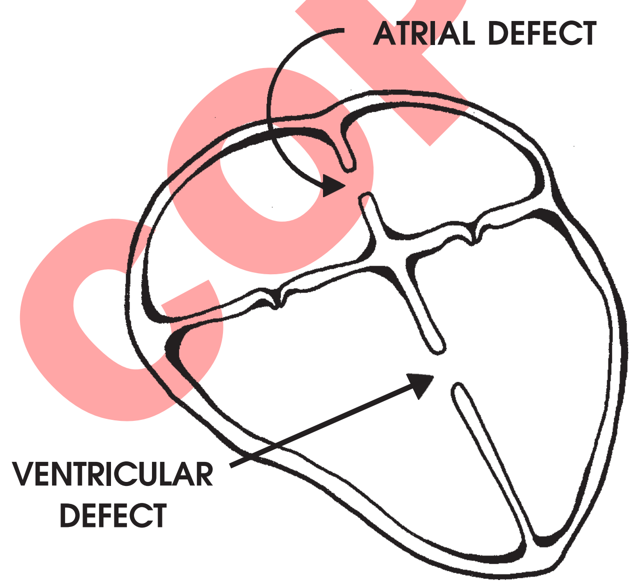
ACTIVITY #5

"MEDICAL IMPLICATIONS"

There are many medical implications related to what you have learned about the heart, and several of these health issues are discussed in this Activity. ***Remember:*** You should always ask your physician to explain health-related problems in a way that you can easily understand. And go to the library. Inform yourself.

ABNORMAL HOLES IN THE HEART

The heart in a fetus has a hole between the right and left atria. This opening allows fetal blood to partially bypass the lung circuit since the lungs aren't needed to get oxygen during life in the womb. Normally, the atrial hole closes shortly after birth. A birth defect results if this hole does not grow closed. Another birth defect occurs when there is an abnormal opening between the right and left ventricles. Both of these heart abnormalities can have serious health implications if left uncorrected.



? QUESTION

1. What important molecule is carried by blood entering the left heart pump and is not in the blood entering the right heart pump?

2. If the fetal hole between the right and left atria does not close, what happens to the blood in these two chambers?

3. Which ventricle operates under the most pressure (does the most work)?

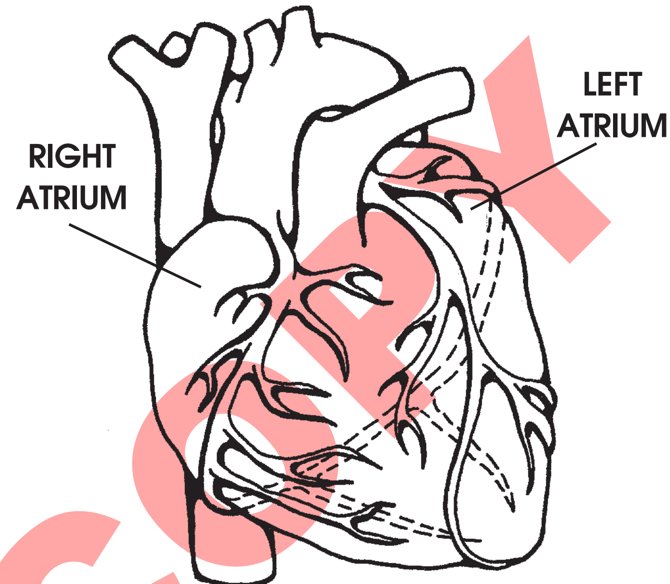
4. What would happen to the pressure in the two ventricles if there was a hole between them?

5. What would the heart do to compensate for the pressure problem created by a ventricle hole? ***Hint:*** People with this abnormal hole must have it repaired while they are young or they won't live long.

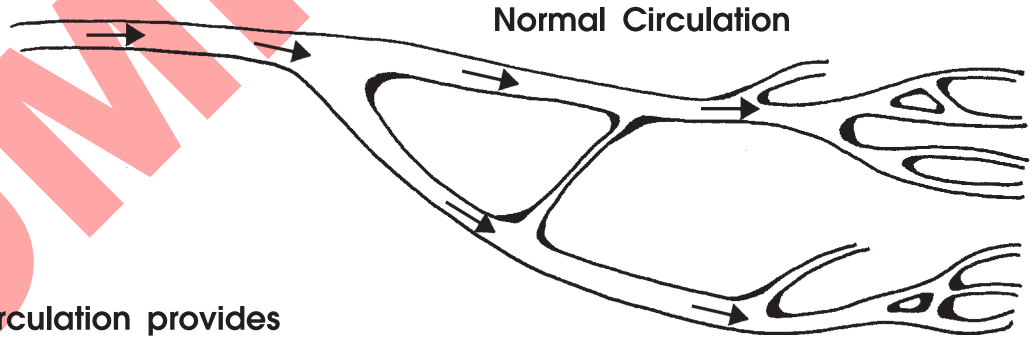
CORONARY ARTERIES

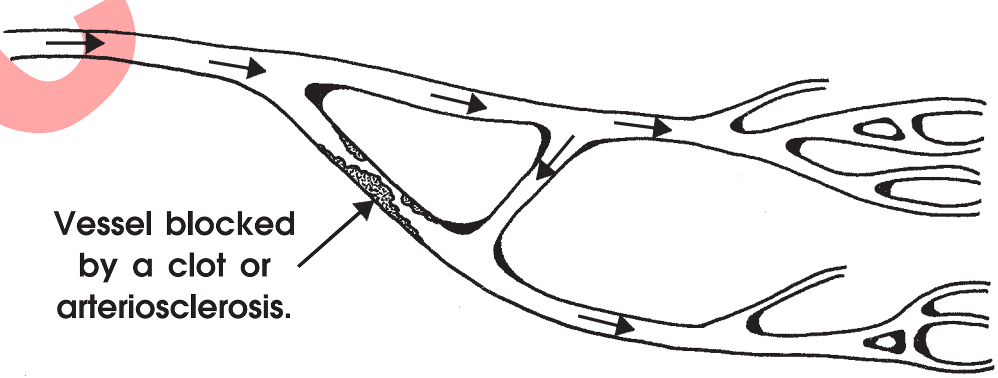
The heart muscle works very hard and it must be supplied with oxygen and nutrients just like any other part of the body. The vessels that supply blood to the heart muscle are called the ***coronary arteries***.

There are two important circulation patterns that you can see in this diagram. The right atrium is fed only by the right coronary artery, and the left atrium is supplied only by the left coronary artery. However, each coronary artery supplies blood to parts of *both* ventricles. The ventricles do more work than the atria, and must be supplied with more blood.



Another important aspect of vessel structure in the coronary arteries is the connection between the arteries. Connections between arteries are called ***collateral circulation***. These connections are alternate routes of blood flow to tissue if one path is blocked. Some parts of the heart have no collateral circulation. Other parts have only very small-diameter collateral vessels because they are unused. Also, there are different amounts of collateral vessels among people. Can you find a collateral vessel in the heart diagram above? Color that vessel.





? QUESTION

1. A patient is told that she has a narrowing of the right coronary artery. Which chambers of her heart are going to be the most affected by this disorder? ____________________

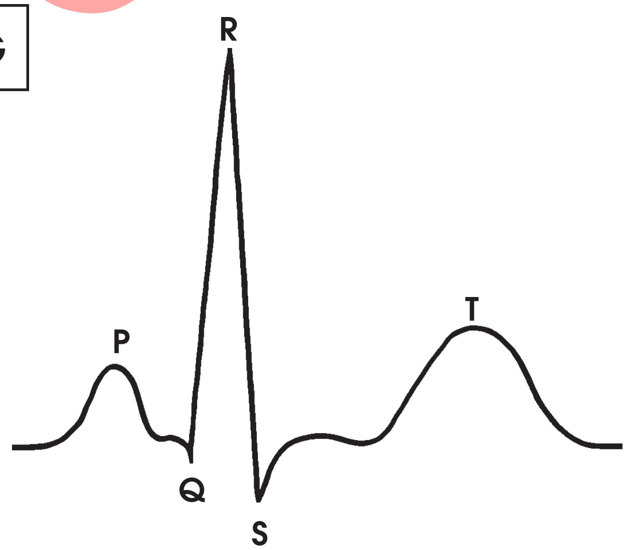
   Which chamber on the right side has to do the most work and could be the most serious health concern? ____________

2. A group of patients were told that they had plugged arteries in their hearts. In addition, they had all suffered a similar size of heart attack. All of these patients survived. Some of them had parts of their injured hearts return almost to normal after several months. The other patients had no such luck. Explain these differences in terms of coronary circulation.

3. A heart attack on which side of the heart would probably cause the most serious immediate risk to the person?

EKG

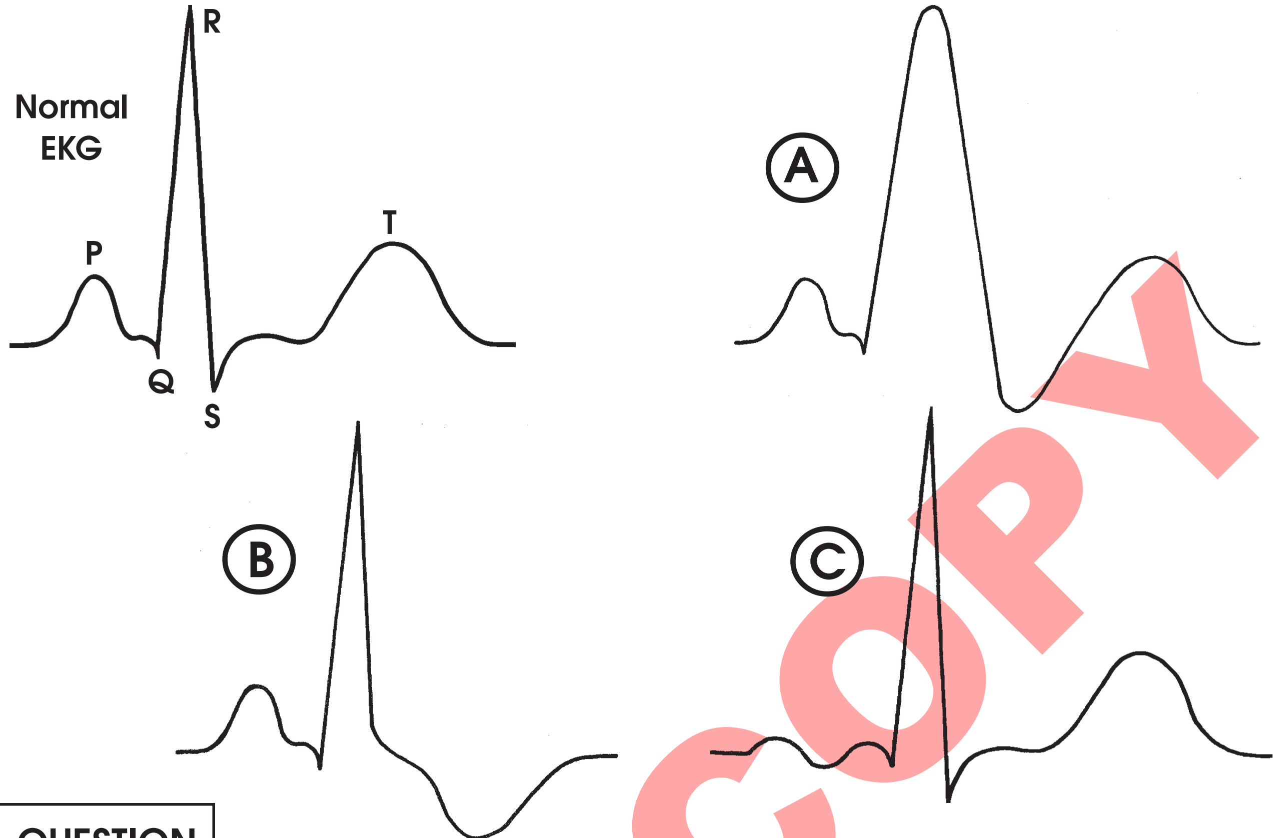
The ***electrocardiogram*** (called ***EKG*** or ECG) is a recording of the small electrical currents produced by the contracting and relaxing heart muscle. These electrical patterns indicate whether there is a normal or abnormal functioning of the heart. A normal EKG is shown here.



The ***P wave*** is a recording of the electrical activity in the atria, and it is especially important in diagnosing problems in the heart's natural *pacemaker*.

The ***QRS wave*** is a recording of the activating current in the ventricles. This current travels along a special conducting pathway 10 times faster than it would be transmitted through normal heart muscle. The result is that all the muscle cells in both ventricles are stimulated at the same time, causing these chambers to contract quickly and strongly.

The ***T wave*** occurs just after the ventricles contract, and is a recording of the normal recovery phase of the ventricles. This is a period when the muscle cells perform various biochemical reactions that prepare the ventricles for the next contraction.



? QUESTION

1. A person who drinks a lot of coffee complains that his heart beats irregularly. Which one of the above EKG waves reflects this problem? ________________ Explain your answer.

2. A person has a greatly enlarged heart from the overwork created by long term high blood pressure. Which abnormal EKG wave reflects this problem? ________________ Explain your answer.

3. A person with poor coronary circulation to the heart muscle has some heart injury, but may not have suffered death of the heart muscle. Which abnormal EKG wave reflects this problem? ________________ Explain your answer.

4. Why is a heart attack sometimes called a "coronary"?