22A-2 Objectives

- Describe the structures of the heart and their functions
- Trace the blood flow through the heart

22A-2 The Heart

The **heart** is a hollow muscular organ that has been described as a four-chambered, double-barreled blood pump. Approximately the size of a clenched fist and weighing about 340 g (12 oz), the heart lies in the thoracic cavity between the lungs, in a slanted position, with the *apex* (point) directed toward the left.

The heart muscle has greater endurance than any other muscle in the body; it contracts about 70 times per minute. At this rate, the heart beats 100 800 times per day, about 37 million times per year. Every heartbeat pushes about 80 mL (2.4 fl oz) of blood from the heart, or 8000 L (2100 gal) per day.

Structure of the Heart

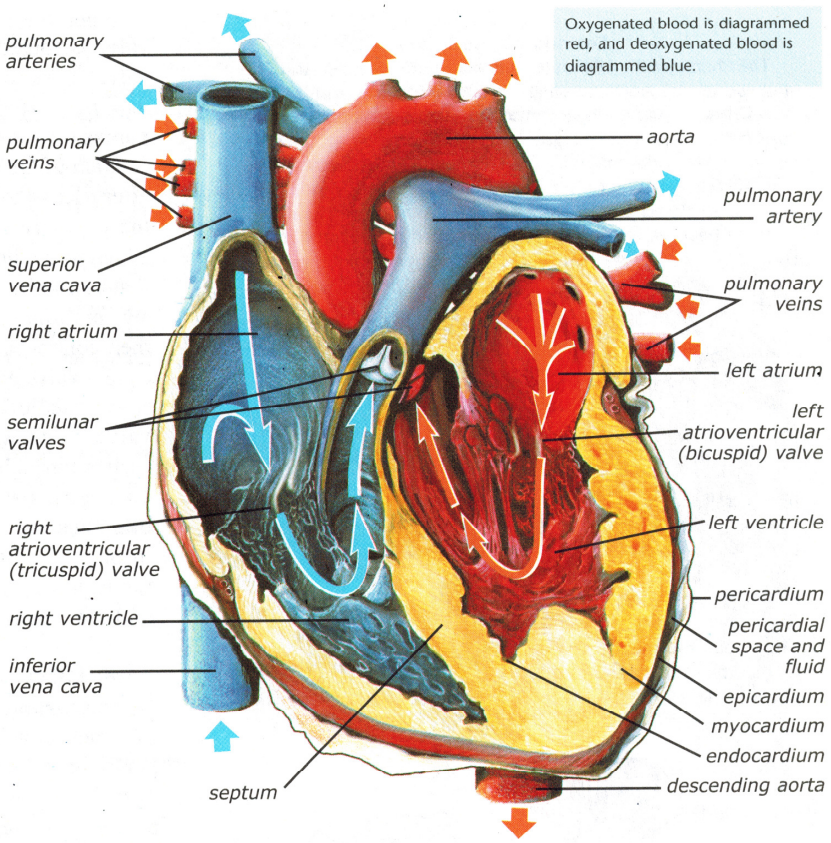
A fibrous sac, the **pericardium** (PEHR ih KAR dee um), loosely covers the heart and prevents it from rubbing against the lungs and inner chest wall. A slight space between the pericardium and the surface of the heart contains a slippery liquid, the *pericardial fluid*, which is secreted by the pericardium. This fluid reduces the friction between the heart and the surrounding structures.

The wall of the heart is made up of three layers.

✦ The **epicardium*** is the outermost layer of the heart and is composed of connective tissue that is tightly attached to the muscular tissue of the heart. This tissue keeps the heart muscle from becoming saturated with the pericardial fluid.

✦ The **myocardium**,* the thickest portion of the heart wall, is the cardiac muscle tissue that contracts and pumps blood.

✦ The inner surface of the myocardium is lined with a thin layer of epithelial tissue, the **endocardium**.* This layer prevents blood from saturating the myocardium.



22A.10 Anatomy of the human heart

A muscular wall called the septum separates the right and left sides of the heart. Each half, in turn, is divided into an upper chamber, the **atrium**, and a lower chamber, the **ventricle**. The atrial myocardium is thin because these chambers primarily receive blood. The ventricles, in contrast, have a thick myocardial layer because they are responsible for pushing the blood into the blood vessels of the body.

Between the atrium and ventricle in each half of the heart are the **atrioventricular** (AY tree oh ven TRIK yuh lur) **valves** (AV valves). The right AV valve is the *tricuspid** *valve*, and the left AV valve is the *bicuspid valve*. The tricuspid valve is composed of three flaps (or cusps, hence the name) of tissue, and the bicuspid is composed of two. These are one-way valves—they permit the flow of blood from the atria to the ventricles but prevent a reverse flow because the flaps close and are anchored to the ventricle walls by fibrous strands.

The **semilunar*** **valves**, located at the exits of the ventricles, have three cup-shaped membranes. They permit the blood flow into the blood vessels but keep it from returning to the ventricles. All heart valves are passive—they do not move by themselves but are moved by the force of the blood during each heartbeat.

epicardium: epi- (upon or over) + -cardium (heart)

myocardium: myo- (muscle) + -cardium (heart)

endocardium: endo- (within) + -cardium (heart)

tricuspid: tri- (Gk. TRI, three) + -cuspid (L. CUSPIS, point)

semilunar: semi- (half) + -lunar (L. LUNA, moon)

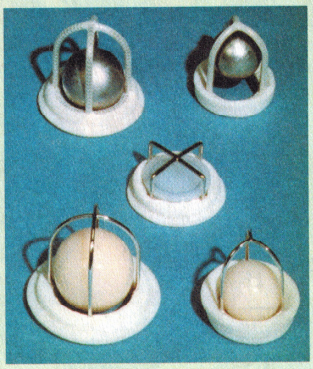
Blood Flow Through the Heart

The *superior vena cava* drains deoxygenated blood from body parts above the heart, including the arms and hands, and the *inferior vena cava* returns deoxygenated blood from body regions below the level of the heart. As the right atrium fills with blood, it contracts, squeezing the blood through the tricuspid valve and into the right ventricle.

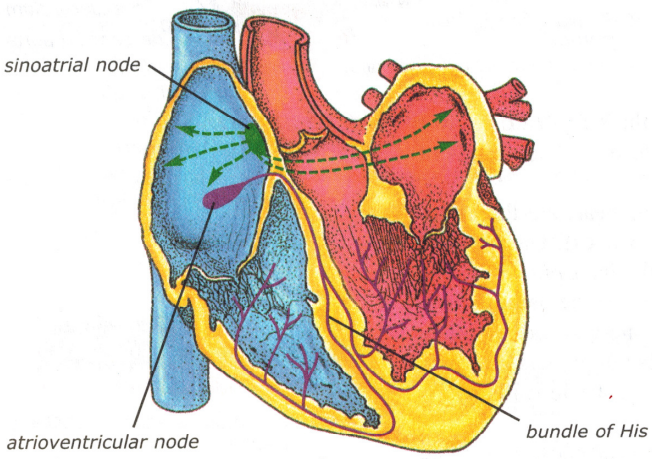
Sounds of the Heart

The characteristic *lubb-dubb, lubb-dubb* sounds heard through a stethoscope are produced when the atrioventricular and semilunar valves close. When the heart muscle contracts, the blood fills the cups of the valves of the heart, which snap together. As the ventricle contracts, the atrioventricular valves snapping closed produce the *lubb* (first heart sound or S_1). When the atria contract, the semilunar valves snap closed producing *dubb* (the second heart sound or S_2).

If the heart valves do not develop properly or become scarred by infection, they may close improperly, allowing blood to leak in the reverse direction. The backward flow of blood through the damaged heart valves creates turbulence in the blood flow producing the abnormal hissing sounds known as heart *murmurs*. If the heart murmurs are heard only after strenuous exercise, they are usually not a threat to a person's health; however, if the murmurs are still heard after a restful night, there may be cause for concern. Sometimes it is necessary to replace a defective valve with an *artificial valve*. Many heart murmurs in children correct themselves as the children mature.



Various types of artificial heart valves



22A.11

The conduction system of the heart. The SA node is located in the right atrium near the entrance of the superior vena cava. The AV node is located at the base of the right atrium near the septum. The bundle of His originates from the AV node and enters the septum, where it divides into two branches. These two branches supply the ventricles. The terminal branches of the bundle of His are called Purkinje fibers.

pulmonary: pulmo- (lung)

systole: (Gk. SYSTOLE, contraction)

diastole: (Gk. DIASTOLE, expansion)

When the right ventricle contracts, the tricuspid valve is forced shut, and the pulmonary semilunar valve opens to allow the blood to flow into the *pulmonary** artery. Thus, the right side of the heart pumps only deoxygenated blood.

Each of the two main branches of the pulmonary artery leads to a lung. As the blood flows through the capillaries surrounding the alveoli, oxygen is added to the hemoglobin of the blood.

The richly oxygenated blood returns to the left atrium through the *pulmonary veins*. The left atrium then contracts, squeezing the blood through the bicuspid valve and filling the left ventricle.

As the left ventricle contracts, the bicuspid valve shuts with considerable force, and blood rushes through the aortic semilunar valve into the *aorta*. All parts of the body receive blood from branches of the aorta. After the blood flows through the body organs, it eventually returns to the right atrium by way of the superior vena cava and the inferior vena cava.

The Cardiac Cycle

The **cardiac cycle**, or heartbeat, is one complete contraction and relaxation of the heart muscle. A person can feel his heartbeat by placing his hand over the region of the heart's apex, which for most people is the level of the fifth and sixth ribs, about 7.6 cm (3 in.) left of the midline.

The contraction of the heart muscle is known as **systole*** (SIS tuh lee). The heart's relaxing and filling with blood is called **diastole*** (dye AS tuh lee).

The regular rhythm of systole and diastole is controlled by *the conduction system of the heart*, specialized tissue embedded in the myocardium. One part of this system, the **sinoatrial** (SYE noh AY tree ul) **node** (SA node), starts each systole and thus sets the pace. The SA node has its own rhythm of about eighty electrical impulses per minute. For this reason it has been called the *cardiac pacemaker*. The SA node rate, however, can be increased or decreased by input from the nervous system.

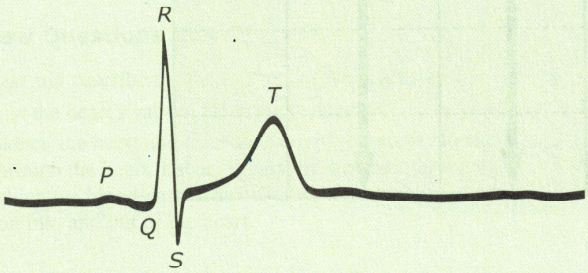
The electrical impulse from the SA node is transmitted through muscle tissue to both atria causing them to contract together. About 0.1 second later, the impulse reaches the **atrioventricular node** (AV node), where there is a brief pause to allow for proper emptying of blood from the atria. When the AV node "fires," it sends an electrical impulse down the *bundle of His* (special cardiac muscle fibers) to the wall of each ventricle. The fibers of the ventricle walls contract together and efficiently push the blood into the pulmonary artery and the aorta.

The Electrocardiogram (EKG)

A special apparatus can record on paper the electrical activity of the heart's conduction system. This graphic representation of heart impulses is known as an *electrocardiogram** (ih LEK tro KAR dee uh GRAM)—EKG or ECG. The various peaks or waves of an EKG, designated by the letters *P*, *Q*, *R*, *S*, and *T*, represent particular activities of the heart. Any deviation from a normal wave pattern indicates some defect in the conduction system or in the structure of the heart.

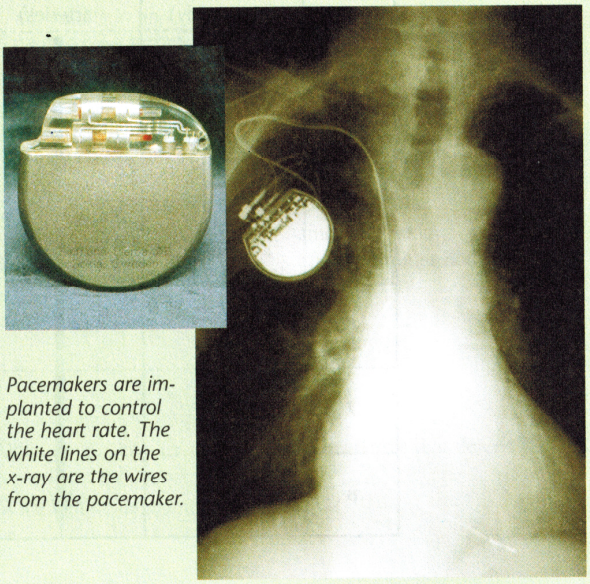
If a portion of the conduction system is injured or diseased, or if the nervous system does not properly regulate the SA node, the impulses do not pass from the atria to the ventricles. This condition is known as a *heart block*. There are different degrees and types of blocks depending on the particular physical defect. For example, in a partial heart block some impulses are missed between the SA node and AV node. This blockage causes the atria to beat somewhat faster than the ventricles.

In a complete heart block there is no communication between the SA and AV nodes, and the atria may beat twice as fast as the ventricles. In heart blocks, the *P* wave of an EKG will be present, but the *QRS* wave may be absent for several heartbeats.



A normal electrocardiogram. P *wave: atria contracting;* QRS *wave: ventricles contracting;* T *wave: rest and preparation for next contraction.*

Such abnormal rhythms may require surgical implantation of an artificial pacemaker. Such a device may be set electronically, or it may stimulate the heart only when the SA node slows in its function. Powered by batteries or nuclear energy, it consists of either a long wire inserted through a vein into the right ventricle or a device implanted in the ventricle wall.



Pacemakers are implanted to control the heart rate. The white lines on the x-ray are the wires from the pacemaker.

electrocardiogram: electro- (electric) + -cardio- (heart) + -gram (letter)

The Heart Rate

The typical resting heart rate of an adult is about 70 beats per minute (bpm); however, during moderate exercise it is commonly about 120 bpm. If the heartbeat is more than 140 bpm, ventricular diastole may be too short for the ventricles to fill with blood. Therefore, less blood is pumped at each heartbeat, and the person begins to tire.

If the heart rate is 72 bpm, about 0.8 sec is required for one heartbeat. During this brief period of time, the atria are in systole for only 0.1 sec, and then they relax and fill with blood for 0.7 sec. The ventricles are in systole for nearly 0.3 sec, and they relax and receive blood from the atria for about 0.5 sec.

Factors That Affect the Heart Rate

The following may increase the heart rate:

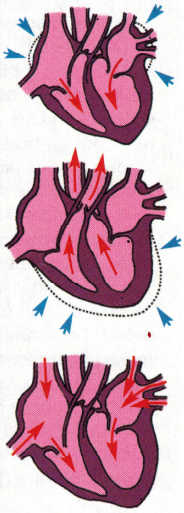
- Increase in body temperature (may increase the heart rate 3–4 bpm)
- Excessive amounts of sodium and potassium
- Certain hormones (may also increase the strength of contraction)
- Caffeine (as in coffee, tea, and many carbonated beverages)
- Increased amounts of blood returning to the heart (Increased muscle contractions during exercise force more blood through the veins into the heart.)
- Increased acidity of the blood

The following may decrease the heart rate:

- Excessive amount of calcium (may cause irregular contractions)
- Extreme deficiency of oxygen (may cause weaker heart contractions)
- Decreased amount of blood returning to heart

Table 22A-3 The Cardiac Cycle

Time (sec)	Atria	Ventricles	AV valves	Semilunar valves	Sounds
.1	systole (blood pumped into ventricles)	diastole (blood enters from atria)	open	closed	
.2	diastole (blood enters from body)	systole (blood pumped into arteries)	closed	open	lubb
.3					
.4					
.5		diastole (blood enters from atria)	open	closed	dubb
.6					
.7					
.8					



Unit 7: The Circulatory System

1. List and describe the three layers of the heart's wall.
2. List the heart's valves and describe their action.
3. Sketch the heart (like on page 687) and trace the path of a drop of blood as it goes from the vena cava to the aorta. Label all the parts of the heart.
4. What causes the sounds of the heart?
5. What is systole? What is diastole?
6. What two masses of tissue control the rhythm of the cardiac cycle? Where is each tissue located?
7. What is a typical resting heart rate for an adult?