Cardiovascular Lab
Using the Electrocardiogram (ECG) to Understand the Basis of Cardiac Arrhythmias
Modified from:
Biology in the laboratory. 3rd edition. Helms, Helms, Kosinski and Cummings.
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The Anatomy of Representative Vertebrates: Circulatory System

OVERVIEW

The circulatory system integrates many of the body's physiological responses. It provides nutrients and oxygen to, and removes wastes and carbon dioxide from, ALL living tissues of the body. It also carries information in the form of hormones and metabolites and plays a major role in immune responses and disease prevention.

Animals too large to accomplish internal transport by diffusion are equipped with a system of branching vessels filled with blood, which is usually propelled through the system by the muscular contractions of the heart. Vertebrates have a closed circulatory system, a circuit of continuous vessels. Other animals, such as Arthropods and Molluscs, have an open circulatory system: blood flows from vessels to open spaces in the tissues and then to vessels again.

Many organisms couple the circulatory system with a respiratory surface such as lungs or gills, where gases can be exchanged between the blood and the environment. In vertebrates other than birds and mammals, a serial circuit delivers blood directly from the respiratory surface to the tissues. The parallel circuitry (pulmonary and systemic systems) present in birds and mammals is more efficient.

Blood traveling in the circulatory system is made up of a fluid matrix called plasma, which carries cells, oxygen, nutrients, wastes, and other materials from one region of the body to another. Blood often contains special respiratory pigments that deliver the oxygen throughout the body. The rate at which the blood is pumped by the heart can be measured as one’s pulse. Blood pressure is a measure of the force exerted by blood against the walls of the blood vessels. Both pulse and blood pressure can be influenced by a variety of factors, including diet, exercise, hormones, age, smoking, alcohol intake, and a number of other environmental factors.

During this laboratory, you will investigate the properties of the heart, blood cells, arteries, and veins. You will explore the structure of the vertebrate heart and determine the effects of exercise, on heart rate and pulse.

STUDENT PREPARATION

Prepare for this laboratory by reading the relevant pages in your text book. Familiarizing yourself in advance with the information and procedures covered in this laboratory will give you a better understanding of the material and improve your efficiency.

Learning Objectives

By the end of this lab you should be able to:

- Describe the path of blood flow in Animals with a two chambered heart.
- Describe the Systemic and pulmonary blood flow in organisms with three and four chambered hearts and identify the branches of the circulatory system that are carrying oxygenated vs. deoxygenated blood.
- Identify the major chambers of the frog heart.
- Identify all chambers of the sheep heart.
- Describe how the anatomy of the sheep heart chambers reveals their function.
- Identify the different valves in the sheep heart and explain their function.
- Describe the anatomical differences between arteries and veins and explain how this reveals their functional differences.
- Identify red and white blood cells.
- Understand diastolic and systolic blood pressure, explain what each represents, and explain how blood is moving through an artery at the moment that each pressure is measured.
THE CIRCULATORY SYSTEM

The circulatory system includes a pump, the heart, and associated vessels: arteries that carry blood away from the heart and veins that carry blood back to the heart.

In vertebrates, the system is closed: blood is contained in vessels in almost all organs and tissues. Capillaries link arteries and veins and penetrate virtually every tissue of the body; these small-diameter, thin-walled vessels permit exchange of solutes and gases. In some tissues such as the liver, blood bathes tissues directly; these open channels, called sinusoids, also function in the exchange of materials.

Pressure supplied by contractions of the heart forces water, dissolved materials, and low-molecular weight molecules through the single cell layer that makes up the capillary wall into the surrounding tissue spaces. As the vessels lose water, the high-molecular-weight molecules in the blood (albumins and other blood proteins) become more concentrated, providing an osmotic gradient that causes most of the fluid filtered from the system to return to the vessels. In terrestrial vertebrates, much of the remaining fluid is eventually returned to the venous system by vessels of the lymphatic system. Within the heart, veins, and lymphatic vessels, one-way valves ensure the proper circulation of blood.

Arteries are thick-walled vessels carrying blood from the heart to the gills in fishes and to the body tissues in all vertebrates. During the course of vertebrate evolution, systems of arteries appear to have been derived from a basic ancestral plan. In this plan, a ventral aorta carries blood anteriorly from the heart to a series of aortic arches located within the pharyngeal arches. (The pharyngeal arches make up the wall of the pharynx; some of these arches bear gills.) Blood passes upward through the aortic arches, where capillaries associated with the gills provide for gas exchange. Blood is then collected by the dorsal aorta.

Evolutionary changes in the arrangement of these aortic arches, including redirection or loss of some and maintenance of others, occurred in response to a redistribution of gas exchange surfaces from gills to lungs, the development and partitioning of the heart, and the formation of paired appendages (Figure 1). Derivatives of these arches carrying blood to the lungs are part of the pulmonary circuit, and those delivering blood to the body are part of the systemic circuit.

Posteriorly, the dorsal aorta branches to form unpaired vessels, including both coeliac and mesenteric arteries, which carry blood to visceral organs. Paired segmental arteries generally supply the "segmented" dorsal body wall. Paired renal and gonadal arteries supply the kidneys and gonads, respectively. A large pair of arteries, the iliac arteries, provides blood to the pelvic appendages. If a tail is present, the dorsal aorta continues into it as the caudal artery.

Trace the evolutionary fates of the ancestral aortic arches as illustrated by the anatomical differences observed in the frog and fetal pig.
As you study the evolution of the aortic arches in vertebrates, observe how these structures of blood supply and drainage became modified as other structures and functions of the animals changed.

(a) In ancestral fishes, the ventral aorta gave rise to six afferent branchial arteries carrying blood to the gills; six efferent branchial arteries picked up the blood from the gills and joined on each side to form a branch of the dorsal aorta.

(c) With the evolution of jaws, the first arch became reduced. With the origin of the swim bladder (lung) in bony fishes, the sixth aortic arch became associated with the pulmonary circulation to the lungs. As the second pharyngeal arch became modified to form the operculum covering the gills in teleost fishes, the second aortic arch became reduced and was eventually lost.

(d) In adult frogs, the portions of the dorsal aorta between the third and fourth arches are lost, separating the general systemic circulation of the head from that of the body. The third aortic arch now carries blood only to the head. The fourth aortic arch serves as the major systemic trunk to the body. The sixth arch is primarily devoted to the pulmocutaneous circulation, providing blood to the skin and lungs, the primary organs of gas exchange in frogs. In some amphibians, the sixth aortic arch remains attached to the dorsal aorta.

(e, f, g, h) In adult reptiles, birds, and mammals, the connection of the sixth aortic arch to the dorsal aorta disappears, leaving a separate pulmonary artery and a single pair of aortic arches to supply blood to the body behind the head.

(h) In mammals, the right aortic arch is lost and the left remains. These changes in the arrangement of arteries near the heart are correlated with the partitioning of the heart to provide parallel, but separate, pumps to deliver deoxygenated blood to the lungs for oxygenation, and oxygenated blood to the body.
Veins

*Veins are thin-walled vessels that conduct blood from the tissues back to the heart.*

- Systemic veins drain the general body tissues. The systemic venous system includes one or two portal systems. Portal veins carry blood from a primary capillary network in one organ to a second capillary network in a different organ before returning the blood to the heart.
  
  a. Renal portal veins (not present in mammals) collect blood from capillaries in the posterior body, including the tail and hind limbs, and carry it to the kidneys where, within a second capillary network, filtered materials are collected before the blood is returned to the heart.
  
  b. Hepatic portal veins carry blood containing many of the products of digestion from the intestines to a second capillary network in the liver where these materials can be metabolized or synthesized into storage products.

- Pulmonary veins (found only in vertebrates with lungs) return oxygenated blood from the lungs to the heart.

_Phylogenetically and developmentally, veins arise as a series of paired vessels along each side of the body._

Anteriorly, two major vessels, the anterior _venae cavae_, tend to persist. Posteriorly, there is an early trend toward the formation of a single posterior vena cava, derived by the fusion of several embryonic veins. This vein serves only the liver, anterior intestinal organs, and the kidneys in vertebrates with a well-developed renal portal system. In mammals, the renal portal system is absent and the posterior vena cava carries blood from all posterior regions of the body back to the heart.

Branches of veins tend to parallel those of arteries, and many have similar names. Because veins are more variable than arteries among vertebrate groups, and also have thin walls that make them more difficult to locate

You will study evolutionary trends by comparing schematic diagrams of the circulatory systems of the four representative vertebrate groups.

- *Describe the basic structural pattern of veins in vertebrates.*
In the diagrams of Figure 2, write the name of each vessel (in boldface type in figure legend) in the appropriate blank(s). Note: These diagrams are schematic and do not show the precise positions of arteries and veins relative to dorsal and ventral aspects of each organism.

**Figure 2** Vertebrate circulatory systems. In these diagrams, only one side of the body is represented, so only one of each pair of vessels is shown. Paired veins drain the head region in all vertebrates. In the shark, two anterior cardinal veins carry blood from the head to the first chamber of the heart. In the frog, turtle, and rat, these veins are called the anterior venae cavae. In the shark, two veins, the posterior cardinal veins, carry blood from the liver, kidney, gonads, and body wall back to the heart. In more derived vertebrates, such as the frog, turtle, and rat, embryonic veins, including the posterior cardinal veins, fuse to form a single posterior vena cava. A hepatic portal system drains the digestive tract, carrying blood to the liver by way of the hepatic portal vein.

In all vertebrates except mammals, a renal portal system drains the posterior parts of the body, carrying blood to the kidneys by way of the renal portal veins. Blood from the kidneys and liver is returned to the systemic circulation through the renal and hepatic veins that join the posterior cardinal veins (in sharks) or the posterior vena cava (in the other representative vertebrates). In the frog and turtle, these portal systems are interconnected by the ventral abdominal vein, allowing blood returning from the posterior portions of the body to pass through either the kidneys or the liver.

In the rat, the renal portal system is absent and blood from all posterior regions of the body returns directly through the posterior vena cava. Blood from the limbs is returned to the posterior vena cava by the paired iliac veins and from the tail by the caudal vein. In vertebrates with lungs, pulmonary veins return oxygenated blood from the lungs to the heart.
After labeling the veins in Figure 2, use your knowledge from Part 1 of this exercise to identify the major arteries shown in each diagram.

Use a pencil to shade those vessels carrying deoxygenated blood in each diagram. Do not shade the chambers of the heart at this time. You will study the structure of the heart in Part 3 of this exercise.

In ancestral vertebrates (without lungs), including living representatives such as the shark, the heart is composed of four chambers arranged in a row, it is a **serial heart**. Blood returning from body tissues flows into the most posterior chamber, the **sinus venosus**, and then to the atrium, which injects blood into the third chamber, the ventricle. The thick muscular walls of the ventricle supply the major force for moving blood through the vascular system. Finally, blood enters the most anterior chamber, the **conus arteriosus**, which connects to the ventral aorta.

All four of these chambers are readily recognizable in the shark, although the heart tube has folded upon itself.

**Shark Heart, Ventral view**
1. ventricle
2. atrium
3. sinus venosus
4. coronary artery
5. conus arteriosus
6. ventral aorta
7. afferent branchial arteries

In other vertebrates the embryonic heart is tubular but, during development, it folds and **twists**, and two of the chambers—the **conus arteriosus** and **sinus venosus** lose their independent existence as they become incorporated into the tissues of the **atrium** and **ventricle**. The rhythm of contraction in the heart originates within the cardiac muscle tissue of the sinus venosus. If the heart is cut into separate parts, the rhythm of the sinus venosus is fastest and, in the intact heart, this rhythm initiates the wave of contraction passing through the heart. In other words, the **sinus venosus acts as a pacemaker**. In mammals, the sinus venosus becomes incorporated into the wall of the chamber anterior to it, the atrium, where it remains as a small patch of tissue that serves as the pacemaker.

With the appearance of lungs during the course of evolution, a septum developed that separated the atrium into two parts: oxygenated blood returning to the atrium from the lungs is separated from deoxygenated blood returning from the body. In the frog, the ventricle remains unpartitioned, allowing some oxygenated blood and deoxygenated blood to mix before being pumped to the body organs. In turtles, the ventricle is partially divided into two chambers by an interventricular septum that is nearly complete, so that little mixing of oxygenated and deoxygenated blood occurs. Oxygenated blood is shunted first to the head and body, while deoxygenated blood is pumped to the lungs.

**Label the right and left atria and ventricle of the frog/turtle heart in Figure 3. Use the following abbreviations: LA = left atrium; RA = right atrium, V = ventricle. The sinus venosus, emptying into the right atrium, is reduced and not shown in this diagram. The conus arteriosus is divided and forms the basal portion of the two arterial trunks-each called a truncus arteriosus-leaving the heart. Label this area TA in Figure 3.**
Figure 3: Frog heart
In birds and mammals (and the crocodile), the partitioning of the ventricle is complete, and systemic and pulmonary blood occupy separate circulatory channels in the heart.

Label the right and left atria and ventricles of the crocodile heart in Figure 4. Use the following abbreviations: LA = left atrium; RA = right atrium; LV = left ventricle; RV = right ventricle. The sinus venosus persists as the pacemaker in the wall of the right atrium. This should not be a difficult task!

![Crocodile Heart Diagram](image)

**Figure 4: Crocodile heart**

Each chamber of the heart is separated from the next by flaps in the wall of the heart, forming valves. The sinus venosus and atrium are separated by the **sinoatrial valve**; the atrium and ventricle by the **atrioventricular valve**; and the ventricle and conus arteriosus by a series of **semilunar valves**. In mammals, the semilunar valves are a remnant of the conus arteriosus. Valves prevent backflow and maintain a directed and effective circulation.

Thus, during the course of evolution, we see the circulatory system evolve from a *serial arrangement* (heart ~ gills ~ systemic circulation ~ heart) to one in which systemic and respiratory flows are *parallel* (heart ~ systemic circulation ~ heart) and (heart ~ pulmonary circulation ~ heart).

Use the following directions to dissect and study the structure of the heart in your specimen. Share what you learn with others in your group. Compare anatomical structures in the four animals to observe evolutionary adaptations to the presence of gills and of lungs.
**Frog**

1. Refer to previous Figures to identify the structures of the frog's heart. Lift the muscular ventricle and follow the posterior vena cava beneath it to the sinus venosus (reduced in size from the sinus seen in the shark). Cut the posterior vena cava and lift the heart forward if necessary. Find the point at which the paired anterior venae cavae enter the sinus venosus, which empties into the right atrium.

2. In the adult frog, the atrium is completely divided by an interatrial septum into right and left chambers, the right atrium receiving the deoxygenated blood from the systemic circulation and the left atrium receiving the oxygenated blood from the pulmonary and cutaneous veins. Blood from both chambers passes into the undivided muscular ventricle. However, deoxygenated systemic blood is injected into the ventricle first and occupies the bottom of the ventricle, and oxygenated pulmonary blood, injected last, occupies the upper portion nearest the conus arteriosus. The conus is highly specialized to direct blood selectively into the three major branches of the ventral aorta on each side: the most oxygenated blood from the pulmonary circulation passes to the head, oxygenated blood returned from the cutaneous circulation passes to the body, and the least oxygenated blood, collected by the sinus venosus, is moved to the respiratory surfaces.

**Circulation and the evolution of parallel loops**

In fishes, the heart is tubular and is composed of a single atrium and ventricle. Deoxygenated blood returning from the body enters a chamber at the rear of the heart and then flows into the atrium. From there, blood flows into the ventricle, which pumps it to the gills (Figure 5). In amphibians, deoxygenated blood returns to the right atrium, and oxygenated blood from the lungs moves into the left atrium. There is only one ventricle, and thus the amphibian heart is "three-chambered." The oxygenated blood entering the ventricle becomes layered on top of returning deoxygenated blood and is pumped to the head, heart, and body while the deoxygenated blood is pumped to the lungs (Figure 5).

In reptiles, there is a trend toward dividing the ventricle to form separate pulmonary (lung) and systemic (body) circulations. In birds and mammals, separation of the ventricle is complete (Figure 5). Systemic and pulmonary circulations are parallel: (heart ~ systemic circulation ~ heart) and (heart ~ lungs ~ heart).

**Figure 5: Vertebrate circulatory systems**
Figure 6 (a) The human heart. Blood returning from the systemic circulation through the superior and inferior vena cavae enters the right atrium and passes to the right ventricle, which propels blood through the pulmonary arteries to the lungs, where it is oxygenated. Blood from the lungs enters the left atrium through the pulmonary veins, passes to the left ventricle, and then is pumped through the aorta to the body tissues.

(b) The beat of the mammalian heart is controlled by a region of specialized muscle tissue in the right atrium, the sinoatrial node, that functions as the heart’s pacemaker. Some of the nerves regulating the heart have their endings in this region. (The tissue of the pacemaker is homologous to that of the chamber at the rear of the fish heart called the sinus venosus. This tissue has an inherent ability to beat and sets the pace of the heartbeat for the fish.)

Excitation spreads from the pacemaker through the atrial muscle cells, causing both atria to contract almost simultaneously. When the wave of excitation reaches the atrioventricular node, its conducting fibers pass the stimulation to the bundle of His, from which excitation spreads along specialized fibers of the ventricles. The result is an almost simultaneous contraction of the two ventricles. Because the fibers of the atrioventricular node conduct relatively slowly, the ventricles do not contract until after the atrial beat has been completed.
In the mammalian heart, the atria and ventricles are separated by atrioventricular valves: on the right side, the tricuspid valve, and on the left, the bicuspid valve. Backflow of blood from the pulmonary arteries that carry blood to the lungs, and from the aorta that carries blood to body tissues, is prevented by semilunar valves. The rhythm of the heartbeat is maintained and controlled by a patch of tissue, the sinoatrial node (SA node) or pacemaker (Figure 6). A wave of excitation initiated in the pacemaker is picked up by a special bundle of conducting fibers (the bundle of His) that originates in an area known as the atrioventricular node (A V node). These fibers conduct the impulse to the walls of the ventricle, causing it to contract.

Objectives
• Trace the pathway of blood through the mammalian heart.
• Trace the evolution of separate systemic and pulmonary circulations in the heart pump.

Procedure
1. Work in pairs. Wear gloves and safety glasses. If any preserved tissue gets into your eye, flush it with water immediately and notify your instructor. Place a fresh or preserved sheep heart in a dissecting pan. Remove any remnants of the covering pericardial membrane surrounding the heart. Use a probe or forceps to scrape away excess fat from the heart and its vessels.
2. Position the heart so that you are looking at its ventral surface (locate the interventricular sulcus on the ventral surface, as shown in Figure 7). When viewing the heart from this aspect, note that structures to your right are actually located on the animal's left (and vice versa). Notice some twisting of the ventricles, with the larger left ventricle lying somewhat behind the right ventricle.
3. Locate the atria-smaller, thin-walled chambers anterior to the ventricles (Figure 7). Identify right and left atria. You should be able to identify the roots of three large arteries leaving the heart between the atria. The pulmonary artery carries deoxygenated blood from the right ventricle to the lungs (branches mayor may not be found in your specimen).

• Why is this vessel called an artery even though it carries deoxygenated blood?

Figure 7 sheep heart

A=right atrium
B=right ventricle
C=tricuspid valve
D=chordae tendinae
E=left ventricle
F=aortic semilunar valve
G=aorta
H=pulmonary vein
I=left atrium
J=bicuspid valve
4. Turn the heart over and examine the dorsal surface. Identify the superior vena cava. This vessel returns deoxygenated blood to the heart from the head and anterior body regions. Also identify the inferior vena cava, which returns deoxygenated blood from the remainder of the body. Try to find the pulmonary veins. These vessels return oxygenated blood from the lungs to the heart.

Can a blood vessel be defined as an artery or vein by the type of blood it carries (oxygenated or deoxygenated)? What determines whether a blood vessel is an artery or a vein?

5. Looking at the dorsal surface of the heart and consulting, begin cut by inserting your scissors into the superior vena cava. Cut through the dorsal wall of this vessel and extend the cut through the inferior vena cava. Begin cut by positioning your scissors in the inferior vena cava and cutting laterally through the right atrium to the base of the pulmonary artery. Make cut through the right ventricle toward the apex of the heart. Separate the chambers and examine the internal structure (Figure 8).

6. Find the tricuspid valve (the right atrioventricular valve). As its name implies, the tricuspid valve is made up of three flaps of the heart wall and prevents backflow of blood during contraction. These flaps are prevented from evertting into the atrium during contraction of the right ventricle by strands of tissue (chordae tendinae) connecting the ventricular wall to the valve flaps (Figure 8). Extend the opening of the ventricle into the base of the pulmonary artery. Locate the pulmonary semilunar valves, made up of three small flaps that prevent backflow of blood from the artery to the ventricle. Note the smooth layer of tissue, the endocardium, lining the cavity of the heart.

7. Now, turn the heart over to the ventral side. Starting about 2 cm from the left edge of the left atrium (Figure 8), cut laterally through the left atrium and then downward through the left ventricle to the apex of the heart.

8. Open the chambers to examine interior structures. Find the pulmonary veins entering the atrium (Figure 8). Note that the left ventricular wall is thicker than the right. Why?

The internal structures of both ventricles are similar. Find the bicuspid (mitral) valve (the left atrioventricular valve). This valve is made up of two flaps which prevent backflow into the left ventricle. Chordae tendinae provide support, as in the right ventricle. Extend your cut toward the aortic trunk and find the two aortic semilunar valves preventing backflow into the left ventricle.

9. On a separate piece of paper, diagram the flow of oxygenated blood from the lungs to the heart to the body and of deoxygenated blood from the body to the heart to the lungs.

Why would parallel circulation be an advantage to active organisms such as mammals? (Hint: Compare the mammalian circulatory system with that of fishes, as shown in Figure 5.)
The Structure of Arteries and Veins

The blood of a closed circulatory system is confined within the blood vessels. Blood leaves the heart through large arteries—the pulmonary artery leads to the lungs and the aorta to the systemic body circulation. These arteries branch into smaller arteries, then into smaller arterioles, and finally into very thin-walled capillaries. The capillaries join to form venules, which join to form larger veins. Veins return blood to the heart.

Figure 9 Diagrammatic representation of the structure and arrangement of blood vessels in the circulatory system. The endothelium is only one cell thick.

Use low power to observe a prepared slide of an artery and a vein. Use high power (400X) to study both blood vessels in more detail. Identify the structures in the following description.

An artery has thick walls with wavy-appearing elastic fibers and a relatively small central cavity (lumen). A vein has a thinner wall and a much larger lumen.

- Why is the wall of the artery thicker, stronger, and more elastic than that of the corresponding vein?

Both arteries and veins consist of three layers that may vary somewhat in size and composition. The inner layer is the endothelium, found in all blood vessels, including capillaries. It is composed of an elastic membrane covered by a single layer of flat squamous epithelial cells. In an artery, this inner layer may also contain elastic connective tissue fibers. The middle layer is an area of smooth muscle fibers and elastic fibers. The middle layer of a vein contains a thinner layer of smooth muscle fibers and fewer elastic fibers than that of an artery. The outer layer of blood vessels consists of connective tissues, nerve fibers, and smaller blood vessels. In an artery, this area is composed chiefly of tough, nondistensible, white, fibrous connective tissue. The outer layer of a vein is even less distensible and elastic than that of an artery. The wall of a capillary consists of just a very thin layer of flat endothelial cells.

2. In the space beside Figure 9, examine the cross sections of an artery and a vein. Note the three layers. Veins contain valves, structures that are not found in arteries. What is their function?

3. Observe a slide (or picture from the Internet) showing the blood vessels of a person with atherosclerosis. Compare the artery in this slide with the normal artery. What difference do you observe?

In atherosclerosis, principally a disease of the large arteries, lipid deposits, called atheromatous plaques, appear in the arteries. These plaques contain an especially large amount of cholesterol and are often associated with changes in the arterial wall. During later stages of the disease, the walls of the arteries become extremely hard due to the presence of fibroblasts in the affected area and the deposition of calcium and lipids. The disease is then called arteriosclerosis, or hardening of the arteries.

- How might atherosclerosis interfere with the normal functioning of an artery?
Microscopic Examination of Human Blood Cells

Blood contains white cells (leukocytes) and red cells (erythrocytes). Mature mammalian erythrocytes are biconcave disks that lack a nucleus and contain hemoglobin for the transport of oxygen. Leukocytes are nucleated cells. Granulocytes and monocytes, types of leukocytes, transform into macrophages that migrate to infected areas, where they perform a clean-up function. Lymphocytes, another type of leukocyte, are responsible for immune reactions. Many infections are characterized by an increase in the white blood cell count.

Objectives
- Recognize and describe red blood cells.
- Recognize and describe granulocytes, monocytes, and lymphocytes.
- Describe the difference between normal and sickle-cell erythrocyte structure.

Procedure
1. Use high power (40x) to observe a prepared slide of human blood. Use the Figure below and the charts in the to help identify cell types.

Figure Blood cell types. R Red blood cells (erythrocytes); white blood cells (leukocytes): E eosinophil (stains dark pink to reddish orange), N neutrophil (stains light pink to lavender), B basophil, L lymphocyte, M monocyte; P platelet (thrombocyte).
• Which type of blood cells are stained pink on your slide?

• Do you see their nuclei?

• What pigment is present in these cells?

• What is its function?

• What proportion of the cells on your slide appear to be leukocytes?

• Granulocytes are characterized by nuclei of many different shapes and by the granules in their cytoplasm. What color are these granules?

• Do you see white blood cells with no granules in the cytoplasm? These are either monocytes or lymphocytes. Monocytes are the largest leukocytes (approximately twice the diameter of lymphocytes). Which do you see?

• Which type of leukocyte is most abundant?

2. Use high power (40x) to examine the slide (on demonstration) of blood from a carrier of sickle-cell anemia. Describe your observations.

The hemoglobin of an individual who carries the recessive sickle-cell allele in the heterozygous condition is less soluble than normal hemoglobin. When the oxygen supply is inadequate or when the carbon dioxide concentration increases, sickle-cell hemoglobin molecules tend to crystallize to form hairlike rods that pile up and transform the cell into a sickle shape. The cells then clump and clog the blood vessels and cannot carry out their function of transporting oxygen. In order to determine whether a person is a carrier of the sickle-cell allele, blood is subjected to a low-oxygen atmosphere and examined with a microscope. In an individual who is homozygous for the sickle-cell allele (that is, has sickle-cell anemia), hemoglobin is abnormal even at normal oxygen and carbon dioxide concentrations.

Mononucleosis is a disease characterized by fever, headache, scratchy throat, fatigue, and enlargement of the lymph glands.

3. Examine a prepared slide of frog blood.
   • How do frog erythrocytes differ from those of humans?

Determining Blood Pressure

A blood pressure reading is a measure of the force exerted by the blood against circulatory vessels, first during systole, contraction of the ventricles of the heart, and then at diastole, relaxation of the ventricles. When the ventricles contract, a greater volume of blood is forced through the open valves and into the arteries than can immediately exit through the narrowest of the arterioles. The result is a rise in pressure inside the arteries as blood pushes against the interior walls. Between ventricular contractions, the aortic valve closes, blood leaves the arteries, and there is a decrease in arterial pressure. The "rebound" of the elastic walls of the arteries helps to give the blood an additional push.

A sphygmomanometer (Figure 10) is used to measure blood pressure. The cuff, designed to fit around the upper arm, can be expanded by pumping a rubber bulb connected to the cuff. The pressure gauge, scaled in millimeters of mercury (mm Hg), indicates the pressure inside the cuff. A stethoscope is used to listen to the subject’s pulse.
Objectives

- Determine systolic and diastolic blood pressure.

Procedure

1. Work in pairs. After your lab partner is seated, has rolled up his or her shirt sleeve, and is relaxed, attach the cuff of the sphygmomanometer snugly around the upper arm.
2. Place the stethoscope at a point directly below the cuff, preferably in the well of the elbow joint.
3. Close off the valve to the bulb by turning it clockwise and pump air into the cuff until the needle on the pressure gauge jumps just past the 200-mm mark.
4. Turn the valve on the bulb counterclockwise to slowly release air from the cuff at a rate of about 2 or 3 mm Hg per second. Listen for a pulse.
5. Just as you begin to hear the pulse, note the pressure on the gauge. This is the systolic pressure. As the cuff was inflated, the brachial artery in the arm collapsed. When the artery begins to expand as you release air from the cuff, you hear the pulse. As pressure in the artery is released, all sound ceases.
6. Continue to listen until the clear thumping sound of the heart becomes strong and then fades. When you hear the last part of the full heartbeat (lub dub), take note again of the pressure. This is the diastolic pressure.
7. Write down the complete blood pressure of your subject: systolic/diastolic =

Record your own blood pressure as measured by your partner:

| Table 1 Normal Blood Pressure for Men and Women (Age 20) |
|-----------------|-----------------|
|                 | Blood Pressure (mmHg) |
| Men             | Women           |
| Systolic        | Systolic        |
| 105-140         | 100-130         |
| Diastolic       | Diastolic       |
| 62-86           | 60-85           |

- Does your subject’s blood pressure lie within the normal range (Table 1)?
- Does your own blood pressure?
- What general circulatory problems may be indicated by high blood pressure (hypertension)?
- Why is hypertension dangerous if it is allowed to continue indefinitely?

- What condition exists when a person’s blood pressure is well below normal?
- How would blood pressure measured in the thigh compare with the reading you just obtained?
- Why?
- The microscope slide on demonstration shows the cross sections of blood vessels from a person with atherosclerosis.
- Explain how a narrowing of blood vessels affects blood pressure.
Measuring Pulse Rate and Blood Pressure
Heart rate, pulse rate, and blood pressure can all be affected by many factors, including fitness, activity, smoking, and drugs.

Objectives
- Determine the relationship between pulse rate and heartbeat rate.
- Determine the effects of both moderate and strenuous exercise on the heart rate and pulse rate.
- Explain how smoking can affect pulse rate.

Relation of the Heartbeat to Circulation
Procedure
Work in pairs. Use a stethoscope to listen to your partner's heart. Your partner should be sitting down. At the same time, take his or her pulse rate by placing the tips of the first two fingers of one of your hands over the radial artery at the base of the wrist on the palm side of your partner's hand. Pulse rate of subject while sitting:

Record your own pulse rate as measured by your partner:
- What is the relation between heartbeat rate and pulse rate?
- Why does this relationship exist?
- What is a pulse?
- Why can a pulse be found only in certain parts of the human body?

Variability of the Heart Rate and Blood Pressure
Procedure
1. Work in pairs. Partner #1 should recline on a mat for 5 minutes. At the end of this time, partner #2 should take the pulse rate of partner #1, who should continue to recline for another 2 minutes. Partner #1 should then stand and the pulse rate should be taken immediately. Record all pulse rates in Table 2.
2. After Partner #1 has remained standing for 3 minutes, record the standing pulse rate.
3. Add to Table 2 the data from Part 1 for partner #1’s pulse rate in the sitting position. Reverse roles and record data on your own pulse rates, as measured by your partner.

The change from a reclining or sitting to a standing position causes blood to "fall" from the upper body under the influence of gravity, resulting in a decrease in blood pressure. Pressure receptors (baroreceptors) in the aortic arch and the carotid arteries compensate by signaling the medulla of the brain to increase the heartbeat, and, consequently, the pulse rate. Did you observe this increase?

Table 2 Pulse Rate (beats/minute)
<table>
<thead>
<tr>
<th>Disposition</th>
<th>Partner #1</th>
<th>Partner #2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reclining</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Immediately upon standing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sitting</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- How might the valves of the blood vessels be involved in the increase in heart rate immediately upon standing and the decrease in heart rate after a period of standing?
- Do you think a person who is more physically fit than another person would exhibit a larger or smaller difference in pulse rate upon standing?
- Compare your partner’s data or your own with those obtained for classmates of the same sex whom you might consider to be less or more physically fit. Does this comparison support your answer?
The Effect of Exercise on Heart Rate

Procedure

1. Work in pairs. Determine your partner's sitting pulse rate ("before exercise" pulse rate).
2. One partner should now exercise moderately by raising alternate knees to the chest for approximately 30 seconds. The other partner should exercise strenuously by running up several flights of stairs as quickly as possible.
3. Record the pulse rate and rate of heartbeat immediately after exercise, then measure the time required for the return of sitting pulse rate for both individuals.
4. Reverse roles and record data for the other type of exercise for each partner. Record all data either for yourself or for your partner in Table 3

<table>
<thead>
<tr>
<th>Table 3 Effect of Exercise on Heart Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Pulse rate</td>
</tr>
<tr>
<td>Rate of heartbeat</td>
</tr>
<tr>
<td>Time required for return of sitting pulse rate</td>
</tr>
</tbody>
</table>

Table 4 lists the expected pulse rate 2 minutes after vigorous exercise in individuals of various physical conditions.

<table>
<thead>
<tr>
<th>Table 4 Pulse Rates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical condition</td>
</tr>
<tr>
<td>Excellent</td>
</tr>
<tr>
<td>Very good</td>
</tr>
<tr>
<td>Average</td>
</tr>
<tr>
<td>Below average</td>
</tr>
<tr>
<td>Poor</td>
</tr>
<tr>
<td>Very poor</td>
</tr>
</tbody>
</table>

The speed with which the sitting pulse rate is restored after exercise serves as one index of circulatory efficiency. Here is an example of a normal response:
before exercise, pulse 80; immediately after exercise, pulse 120; 2 minutes after exercise, pulse 84.

- How efficient is your circulatory system?
- Why should people with "weak" hearts avoid strenuous exercise such as climbing stairs?
Cardiovascular Terms – for lab quiz
Aortic arches (changes over evolutionary time)
Open versus closed circulation
Systemic veins
Portal veins
Renal portal veins
Hepatic portal veins
Pulmonary veins
Vena cavae
Structure of veins and arteries
Ventral abdominal vein
Ventricle
Atrium
Sinus Venosus
Coronary artery
Conus arteriosus
Aorta
Interatrial septum
Conduction system of the hear (and all the parts therein)
Tricuspid/R. atrioventricular
Bicuspid/Mitral/L atrioventricular
Chordae tendonae
Erythrocytes and their function
Leukocytes and their function
Hemoglobin
Blood pressure: how it is obtained and what the numbers indicate

Practice question Recap – could be used in the Interpretation section:
1. Does your subject’s blood pressure lie within the normal range?
2. What circulatory problems may be indicated by high blood pressure (hypertension)?
3. Why is hypertension dangerous if it is allowed to continue indefinitely?
4. What condition exists when a person's blood pressure is well below normal?
5. How would blood pressure measured in the thigh compare with the reading you just obtained? Why?
6. Explain how a narrowing of blood vessels affects blood pressure.

Relation of the Heartbeat to Circulation
7. Pulse rate of subject while sitting:
8. What is the relation between heartbeat rate and pulse rate?
9. Why can a pulse be found only in certain parts of the human body?

Variability of the Heart Rate and Blood Pressure
10. How might the valves of the blood vessels be involved in the increase in heart rate immediately upon standing and the decrease in heart rate after a period of standing?
11. Why should people with "weak" hearts avoid strenuous exercise such as climbing stairs.