INTRODUCTION:

All mammals (in fact, all higher animals), have a closed circulatory system. That is, the blood is completely contained within blood vessels as it passes to, through, and from various organs. The blood also moves around the body under relatively high pressure, allowing it to flow against gravity and against the resistance which the vessels normally provide.

Although the heart is undoubtedly the best known organ of the circulatory system, it is certainly not the only important one. The heart and blood vessels must work together to move blood around the body in the most efficient manner possible, getting it to the correct organs at the correct time, correct volume, and correct pressure. Since all other tissues, organs, and systems depend on the circulatory system to deliver the materials they need and remove waste products they do not need, the circulatory system is one of the most vital systems in the body. Indeed, the classic definition of death, at least until brain activity could be evaluated, was failure of this system.

Contraction of the heart, called systole, provides the propulsive force which moves blood around the system. Relaxation of the heart, called diastole, allows its chambers to refill with blood for the next systole. The heart has a series of one-way valves which ensure that blood flow occurs in only one direction during systole and diastole. However, it would be a mistake to view blood vessels as simply passive tubes through which the blood flows. Vessels throughout the body are constantly adjusting their pressure and flow to meet changing needs of different tissues and organs, and malfunctions of the blood vessels can be just as dangerous as malfunctions of the heart.

Gross Anatomy of the Heart:

The heart is a cone-shaped organ, with the broad part superiorly and the time facing inferiorly and to the left. It lies within the center, or mediastinum, of the thorax and consists of four hollow chambers through which the blood is pumped. It is approximately the size of your fist covered with your other hand, with a mass of approximately 300 grams when empty. The vast majority of this mass consists of cardiac muscle tissue, but layers of connective tissue are also found lining both the internal and external surfaces of the heart. It is anterior to the bodies of thoracic vertebrae, posterior to the body of the sternum, and flanked laterally on both sides by the lungs. Its inferior, more pointed apex extends slightly toward the left and lies approximately at the level of the fifth intercostal space. Its superior, broader base lies approximately at the level of the second rib, and it is here that all of the large arteries and veins leading into and out of the heart, collectively called the "great vessels", are attached.
The heart rotates during embryonic development so that in the adult the **right atrium** and **right ventricle** face anteriorly while most of its posterior surface is formed by the **left atrium** and **left ventricle**. The heart also rotated at a different angle so that the right ventricle also forms most of the inferior surface of the heart, which rests against the diaphragm. The entire heart is surrounded by a double-layered serous membrane called the **pericardium**, with the **pericardial cavity** between these two layers. Lubricant within this pericardial cavity allows the heart to rotate with very little or no friction which would damage it.

**Exercise 1:** On yourself or your lab partner, identify the position of the heart within the thorax. It lies in the center of the chest, from the second rib to the space between the fifth and sixth ribs. See if you can feel your heartbeat at various points within this area. The torso models and Figure 19.2 of your Saladin text can be used as a reference. On a human skeleton, identify where the heart would lie. When you go home tonight, take off your shirt (or the shirt of another person) and use a felt-tip marker to draw the location and shape of the heart directly on the chest.

**Exercise 2:** Using the text and Figures 19.2 and 19.3 of your Saladin text, be sure you understand the relationship of the **pericardium** and **pericardial cavity** to the heart itself. Be sure you can identify the **visceral layer** and the **parietal layer** of the pericardium, and be sure you understand how the pericardial cavity is a completely enclosed sac between them.

**Questions for discussion:**

*Which layer of the pericardium lies next to the heart and moves with it as the heart contracts and relaxes?*

*Which layer of the pericardium lies superficial to the pericardial cavity and does not move as the heart contracts and relaxes?*

**Exercise 3:** Examine models of the human heart, using the text and Figure 19.5 of your Saladin textbook as a reference. Identify the following structures on the exterior surface of the heart: We have different types of heart model which show structures in different ways: be sure you examine all of the different models

- **Base**
- **Apex**
- **Right and left atria**
- **Right and left ventricles**
- **Right and left atrioventricular sulci (grooves)**
- **Anterior and posterior interventricular sulci (grooves)**
The following "great vessels" carry blood into and out of various chambers of the heart. On the models, identify where they connect to the heart and which chamber they carry blood into or out of:

- Ascending aorta
- Pulmonary trunk
- Superior vena cava
- Inferior vena cava
- Pulmonary veins

**Questions for discussion:**

*Blood enters the ascending aorta from which chamber of the heart? To which parts of the body is this blood going?*

*Blood enters the pulmonary trunk (also called the pulmonary artery) from which chamber of the heart? To which parts of the body is this blood going?*

*Blood in the superior vena cava enters which chamber of the heart? From which parts of the body is this blood coming?*

*Blood in the inferior vena cava enters which chamber of the heart? From which parts of the body is this blood coming?*

*Blood in the pulmonary veins enters which chamber of the heart? From which parts of the body is this blood coming?*

**Exercise 4:** Be sure you understand the three-dimensional positioning of the heart within the thoracic cavity. Note specifically on the model that:

- The anterior surface of the heart is formed primarily by the right atrium and right ventricle
- The posterior surface of the heart is formed primarily by the left atrium and left ventricle
- The right lateral border of the heart is formed by the right atrium
- The left lateral border of the heart is formed by the left ventricle
- The inferior surface of the heart (which rest on the diaphragm) is formed by the right ventricle
Questions for discussion:

On which surface of the heart (superior, inferior, anterior, posterior, right lateral, left lateral) would you see most of the left atrioventricular sulcus?

On which surface of the heart would you see most of the right atrioventricular sulcus?

On which surface of the heart would you see the anterior interventricular sulcus?

On which surface of the heart would you see the posterior interventricular sulcus?

The apex of the heart is part of which chamber of the heart?

If you opened your lab partner’s chest by splitting the sternum into right and left halves but left the heart in place, which chamber(s) of the heart would you be able to see? Which chambers would you NOT be able to see?

The medial surface of the left lung lies next to which chamber of the heart?

The medial surface of the right lung lies next to which chamber of the heart?

Exercise 5: On the heart models (again, be sure you examine all of the different types of models), open up the chambers and identify:

- Right atrium
- Left atrium
- Right ventricle
- Left ventricle
- Interventricular septum
- Interatrial septum (this should be just a thin membrane, but is quite thick on some of the models)

Notice that the walls of the different chambers vary significantly in thickness. The walls of the right atrium and left atrium are relatively thin; the wall of the right ventricle is thicker, and wall of the left ventricle is very thick. The interventricular septum functions more to propel blood out of the left ventricle than to propel blood out of the right ventricle, so it is also very thick.
Exercise 6: Identify each of the following four valves within the heart. Although your textbook uses "semilunar", "bicuspid", and "tricuspid", the names listed below are the ones by which you should show them. Using Figures 19.7 and 19.8 in your Saladin text as references, be sure you understand where each of these valves is located. Be sure you understand where the blood is coming from and where it is going to as it passes through each valve:

- Right atrioventricular valve
- Left atrioventricular valve
- Pulmonary valve
- Aortic valve

In the right atrium, identify the openings of the **superior vena cava**, **inferior vena cava**, and **coronary sinus**

In the left atrium, identify the openings of the **pulmonary veins**.

In both ventricles, identify the **papillary muscles**, which are attached to the atrioventricular valves by **chordae tendineae**. The ridges on the wall of the right ventricle are called **trabeculae carneae**.

Confirm that the right atrioventricular sulcus and the left atrioventricular sulcus on the surface of the heart lie at the edges of the divisions between atria and ventricles on the inside of the heart. Confirm that the anterior interventricular sulcus and the posterior interventricular sulcus on the surface of the heart lie at the edges of the divisions between the right and left ventricles on the inside of the heart, that is, they lie over the interventricular septum.

**Questions for discussion:**

- Why is the wall of the left ventricle so much thicker than the wall of the right ventricle?
- Do all four valves have chordae tendinae attaching them to papillary muscles?
- What is the function of chordae tendinae and papillary muscles?
- What would happen if the right atrioventricular valve became stiff and could not open completely?
- What would happen if the left atrioventricular valve became stiff and could not open completely?
- What would happen if the pulmonary valve became stiff and could not open completely?
- What would happen if the aortic valve became stiff and could not open completely?
- What would happen if the chordae tendinae attached to the left atrioventricular valve were all cut?
**Exercise 7:** Be sure you can trace the flow of blood through the heart and lungs, beginning with the superior and inferior vena cava and ending with the aorta, including all chambers, valves, and vessels through which the blood flows. Diagram that flow in the space below:

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**Coronary Circulation of the Heart:**

Even though more than five liters of blood are pumped through the chambers of the heart every minute, or more than three hundred liters every hour, the tissues of the heart itself get very little nutrition from this blood. Instead, the heart contains millions of capillaries to deliver blood directly to its cells (just like all other organs), and these capillaries are supplied by their own arteries and veins. These are called the **coronary arteries** and **cardiac veins**.

Like those in all organs and tissues, the cells of the heart require blood which is high in oxygen, low in carbon dioxide, and delivered to the capillaries under relatively high pressure. The blood leaving these capillaries, just like the capillaries in all other tissues and organs, will be low in oxygen, high in carbon dioxide and other cellular waste products, and under low pressure. To accomplish this, the coronary arteries begin from the aorta just distal to the aortic valve while the cardiac veins return the "used" blood to the right atrium of the heart. The larger, named arteries and veins are located on the surface of the heart and can thus be relatively easily identified.

**Exercise 8:** Examine the anterior surface of the heart models; Identify the **Left coronary artery** and **Right coronary artery**. Observe how the **right coronary artery** lies in the **right atrioventricular sulcus**. As it gets near the inferior surface of the heart it gives off the **mariginal coronary artery**, then continues around onto the posterior surface of the heart. At the **posterior interventricular sulcus**, it forms the **posterior interventricular artery** which extends toward the apex of the heart.

Return to the anterior surface of the model and identify the left coronary artery. This will be very short since it branches into two equal divisions high on the base of the heart. The **anterior interventricular artery**, also called the **left anterior descending artery**, runs along the **anterior interventricular sulcus** toward the apex of the heart. The other division is the **circumflex artery**, which follows the **left atrioventricular sulcus** onto the posterior surface of the heart. The circumflex artery gives off a number of smaller branches, but you do not need to know these.
Although it may not be obvious on the models, you should realize that both the right and left coronary arteries begin as branches of the ascending aorta, just above the aortic valve. Notice also that small connections exist between the circumflex and right coronary arteries on the posterior surface of the heart, and between the anterior interventricular and posterior interventricular coronary arteries at the apex of the heart. Thus, a limited amount of blood can flow between branches of the two major vessels.

**Questions for discussion:**

Which parts of the heart receive their blood from the right coronary artery?

Which parts of the heart receive their blood from the circumflex coronary artery?

Which parts of the heart receive their blood from the anterior interventricular coronary artery?

Which parts of the heart receive their blood from the posterior interventricular coronary artery?

What would happen if the left coronary artery were blocked just distal to its origin from the aorta?

What would happen if the right coronary artery were blocked just distal to its origin from the aorta?

What would happen if the circumflex coronary artery were blocked just distal to its origin from the left coronary artery?

**Exercise 9:** Examine the posterior surface of the heart models and identify the coronary sinus lying in the left atroventricular sulcus. Identify the three major veins which deliver blood into it:

The small cardiac vein lies alongside the marginal coronary artery on the anterior surface of the heart, then turns and follows the right coronary artery onto the posterior surface. Trace the direction of blood flow through this vessel and compare it to the direction in which blood is flowing through the arteries.

The middle cardiac vein lies alongside the posterior interventricular coronary artery in the posterior interventricular sulcus. Trace the direction of blood flow through this vessel and compare it to the direction in which blood is flowing through the artery.

The great cardiac vein lies alongside the anterior interventricular coronary artery in the anterior interventricular sulcus, then turns and follows the circumflex coronary artery onto the posterior surface. Trace the direction of blood flow through this vessel and compare it to the direction in which blood is flowing through the arteries.

**Reminder:** We have three different types of heart models in the lab. Be sure you can identify the structures in Exercises 3 through 9 on all three types of model.
Histology of the Heart:

The wall of each chamber of the heart is formed by three layers of tissue called endocardium, myocardium, and epicardium. The innermost endocardium is the thinnest, composed of a simple squamous epithelium. It lines the inside of each chamber and is therefore the only tissue with which the blood comes into contact as it is pumped through the heart.

The middle layer of tissue, the myocardium, is the thickest. It is composed of cardiac muscle tissue, which contracts to produce the force by which blood is pumped around the entire body. Unlike the endocardium, the myocardium is not the same thickness in all parts of the heart but instead varies according to the amount of force which must be produced by each chamber. It is thin in the right atrium and left atrium, which can easily propel blood into the ventricles. The myocardium is moderately thick in the right ventricle, which needs to contract with more force to pump blood out the pulmonary trunk to the lungs. Contraction of the left ventricle, in contrast, must produce a very large force to propel blood out the aorta against the resistance of the peripheral blood vessels, so the myocardium is very thick there.

The epicardium lines the external surface of the heart. It consists of a loose, areolar connective tissue (next to the myocardium) covered by a simple squamous epithelium which is actually the tightly adherent visceral layer of the pericardium. In some regions of the heart, there is a lot of fat in the connective tissue, while in other regions the epicardium is so thin that the myocardium can easily be seen through it.

Exercise 10: Identify these three layers on the models of the heart (remember: one or more may be microscopically thin and this may not show clearly on the model). Notice that

The endocardium covers the entire inner surface of all of the chambers

The myocardium is thinnest in the walls of the two atria, thicker in the wall of the right ventricle, and thickest in the wall of the left ventricle. It is also very thick in the interventricular septum, which functions primarily as part of the left ventricle.

The epicardium covers the entire external surface of the heart. Some of the models show fat in certain regions of this layer.

Questions for discussion:

Suppose your lab partner stuck a long, sharp pin through your chest wall into your right ventricle. In what order would the pin pierce each of these three layers?

What effect would it have on the body if the myocardium of the left ventricle were only as thick as it is in the right ventricle?

What effect would it have on the body if the myocardium of the right ventricle grew until it was as thick as it is in the left ventricle?
Exercise 11: Under low power (40x or 100x), microscopically examine slide #1, cardiac muscle. Notice that the myocytes are not oriented in the same direction, but gradually change orientation as you move through the layer of muscle. Almost all of these slides show only the cardiac muscle from the myocardium, but don’t be surprised if you see some of the epicardium (loose connective tissue) or some of the endocardium (simple squamous epithelium) along an edge.

Select a region of the slide where the cardiac myocytes were cut in longitudinal section, and switch to 400x magnification. Identify nuclei within the myocytes and the intercalated disks which separate them end-to-end. You may be able to vaguely see the striated banding pattern of cardiac muscle, but this is difficult so don’t be concerned if you can not do this easily. Compare what you see under the microscope with Figure 19.11 and other pictures of cardiac muscle in your textbook and be sure you understand the three-dimensional structure of cardiac muscle.

Preserved Specimens

Exercise 12: Wearing gloves, examine a coronally sectioned human or sheep heart. Notice that the surface may be covered with adipose tissue which obscures the coronary arteries and cardiac veins.

Question for discussion:

In which layer of the heart (endocardium, myocardium, or epicardium) would this adipose tissue be located? Remember that adipose tissue is a form of connective tissue.

On the outside of the preserved heart identify the:

- Base
- Right atrium
- Right ventricle
- Anterior interventricular sulcus
- Aorta
- Apex
- Left atrium
- Left ventricle
- Posterior interventricular sulcus
- Pulmonary trunk

Open up the preserved heart and identify the:

- Right atrium
- Right ventricle
- Interventricular septum
- Papillary muscles in right and left ventricles
- Right atrioventricular valve
- Pulmonary valve
- Left atrium
- Left ventricle
- Interatrial septum
- Left atrioventricular valve
- Aortic valve
- (may not be easily visible)
- (may not be easily visible)
Do not attempt to identify any of the coronary arteries or cardiac veins on the preserved hearts. Although they are visible, they are difficult to identify without blood in them. Similarly, the pulmonary veins, inferior vena cava, and superior vena cava are often damaged during removal of the heart and will be difficult to identify even if they are still there.

Please be careful not to damage or further dissect the human specimens.

**Exercise 13:** With gloves, examine the heart of the cadaver. It has been dissected in such a way that her heart has been exposed by incision of the pericardium, but otherwise has been left in place and not further dissected. Confirm that it is positioned as described on page 1:

- Anterior to the bodies of vertebrae,
- Posterior to the sternum,
- Surrounded by the lungs.

Most of the anterior surface of the heart is formed by the right atrium and right ventricle,

Most of its posterior surface is formed by the left atrium and left ventricle,

The inferior surface of the heart rests against the diaphragm.

Identify the parietal layer of the pericardium, and realize that the visceral layer is firmly attached to the heart to form part of the epicardium

Notice the position of the heart relative to the lungs. If you lift up the apex of the heart you should be able to partially feel the bodies of the vertebra posterior to it.