INTRODUCTION:

The human circulatory system is a closed transport system. The right and left ventricles of the heart force blood into large elastic arteries, from which it is distributed to medium-sized muscular arteries, then arterioles to reach the capillaries throughout the body. From these, blood gathers into venules from which it is carried into veins of increasingly larger size until it returns to the right atrium (systemic circuit) or left atrium (pulmonary circuit) of the heart, then back to the ventricles for another circuit.

Arteries and veins are transport organs whose role is to deliver blood from one place to another. It would be a mistake, however, to assume that they are just passive “pipelines”; they are constantly, on a second-by-second basis, readjusting their size to regulate both the rate and the pressure at which blood flows through them. For example: constriction (narrowing) of the femoral artery in the front of the thigh will have at least three effects: it will reduce the amount of blood delivered to capillaries throughout the lower limb, it will increase the resistance or “back-pressure” against which the heart has to push, and it will decrease the blood pressure throughout the limb and thus the perfusion of blood through capillaries. Dilation (widening) of this artery will have the opposite effects: more blood will flow into the limb, the heart will not have to push as hard to get it there, and blood will flow into capillaries with more pressure. Changes in the size of the femoral vein, obviously, will have similar effects on blood flowing OUT of the limb.

Capillaries, on the other hand, are where the exchange of material occurs between the blood and the extracellular fluid (see your notes from chapters 3 and 5 if you need to review what this is) within other tissues. For example, oxygen diffuses into the blood through capillaries of the lungs, then diffuses out again when the blood reaches capillaries in other organs where it will be used. The movement of carbon dioxide is the reverse of that: it diffuses into the capillary blood from organs which are producing it as a metabolic waste product, then diffuses out of the blood from capillaries in the lungs when the blood reaches there. Nutrients enter the blood in capillaries of the intestine, then leave the blood when it reaches capillaries in organs which need them. The hormone insulin diffuses into the blood in capillaries in the pancreas, then diffuses out again from capillaries in other organs. Leukocytes enter capillaries in the bone marrow by diapedesis, then leave again from capillaries in other tissues of the body. Water is constantly being exchanged in and out of capillaries. All of this, and much more, is possible only because of the extremely thin walls of capillaries which allow things to pass easily through them.

In this exercise, we will examine the microscopic structure of vessels; identify major arteries and veins of both pulmonary and systemic circuits; and examine vessels on both human cadavers and the cat.


**Structure of Blood Vessels**

Except for capillaries, which have only a tunica intima, the walls of blood vessels are composed of three layers, or tunics: an innermost tunica intima, covered by a tunica media, with a tunica adventitia or tunica externa on the outside of the vessel. The entire circulatory system, including the heart as well as all vessels, is lined by a simple squamous epithelium called the endothelium. You should understand this from your reading assignment for this lab, but let's review:

**Exercise 1:**
A. Describe within your lab group the histologic structure of the tunica intima of a medium size artery and a medium size vein (that is, what specific types of tissue are arranged in what specific pattern)

B. Describe among your lab group the histologic structure of the tunica media of a medium size artery and of a medium size vein.

C. Describe among your lab group the histologic structure of the tunica adventitia of a medium size artery and of a medium size vein.

**Exercise 2:** In the space below, draw (freehand! Do not copy!) the typical structures for a medium size artery and vein. Include, and draw clearly: endothelium, basement membrane, connective tissue, smooth muscle tissue, and vasa vasorum.

Artery

Vein

**Exercise 3:** Verbally explain to other members of your lab group the differences between a continuous capillary, a fenestrated capillary, and a sinusoidal capillary (sinusoid). If other members of your lab group are not explaining these correctly, be sure to help them understand these different types of capillary structure.

**Exercise 4:** Verbally explain to other members of your lab group why an artery will typically have a thicker wall than a vein of the same size. If other members of your lab group are not explaining this correctly, be sure to help them understand it.
**Exercise 5:** Examine Slide #3 from the slide set at your table. Locate the artery and the vein: these would be classified as a medium or muscular artery and a medium vein. The artery has a smaller lumen and a thicker wall, and the vein may be partially collapsed as shown in Figure 20.1 of your Saladin text. Either or both of these vessels may contain some blood cells.

Each vessel has the three tunics discussed above. Identify each tunic in both vessels. Notice that the tunica media of the artery has more smooth muscle tissue, while this layer in the vein is primarily composed of connective tissue. The loose areolar connective tissue of the tunica adventitia should be evident around both vessels, and will blend into a single layer where the vessels lie near each other.

**Pathways of Blood Flow**

In the simplest (and most common) pattern, blood leaves a ventricle, flows through arteries to reach capillaries in some organ such as your brain or your biceps brachii muscle, then flows back to the heart through veins. However, this doesn't meet the needs of all organs of the body, nor does it always meet the homeostatic needs of the body as a whole, so there are a number of variations on this basic pattern.

**Exercise 6:** Explain to other members of your lab group the differences between the "systemic circuit" and the "pulmonary circuit" of blood vessels. If other members of your lab group are not explaining this correctly, be sure to help them understand. You will only hurt them, and eventually yourself, if you let them give a poor explanation. Don't move on until every single person in the lab group clearly understands these circuits.

**Exercise 7:** In the space below, draw the basic pattern of a portal system in some way that makes it clear you did not just copy the figure from your textbook. Be sure to include the heart with both an artery and a vein connecting to it.

Compare your drawing with those of other members of your lab group. Did you get it right? Did they? Do not move on in this exercise until every member of your lab group understands portal systems.
**Exercise 8:** Identify at least two places in the human body which have portal systems. Select one of these, and redraw a figure similar to one you made in Exercise 7 showing the specific organs or tissues in which the two capillary beds are found (you might find Figures 17.4 and 20.33 in your Saladin textbook helpful).

**Exercise 9:** In the space below, draw the basic pattern of circulation in which the capillaries can be bypassed by an arteriovenous anastomosis (often called an arteriovenous shunt). Be sure to include the heart with both an artery and a vein connecting to it. Again, it should be evident that you did not just copy the figure from your textbook.

Compare your drawing with those of other members of your lab group. Did you get it right? Did they? Again, do not move on until every member of your lab group understands this.

**Exercise 10:** One of the most extensive systems with arteriovenous anastomoses is found in the skin - blood can either be sent through the capillaries, or it can bypass them and flow directly from arteries to veins. Verbally explain to other members of your lab group what homeostatic advantage this provides your body (that is: why would it be a good idea for blood to flow though capillaries of the skin under certain conditions, but not under other conditions?)

**Exercise 11:** Verbally explain to other members of your lab group (you don’t need to draw them) what arterial anastomoses and venous anastomoses are, and what advantage they give to the body. If other members of your lab group are not explaining these correctly, be sure to help them understand.

Identify at least one place in the body where you would find arterial anastomoses, and one place where you would find venous anastomoses. A careful examination of some of the figures in the latter half of Chapter 20 of your Saladin text will help you do this. This may take some time.
**Identifying Major Vessels of the Human Body**

**Exercise 12:** Examine one of the human torso models. Remove the heart and lungs. Identify the pulmonary trunk and pulmonary arteries - these are colored blue to show that they are carrying blood which is low in oxygen and high in carbon dioxide. Replace the heart and notice how short the pulmonary arteries are. Find their major branches in the lungs.

Next, locate the aorta as it leave the heart. A small part of the ascending aorta is visible. Which chamber of the heart is it actually leaving?

Remove the heart from the torso model and follow the aortic arch on the model. Note that it arches posteriorly and slightly to the left. Part of the descending thoracic aorta is visible. Note that it passes behind the trachea. Although not visible on the torso models, you should understand from the diagrams in your Saladin text that intercostal arteries arise from the descending thoracic aorta and extend around the body wall, lying inferior to the ribs.

Three large arteries branch off from the aortic arch, although they are somewhat obscured by the brachiocephalic vein. These three branches supply blood to both upper limbs and both sides of the head and neck. From right to left (remember, the terms "right" and "left" ALWAYS refer to the person or model being viewed, never the right or left of the person doing the viewing), these branches are the brachiocephalic artery, the left common carotid artery, and the left subclavian artery. Compare these to Figures 20.21 and 20.23 in your Saladin text.

Trace the brachiocephalic artery upward until it splits into the right common carotid artery and the right subclavian artery. Follow both common carotid arteries up the neck. Look carefully and find the path of the left subclavian artery out toward the shoulder as shown in Figures 20.27 and 20.34 in Saladin.

**Questions for discussion:**

Which part of the body would lose its blood supply if the brachiocephalic artery were completely blocked?

Which part of the body would lose its blood supply if the right subclavian artery were completely blocked?

Which part of the body would lose its blood supply if the left subclavian artery were completely blocked?

Which part of the body would lose its blood supply if the right common carotid artery were completely blocked?

Which part of the body would lose its blood supply if the left common carotid artery were completely blocked?
Exercise 13: Remove the abdominal viscera from the model. Inferior to the diaphragm, find the descending abdominal aorta which lies posterior to the abdominal cavity slightly to the left of the midline. Note three unpaired stubs of major arteries that project anteriorly from it - these supply blood to digestive organs in the abdomen and to the spleen. The upper one, nearest the diaphragm, is the celiac trunk. Near the renal artery, locate the beginning of the superior mesenteric artery. The lowest unpaired vessel is the inferior mesenteric artery. Figures 20.30 and 20.31 in your Saladin text will help.

Questions for discussion:

Which organs would lose their blood supply if the celiac trunk were completely blocked?

Which organs would lose their blood supply if the superior mesenteric artery were completely blocked?

Which organs would lose their blood supply if the inferior mesenteric artery were completely blocked?

Notice also that there are a number of paired arteries which extend to each side from abdominal aorta. You should have no trouble finding the renal arteries to the kidneys and the gonadal arteries which deliver blood to the ovaries or testicles. You should also be able to locate several lumbar arteries in this region which supply blood to the wall of the abdomen.

Finally, locate the termination of the aorta as it splits to form the right and left common iliac arteries. On the right side, you can see this split into two branches. The internal iliac artery, which carries blood to organs of the pelvis, can be seen along the pelvic wall near the rectum. The other branch of the common iliac artery is the external iliac artery. As it passes from the abdomen into the thigh, this will become the femoral artery.

Questions for discussion:

Which organ(s) or regions of the body would lose their blood supply if one of the renal arteries were to be completely blocked?

Which organ(s) or regions of the body would lose their blood supply if one of the gonadal arteries were to be completely blocked?

Which organ(s) or regions of the body would lose their blood supply if one of the common iliac arteries were to be completely blocked?

Which organ(s) or regions of the body would lose their blood supply if one of the internal iliac arteries were to be completely blocked?

Which organ(s) or regions of the body would lose their blood supply if one of the external iliac arteries were to be completely blocked?
Exercise 14: In the thorax of the model with the heart and lungs removed, identify the pulmonary veins. These are colored red to show that they are carrying blood which is high in oxygen and low in carbon dioxide. Find their major branches within the lungs. On the heart, inferior to the pulmonary arteries, identify where these veins enter the left atrium.

Find the superior vena cava in the thorax of the model. Trace it superiorly until it splits into the right and left brachiocephalic veins. Follow each of these until it divides into an internal jugular vein and a subclavian vein.

Questions for discussion:

Each brachiocephalic vein is carrying blood toward the heart from capillary beds in which region(s) of the body?

Each internal jugular vein is carrying blood toward the heart from capillary beds in which region(s) of the body?

Each subclavian vein is carrying blood toward the heart from capillary beds in which region(s) of the body?

What would be the result if a large blood clot suddenly blocked one brachiocephalic vein?

Where in the thorax (point on your own body) do the right and left brachiocephalic veins join together to join the superior vena cava?

In the abdomen of the model, identify the inferior vena cava and follow this superiorly as it passes behind the liver and through the diaphragm to reach the heart. Notice that it lies on the posterior body wall, just like the descending aorta except on the right side. At its inferior end, it divides into the two common iliac veins which lie alongside the common iliac arteries. By analogy with the arteries of the same name, identify the following veins: renal veins, gonadal veins, lumbar veins, internal iliac veins, external iliac veins and femoral veins. The femoral vein is about as long as the femoral artery in the model. It goes deep, leaving the large greater saphenous vein and other branches on the surface. Of the several branches shown, the greater saphenous vein is the larger medial branch.

It is possible to find the hepatic portal vein (and some of its branches) on this model. Look on the detachable piece containing the pancreas. On the posterior surface of this piece, the hepatic portal vein is shown in purple. Its continuation is also depicted on the liver near the common bile duct.
Questions for discussion:

Blockage of one of the common iliac veins would interfere with the return of blood to the heart from which region(s) of the body?

How about blockage of one of the external iliac veins?

How about blockage of one of the internal iliac veins?

The hepatic portal vein is carrying blood toward the heart from capillary beds in which part(s) of the body?

Exercise 15: On one of the large charts of human blood vessels, identify each of the following:

Pulmonary trunk and pulmonary arteries;

- Descending aorta
- Brachiocephalic artery
- Left and right common carotid arteries
- Left and right subclavian arteries
- Renal arteries
- Right and left common iliac arteries
- Internal and external iliac arteries
- Right and left axillary arteries
- Right and left brachial arteries
- Right and left radial arteries
- Right and left ulnar arteries
- Right and left femoral arteries
- Right and left popliteal arteries
- Right and left anterior tibial arteries
- Right and left posterior tibial arteries

- Superior vena cava and inferior vena cava
- Right and left brachiocephalic veins
- Internal jugular veins
- Subclavian veins
- Renal veins
- Right and left common iliac veins
- Internal and external iliac veins
- Axillary veins
- Brachial veins
- Radial veins
- Ulnar veins
- Femoral veins
- Popliteal veins
- Anterior tibial veins
- Posterior tibial veins
**Vessels of the Cadavers**

**Exercise 16:** With the female cadaver supine (face up), identify the pulmonary trunk and ascending aorta as they emerge from the heart. Identify the brachiocephalic, left common carotid, and left subclavian arteries as they branch from the arch of the aorta. Identify the left and right brachiocephalic veins and follow these to where they combine to form the superior vena cava leading to the right atrium of the heart.

In the left axilla, identify the axillary artery and vein. In the arm, identify the brachial artery and follow this to its division in the forearm to the radial artery and ulnar artery (the brachial, radial, and ulnar veins are no longer present).

Remove the intestines from the abdomen of the female cadaver. Identify the descending aorta and inferior vena cava. Identify the renal arteries.

**Vessels of the Cat**

Finally, we will begin to dissect the thorax and abdomen of the cat to identify major arteries and veins of the thorax and abdomen. We will not attempt to expose vessels of the head, neck, or limbs. Please note that almost all of this dissection will be done by pushing tissues out of the way with a blunt probe - except for opening up the thoracic, pericardial, and abdominal cavities, no cutting will need to be done. We will use the same cats to examine structures of other systems.

Take your cat, in its bag, to the sink and cut off one end of the bag. Do not otherwise damage the bag - you will need to use it to store the cat between labs. Dump the cat into the sink, letting the fluid drain away, rinse it briefly with water, and let it drain. Take it to your table on a dissecting tray. You should wear gloves whenever handling the cat.

**Exercise 17:** With the cat supine (face up), use a large scissors to make a longitudinal incision through the body wall of the abdomen, starting just superior to the midline of the pubic bone and continuing in the midline toward the head as shown. When you reach the thorax, include the sternum or ribs in your incision and extend it to the base of the neck. Make two lateral cuts through the body wall on either side, one near the pubic bone and one just posterior to the diaphragm as shown. Spread the flaps of skin and muscle to expose the organs of the abdominal and thoracic organs.
In the thoracic cavity, identify the heart (still covered by the fibrous parietal pericardium) and lungs. You may need to use a blunt probe to push away some connective tissue, but do as little damage as possible and don’t cut anything at this stage. In the abdomen, the intestine may be covered with a layer of fat - remove this to expose the intestine. Identify where the small intestine meets the large intestine, then push them to either side and identify the liver, stomach, and spleen.

Lift up a piece of the pericardium with a pair of forceps, then use a small scissors to make a nick in it. Carefully slit the pericardium and then cut it away, and locate the base and apex of the heart. Identify the aorta as it leaves the left ventricle, but this stays close to the heart as it curves posteriorly so you may have difficulty following it very far. Identify the superior vena cava as it enters the right atrium, and follow it superiorly into the thoracic cavity. We will identify the inferior vena cava later.

Use your probe to clear the arch of the aorta. Identify two major vessels which branch from it and extend anteriorly (toward the head) - the brachiocephalic artery and the left subclavian artery. Follow the brachiocephalic artery until it branches into the right subclavian artery, right common carotid artery, and left common carotid artery. Note that this is a different pattern than in the human: the left common carotid artery arises from the brachiocephalic artery in the cat but directly from the arch of the aorta in the human. In both species, the left subclavian artery is a direct branch of the aorta.

Return to the superior vena cava. Identify where it divides to form the right and left brachiocephalic veins. Follow each of these until it branches to the subclavian vein and internal jugular vein on that side, but don’t attempt to follow these for more than about a centimeter.

In the abdomen, find the descending aorta and inferior vena cava as they pass through the diaphragm. Identify the renal arteries and renal veins. Follow these posteriorly (toward the tail) until you can identify the common iliac arteries and common iliac veins.

Use one of the tags provided to label your cat in any way which will allow you to recognize it, then return it to its bag and use a rubber band to seal the open end. Leave the specimen in the box as instructed. This will be your cat for the remainder of the course.
**Vessels of the Living Human**

**Exercise 18:** This exercise will require you to remove clothing, so you should do it at home. On yourself (using a mirror) or another person, use a water-soluble pen or marker to draw the position of the heart on the chest. From that, draw the **aorta** and **pulmonary arteries**. On one upper limb (opposite the one you use to write), add the positions of the subclavian, axillary, brachial, ulnar, and radial arteries. Starting at the inguinal ligament (see Figure A.12) draw on one lower limb the positions of the femoral, popliteal, anterior tibial, and posterior tibial arteries. Use the diagrams in your textbook to be sure you are drawing them in the correct positions on each limb - don't guess.

On the back of another person (if available) draw the position of the descending aorta in the thoracic and lumbar regions. From this, draw the positions of the intercostal arteries, renal arteries and ovarian/testicular arteries. At the level of lumbar vertebra #4, draw the division of the aorta to form the right and left common iliac arteries.

Show off your artwork to your roommate or mother if you wish, then go take a shower to wash off the pen.