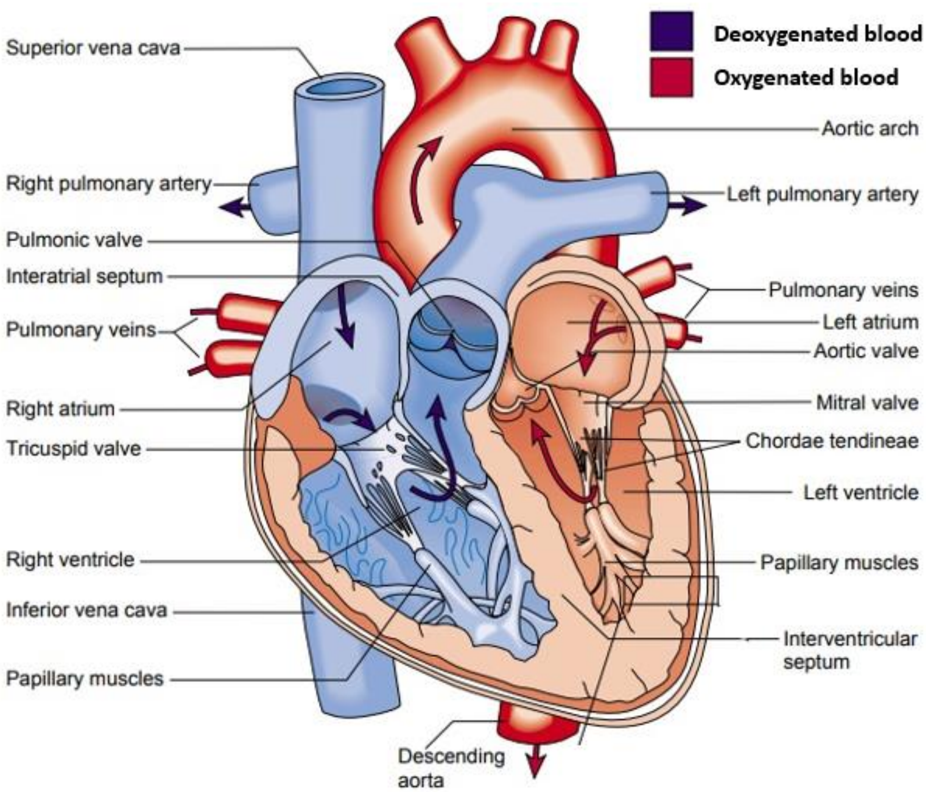
Anatomy Lecture Notes Section 4: The Cardiovascular System

The cardiovascular system consists of the **heart** (cardio) and the **blood vessels** (vascular). This is a closed system, meaning that the blood flowing through the heart and vasculature always remains within those structures as it circulates around the entire body. Stable blood pressure is maintained by having a consistent total volume of blood (usually about 5.0 L) within this system at all times. As we will see, exchange between the cardiovascular system of the systemic (body) and the pulmonary (lung) circuits occurs at the capillary level of the vasculature. As we will see, blood is the fluid connective tissue that is contained within the cardiovascular system. The details regarding the components of blood will follow.

The Heart

The heart is the central orchestrator of blood flow in the body. As an organ (seen image below), the heart is composed of **four chambers**: It has two upper chambers called the right and left **atria** (singular = atrium); and two lower larger chambers called the right and left **ventricles**.

The word **atrium** means 'entrance hall', as it's much like a receiving room. It is useful to know that it is the atria that always *receives* the blood that is returning to the heart, whether from the body or the lungs. The **right atrium** receives deoxygenated blood returning from the body, and the **left atrium** receives oxygenated blood returning from the lungs. The right atrium is connected to the **right ventricle** below it, and the left atrium is connected to the **left ventricle** below that. In between them are the **atrioventricular** (AV) **valves** that ensure unidirectional (one way) flow of blood in the heart.



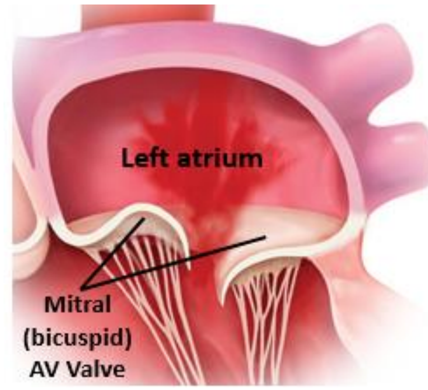
Circulation of Blood in the Heart

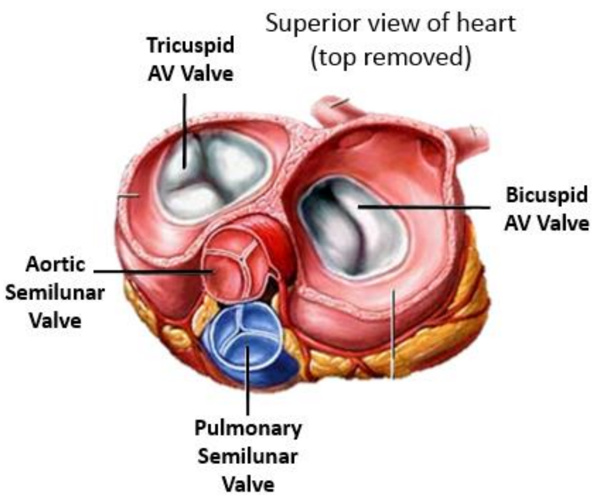
As seen in the figure above, there are four chambers in the heart, 2 superior atria, and 2 large inferior ventricles. When looking at most artistic renderings of the heart, it is color coded to account for the differences in the oxygen levels of the blood in specific regions of the heart and body.

Chambers and vessels carrying **deoxygenated blood** are usually displayed in **blue**, while those carrying **oxygenated blood** are displayed as **red**. As will be discussed in the blood section, the molecule **hemoglobin** (Hb) which is found inside red blood cells, is a pigmented protein molecule that changes color. It is bright red when oxygen (O_2) is bound and a deeper sort of purple (blue/red) when is it lacking O_2.

Heart Valves

There are 4 heart valves and their role is to prevent retrograde (back) flow of blood in the heart, ensuring that the flow is always in one direction - called **unidirectional** flow. There are 2 atrioventricular (AV) valves that are situated in between the atria and the ventricles. The valve between the right atrium and right ventricle is the **right tricuspid AV valve**, because it has 3 cusps. The valve between the left atrium and left ventricle is the **left bicuspid AV valve**, because it has 2 cusps. This bicuspid AV valve is also commonly referred to as the *mitral valve*, due to its resemblance to a mitre, a hat worn by bishops.





The other two heart valves are called the **semilunar valves**, as they resemble half-moon shapes. The **pulmonary semilunar valve** sits in between the right ventricle and the pulmonary trunk (which is a large artery). The **aortic semilunar valve** sits in between the left ventricle and the aorta (which is the largest artery in the body). These valves open when the blood is being ejected from the ventricles, and close to prevent backflow from the arteries into the ventricles.

The Circuits of the Body

There are actually three circulations or circuits in the body, the two major circulations - the **Pulmonary** and **Systemic** circuits - plus the **Coronary** circulation, which is the circulation of the heart itself. The term circuit comes from the Latin circuitus, from circuire meaning 'go round', like a circle. All three of these circuits go away and come back to the heart.

The Pulmonary Circuit

The pulmonary circulation goes from the heart, to the lungs and returns to the heart. Succinctly, blood in this circuit goes from the right ventricle to the left atrium (RV to LA). This circuit starts in the **right ventricle**, where the deoxygenated blood leaves the right ventricle of the heart and travels through the pulmonary trunk (a large artery), and then branches into the L and R pulmonary arteries (seen as blue vessels in images) to deliver the deoxygenated blood to the L and R lungs respectively. In the lungs, the blood gathers oxygen (O_2) wherein the blood now becomes oxygenated. It also drops off carbon dioxide (CO_2) at the lungs. This blood then returns from both of the lungs to the **left atrium** of the heart by way of the L and R pulmonary veins (seen as red vessels in images). That is the end of the pulmonary circuit and where the systemic circuit picks up.

The Systemic Circuit

The other main circulation in the body is called the systemic circuit, where blood travels from the **left ventricle** of the heart and goes to the body and returns to the **right atrium**. Starting at the **left ventricle**, the fully oxygenated blood leaves the left ventricle through the aortic semilunar valve into the aorta (largest artery of body). Many arteries branch off the aorta as it travels around the entire body, delivering O_2 and nutrients. As the systemic vessels return from the body (via veins), the blood they carry is depleted of O_2 and has collected CO_2 from the tissues. This deoxygenated blood is returned to the **right atrium** of the heart by way of 3 different vessels to the right atrium: **1)** the superior vena cava (from above the heart); **2)** the inferior vena cava (from below the heart); and **3)** from the coronary sinus (from the heart's own circulation). The right atrium is the end of the systemic circuit. This blood then goes directly into the right ventricle below it, which is the start of the pulmonary circuit, and the cycle repeats.

Important note about arteries and veins: They are named for where they are taking blood, not the level of O_2 in the blood.

- **Arteries** are vascular tubes that <u>take blood away from the heart</u>.
- **Veins** are vessels that <u>return blood to the heart</u>.

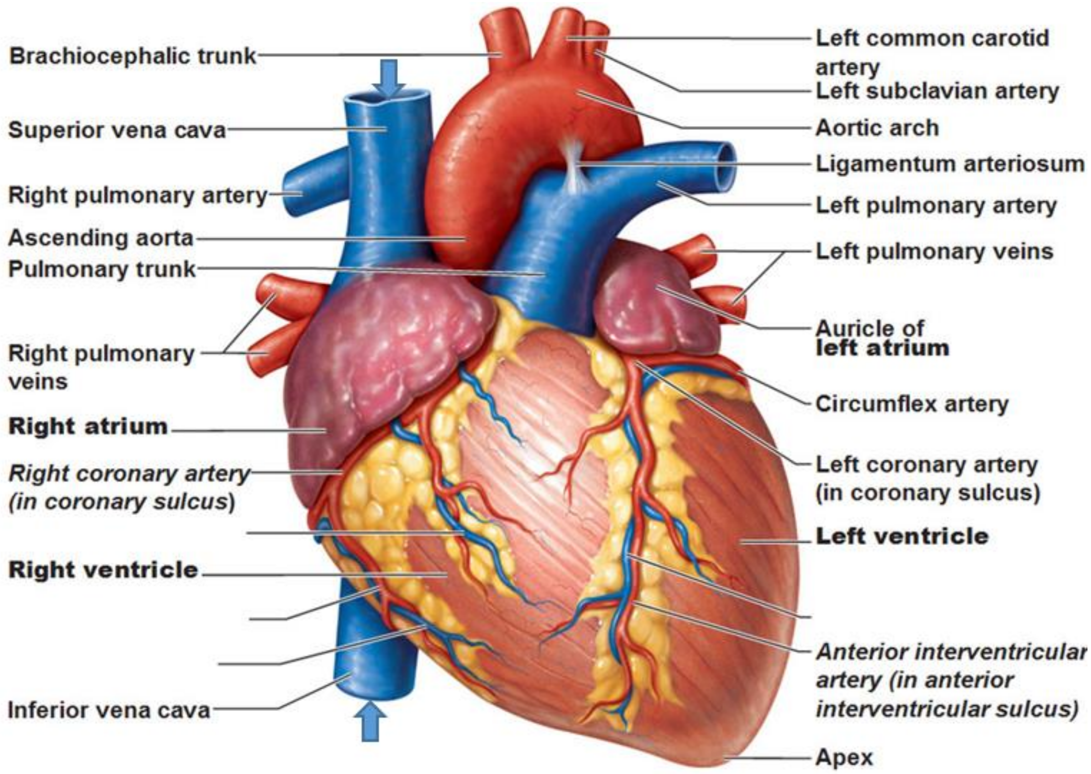
It is true that most arteries carry oxygenated blood and most veins carry deoxygenated blood, but there are a some important exceptions to that rule. A better understanding of blood vessels is that in the **systemic circuit**, arteries are carrying O_2 rich blood and veins are returning O_2 poor blood to the heart. While in the pulmonary circuit, it is the opposite, arteries still carry blood away from the heart, but have low O_2 levels, and the pulmonary veins that return blood to the heart have very high O_2 levels.

The General Sequence of Blood Vessels

In both the systemic and pulmonary circuits, the blood vessels leaving and returning to the heart make a type of 'loop', and it usually follow this sequence:

Heart > **Artery** > **Arteriole** > **Capillary** > **Venule** > **Vein** > Heart.

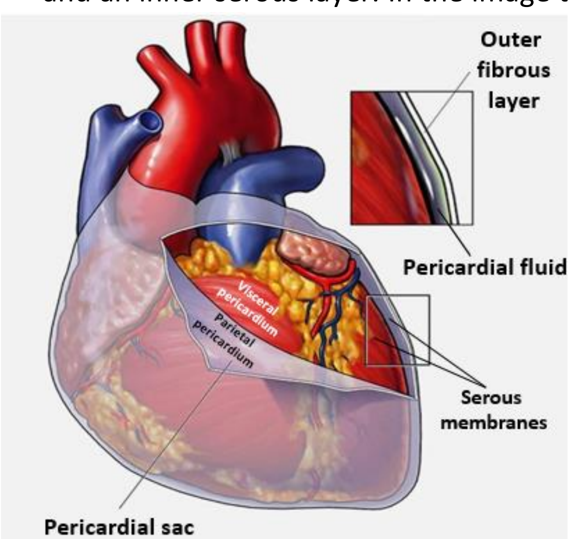
There are important exceptions to this sequence, but they are rare and will be covered separately. We can use the sequence shown above as we describe the circuits. For the systemic circuit, the first blood vessel that leaves the heart is the largest artery in the human body, the **aorta**, which is the foundational vessel of the entire systemic arterial system. The aorta branches into many arteries as is travels away from the heart to deliver O_2 rich blood throughout the body. As they branch, the vessels become smaller and smaller, until they become **arterioles**, which is the next main category of blood vessels. The arterioles are the structures that control blood pressure and blood flow in the body. As these continue to get smaller they become **capillaries**. The capillaries are the site of exchange with the cells of the body. The blood here in the capillaries is often described as sort of purple (not red and not blue). This is because the capillaries are the interchange between the O_2 rich arteries (red) and the O_2 poor veins (blue) of the systemic circuit. After the capillaries, the blood vessels chuck a U-ie, that is, they make a U-turn and begin to head back to the heart – so now they are veins. As the capillaries end, they merge and enlarge to become **venules**, which are like small veins (as the name implies). The venules merge and become larger and become **veins**. Veins are the largest type of blood vessel (diametrically). Although they have low pressure, because they are so large, the blood flow is high. This blood returning from the body is delivered to the receiving room of the systemic circuit, which is the right atrium.



Recall that blood inferior to the heart returns to the heart by the *inferior* vena cava. The blood superior to the heart returns to the heart by the *superior* vena cava. And finally, the blood from the heart returns to the heart by the *coronary* sinus (a large vein).

The Pericardial Sac

The heart is located in a tough, fibrous bag known as the **pericardial sac**, which has an outer fibrous layer and an inner serous layer. In the image to the left, the sac is open and the pericardial cavity can be seen, which contains pericardial fluid to reduce friction between surfaces that move across each other. The outer surface of the heart is a serous membrane, it is called the **visceral pericardium** because it is 'of the organ'. This outermost layer of the heart is also called the **epicardium**. The inner lining of the pericardia sac is also a serous membrane, called the **parietal pericardium**. Thus, the two serous membranes face each other with a thin layer of serous fluid in between them to reduce friction of the constantly moving heart.

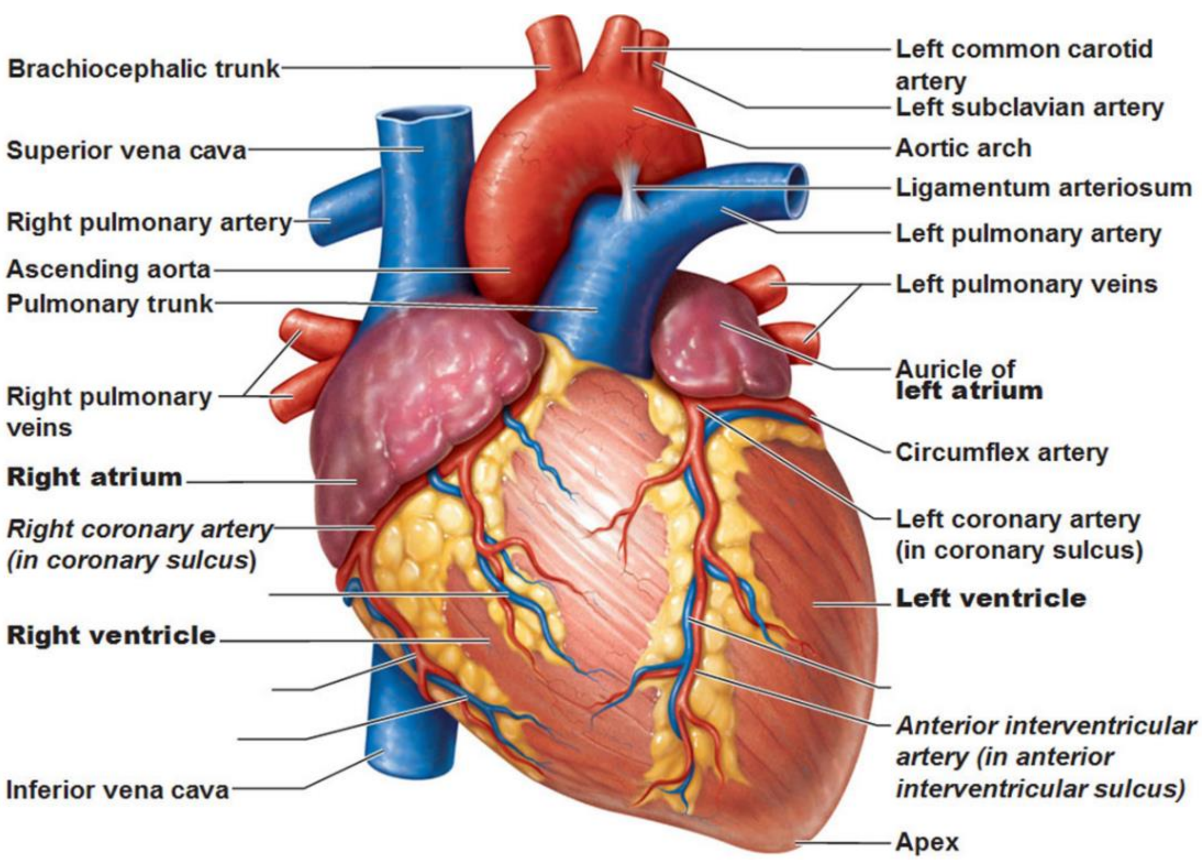


Brief Overview of Coronary Circuit

The apex of the heart is the inferior tip, and the base of the heart is the broad superior border. The **right coronary artery** branches directly from the ascending aorta and leads further down to the **right marginal artery**. The **left coronary artery** also branches directly from the ascending aorta and takes blood around the heart sheltered within the coronary sulcus, also known as the atrioventricular (AV) sulcus. The left coronary artery continues on to become the **anterior interventricular artery** and the **circumflex artery**. The large cardiac veins can also be seen on the anterior and posterior sides of the heart. The **great cardiac vein** is embedded within the anterior interventricular sulcus and the **middle cardiac vein** runs within the posterior interventricular sulcus. The large dilated **coronary sinus** sits in the posterior portion of the coronary sulcus. *The term *sinus* in the cardiovascular system means a large vessel, usually a vein. Using your lab manual as a guide, label all of the major vessels on the heart, as well as the vessels entering and exiting the heart.

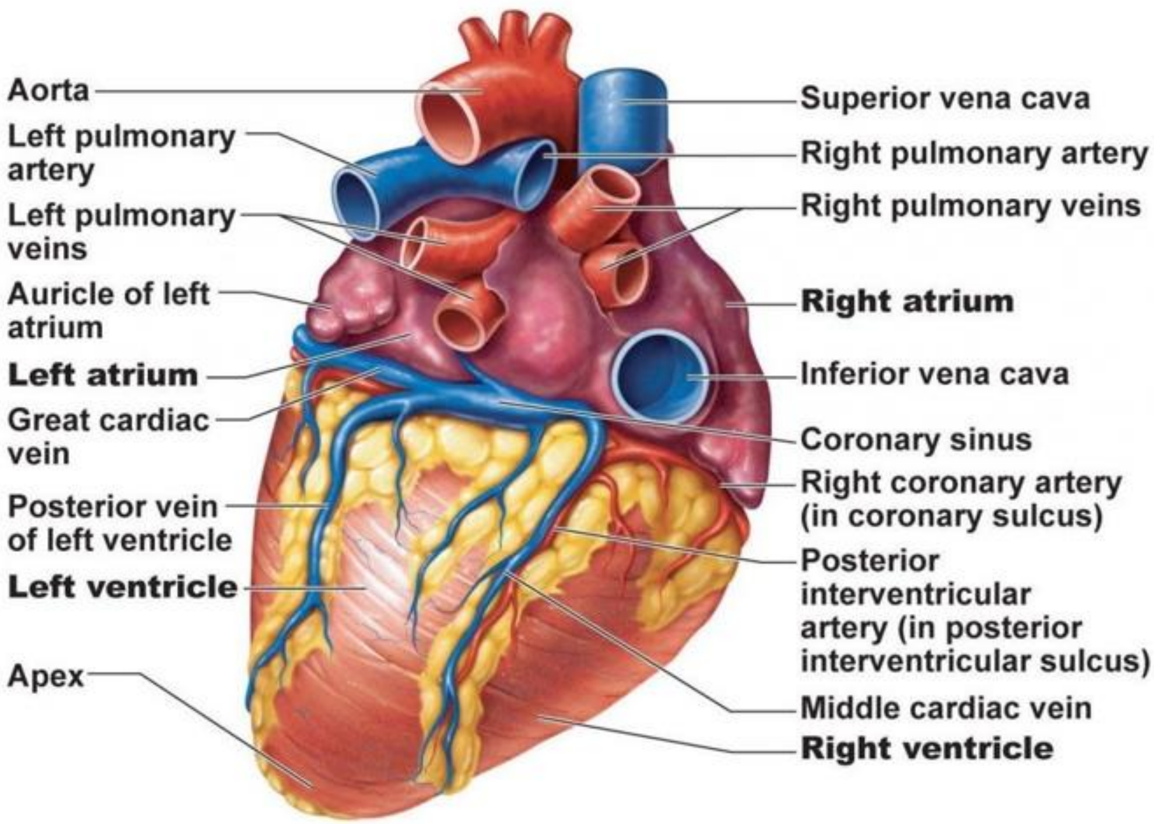
Anterior Surface View of Heart

Many of the external surface features of the heart are easily seen, and they also provide landmarks for the chambers of the heart. The two atria have an external feature called **auricles** (meaning ear). They allow for an expansion of atrial blood volume in times of greater cardiac output (during enhanced filling). Another notable external structure are the sulci (singular sulcus). These are shallow grooves on the external surface of the heart that are filled with fat and hold coronary blood vessels. As seen in the images below, the major coronary blood vessels are situated within these sulci. The **anterior interventricular sulcus** is seen on the anterior surface of the heart, and the **posterior interventricular sulcus** is seen on the posterior surface of the heart. The **coronary sulcus** is a shallow groove that encircles the heart, located snugly between the atria and ventricles. This sulcus is also filled with adipose tissue and blood vessels.

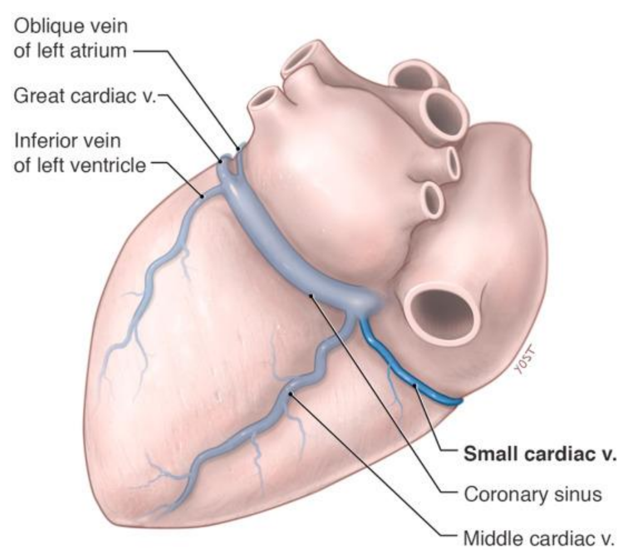


Posterior Surface of Heart

As mentioned, the posterior side of the heart has arteries and veins that sit in the various sulci. The **posterior interventricular artery** sits in between the ventricles on the posterior surface of the heart, held in place by adipose tissue within the posterior interventricular sulcus. This vessel receives blood from the right coronary artery. The **middle cardiac vein** carries runs the opposite direction as it is taking blood into the coronary sinus, to be returned to the right atrium. The **small cardiac vein** is also found on the posterior surface of the heart and enters the coronary sinus from the opposite direction.

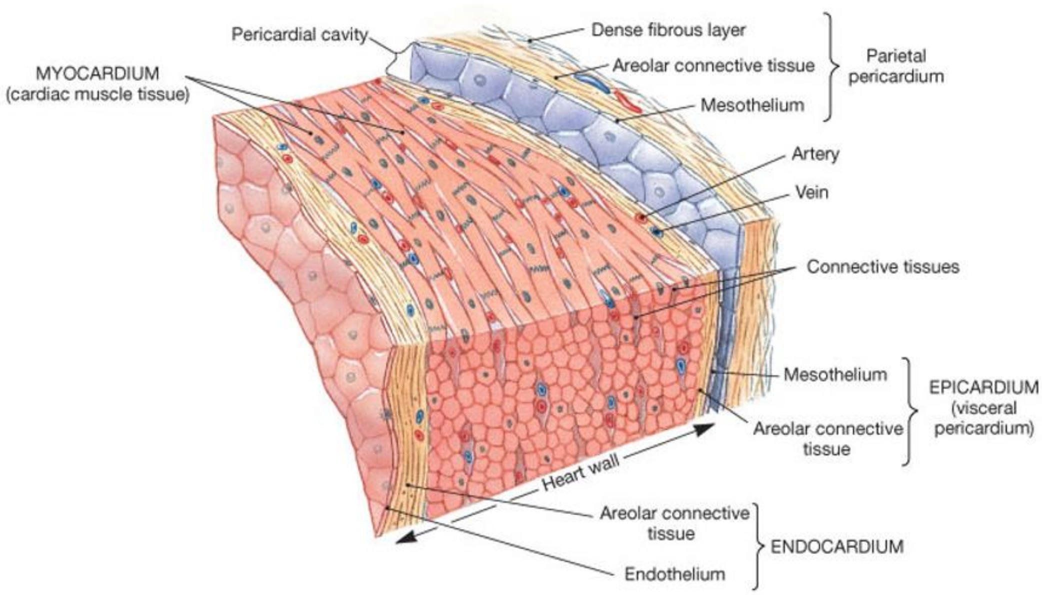


In the drawing to the right that shows only the venous return on the posterior aspect of the heart, it can be more clearly seen how the **great and small cardiac veins** approach the coronary sinus from opposite directions. The **oblique vein** drains blood from the left atrium into the large dilated coronary sinus. Also shown are the veins returning from the left ventricle, the **inferior vein of left ventricle**, and the **middle cardiac vein** that sits right in between the two ventricles nestled within the posterior interventricular sulcus.

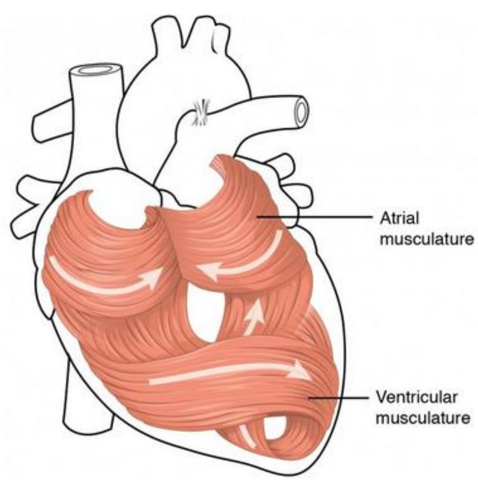


The Heart Tissue

The heart is composed of three layers of tissues. The innermost is the **endocardium** - this is the surface that blood flows along. The middle layer is the **myocardium** – this is by far the thickest layer of the heart and composed of cardiac muscle tissue. Finally, the outermost layer is the **epicardium**, which is a serous membrane made of simple squamous epithelium and areolar connective tissue. Recall that this can also be called the **visceral pericardium**.



As mentioned, the **myocardium** is the thickest layer of the heart. The cardiac muscle pattern is actually extremely complex and elegantly arranged in complimentary spiral patterns incorporated into all 4 chambers of the heart. The spiral arrangement forms a figure 8 pattern around the atria. The deeper ventricular cardiac muscles also form a figure 8 around the two ventricles and spiral toward the apex, but also up toward the base of the heart.

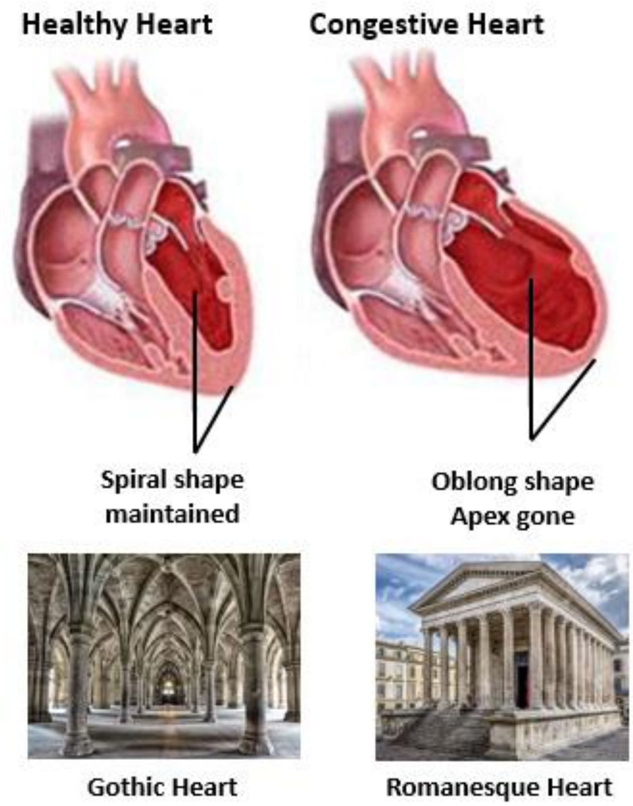


As early as **1749** it was suggested that the left ventricle of the heart had a ***helical configuration***, but much more recent findings published in the scientific literature in **1980** show that the muscle fibers of the entire heart are arranged in what is termed a **helical ventricular myocardial band** (see image left). The heart is literally one continuous strip of muscle that is folded in and coiled upon itself. Somewhat like an intertwined **double helix**, only more complex.

The left and right ventricles pump the same amount of blood per contraction, but the muscle of the left ventricular wall is about 3 times thicker than the right ventricle, and indeed pumps about 3 times greater pressure than the right side. The right ventricle does not need to generate as much pressure, since the pulmonary circuit is very close by, and thus requires much less force due to the lower resistance.

Healthy hearts need this complex structural arrangement in order to effectively conduct blood flow in the heart. If they lose this anatomical structure (or architecture), they can no longer effectively conduct blood flow and become dysfunctional, leading to various ailments.

In a 2001 study published in a peer reviewed journal for cardiac surgeons it was stated that in a **healthy heart** the left ventricle has a **Gothic architecture** wherein the heart's remarkable efficiency results from the arrangement of myocardial fibers supported by the collagen matrix scaffold. In contrast, the dramatic changes that occur to the structure of the heart in the serious and prevalent condition of **congestive heart failure** is associated with a transformation of the heart to a **Romanesque architecture**, leading to the diseased heart, particularly the left ventricle (see images below).



Their conclusions came from the analysis of gothic and roman buildings and three-dimensional images obtained by MRI with mathematic methods for measurements of the curvature and thickness of the heart's ventricular walls.

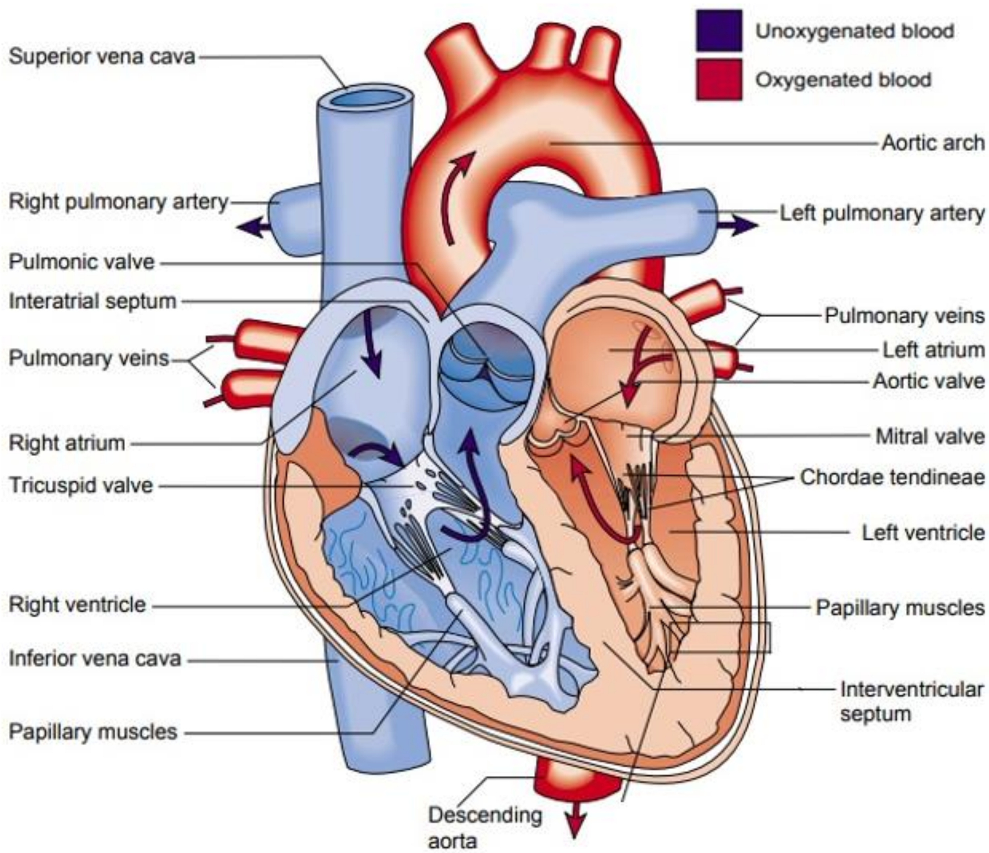
The changed **architecture** of the heart can be clearly seen in the two representations of the heart above to the right, as the spiral gothic shape is retained in the healthy heart compared to the loss of that form in the blown-out shape of the congestive heart.

The article declared that this understanding of the <u>architecture of the healthy heart</u> was certain to bring about dramatic changes in the design of surgical strategies to improve ventricular function by restoring the heart to its healthy architecture. It has now been over 20 years since this revelatory study and have you ever heard anything about the perfect Gothic architecture of a healthy heart? Me neither. Never heard a single thing about it until I started seeking information that made more sense than the usual drivel that is served up. Studies like these underscore that so much more is known about the heart and the impact of architecture on our health, but very little of it seems to be openly disclosed to us.

Arteries and Veins

As we have already discussed, an arterial system of blood vessels takes blood away from the heart, and a venous system of blood vessels take blood back to the heart. We will also discuss how there is one set of systemic arteries, but there are 2 sets of systemic veins. The 2 sets of veins are: **1)** deep veins – these run parallel to their arterial companion and almost always have the same names. For example, the brachial artery has the companion brachial vein, the femoral artery has the companion femoral vein. **2)** superficial veins – these are a unique set of veins that have no arterial companion and have unique names. This second set of superficial veins are found close to the external surface of the skin in the upper and lower limbs. The basilic and the cephalic veins of the arm are a good example, as well as the great and small saphenous veins of the thigh and leg.

In the image below, the aorta represents the beginning of the systemic arterial vessels. It leaves the heart as the ascending aorta, curves or arches over to the left side of the body in the aortic arch, and then travels down the left side of the body as the descending thoracic aorta. It travels through the large dome-shaped muscle, the diaphragm, through a hole in that muscle called the **aortic hiatus**. Once it passes through the diaphragm it is called the descending abdominal aorta. There are many branches off the aorta in the abdomen, there are 3 unpaired branches and 5 paired branches as it continues downward. At the end of the aorta, it does 'the splits' and becomes the L and R common iliac arteries, with the single median sacral artery springing out from the split in the middle. The common iliac arteries become the internal and external iliac arteries before they cross the inguinal ligament into the thigh region and become the femoral arteries. The arteries continue down to the toes, and then turn around for the return voyage.



BLOOD

Blood consists of plasma and formed elements. The plasma is the fluid portion of the blood and consists of water, proteins, and dissolved materials such as oxygen, carbon dioxide, electrolytes (ionic particles), glucose, aminos acids, lipids and other materials. Plasma makes up about **55%** of the blood volume. The formed elements are also called the **cellular** elements of blood. This makes up about **45%** of the blood volume and consists of erythrocytes (red blood cells), leukocytes (white blood cells) and thrombocytes (platelets).

By far, the most numerous type of cell in blood is the red blood cells (RBC), they represent over **99%** of all cells in the blood. They are the smallest blood cell and have a biconcave shape, meaning they are indented on both sides in order to maximize surface area for gas exchange. The special features of the RBC that are specific to their function will be discussed in more detail in the next section.

Briefly, there are about 5 million erythrocytes per cubic millimeter of blood. The erythrocytes do not have a nucleus and they appear like a with a thin spot instead of the donut hole. About a third of the weight of a red blood cell is due to hemoglobin which makes the cells red. Note also the size of the thrombocyte.

There are about 7 thousand leukocytes per cubic millimeter of blood. There are two main types of white blood cells are called **leukocytes**; granular leukocytes and agranular leukocytes. In total, there are 5 types of: These include neutrophils, eosinophils, and basophils, all of which are granular leukocytes; then there are monocytes and lymphocytes, which are agranular leukocytes. There are also thrombocytes, which are fragments of the very large cells called megakaryocytes. There are about 200,000-450,000 thrombocytes per cubic millimeter of blood. They assist the body in clotting to prevent blood from flowing out of small ruptures in blood vessels.

The granular leukocytes have cytoplasmic granules that either stain pink, dark purple or do not stain much at all. The granular leukocytes that do not stain much at all are called neutrophils because the granules are neutral to the stains. They are the most numerous of the leukocytes making up 60-70% of the leukocytes. Neutrophils have a three to five lobed nucleus.

The eosinophils are granular leukocytes that have pink or orange staining granules. The nucleus is generally two-lobed. Eosinophils make up about 3 percent of the white blood cells. Basophils are a rare granular leukocyte in that they make up less than one percent of the white blood cells. The nucleus is S shaped but it is frequently difficult to see because it is obscured by the dark staining cytoplasmic granules.

The two kinds of agranular leukocytes are the lymphocytes and the monocytes. The lymphocytes can be large or small and they make up 20-30% of the leukocytes. The cytoplasm is light blue and the nucleus is purple. The nucleus of the lymphocyte is dented or flattened. Lymphocytes come in two kinds. B cells secrete antibodies (antibody-mediated immunity) and T cells which are involved in cell-mediated immunity.

The monocytes are large cells (about 3 times the size of a red blood cell) and they have a strongly lobed nucleus. Some people say this looks like a kidney bean or a horseshoe. They represent only about 5% of the leukocytes.

The Specific Internal Structures of the Heart

Deoxygenated blood enters the right atrium of the heart by three vessels: the superior vena cava, the inferior vena cava and the coronary sinus. The walls of the right atrium are thin-walled as they only have to pump blood to the right ventricle. The blood in the right atrium is in contact with the fossa ovalis which is a thin spot in the interatrial septum. This thin spot is a remnant of a hole in the fetal heart known as the foramen ovale. Blood in the right atrium flows through the cusps of the tricuspid or right atrioventricular valve into the right ventricle.

The tricuspid valve is made of the three cusps, the chordae tendineae and the papillary muscles that hold the chordae tendineae to the ventricle wall. The ventricle wall is lined with trabeculae carneae that act as struts along the edge of the wall. The wall between the ventricles is known as the interventricular septum.

From the right ventricle, blood passes through the pulmonary semilunar valve and into the pulmonary trunk where the blood goes to the lungs. In the lungs the blood is oxygenated. From the lungs the blood returns to the left atrium of the heart. Blood in the left atrium moves to the left ventricle through the left atrioventricular valve or the bicuspid valve. This valve has two cusps, chordae tendineae and papillary muscles. When the left ventricle contracts, the blood moves through the aortic semilunar valve and into the ascending aorta.

Superior Aspect of the Heart

This view of the heart is seen as if the atria and the major vessels have been removed. You should be able to see all of the major valves of the heart. The most anterior valve is the pulmonary semilunar valve that occurs between the right ventricle and the pulmonary trunk. Label and color this valve blue. Posterior to this is the aortic semilunar valve. It occurs between the left ventricle and the aorta. Label this valve and color it in red. Both of these valves prevent blood from returning to the

ECG Conduction Pathway

The heart has specialized cells that initiate an electrical impulse that radiates throughout the heart. The cells are clustered in a particular area known as the sinoatrial node or the pacemaker. These cells produce a depolarization that travels across the atria which depolarize and then contract. Depolarization is an electrical event while contraction is a mechanical event. Between the wall of the right atrium and the right ventricles once they have finished contracting. On the right side of the illustration (and on the right side of the heart) is the right atrioventricular (or tricuspid) valve, so named because it has three flaps or cusps. This valve occurs between the right atrium and the right ventricle. It prevents the blood from returning to the right atrium during ventricular contraction. Label this valve and color it blue. On the left side of the heart is the left atrioventricular (bicuspid) valve. It prevents blood from moving back to the left atrium when the left ventricle contracts.

Within the right ventricle is a tissue known as the atrioventricular (AV) node. Once the impulse reaches this area the AV node pauses a moment before sending the impulse to the atrioventricular bundle. This bundle divides into the bundle branches and then the impulse travels to the conduction (Purkinje) fibers. These fibers reach the muscle of the ventricles and stimulate them to contract.

Overview of the Vessel Walls

The blood vessels have different thickness due to the differences in pressure that occur in them or their function with respect to exchanging nutrients with the cells.

Arteries have thick walls due to the higher pressure found in them. Just as high pressure hoses have thick walls, so do arteries. The outer layer of the artery is the tunica externa (tunica adventitia). The middle layer of the artery, the tunica media is the thickest layer and it is made of smooth muscle and elastic fibers. The innermost layer of the artery is the tunica intima (tunica interna) and it has a special elastic layer called the lamina elastic interna. The area in the artery where the blood flows is called the lumen.

Veins are thinner walled than arteries and they do not have the same elastic fibers in the tunica media as arteries. The tunica interna of veins is folded into valves that allow for a one-way flow of blood through veins.

Capillaries are different from both arteries and veins in that they are composed of only simple squamous epithelium (called endothelium). The thin nature of capillaries allows them to exchange nutrients, water, carbon dioxide and oxygen with the cells.

Artery Overview

One of the ways to study arteries is to draw them as if you were making a street map. Begin with the heart and draw the blood vessels that travel out and deliver blood to the head, upper limbs, abdomen, internal organs, lower limbs etc. Arteries in the systemic circuit when viewed on models or in textbooks are typically colored red, as they are richly oxygenated. Use the list of arteries in your lab manual as your guide and notice how one vessel becomes another vessel as the branching pattern continues. The standard abbreviation for artery is a., and for arteries it is a.a. Similarly for vein it is v., and for veins it is v.v.

Head and Aortic Arteries

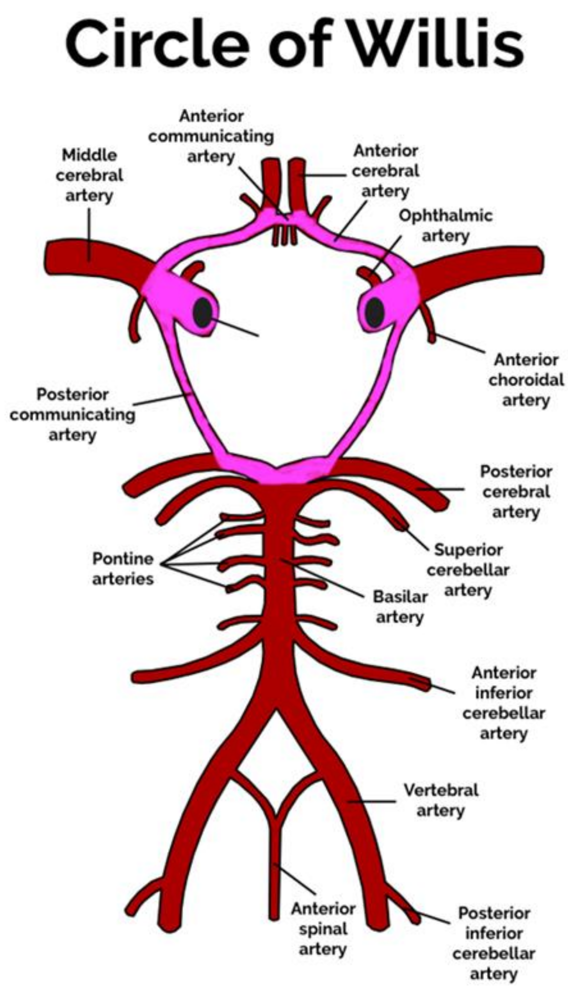
Blood from the heart exits the **brachiocephalic artery** and takes two main pathways to the right side of the head. One of these is the right common carotid artery which exits the brachiocephalic artery and then splits into the external carotid artery and the internal carotid artery. The external carotid artery has several branches, among them the facial artery, the superficial temporal artery, the maxillary artery, and the occipital artery. The internal carotid artery takes blood through the carotid canal of the skull and into the brain. The other main pathway of blood to the right side of the head is the vertebral artery which arises from the subclavian artery. The left side of the head has a similar pathway except that the left common carotid artery and the left subclavian artery arise from the aortic arch and not from the brachiocephalic artery.

Arteries of the Brain

The brain is nourished by two main arterial conduits. The first of these is from the **internal carotid arteries**. The other blood vessels that directly deliver blood to the brain are L and R vertebral arteries that travel through and are protected by the transverse foramen of the cervical vertebrae.

The L and R **common carotid arteries** branch off at the carotid sinus and become the **external carotid arteries** (which deliver blood to the face and head), and the **internal carotid arteries** that travel through the carotid canal within the petrous portion of the temporal bone as they deliver blood to the brain.

The blood from the internal carotid arteries comes from the neck and enters a circular pathway known as the **arterial circle** (circle of Willis). These arteries connect at a vessel called the basilar artery and it leads to the arterial circle. The arterial circle consists of the anterior communicating arteries and the posterior communicating arteries. From this circle blood then moves **into** one of many arteries that feed the brain. The cerebrum is fed by the anterior, middle and posterior cerebral arteries. The cerebellum is fed by the cerebellar arteries.



Arteries of Upper Limb

The arteries of the upper limb receive blood from the subclavian artery which takes blood to the axillary artery. Blood in the axillary artery travels to the anterior scapula by the subscapular artery to the external chest wall by the lateral thoracic artery, to the upper humeral region by the posterior circumflex humeral artery, and to the distal regions of the arm by the brachial artery. The brachial artery is the major artery of the arm and it divides distally to form the radial and ulnar arteries. The radial artery is frequently palpated at the wrist to determine the pulse rate. The radial and ulnar arteries rejoin (called collateral circulation) in the hand as the superficial and deep palmar arch arteries. These arteries take blood to the fingers as digital arteries.

Arteries of Lower Limb

Blood in the lower limb comes from the branches of the iliac arteries. Blood in the common iliac artery flows into the internal iliac artery and into the external iliac artery. Once it passes by the inguinal ligament (a connective tissue band that stretches from the ilium to the pubis) the external iliac artery becomes the femoral artery. The femoral artery takes blood down the anterior thigh but there is a branch called the deep femoral artery that takes blood closer to the bone. The femoral artery moves posteriorly to become the popliteal artery and branches of the popliteal artery become the anterior and posterior tibial arteries and the peroneal (fibular) artery. The tibial arteries take blood to the dorsal arcuate artery, the dorsalis pedis artery, and the dorsal metatarsal arteries which take blood to the digital arteries.

Abdominal and Thoracic Arteries

The aorta starts at the ascending aorta and curves via the aortic arch. The thoracic aorta is a portion of the descending aorta. It has several branches that take blood to most of the ribs and intercostal muscles. These are the posterior intercostal arteries. Below the diaphragm the descending aorta is known as the abdominal aorta and it has several branches. The first of these is the celiac trunk and it branches to take blood to the stomach, spleen and liver. The next branch is the superior mesenteric artery. Below this are the renal arteries that take blood to the kidneys. The gonadal arteries are found inferior to the renal arteries and they take blood to the testes in males or the ovaries in females. A single inferior mesenteric artery is found below the gonadal arteries. The aorta terminates as it divides into the common iliac arteries.

Arteries of the Digestive System

The celiac trunk splits into three branches, the common hepatic artery, the left gastric artery and the splenic artery. There are other branches to the stomach which have collateral circulation (two or more arteries taking blood to one area). One of these is the right gastroepiploic artery and another is the left gastroepiploic artery. Below the celiac trunk is the superior mesenteric artery which takes blood to the small intestine and to several of the colic arteries that supply blood to the proximal portion of the large intestine. These are the middle colic artery, the intestinal branches, the right colic artery and the ileocolic artery. The inferior mesenteric artery takes blood to the distal portion of the large intestine via the left colic artery, sigmoid artery and the rectal artery.

Male and Female Pelvic Arteries

The common iliac artery takes blood to the external iliac artery and the internal iliac artery that takes blood to the pelvis. In females, branches of the internal iliac artery take blood to the inner pelvis. The vesical arteries take blood to the bladder, the uterine arteries take blood to the uterus, the vaginal arteries feed the vagina, the rectal arteries feed the rectum, and the sacral arteries go to the sacrum. The pudendal artery takes blood to the external regions where it supplies blood to the pelvic floor, the labia majora and minora and the clitoris. In males the internal iliac artery takes blood to the bladder, rectum, sacrum, the prostate, and seminal vesicles on the inside. The pudendal artery takes blood to the scrotum, penis and external pelvic floor. In both sexes the obturator artery takes blood from the internal iliac artery to the medial thigh while the gluteal arteries take blood to the muscles posterior to the pelvic cavity.

Veins

Veins are blood vessels that return blood to the heart. They are characteristically colored in blue on illustrations. The deep veins typically take the name of the artery next to them or the name of the organ that provides them with blood. Therefore, the femoral vein runs next to the femoral artery and the splenic vein receives blood from the spleen. Some veins have names unique to them and these are typically the superficial veins. Use the list of veins in your lab manual and begin to draw and label the major veins of the body.

Head and Neck Veins

Superior Vena Cava Veins. The drainage of the head occurs by the jugular veins or the vertebral veins. Some of the blood coming from the brain travels down the superior sagittal sinus and through the large internal jugular veins. These veins take blood down both sides of the neck and enter the brachiocephalic veins. The external portion of the head is drained by several veins. The facial vein and the maxillary vein take blood to the internal jugular vein while the superficial temporal vein and the posterior auricular vein take blood to the external jugular vein which then flows into the subclavian vein before reaching the brachiocephalic vein.

The Two Sets of Veins

The veins of the upper and lower limbs are arranged in two sets, the deep set that are parallel to their arterial companions of the same name, and superficial veins, that are much closer to the surface of the body, do not have an arterial companion and have unique names.

Veins of the Upper Limb

The veins of the upper limb are somewhat variable and have many cross connections between them but they can be divided into the deep veins and the superficial veins. The deep veins of the upper limb frequently form a meshwork around the arteries (venae comitantes) which allows for a great amount of heat transfer. Cool blood from the extremities is warmed by the arterial blood flowing in a counter current. Blood in the fingers returns to the forearm by the digital veins and then the superficial and deep palmar arch veins. The deep veins of the upper limb are the radial veins, the ulnar veins, and the brachial veins. The brachial veins lead to the axillary vein which takes blood to the subclavian vein.

As already mentioned, in the venous system of the systemic circuit there are two sets of veins: The deep set (discussed above) that are parallel to their arterial companions of the same name, and the **superficial veins**, that are unique. The superficial veins of the upper limb are the **basilic** vein, found on the medial aspect of the forearm and arm, the **median antebrachial** vein, on the anterior aspect of the forearm, and the **cephalic** vein, found on the lateral aspect of the forearm and arm and a small vein that connects the basilic vein with the cephalic vein called the median cubital vein. This median antebrachial vein is used frequently the one used to withdraw blood.

Veins of the Lower Limb

Blood in the toes returns by the digital veins. These veins take blood to the dorsal metatarsal veins and the dorsal venous arch veins. On the underside of the foot are the plantar veins. Blood moves up the leg by the posterior and anterior tibial veins and the great and small saphenous veins. The anterior and posterior tibial veins join together to form the popliteal vein posterior to the knee. The **small saphenous** vein joins the popliteal vein taking blood to the femoral vein. The **great saphenous** vein begins around the medial malleolus and runs the entire length of the medial lower limb when it enters into the femoral veins. Once the femoral vein crosses the inguinal ligament it becomes the external iliac vein.

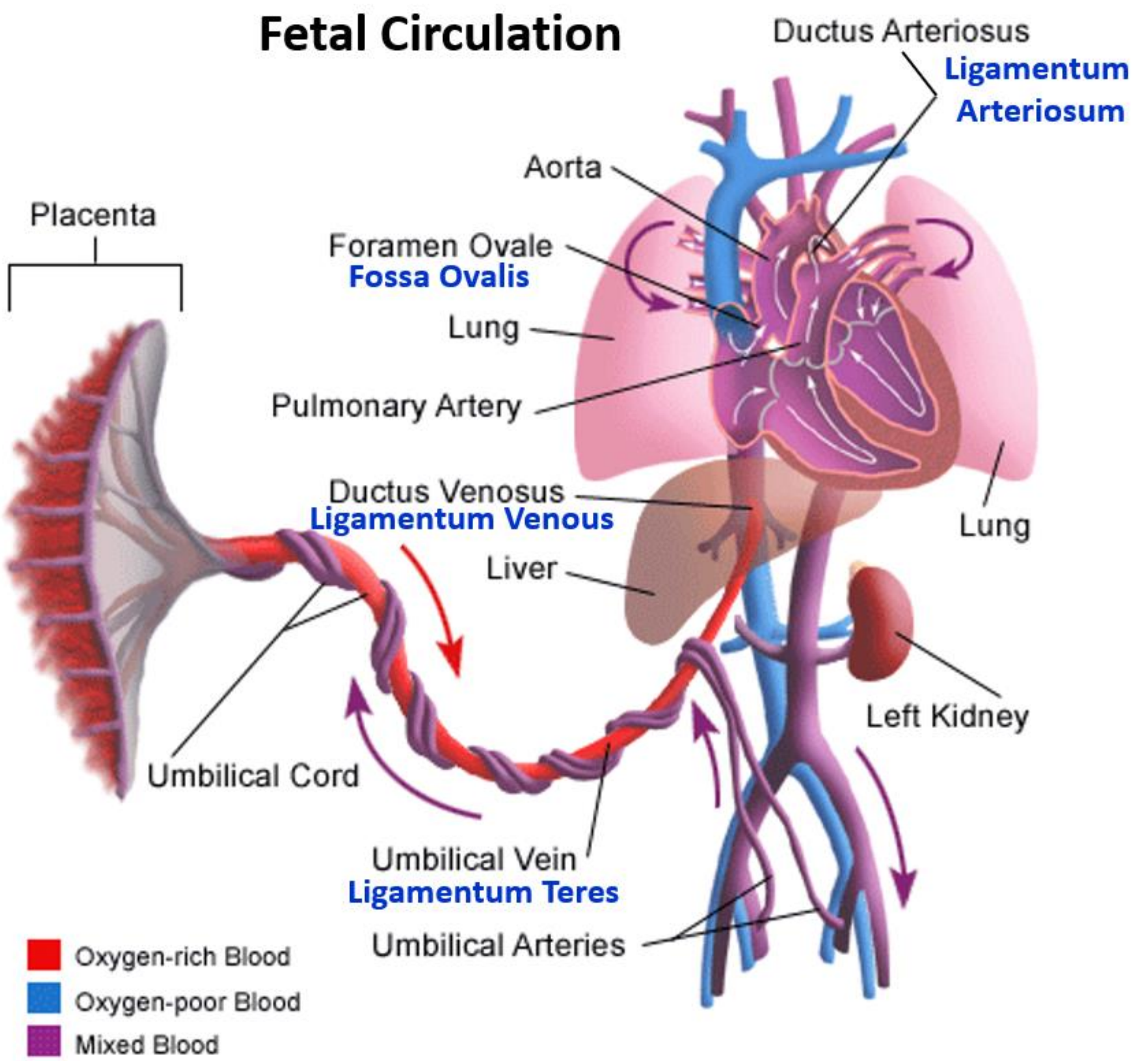
Hepatic Portal Veins, Trunk Veins

Most of the blood of the body returns to the heart by capillaries flowing into venules and finally into veins before reaching the heart. In a portal system blood moves from one capillary system to another capillary system before reaching the heart. The hepatic portal system takes blood from the capillary beds of many of the abdominal organs and carries it to the liver where metabolic processing takes place. The hepatic portal vein receives blood from various veins including the splenic vein, the gastroepiploic vein, the left gastric vein and the colic veins which take blood to the superior mesenteric and inferior mesenteric veins. Once the blood is processed in the liver it enters the systemic circulation by the hepatic veins.

The return of blood from other parts of the pelvic and abdominal cavities does not go through the hepatic portal system but enters the inferior vena cava. The renal veins take blood from the kidneys to the inferior vena cava. The gonadal veins take blood from the testes or the ovaries. The left gonadal vein enters the left renal vein while the right gonadal vein enters the inferior vena cava. The intercostal veins take blood to the hemiazygos and the azygos veins.

The Fetal Circulation

The significant difference in fetal circulation from adult circulation lies in the fact that the lungs are non-functional in the fetus. The source of oxygen for the fetus is the placenta where maternal blood carries oxygen and nutrients to the fetus. Blood from the placenta travels to the fetus by the umbilical vein. It is called a vein because it carries blood to the fetal heart. The blood flowing in the umbilical vein is oxygenated blood which is not typical of most blood that occurs in veins. From the umbilical vein the blood passes through a small shunt vessel known as the ductus venosus and enters the inferior vena cava where it mixes with blood returning from the lower extremities. The fetus receives a mixture of oxygenated and deoxygenated blood.



This mixed blood reaches the fetal heart and begins the first of two bypass routes. Since the lungs do not oxygenate blood in the fetus they do not require the entire blood volume to pass through them. The first bypass route is through the foramen ovale, a hole between the right and left atria of the heart. Another bypass route occurs as the blood enters the pulmonary trunk. Blood moves from the pulmonary trunk through the ductus arteriosus and into the aortic arch. Blood traveling back to the fetus is not fully deoxygenated but is a mixture of oxygenated and deoxygenated blood. This blood flows from the internal iliac arteries of the fetus and into the umbilical arteries. From the umbilical arteries the blood flows into the placenta.

Overview of the Lymphatic System

The lymph system is composed of lymphatics or lymph vessels and glands and is a system with many functions. Fluid that bathes the cells (interstitial fluid) is returned to the cardiovascular system, in part, by the lymph system. This fluid, called lymph, passes through lymph nodes where impurities and foreign microbes are removed. Other parts of the lymph system include lymph organs such as the spleen. These organs produce cells that protect the body from foreign compounds, and have other immune functions such as cleansing the body of cellular debris and removing old blood cells from circulation.

The main exchange of fluid from the cardiovascular system occurs at the capillary level. Arterioles carry blood to the capillary bed and the venules return blood from the capillaries. About 90% of the fluid that flows from the blood capillaries to the interstitial fluid around the cells is reabsorbed by the capillaries. The remaining 10% of the interstitial fluid enters the lymph system at the **initial lymphatics** (also called lymphatic capillaries). Once the tissue fluid is inside the lymphatic vessel it is called lymph. The initial lymphatics are highly permeable, thin walled vessels that absorb tissue fluid in order to ultimately return this fluid to heart. As lymph and travels through the lymphatic vessels, they become larger in size, much like veins get larger as they get closer to the heart. The larger collective lymphatic vessels have one-way valves in them that prevent the fluid from falling back, ensuring the one-way flow of lymph from the tissues to the heart. The lymph continues to travel back to the heart into larger lymphatic trunks, which merge into a large lymphatic vessel at the base of the abdomen called the **cisterna chyli**. This vessel, in turn, takes lymph to the largest lymphatic vessel, called the **thoracic duct**, which returns the lymph to the left subclavian vein and therefore back to the cardiovascular system.

Return Drainage

One of the functions of the lymph system is to return tissue fluid to the cardiovascular system. The right lymphatic duct returns blood to the right internal jugular vein. This occurs at the junction where the right subclavian vein and the right internal jugular vein reach the right brachiocephalic vein. The thoracic duct enters the cardiovascular system at the point where the left internal jugular vein and the left subclavian vein enter the left brachiocephalic vein. Lymph nodes occur along the path and cleanse the lymph. The thymus is a lymph organ that occurs near these drainage areas. The thoracic duct receives lymph from most of the body while the right lymphatic duct receives lymph from the right side of the head, the right pectoral region, and shoulder and right upper extremity.