SBI3U-C

Lesson
11

The Human Circulatory System

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Introduction

The human circulatory system, also known as the cardiovascular system, is responsible for delivering food, oxygen, and other needed substances to all cells in all parts of the body while eliminating waste products. You could not exist without it. If you did not have a circulatory system, it would take three years for oxygen to diffuse from your lungs to the cells of your toes.

In this lesson, you will learn about the parts of the human circulatory system including the vessels, and heart. You will also examine ways to measure heart rate, and determine how the circulatory system responds to exercise, disease, and environmental toxins like tobacco.

Planning Your Study

You may find this time grid helpful in planning when and how you will work through this lesson.

Suggested Timing for This Lesson (hours)	
The Human Circulatory System	½
Composition of Blood	1
Types of Blood Vessels	½
Structure of the Heart	¼
Pulmonary and Systemic Circulation	½
Activity: Making a Stethoscope	½
Activity: The Pulse of Life	½
Key Questions	1

What You Will Learn

After completing this lesson, you will be able to

- explain the anatomy of the circulatory system (blood components, blood vessels, the heart) and its function in transporting substances that are vital to health
- use appropriate terminology related to animal anatomy, including systolic, diastolic, diffusion, coronary, and cardiac
- use medical equipment (like a stethoscope,) to monitor the functional responses of the respiratory and circulatory systems to external stimuli (for example, heart rate after exercise)
- compile accurate data from laboratory and other sources, and organize and record the data using appropriate formats, including tables, flow charts, graphs, and diagrams
- select appropriate instruments and materials, and identify appropriate methods, techniques, and procedures, for each inquiry

The Human Circulatory System

The basic components of the cardiovascular system are the heart, the blood vessels, and the blood. As blood circulates through the body in the blood vessels, it picks up oxygen from the lungs, nutrients from the small intestine, and hormones from the endocrine glands, and delivers these to the cells. Blood then picks up carbon dioxide and cellular wastes from cells, and delivers these to the lungs and kidneys, where they are excreted.

Maintaining a Healthy Circulatory System

Your cardiovascular system works very well without you being aware of it. However, there are lifestyle choices you can make that affect how well it works. The three most important choices are related to exercise, diet, and smoking.

Exercise

Today, fewer adults are regularly engaging in any kind of physical activity. There are many reasons for this, including our use of labour-saving devices and busy schedules that leave little time for exercise. Also, many people now spend much of their day sitting while they use a computer or watch television. But our lack of physical activity comes at a cost to our health. A sedentary lifestyle doubles the risk of coronary (heart) disease, making it as risky as smoking, high cholesterol, or high blood pressure.

The more physically active you are, the lower your risk for heart disease. Research comparing highly sedentary people with highly active people found that physical activity lowered the risk of coronary disease by about half. Exercise also makes you feel better mentally. It reduces stress, which can be a trigger for heart problems. You will learn more about the specific ways that exercise affects the circulatory system in the last section of this lesson.

Diet

You are what you eat. A poor diet increases your risk of coronary disease in many ways. It increases the levels of low-density lipoprotein (LDL) or "bad" cholesterol and triglycerides (saturated fats), both of which can lead to a buildup of plaque in your blood vessels. Plaque is a sticky substance made up mostly of cell debris and cholesterol that sticks to the artery walls. It can eventually build up to be so thick that it blocks the artery. If it blocks an artery leading to the heart muscles, it can cause a heart attack. If it blocks an artery in your brain, it can lead to a stroke. Aside from plaque, a poor diet too high in fats and refined sugars can also result in high blood pressure, diabetes, and obesity.

There is strong evidence that diet directly affects the chances of developing full-blown coronary disease and having a heart attack. Research shows that people who regularly eat a Mediterranean-style diet are 50% to 70% less likely to suffer from heart disease and stroke. This type of diet includes a lot of fruits, vegetables, beans, whole grains, and nuts. It uses olive oil and other types of unsaturated fats for cooking. It also involves eating more fish and poultry and less red meat (like beef) and drinking wine in moderation.

Numerous studies also indicate that eating more omega-3 fats (found in certain fish and nuts as well as supplements) may be particularly heart-healthy. Just about everyone can benefit from a heart-healthy diet. However, no single food will prevent or reverse heart disease even if it comes with a label saying it is "heart-healthy."

Smoking

Tobacco smoking dramatically increases the risk of cardiovascular disease like heart attacks and strokes. It does this in many ways, as you will see throughout this lesson. Smoking hardens and narrows the arteries, lowers the oxygen-carrying capacity of the blood, and increases blood cholesterol levels. Smoking is so hazardous to cardiovascular health that it is recognized by Canadian government health agencies as the single most important preventable risk to human health.

Structure of the Human Circulatory System

The circulatory system interacts with many other body systems, including the digestive system, the respiratory system, and the urinary system to maintain the body's internal environment.

The circulatory system has many functions:

- delivering nutrients such as oxygen to all the cells in the body;
- eliminating waste products like carbon dioxide;
- transporting chemical messengers like hormones from one location in the body to another;
- helping to maintain a constant body temperature; and
- playing an active role in blood pressure control.

The human circulatory system is made up of the heart, blood, and vessels through which blood travels such as arteries, veins, and capillaries. Figure 11.1 shows how the circulatory system looks in the human body.

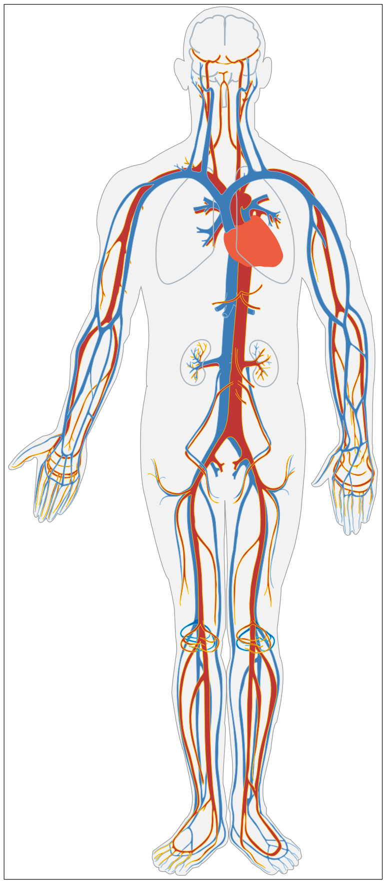


Figure 11.1: The human circulatory system

Source: Wikimedia Commons

In the following sections, you will examine each part of the circulatory system in more detail.

Support Questions

Be sure to try the Support Questions on your own before looking at the suggested answers provided.

39. What do the Canadian government health agencies say is the single most preventable risk to human health? Suggested answer

40. What is another name for the circulatory system? Suggested answer

Composition of Blood

Human blood is actually a very complex substance. It is a type of connective tissue consisting of several types of cells suspended in a liquid called plasma. As in other tissues, the individual cells in the blood work together for a common purpose.

The average human adult contains 4 to 6 L of blood. Approximately 55% of the blood is liquid; the remaining 45% is composed of blood cells. The main cellular components of blood are the red blood cells (erythrocytes), the white blood cells (leukocytes), and the platelets (Figure 11.2). The percentage of red blood cells in the blood is called the hematocrit.

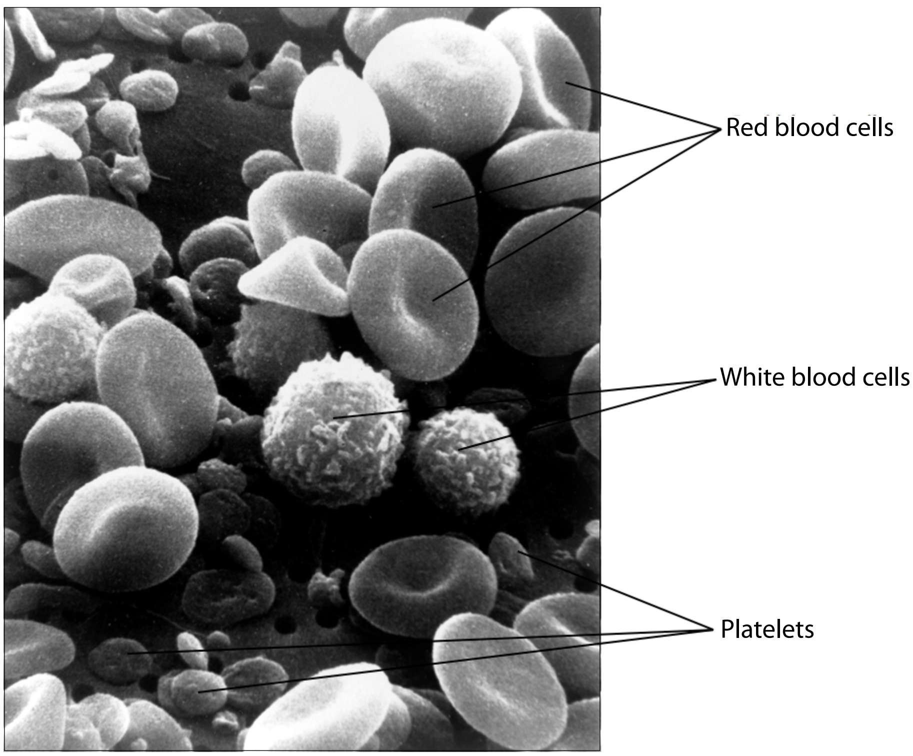


Figure 11.2: Types of blood cells seen in a scanning electron microscope image

Source: Wikimedia Commons

If a blood sample is taken, the cells can be separated from the plasma in a centrifuge, a device that rotates at very high speed to separate liquids from solids.

Figure 11.3: Photograph of a centrifuge. You put tubes of liquid into the holes. The device spins very fast and the materials in the tube separate based on weight.

Source: Wikipedia

Figure 11.4: Photograph of a tube of blood after it has been in the centrifuge. You can see the different parts of the blood separated into layers. The heaviest parts go to the bottom and the lightest go to the top.

Source: Wikipedia

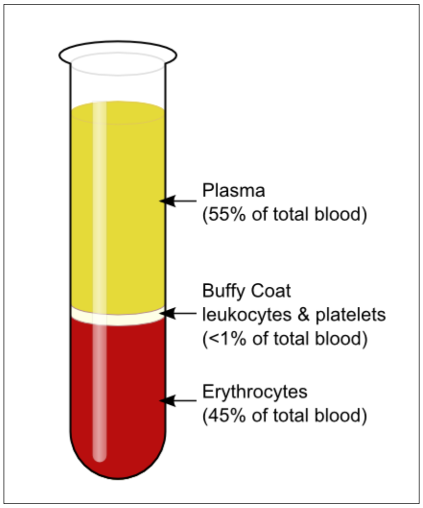


Figure 11.5: Diagram showing blood separated after centrifugation
Source: Wikipedia

In the following sections, you will examine each blood component in more detail.

Plasma

The liquid portion of the blood is referred to as the plasma, which is 90% water, allowing it to be described as a fluid tissue; many substances are dissolved in this fluid, such as salts, glucose, proteins, hormones, nutrients, gases, and waste products. Important proteins found in the plasma are:

- fibrinogen, an important protein involved in blood clotting;
- albumin and globulin, which aid in the regulation of fluid in and out of the blood vessels by establishing an osmotic pressure that draws water back into the capillaries and helps maintain body fluid levels; and
- gamma globulins, which act as antibodies to help protect the body against foreign substances called antigens and invading microbes.

The salts present in plasma include those based on sodium, potassium, calcium, magnesium, chloride, and bicarbonate. They are involved in many important body functions such as muscle contraction, the transmission of nerve impulses, and regulation of the body's acid–base balance.

Red Blood Cells—Erythrocytes

Red blood cells are the most abundant cells in the blood, giving blood its red colour. They are manufactured in the bone marrow and stored in the spleen. Their primary function is to carry oxygen. Their small size allows them to squeeze through microscopic blood vessels called capillaries. There are, on average, 25 trillion red blood cells in the body's 5 L of blood, or about 5 million per cubic millimetre of blood. These cells are constantly being destroyed and replaced. Studies suggest that two million red blood cells are destroyed in the body every second.

Red blood cells are unique because they do not contain a nucleus or mitochondria. The structure of the red blood cell is a biconcave disk, thinner in the centre than at its edges (Figure 11.6). This biconcave shape allows the red blood cell to fold and squeeze through capillaries. Red blood cells lack mitochondria, so they cannot carry out aerobic respiration. Since the major function of the red blood cell is to carry oxygen to the body cells for aerobic cellular respiration, it would not be efficient if the red blood cell's own energy requirements consumed the oxygen that they were carrying.

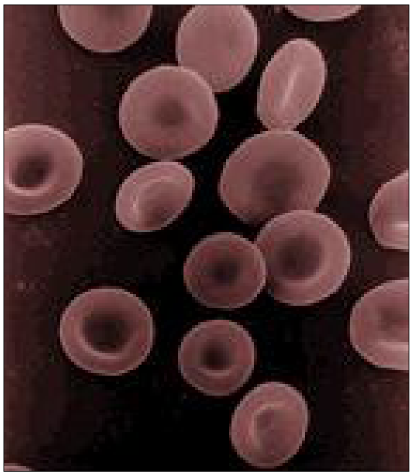


Figure 11.6: Image of red blood cells as seen under a microscope

Source: Wikipedia

Hemoglobin

The cytoplasm of red blood cells consists of a watery solution containing hemoglobin, a type of protein molecule that binds to oxygen. Each red blood cell contains 250 million molecules of hemoglobin, and one hemoglobin molecule can bind four oxygen molecules to itself. Hemoglobin combines with oxygen in the lungs, transporting that oxygen to the tissues throughout the body. It also carries carbon dioxide from the tissues back to the lungs, where some of the carbon dioxide is exhaled.

Hemoglobin is a protein pigment that contains iron and gives red blood cells their distinctive colour. Each red blood cell lives only about 120 days and, when it is destroyed, the iron is recycled in the bone marrow and incorporated into a new red blood cell.

Carbon monoxide (CO) is a colourless, odourless gas produced from the incomplete burning of virtually any combustible product. Symptoms of CO exposure may mimic influenza and include fatigue, headache, dizziness, nausea and vomiting, mental confusion, and rapid heart rate. Carbon monoxide exposure can lead to death.

Figure 11.7: Photograph of a carbon monoxide detector

Source: Wikipedia

Anemia

Anemia, one of the more common blood disorders, occurs when the level of healthy red blood cells in the body becomes too low, which decreases oxygen delivery to the tissues. Anemia can cause a variety of complications, including fatigue and stress on bodily organs. Anemia is not an actual disease; it is a condition caused by some other problem. There are three basic ways that anemia can develop: rapid destruction of red blood cells, blood loss, or low production of healthy red blood cells.

Anemia is often caused by an iron deficiency. There are two types of iron in our diet: heme and non-heme iron. Heme iron is found in animal products such as red meat, fish, and poultry. Non-heme iron is found in plant products such as grains, nuts, beans, legumes, vegetables, and fruit. Heme iron from animal products is more easily absorbed than non-heme iron from plant products. Vitamin C aids in the absorption of non-heme iron.

White Blood Cells—Leukocytes

White blood cells, often called leukocytes, are part of the body's immune system. They defend the body against viruses, bacteria, and other invading micro-organisms. White blood cells are colourless because they contain no hemoglobin. They do have a nucleus, and are irregular in shape (Figure 11.8). There are fewer white blood cells than red blood cells. They can change their shape easily, and this allows them to squeeze through the walls of blood vessels into the inter-cellular spaces.

All white blood cells are produced in the bone marrow. Some types are carried in the blood, while others travel to different body tissues. There are about 5000 to 10 000 white blood cells per cubic millimetre of blood in the human body. This number can greatly increase when the body is fighting off infection.

There are several kinds of white blood cells. Two of the most important are macrophages and lymphocytes. Each plays a specific role in the body's immune system. Macrophages are used to destroy pathogens like bacteria. They engulf and digest bacteria as well as debris from our own dead cells (Figure 11.9) .

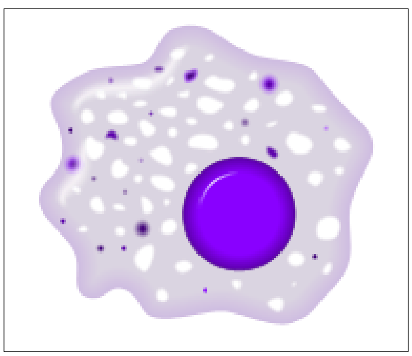


Figure 11.8: A macrophage
Source: Wikipedia

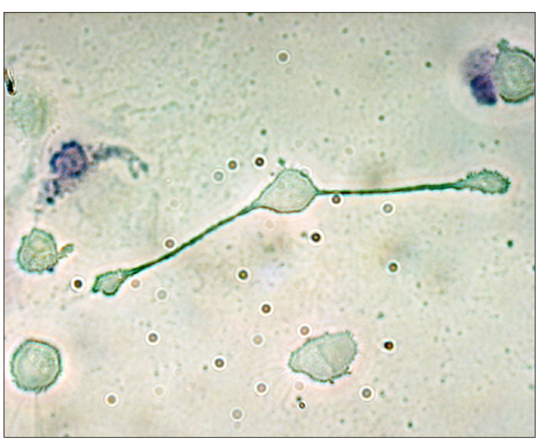


Figure 11.9: Microscope image of a macrophage stretching out to engulf two particles, which may be pathogens
Source: Wikipedia

Lymphocytes do not engulf foreign cells, but help the body identify infections so the immune system can attack the pathogens. Lymphocytes become specialized to identify particular strains of infection, and make up roughly 25% of all white blood cells in the body. They are divided into two classes: T lymphocytes and B lymphocytes. The letters T and B refer to the location in the body where the cells mature: T cells in the thymus, an organ located in the upper chest region, and B cells in the bone marrow. T lymphocytes are further divided into four types. Of these four, helper T lymphocytes are the most important. They direct or manage the body's immune response, not only at the site of infection but throughout the body. HIV, the virus that causes acquired immunodeficiency syndrome or AIDS, attacks and kills helper T lymphocytes. The disease cripples the immune system, leaving the body helpless to fight off infections. As AIDS progresses, the number of helper T lymphocytes drops from a normal amount of 1000 to 0.

Platelets

Platelets are small, disk-shaped fragments of cells (Figure 11.2). They are not cells, but pieces broken off from other cells in the bone marrow called megakaryocytes. Stimulated by the hormone thrombopoietin, platelets break off the megakaryocytes and enter the bloodstream, where they circulate for about 10 days before ending their short lives in the spleen. Platelets number about 250 000 per cubic millimetre of blood.

Platelets help control bleeding in a complex process called hemostasis. When an injury to a blood vessel causes bleeding, platelets stick to the ruptured blood vessel, break open, and release chemicals called clotting factors into the blood, attracting other platelets and eventually forming a temporary blood clot. Through a series of more complex chemical reactions, the plasma protein fibrinogen is converted into fibrin. Fibrin molecules form threads that trap red blood cells and platelets, producing a clot that seals the cut in the blood vessel. Calcium and vitamin K must be present in blood to support the formation of clots. If your blood is deficient in these nutrients, it will take longer than normal for your blood to clot. If these nutrients are completely missing, you could bleed to death. A healthy diet provides most people with enough vitamins and minerals, but vitamin supplements are sometimes needed. In an inherited disorder called hemophilia, one or more clotting factors is missing in the blood. Individuals with this disorder bleed excessively after injury because their blood does not clot properly.

A scab is an external blood clot that we can easily see, but there are also internal blood clots. A bruise is the result of a blood clot. Both scabs and bruises are clots that lead to healing. Some clots can be extremely dangerous. A blood clot that forms inside of a blood vessel can be deadly because it blocks the flow of blood, cutting off the supply of oxygen. A stroke is the result of a clot in an artery of the brain. Without a steady supply of oxygen, the brain cannot function normally. If the oxygen flow is broken, paralysis, brain damage, loss of sensory perceptions, or even death may occur.

Blood Types

Not all blood is identical. If you get a blood transfusion, the transfused blood must match your type; that is, it must have the same antigen proteins as your red blood cells. If you get a transfusion of blood with antigens different from yours (incompatible blood), your immune system destroys the transfused blood cells. This is called a transfusion reaction and can cause serious illness or even death. This is why matching blood type is so important. It also allows complex surgeries to be carried out, because any blood the patient loses during the operation can be replaced with the correct type.

Rhesus factor, or Rh, is another example of an antigen protein that is important in blood matching. There are two blood types for this antigen: Rh-positive and Rh-negative. If a pregnant woman with Rh-negative blood has a baby (fetus) with Rh-positive blood (a possibility if the father has Rh-positive blood), a response called Rh sensitization may occur. Rh sensitization happens when the baby's blood mixes with the mother's blood during pregnancy or delivery. This causes the mother's immune system to make antibodies against the baby's red blood cells in future pregnancies. Depending on when it happens, this can destroy the red blood cells of the baby before or after it is born. If sensitization happens, a fetus or newborn can develop mild to severe problems (called Rh disease or erythroblastosis fetalis). In rare cases, if Rh disease is not treated, the fetus or newborn may die.

Click on the following link for additional information on blood types.

Support Questions

41. What are the general types of materials present in the plasma? Suggested answer

42. If 25 mL of blood is spun in a centrifuge, how many millilitres of plasma can be extracted? Suggested answer

43. List five functions of the cardiovascular system. Suggested answer

44. What are the three main components in the human circulatory system? Suggested answer

45. Why is blood considered a tissue? Suggested answer

46. List three important proteins found in plasma, and describe their function. Suggested answer

47. Match the type of cell to the concentration found in the blood. Suggested answer

Cell type	Concentration (per cubic millimetre of blood)
1. Red blood cell	A. 5000 to 10 000
2. White blood cell	B. 250 000
3. Platelet	C. 5 000 000

48. What is the function of hemoglobin? Suggested answer

49. How does smoking interfere with gas exchange? Suggested answer

50. Explain the difference between a red blood cell and a platelet. Suggested answer

Types of Blood Vessels

Blood vessels transport blood from one part of your body to another, and connect all the body systems. The main types of blood vessels are arteries, capillaries, and veins.

Arteries

Arteries are the blood vessels that carry blood away from the heart to organs throughout the body. The largest artery in the body is the aorta, which extends from the left ventricle of the heart down to the abdomen. Arteries must be able to withstand pressure to deliver blood to the various organs of the body. Arteries consist of three distinct layers: an outer layer of connective tissue and elastic fibres, a middle layer of smooth muscle, and an inner layer of epithelial cells (Figure 11.10). Arterioles are smaller in diameter than arteries, and they are a little less elastic.

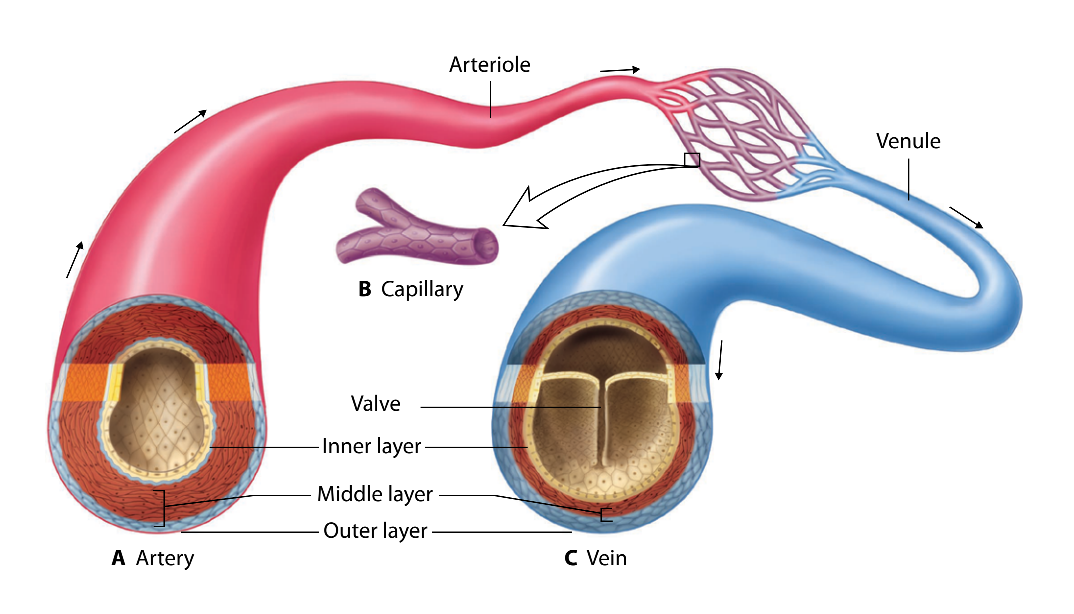


Figure 11.10: Cross-section views of an artery (A), capillary (B), and vein (C)

Source: McGraw-Hill Biology 11

Each time the heart contracts, blood surges from the heart and enters the arteries. The arteries stretch to accommodate the influx of blood. Having muscular and elastic tissue enables the walls of the arteries to handle the high pressure. The pulse you can feel near your wrist and on either side of your neck is created by changes in diameter of the arteries following heart contractions.

Capillaries

Together, the arteries and arterioles carry blood from the heart to even smaller vessels called capillaries (Figure 11.10). Capillaries are the narrowest blood vessels, composed of a single layer of cells, and they are the site of fluid and gas exchange between the blood and body cells. Capillaries are distributed throughout the body tissue. No cell is farther than two cells away from a capillary, and many active cells, such as muscle cells, may be supplied by more than one capillary. The diameter of the capillaries is so small that red blood cells have to travel through them single file, allowing them to pick up carbon dioxide and unload oxygen by diffusion into the tissue cells. Despite its slow movement through the capillaries, a red blood cell will remain in a capillary for only one to three seconds. Branching of capillaries increases the surface area available for diffusion; this branching or network is referred to as a capillary bed. Capillaries can easily be destroyed due to high blood pressure or an impact force, both of which will rupture the capillary's thin wall. Bruising occurs when blood rushes into the space between tissues.

Capillaries provide a bridge between the arteries and veins. Oxygen diffuses from the blood into the surrounding tissue through the thin walls of the capillaries into the body cells. Oxygenated blood, which appears red, assumes a dark blue colour as the oxygen leaves the capillary. The deoxygenated blood collects in small veins called venules, and is carried back to the heart through veins.

Veins

Veins transport blood back to the heart. Capillaries merge and become larger vessels called venules (Figure 11.10). The walls of the venules contain smooth muscle, unlike capillaries. Venules merge into veins which have thinner walls, less muscle, and larger diameters than arteries. These features help them receive blood from the capillary network.

Blood is under much less pressure in the veins compared to the arteries, so circulation back to the heart is much slower. Most veins are below the heart, and must work against gravity to return to the heart. To allow for the movement of blood towards the heart, veins have valves that allow blood to flow in only one direction, steering blood towards the heart, and not allowing blood back in the other direction (Figure 11.11). Skeletal muscles also keep blood flowing in one direction by squeezing blood when they contract.

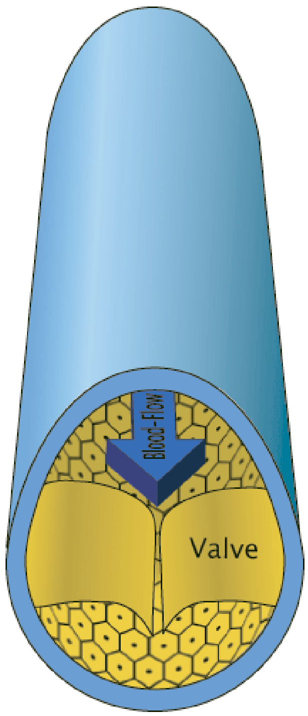


Figure 11.11: Cross-section of a vein, with valve showing how blood can only flow one way.

Source: Wikimedia Commons

Blood flow to the heart is affected by physical activity. If you stand or sit for long periods of time, this prevents skeletal muscles from squeezing blood back to your heart. As a result, veins expand and the blood accumulates in them. If veins are stretched constantly in this manner, they will lose their elasticity and a bulge may appear, resulting in varicose veins. Individuals with sedentary lifestyles are more prone to varicose veins.

Together, arteries, capillaries, and veins constitute a closed system for transporting material and wastes within the body.

Support Questions

51. What roles do the arteries, veins, and capillaries play in the circulation of the blood?

Suggested answer

Structure of the Heart

The heart is a cone-shaped organ about the size of a clenched fist, located just beneath the sternum (breast bone). The heart works as a pump, moving blood around our bodies to nourish every cell. It is composed of cardiac muscle, which is an involuntary striated muscle tissue found only within this organ. The average human heart, beating at 72 beats per minute, will beat approximately 2 to 3 billion times during its lifetime. The heart is enclosed in a sac with a two-layered wall called the pericardium. A lubricating fluid fills the space between the two walls, enabling them to slide past each other as the heart beats.

The walls of the heart are made up of three layers: the superficial layer, called the visceral layer, the middle layer, called the myocardium, and the inner layer, called the endocardium. The heart is divided into four chambers (Figure 11.12).

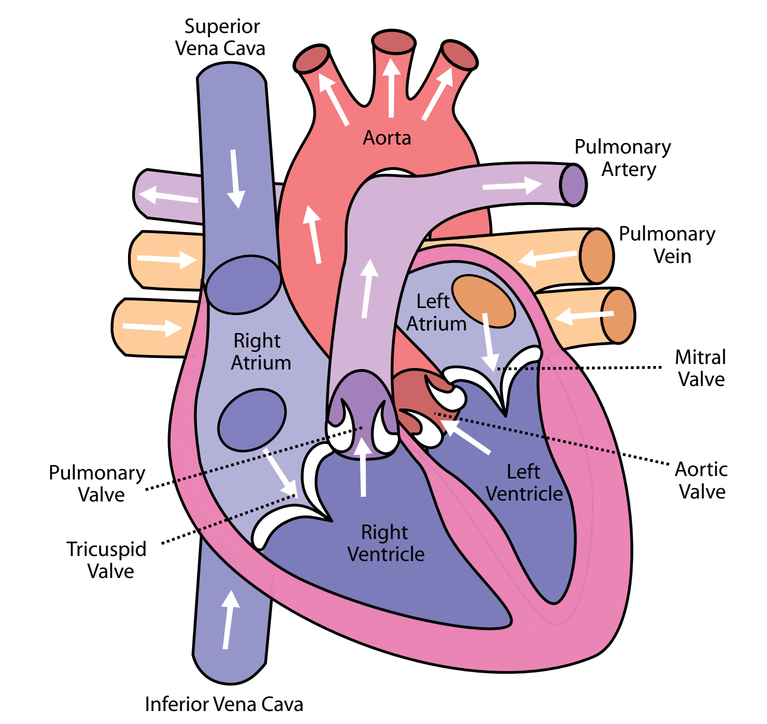


Figure 11.12: Structures of the human heart. The atria are the receiving chambers, and the ventricles are the discharging chambers.

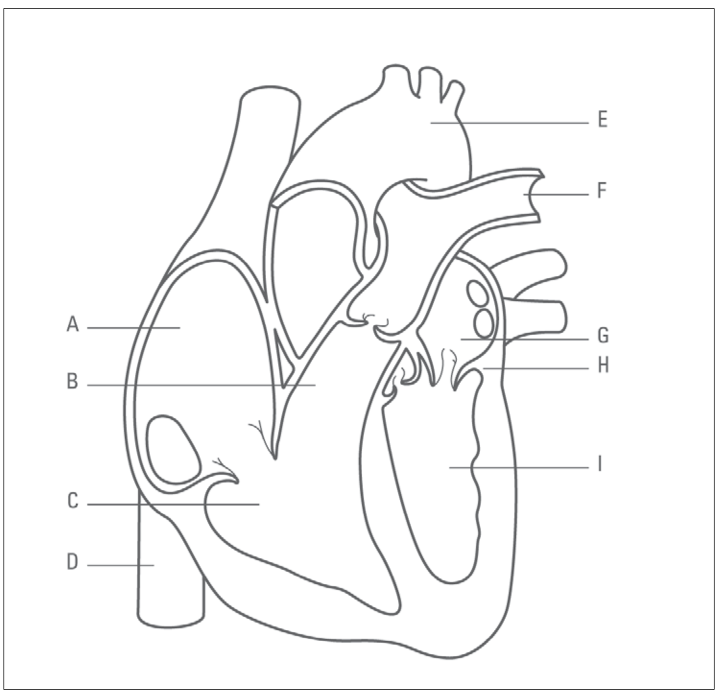
Source: Wikimedia Commons

A septum or partition divides it into a left and right side. Each side is further divided into an upper and lower chamber. The upper chambers, called atria (singular: atrium), are thin-walled. They receive blood entering the heart and pump it into the lower chambers, called ventricles. The walls of the ventricles are thicker and contain more cardiac muscle than the walls of the atria. This enables the ventricles to pump blood out to the lungs and the rest of the body. Blood flows through the heart in one direction, from the atria to the ventricles, and out of the great arteries (the aorta, for example). This is done by four valves: the tricuspid atrioventicular valve, the bicuspid atrioventicular valve (also called the mitral valve), the aortic semilunar valve, and the pulmonary semilunar valve (Figure 11.12).

The right and left atria have relatively thin walls, and function as collection chambers for blood returning to the heart, pumping blood only a short distance to the ventricles. The ventricles have thicker walls, and are much more powerful than the atria. The left ventricle is very thick, as it must be strong enough to pump blood out to all body organs. The right ventricle is thinner because it only has to pump the blood to the lungs, which are relatively near.

Support Questions

52. Name the parts of the heart labelled A to I in the following diagram. Suggested answer



Pulmonary and Systemic Circulation

The flow of blood in the human circulatory system is complex. It can be divided into two circuits: pulmonary and systemic.

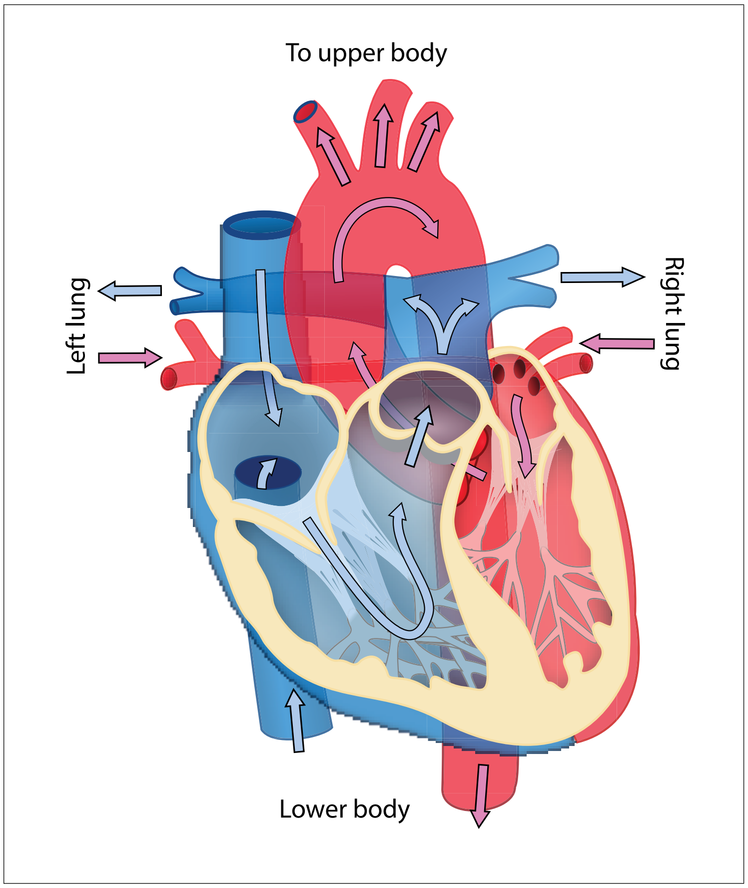


Figure 11.13: Blood flow through the human heart. Pulmonary circulation occurs using the right atrium and ventricle, and systemic circulation occurs using the left atrium and ventricle.

Source: Wikimedia Commons

Circulation through the Body

Pulmonary Circulation

The pulmonary circuit is a low-pressure system where deoxygenated blood enters the heart at the right atrium. Blood then flows to the right ventricle. The tricuspid valve prevents blood from flowing back into the right atrium. From the right ventricle, the blood passes through the cup-like pulmonary semilunar valve and enters the pulmonary trunk (Figure 11.13). From the pulmonary trunk, blood is pumped to both lungs by way of two pulmonary arteries. As blood travels through the capillaries in the lungs, it picks up oxygen and releases carbon dioxide. The oxygenated blood will travel from both lungs through the four pulmonary veins to return to the heart at the left atrium. From the left atrium, the blood enters the left ventricle through the bicuspid valve and is then pumped to the rest of the body through the systemic circuit. The aorta, the largest artery in the body, originates from the left ventricle. It is interesting to note that pulmonary veins contain blood with oxygen while the pulmonary arteries carry blood with no oxygen. This is why biology is so interesting and complex—there are always exceptions to the rules.

Systemic Circulation

The systemic circuit is a high-pressure system that must propel blood with enough force for it to travel to all parts of the body. That is why the left ventricle is more muscular than the right ventricle. When oxygenated blood leaves the left ventricle, it travels through the aortic semilunar valve and enters the aorta (Figure 11.13). As you have already learned, the aorta has many branches throughout the body called arteries, which branch off into arterioles, which in turn branch off into capillaries that enable oxygen to be released to individual cells. The capillaries rejoin as venules, which then gather to form veins. Oxygen-depleted blood from the upper body returns to the heart through the superior vena cava, and oxygen-depleted blood from the lower body returns to the heart through the inferior vena cava. These two large veins empty into the right atrium.

Each time the aorta branches off into arteries, the area through which blood is travelling becomes spread out, and the blood velocity (speed) slows down. The capillaries cover the largest amount of area, so blood velocity is the slowest here, enabling the exchange of nutrients, gases, and waste. When the capillaries rejoin to form venules, the area decreases, and the blood velocity speeds up again.

Recommended activity:

Do an Internet search using the terms “blood circulation” and watch a video showing how blood flows through the human body.

Blood Pressure

Blood pressure is the force of the blood pushing against the walls of the arteries. It is an important measurable aspect of the circulatory system. Blood pressure is related to the rate at which the heart beats. Each time the heart beats (about 60 to 70 times a minute at rest), it pumps blood into the arteries. Your blood pressure is at its highest when the heart beats, pumping the blood. This is called systolic pressure. When the heart is at rest, between beats, your blood pressure falls. This is called diastolic pressure.

Blood pressure is always given as these two numbers, the systolic and diastolic pressures. Both are important. When the two measurements are written down, the systolic pressure is the first or top number, and the diastolic pressure is the second or bottom number. For example, if your blood pressure is 120/80, you say that it is "120 over 80."

Blood pressure changes during the day. It is lowest as you sleep, and rises when you get up. It also can rise when you are excited, nervous, or physically active. Systemic blood pressure is highest in the aorta, which receives all the blood pumped by the left ventricle. As blood travels farther away from the heart, blood pressure decreases. The pressure of arterial blood is largely dissipated when the blood enters the capillaries. Although the diameter of a single capillary is quite small, the number of capillaries supplied by a single arteriole is so great that the total area available for the flow of blood is greatly increased. Therefore, the pressure of the blood as it enters the capillaries decreases. When blood leaves the capillaries and enters the venules and veins, little pressure remains to force it along, so it is helped back to the heart by the squeezing effect of muscles contracting on the veins.

What Affects Blood Pressure?

Alcohol has been shown to raise blood pressure by interfering with the flow of blood to and from the heart. When alcohol courses through your bloodstream, it pushes blood rich in nutrients away from your heart. Studies have shown that it is much more difficult to control blood pressure if you drink heavily.

Smoking also takes a heavy toll on the heart. Nicotine, one of thousands of chemicals found in cigarettes, causes the blood vessels to constrict. This narrowing of the vessels increases blood pressure.

Recommended activity:

Blood pressure is measured by a sphygmomanometer (a blood pressure cuff). If possible, visit your local pharmacy to see if they have a blood pressure testing station. You can take your blood pressure there by following the instructions on the machine, and probably find pamphlets and information about blood pressure too.

Circulation within the Heart Muscle

Just like the rest of the tissues in your body, your heart muscle needs blood to function. Coronary circulation refers to the movement of blood through the tissues of the heart. Many people believe the heart does not need arteries supplying it with blood, since blood is passing though it all the time. However, the truth is that the blood passing through the chambers of the heart does not supply the heart muscle itself, because the inside of the chambers is lined with the endocardium. But even if this lining did not exist, the blood supply provided simply by contact between the passing blood and the inside of the muscle walls would not be nearly enough, because the heart is the hardest-working muscle in the body. To supply it with the oxygen it needs, coronary circulation (Figure 11.14) provides an amazing amount of capillaries called cardiomyocytes to the cardiac muscle.

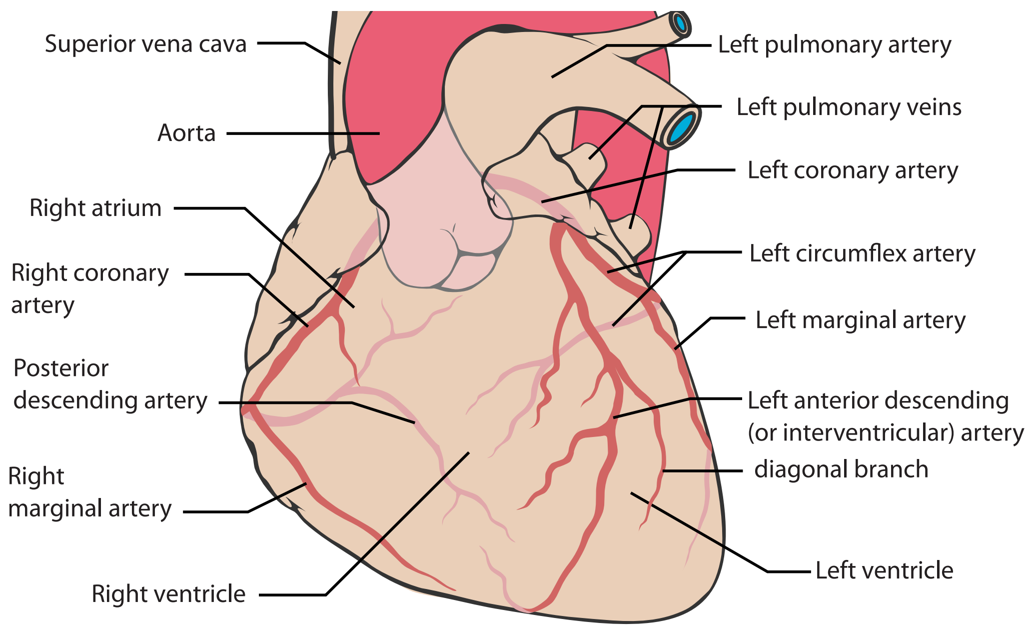


Figure 11.14: Coronary circulation. This diagram illustrates blood flow to the muscles of the heart itself, not inside the chambers.

Source: Wikipedia

Coronary Arteries

There are two major coronary arteries: the right and the left (Figure 11.14). These two arteries branch out of the aorta immediately after the aortic valve.

The right coronary artery splits into the right marginal artery, which feeds blood into the right ventricle, and the posterior descending artery, which supplies the right ventricle.

The left coronary artery is notably larger than the right coronary artery because it feeds the left side of the heart including the left ventricle, which, as a result of its more powerful contractions, requires a more vigorous blood flow. The left coronary artery splits into the anterior descending (or interventricular) artery and the circumflex artery. The anterior descending artery runs towards the middle of the heart, providing blood for both of the ventricles and the ventricular septum. The circumflex artery, on the other hand, follows the groove between the left atrium and the left ventricle, providing blood supply to both of these chambers until it reaches and joins with the right coronary artery in the posterior of the heart.

The coronary arteries are especially subject to blockage and narrowing, which can cause a depletion of blood to certain parts of the heart, possibly causing a heart attack. Angina (chest pains) occurs when too little oxygen reaches the heart because of blockages in the coronary arteries.

How the Heart Contracts

First the atria contract together, followed by the ventricles. Contraction is initiated at the sinoatrial (SA) node, the small cluster of cardiac muscle cells embedded in the upper wall of the right atrium. The cells of the SA node (labelled #1 on Figure 11.15) act as a pacemaker for the rest of the heart. A spontaneous depolarization wave (an electric discharge in the cell membranes) travels through all fibres of both atria. After a delay of 0.1 seconds, this depolarization crosses towards the left ventricle through the atrioventricular (AV) (labelled #2 in Figure 11.15) node made of cardiac muscle fibres. These fibres connect to specialized fibres in the left ventricle called the Bundle of His. The Bundle of His fibres divide into fibres that reach both ventricles. In each ventricle, there are Purkinje fibres that initiate the contraction there.

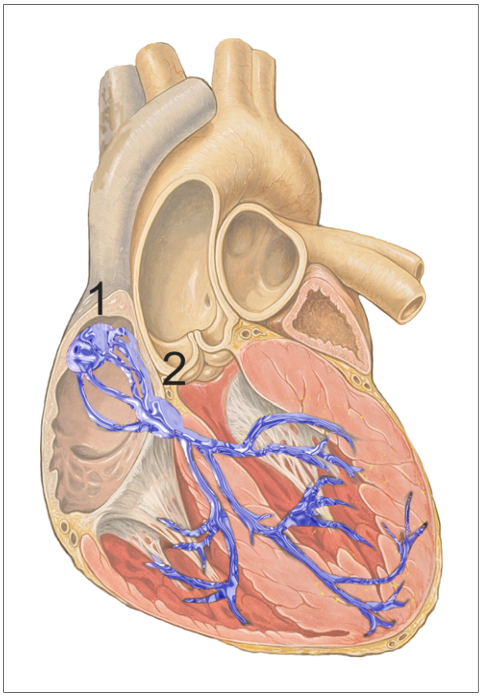


Figure 11.15: Diagram showing the conduction system in the heart
Source: Wikipedia

Support Questions

53. What cells within the heart act as a pacemaker? Suggested answer

54. A friend asks you about angina. Write an email (or letter) to them explaining what angina is. Include some suggestions on how diet can improve overall cardiovascular health.

Suggested answer

The Cardiac Cycle and Heart Sounds

The cardiac cycle is the cycle of events that occurs as the heart contracts. There are two phases of the cardiac cycle. In the diastole phase, the heart ventricles are relaxed, and the heart fills with blood. In the systole phase, the ventricles contract and pump blood into the arteries.

The sequence of events in the diastole phase is as follows:

1. the tricuspid and bicuspid atrioventricular valves are open;
2. the sinoatrial (SA) node, which starts cardiac conduction, contracts causing atrial contraction;
3. the atria empty blood into the ventricles; and
4. the semilunar valves close, preventing backward flow into the atria.

During the systole phase, the ventricles contract, pumping blood into the arteries. The right ventricle sends blood to the lungs via the pulmonary artery. The left ventricle pumps blood to the aorta.

The sequence of events in the systole phase is as follows:

1. the ventricles contract;
2. the atrioventricular valves close and semilunar valves open; and
3. blood flows to either the pulmonary artery or aorta.

One cardiac cycle is completed when the heart fills with blood and the blood is then pumped from the heart. The audible sounds that can be heard from the heart are made by the closing of the heart valves. These sounds are referred to as the "lub-dub" sounds. The "lub" sound is made by the contraction of the ventricles and the closing of the tricuspid and bicuspid atrioventricular valves. The "dub" sound is made by the pulmonary and aortic semilunar valves closing. This "dub" sound is typically heard as a sharp snap because the semilunar valves tend to close much more rapidly than the atrioventricular tricuspid and bicuspid valves. Because diastole occupies more time than systole, a brief pause occurs after the second heart sound when the heart is beating at a normal rate. Therefore, the pattern that one hears is "lub-dub" pause, "lub-dub" pause, and so on.

Figure 11.16: A stethoscope

Activity: Making a Stethoscope

Background Information

The stethoscope was invented in 1816 to assist in diagnosing cardiovascular issues. Although we have developed more advanced tools over the years, doctors still routinely use the stethoscope.

Purpose

To build your own stethoscope and listen to your cardiac cycle

Materials

- 2 small plastic kitchen funnels, with an opening no larger than 3 inches in diameter and a spout no larger than ½ inch in diameter. Funnels can be purchased at discount stores or grocery stores.
- 1 piece of rubber or vinyl tubing, 18 inches long, with a diameter of ⅝ inch or wide enough to fit snugly over the funnel spout. Tubing can be purchased at hardware stores (look in the pond/garden or plumbing departments).

Procedure

1. Insert the spout of each funnel into either end of the tubing as shown in Figure 11.17, below.
2. Bring the funnel from one end of the tubing to your ear while placing the other funnel over your chest.
3. Listen to your heart. You should be able to hear it beating, as the funnels will capture sound and send the vibrations up the tube to the ear.

Figure 11.17: A homemade stethoscope

Activity: The Pulse of Life

Background Information

Every time the lower chambers of the heart contract, the blood in the left ventricle rushes upward into the aorta; it quickly speeds away from the heart, causing the aorta to expand as it passes. As the blood races along, some of it pushes into the first artery that branches off from the aorta. Some of the blood enters the next artery. The blood from each contraction of the heart produces a bulge in the artery. We call that bulge a pulse. One pulse equals one heartbeat.

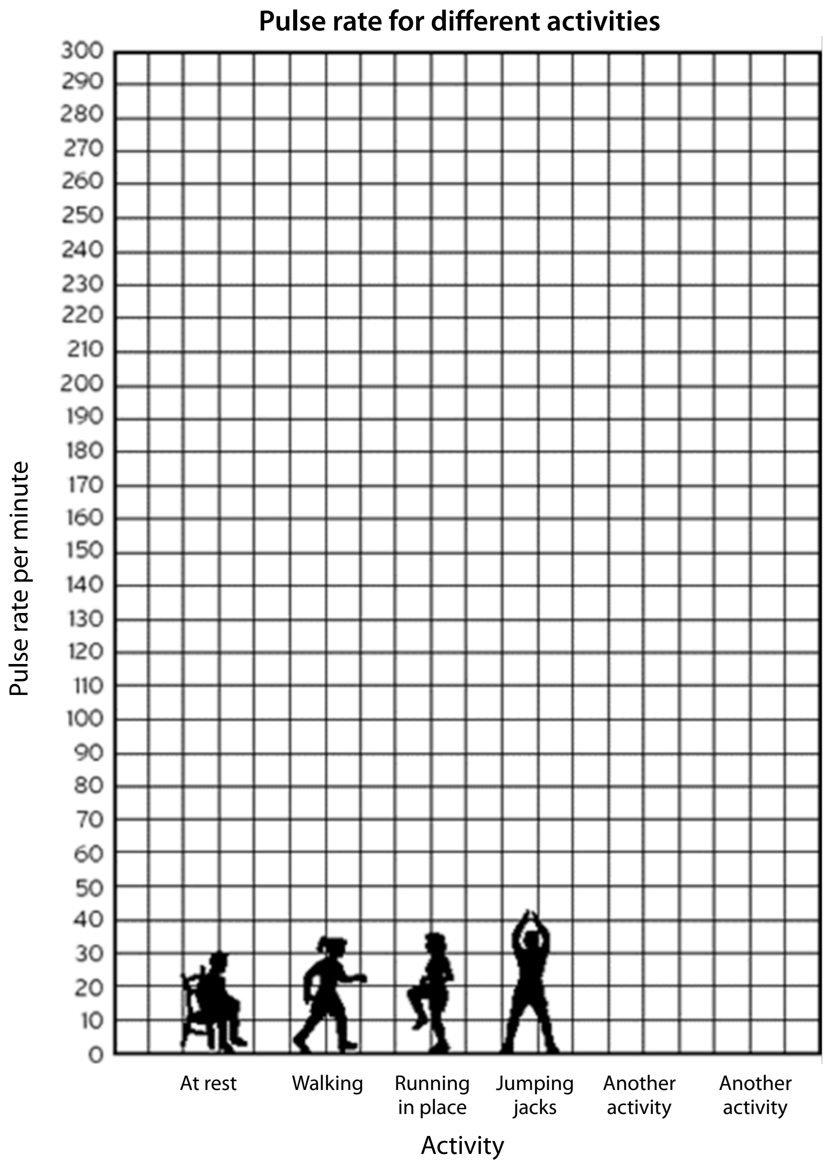
The pulse can be felt anywhere an artery passes close to the skin. Common places to feel a pulse include the wrist, neck, temple, behind the knees, and on top of the foot.

Purpose

To locate and monitor your pulse after various types of activities

Procedure

1. Locate your pulse points either on your wrists or neck. Place your right index and middle finger on the palm side (palm towards the ceiling) of your left wrist. On the neck, the pulse point is located beneath the ear and jawbone.
2. Sit down and rest for a minute. Then take your pulse and count the number of beats in 15 seconds. Multiply this by four (there are 60 seconds in one minute; $15 \times 4 = 60$). This is how many times the heart beats in one minute. Enter your calculated value as the "at rest" heart rate on the chart included below.
3. Do some light exercise such as walking, running in place, jumping jacks, stair climbing, or other exercise for one minute. Stop and count your pulse again over 15 seconds. Repeat this for two or three exercises of varying difficulty. Calculate the heart rate for each activity, and enter those values on the chart.
4. Answer Support Question 55, below.



Support Questions

55. Which activity increased your heart rate the most? Why?

Suggested answer

Key Questions

Now work on your Key Questions in the online submission tool. You may continue to work at this task over several sessions, but be sure to save your work each time. When you have answered all the unit's Key Questions, submit your work to the ILC.

(17 marks)

32. What is the difference between pulmonary and systemic circulation? **(4 marks: 2 marks for each definition)**

33. The following is a list of different blood pressures taken at various points along the circulatory system of one individual:

Point 1: 70/40 mm Hg

Point 2: 90/60 mm Hg

Point 3: 150/105 mm Hg

a) Which point likely represents the blood pressure at the aorta? Explain. **(2 marks: 1 mark for the correct point, 1 mark for the explanation)**

b) Why would the pulmonary artery pressure be less than the pressure in the aorta? **(1 mark)**

c) How does blood pressure change as one moves further away from the heart? Why? **(2 marks: 1 mark for the change, 1 mark for the explanation)**

34. A family member who smokes has had a heart attack. Write an email message (or letter) to them that explains what a heart attack is **(4 marks)** and describe two lifestyle changes they can make to improve their overall cardiovascular health. Be sure to explain how these lifestyle changes can improve their health. **(4 marks)**

Now go on to Lesson 12. Send your answers to the Key Questions to the ILC when you have completed Unit 3 (Lessons 9 to 12).