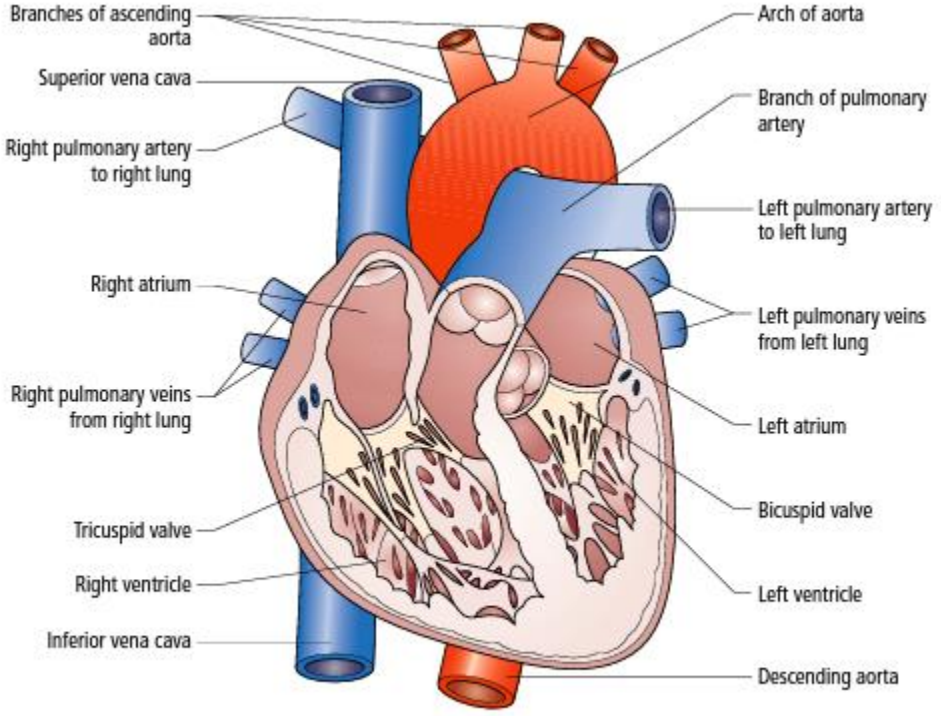
Cardiovascular system

The cardiovascular system is the name given to the system by which blood is circulated around the body and it includes the heart, blood and blood vessels.

Heart

The heart is the centre of the cardiovascular system and is the driving force of the blood circulatory system because it is responsible for pumping the blood around the body. It is situated in the thoracic cavity between the lungs contained within a membrane called the pericardial sac and protected by the sternum. The centre of the heart lies centrally in the body but slightly angled to the left; in addition, the left-hand side of the heart is larger, leading to the misconception that the heart is on the left-hand side of the chest.

The heart is made of cardiac muscle tissue and contains four hollow chambers through which the blood is pumped by the contraction of the cardiac muscle tissue. The blood flow is controlled by the opening and closing of valves contained within the organ and it is the sound of these valves closing that give rise to the heart beat.

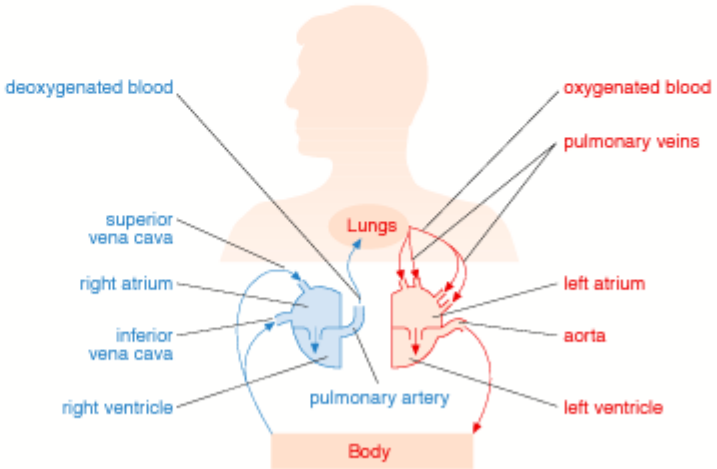


△ Structure of the heart

Blood circulation

As mentioned previously, blood is moved along the vessels by the pumping action of the heart. The heart has four chambers: right atrium, right ventricle, left atrium and left ventricle. A wall separates the left and right sides and valves that open and close separate the top chambers from the bottom. The tricuspid valve separates the right atrium from the right ventricle; the bicuspid or mitral valve separates the left atrium and ventricle.

The valves allow blood to flow from the top atria into the bottom ventricles. When the heart contracts or beats, the right side beats just before the left and this pushes blood out of the ventricles into the blood vessels. The aortic valve and pulmonary valve in the vessels prevent the blood from reversing back into the heart so that when it relaxes blood is drawn into the atrium. The vessels from the lower right ventricle carry blood to the lungs where it gives up carbon dioxide and takes on fresh oxygen. It then returns to the heart, entering the top left atrium. The blood passes through the mitral valve into the bottom left ventricle where it is pumped out along a large vessel called the aorta, which supplies the whole body with blood. To complete the journey, blood returns from the areas of the body through the inferior and superior vena cava to the top right chamber to begin the cycle again.



△ Simplified diagram of the blood circulation

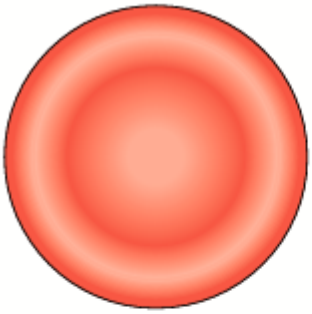
Blood circulatory systems

There are a number of blood circulatory systems throughout the body:

- The pulmonary circulation system is the blood supply between the lungs and the right atrium of the heart, carrying deoxygenated blood which is then replaced with oxygenated blood by an interchange of gases within the lungs.
- Systemic (general) circulation system is the oxygenated blood supply to the body from the left ventricle of the heart omitting the pulmonary circulation.
- Coronary circulation system is the circulation concerned with the heart itself as a working organ. Blood vessels called the coronary arteries branch off the aorta almost immediately as it leaves the heart to supply freshly oxygenated blood to the cardiac muscle of the heart in order for it to contract.
- Portal/hepatic circulation system is part of the general blood circulation but specific from the digestive system to the liver where the latter metabolises and maintains safe levels of glucose, fats and protein in the blood before it is returned to the heart.

Blood

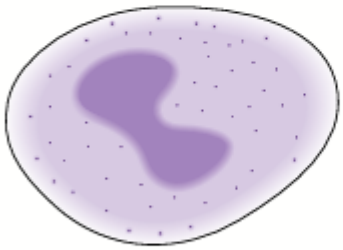
Blood is a liquid that is pumped by the heart through the blood vessels. There are approximately 5–6 litres of blood in an average-sized adult. Around 55 per cent of blood is made up of a yellowish/clear liquid called plasma, which consists of mainly water (90–92 per cent) in which mineral salts such as sodium chloride, nutrients from digestion such as amino acids and waste products are dissolved. Blood also transports hormones, antibodies, enzymes and proteins around the body. The other 45 per cent of blood is made up of red and white blood cells or corpuscles and thrombocytes.



△ Erythrocyte

Red blood cells (erythrocytes)

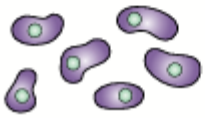
These are small biconcave discs with no nucleus which contain a protein called haemoglobin. They are capable of combining with oxygen to make oxy-haemoglobin, for which iron and vitamin B12 are required. Arterial blood containing a high percentage of oxygen will appear bright red in colour; whereas venous blood is a much darker red.



△ Leucocyte

White blood cells (leucocytes)

Leucocytes are large, irregular-shaped cells that fight infection. They are produced in bone marrow and lymph nodes. They fight against disease and infection by destroying micro-organisms and ingesting bacteria, dead tissues and foreign bodies that may enter the body.



△ Thrombocyte

Thrombocytes (platelets)

Thrombocytes are responsible for blood clotting, preventing entry of micro-organisms into the body.

Functions of blood

Transport:

- Oxygen is carried from the lungs to all living tissues.
- Carbon dioxide is carried from the tissues to the lungs to be exhaled.
- Nutrients from the digestive system are carried to the tissues.
- Excess water is taken from the tissues to the kidneys for excretion.
- Waste products from cell activity are taken to the kidneys or skin for excretion.
- Hormones released from endocrine glands are carried to their target organs.

Defence:

- White blood cells are taken to a site of injury to fight invading bacteria and so stop infection.
- Other white blood cells produce antibodies that fight diseases that have entered the bloodstream.
- Blood proteins and platelets combine at the site of injury or damage to form a clot that plugs the wound, preventing blood loss and the invasion of bacteria. The clot hardens to form a scab, which protects the area while new tissue grows underneath.

Heat distribution and regulation:

- Body heat produced in the organs and muscles of the body is distributed around the body to maintain a temperature of 37°C.
- The dilation of the blood capillaries in the skin allows excess heat to be lost to the atmosphere. When the temperature of the body needs to be maintained, the blood capillaries constrict, preventing blood from nearing the surface of the skin.

Blood vessels

Blood is transported in a continuous network of vessels around the body. Blood is carried away from the heart in arteries and returns to the heart in veins.

The circulation away from the heart is very successful as the blood is under the most pressure in the arteries but there comes a problem when the blood tries to return to the heart. This is because there is reduced pressure in veins and, in the case of the legs, the blood needs to travel against the force of gravity. The blood circulation needs help from the contraction of nearby muscles to force the blood upwards. The important muscles in this are the gastrocnemius and the soleus. Blood is also further pushed upward when the diaphragm contracts and flattens during inhalation. This pushes the abdominal organs down, reducing the size of the cavity and causing blood to be pumped upward. As well as this, a suction pressure within the chest is created by inhaling and this draws blood from the lower parts of the body to the heart.

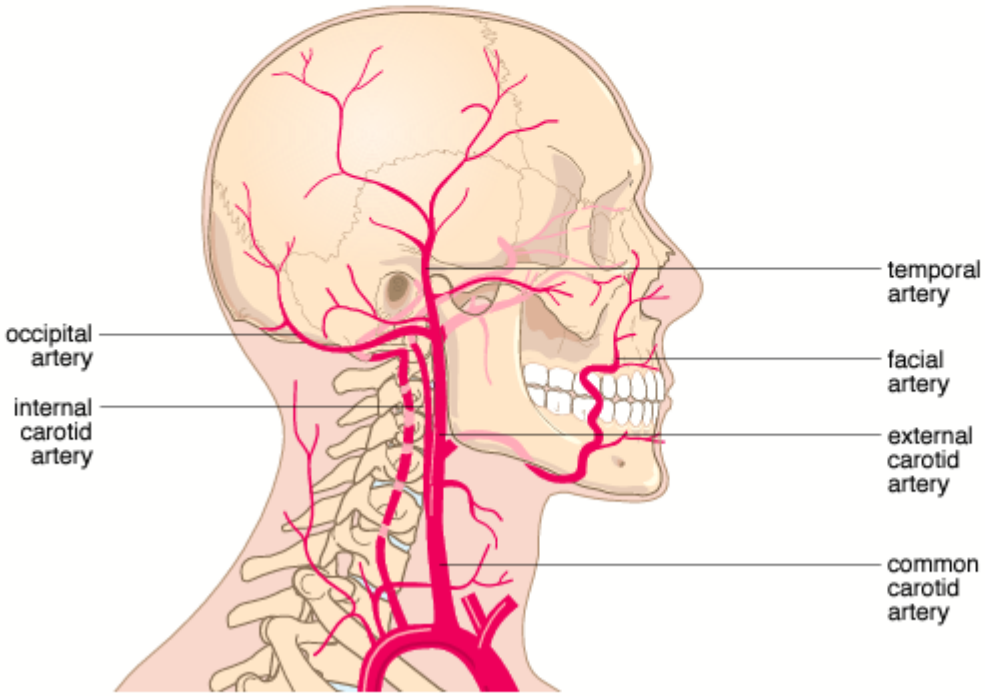
Structure and function of blood vessels

There are several types of blood vessels:

- Arteries: thick-walled blood vessels which transport blood away from the heart, carrying oxygen and nutrients to the cells and tissues. They vary in size but all have the same structure, with the walls consisting of involuntary muscle tissue that expands as blood is pumped into the artery. The artery then recoils, pushing the blood further on its way round the body, helping the blood to circulate around the body. The pulse or heart beat can be felt within the walls of these vessels and they assist in the maintenance of blood pressure.
- Arterioles: these are smaller arteries that extend from arteries and are formed mainly from muscular tissue, which are controlled by adrenaline from the sympathetic nervous system. These vessels are able to close off the supply of blood to some extent, for example from the skin tissues in order to conserve heat within the centre of the body. The arterioles open up again in conditions of warmth to allow heat from the centre of the body to reach the skin, where cooling will take place.
- Capillaries: the arterioles split up into a number of minute vessels known as capillaries. They are very fine vessels with walls that are one cell thick, which allows for the exchange of food and waste material, oxygen and carbon dioxide to and from the body cells. This is the only part of the circulation where exchange can take place. The dilation and contraction of these minute vessels help to regulate the body temperature and control the passage of blood in different parts of the body according to need.
- Veins: these are thinner-walled, muscular tubes which take blood away from the tissues and back to the heart. They have valves which prevent back-flow of blood. There is usually more blood than the amount needed for the circulation and the larger veins store this blood.
- Venules: these are small venous vessels which carry blood from capillaries to veins.

Blood vessels of the head, neck and face

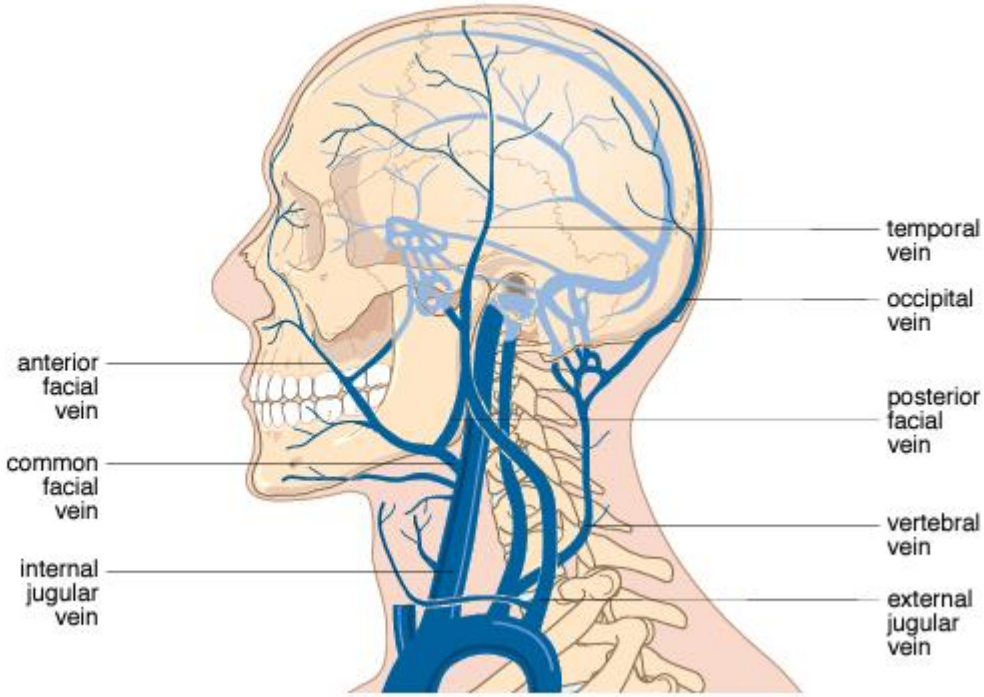
Oxygenated blood leaves the heart through the aorta. This large vessel stretches upwards in front of the heart and then arches over to run down behind it. As it does so, two smaller arteries branch off and travel upwards on either side of the neck. Once in the neck area they are called the common carotid arteries and as they near the head they divide to form the external and internal carotid arteries. At the level of the ear, the internal carotid disappears through a hole in the skull to supply blood to the brain and eyes. The external carotid artery splits further to supply blood to the skin and muscles of the face and scalp. There are three main branches, called the facial artery, the temporal artery and the occipital artery and they supply blood to the areas after which they are named.



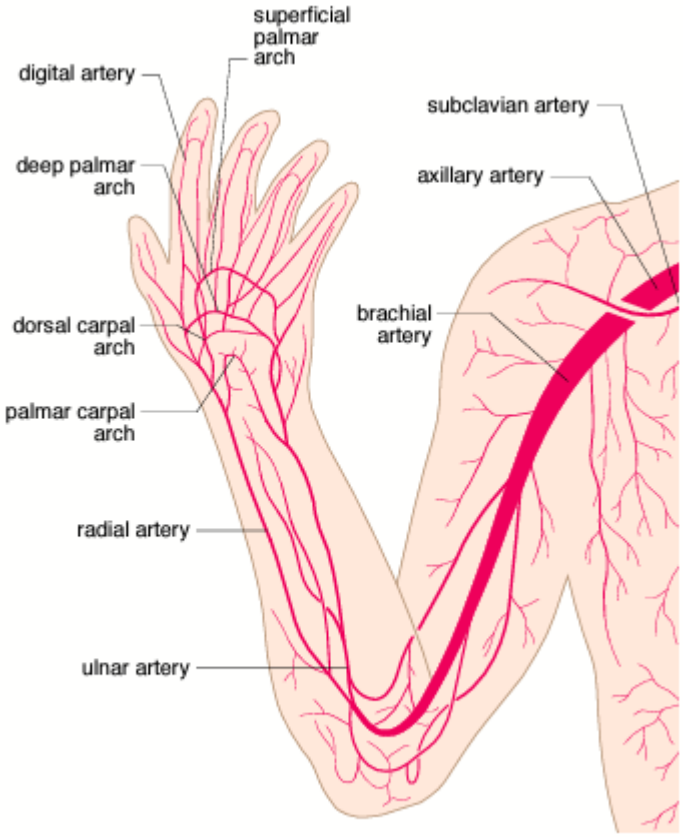
△ Arteries of the head, neck and face

Once the exchange of nutrients for waste products and oxygen for carbon dioxide has occurred in the capillaries the blood begins its journey back to the heart. The veins returning the blood back to the heart from the head and neck are called the internal and external jugular veins. The former exits the skull through a hole near the ear as before and the external jugular vein drains blood from the facial, temporal and occipital veins.

The internal and external jugular veins do not join together but run down the neck independently to join a large vein called the superior vena cava, which eventually returns the blood to the heart.



△ Veins of the head. neck and face



△ Arteries of the arm and hand

Blood vessels of the arm and hand

The blood supply to the arm begins with the subclavian artery, which branches off the aorta. The subclavian artery becomes the axillary artery and then the brachial artery, which runs down the inner aspect of the upper arm to about 1cm below the elbow, where it divides into the radial and ulnar arteries. The radial artery runs down the forearm next to the radius bone to the wrist, where it nears the surface and can be felt as the radial pulse. It continues over the carpals to pass between the first and second metacarpals into the palm. The ulnar artery runs down the forearm next to the ulna bone, across the carpals into the palm of the hand. Together they form two arches in the hand – the deep and superficial palmar arches. From all these arteries branch others to supply blood to the structures of the upper arm, forearm, hand and fingers.

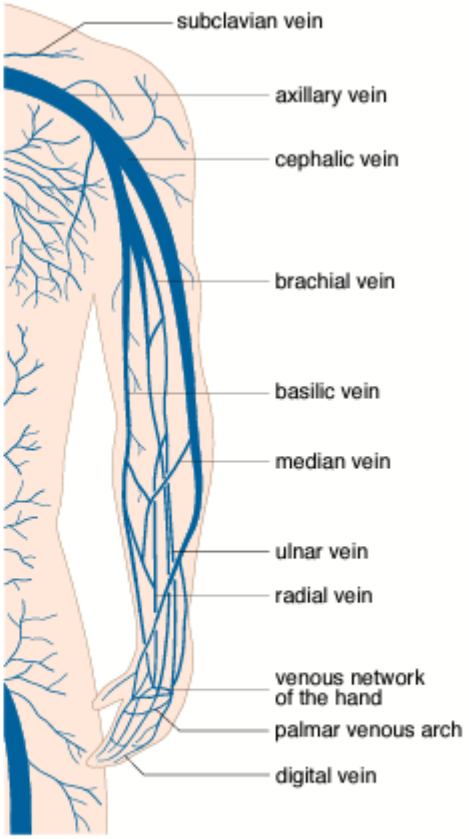
The venous return of blood from the hand begins with the palmar arch and plexus, which is a network of capillaries present in the palm. Three veins carry the deoxygenated blood up the forearm: the radial vein, the ulnar vein and

the median vein. The former two run parallel to the bones of the same name, the latter runs up the middle. Just above the elbow, the radial and ulnar veins join to become the brachial vein, and the median vein joins the basilic vein, which originates just below the elbow along with the cephalic vein. As the veins continue over the elbow they link to form a network that eventually divides, with the basilic vein joining the brachial vein, which then becomes the axillary vein. The cephalic vein travels up the arm separately and becomes the subclavian vein in the upper chest.

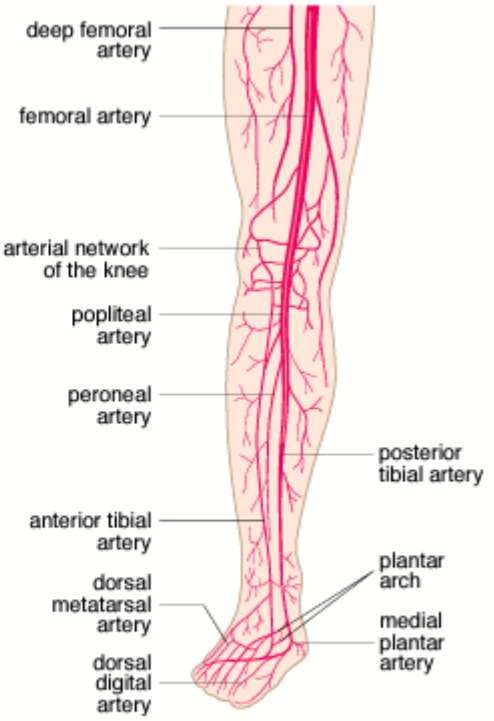
Blood vessels of the leg and foot

The aorta travels down the length of the trunk to the lower abdomen where it divides into two arteries which supply either leg. The artery in the thigh is called the femoral artery, named after the bone of the thigh. At the knee the femoral artery becomes the popliteal artery, which divides into two below the knee. One of these arteries runs down the front of the lower leg and is called the anterior tibial artery, while the other runs down the back and is known as the posterior tibial artery. This artery divides at the inside of the ankle, becoming the medial plantar artery on the inside of the foot and the plantar arch on the sole of the foot. The anterior tibial artery becomes the dorsal metatarsal artery on top of the foot.

There is a network of veins in the foot that become the dorsal venous arch on top of the foot. This travels the inside of the foot to the ankle, where it becomes the small saphenous vein. It continues up the back of the whole leg to the thigh, where it is known as the great saphenous vein. Two small veins called the anterior tibial veins travel up the front of the lower leg while two veins, the posterior tibial veins, run up the back. These four veins converge just below the knee to become the popliteal vein at the back of the knee and then eventually the femoral vein in the thigh. The great saphenous vein and the femoral vein join at the groin and return to the heart via the iliac vein inferior vena cava.



△ Veins of the arm and hand

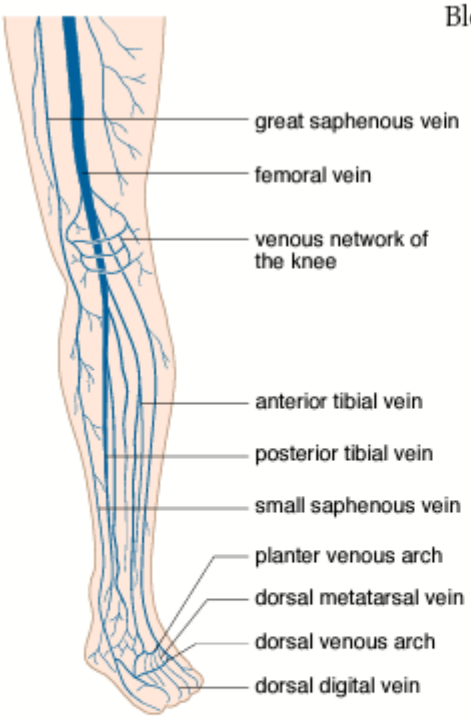


△ Arteries of the leg and foot

Blood pressure

Blood pressure is the force which is exerted on the walls of the blood vessels by the blood. It varies between the types of vessel, the highest being within arteries and the lowest in capillaries.

Blood pressure is measured using a sphygmomanometer and for medical purposes is measured in an artery, commonly the brachial artery in the arm. The pressure is measured by inflating a cuff placed around the arm which temporarily prevents the blood from flowing. The pressure is represented by two figures, one when the heart muscle contracts – systolic pressure – and the other when the heart is relaxing – diastolic pressure. A healthy adult will have a blood pressure of 120/80 mmHg (or millimetres of mercury).



△ Veins of the leg and foot

Blood pressure is affected by:

- cardiac output: blood pressure increases with exercise
- vasoconstriction: hormones such as adrenaline will cause the blood vessels to constrict, increasing blood pressure
- blood volume: during extensive blood loss, blood pressure is lost. The opposite is true of oedema because swelling increases blood pressure
- viscosity of the blood: the thicker the blood the higher the blood pressure; sitting still for several hours, such as when on an aeroplane, will cause the blood pressure to rise
- elasticity of the vessel walls: a loss of elasticity in blood vessels causes hardening of the artery walls and an increase in blood pressure.

Changes in blood pressure can be caused by:

- a decrease in the volume of blood caused by excessive blood loss, resulting in a drop in blood pressure
- an increase in volume such as that caused by fluid retention will cause a rise in blood pressure
- an increase in body temperature and increased activity and exercise. Stress will also cause an increase in blood pressure as the blood vessels constrict
- a period of inactivity such as relaxing and during treatments such as massage, both of which will cause blood pressure to drop.

Other systems connected to the cardiovascular system

The liver has numerous functions but its connection to the cardiovascular system is that it:

- breaks down worn out blood cells and destroys micro-organisms
- stores iron from broken down red blood cells.

The spleen assists the cardiovascular system by:

- destroying old and abnormal erythrocytes, leucocytes, platelets and microbes
- producing lymphocytes, namely B- and T-lymphocytes, in response to invasion of the body by disease-forming micro-organisms
- producing blood cells when needed.

Disorders of the cardiovascular system

Disease/disorder	Cause	Description
Angina	Obstruction within the coronary arteries	Chest pain associated with a lack of oxygen to the heart. The sufferer experiences pressure, heaviness, tightness, squeezing, burning or choking sensations
Hypertension (high blood pressure)	Sedentary lifestyle, obesity, smoking and stress all contribute to hypertension	Heart is placed under exertion as it is more difficult to pump blood around the body
Hypotension (low blood pressure)	Shock, blood loss; can indicate serious heart, endocrine or neurological disorder	Symptoms include dizziness and fainting. In someone who exercises frequently it can be a sign of good health
Stroke	Inadequate supply of blood to the brain because of a blockage in the blood vessels such as a clot or when a blood vessel in the brain bursts	Symptoms vary depending on the part of the brain affected but typically there is loss of sensation and movement to one side of the face and/or body
Deep vein thrombosis (DVT)	Blood clot in the deep veins of the leg normally but can affect the arm. Can occur after surgery and long periods of immobilisation, associated with obesity, injury or advanced age and on long haul flights	Affected limb will be painful, swollen, red and warm to the touch
Varicose veins	Can be hereditary but contributing factors are obesity, pregnancy, ageing, prolonged standing, leg injury, abdominal straining, and crossing legs at the knees or ankles	Condition affecting the superficial veins of the legs, although can affect any vein. As the walls are thinner, they stretch and the valves in the veins no longer meet, allowing blood returning up the leg to accumulate and stagnate in the vein. The thin walls then balloon, giving rise to the appearance of enlarged and bulbous blue/purple veins