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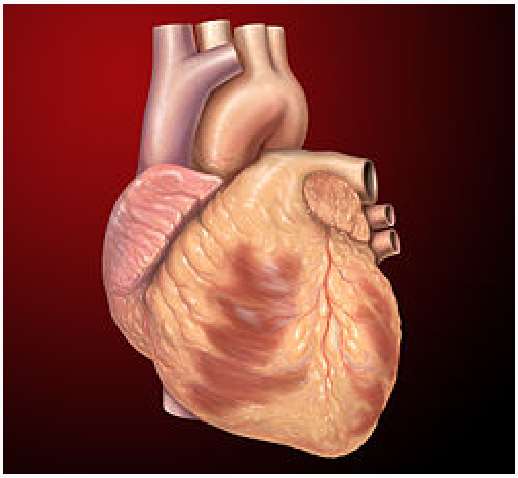
Heart

From Wikipedia, the free encyclopedia

This article is about the internal organ. For other uses, see Heart (disambiguation).

Heart	
	
The human heart	
Details	
System	Circulatory
Artery	Aorta,[a] pulmonary trunk and right and left pulmonary arteries[b] Right coronary artery, left main coronary artery[c]
Vein	Superior vena cava, inferior vena cava,[d] right and left pulmonary veins,[e] great cardiac vein, middle cardiac vein, small cardiac vein, anterior cardiac veins.[f]
Nerve	Accelerans nerve, Vagus nerve
Identifiers	
Latin	*cor*
Greek	*kardía (καρδία)*
MeSH	*A07.541*
TA	A12.1.00.001
FMA	7088
Anatomical terminology	
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The **heart** is a muscular organ in humans and other animals, which pumps blood through the blood vessels of the circulatory system.[1] Blood provides the body with oxygen and nutrients, and also assists in the removal of metabolic wastes.[2] The heart is located in the middle compartment of the mediastinum in the chest.[3]

In humans, other mammals, and birds, the heart is divided into four chambers: upper left and right atria; and lower left and right ventricles.[4][5] Commonly the right atrium and ventricle are referred together as the *right heart* and their left counterparts as the *left heart*.[6] Fish in contrast have two chambers, an atrium and a ventricle, while reptiles have three chambers.[5] In a healthy heart blood flows one way through the heart due to heart valves, which prevent backflow.[3] The heart is enclosed in a protective sac, the pericardium, which also contains a small amount of fluid. The wall of the heart is made up of three layers: epicardium, myocardium, and endocardium.[7]

The heart pumps blood through the body. Blood low in oxygen from the systemic circulation enters the right atrium from the superior and inferior

Normal heart sounds
Normal heart sounds as heard with a stethoscope

Авар
Aymar aru
Azərbaycanca
বাংলা
Bahasa Banjar
Bân-lâm-gú
Basa Banyumasan
Башҡортса
Беларуская
Беларуская (тарашкевіца)
Bikol Central
Български
Bosanski
Brezhoneg
Буряад
Català
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Cebuano
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venae cavae and passes to the right ventricle. From here it is pumped into the pulmonary circulation, through the lungs where it receives oxygen and gives off carbon dioxide. Oxygenated blood then returns to the left atrium, passes through the left ventricle and is pumped out through the aorta to the systemic circulation–where the oxygen is used and metabolized to carbon dioxide.[8] In addition the blood carries nutrients from the digestive tract to various organs of the body, while transporting waste to the liver and kidneys. Normally with each heartbeat the right ventricle pumps the same amount of blood into the lungs as the left ventricle pumps to the body. Veins transport blood to the heart and carry deoxygenated blood - except for the pulmonary and portal veins. Arteries transport blood away from the heart, and apart from the pulmonary artery hold oxygenated blood. Their increased distance from the heart cause veins to have lower pressures than arteries.[2][3] The heart contracts at a resting rate close to 72 beats per minute.[9] Exercise temporarily increases the rate, but lowers resting heart rate in the long term, and is good for heart health.[10]

Cardiovascular diseases (CVD) are the most common cause of death globally as of 2008, accounting for 30% of deaths.[11][12] Of these more than three quarters follow coronary artery disease and stroke.[11] Risk factors include: smoking, being overweight, little exercise, high cholesterol, high blood pressure, and poorly controlled diabetes, among others.[13] Diagnosis of CVD is often done by listening to the heart-sounds with a stethoscope, ECG or by ultrasound.[3] Specialists who focus on diseases of the heart are called cardiologists, although many specialties of medicine may be involved in treatment.[12]

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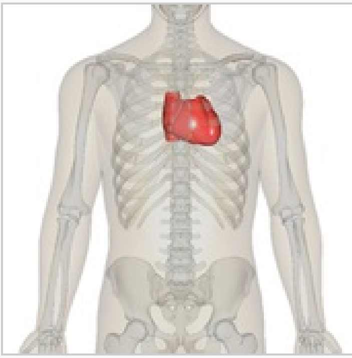
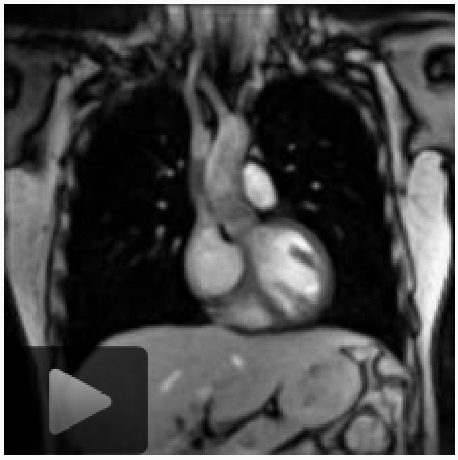
Structure



The human heart is in the middle of the thorax, with its apex pointing to the left.[14]



Real-time MRI of the human heart

The heart is situated in the middle mediastinum behind the breastbone in the chest, at the level of thoracic vertebrae T5-T8. The largest part of the heart is usually slightly offset to the left side of the chest (though occasionally it may be offset to the right) and is felt to be on the left because the left heart is stronger, since it pumps to all body parts. Because the heart is between the lungs, the left lung is smaller than the right lung and has a cardiac notch in its border to accommodate the heart.

The heart is supplied by the coronary circulation and is enclosed in a double-membraned sac–the pericardium. This attaches to the mediastinum, providing anchorage for the heart.[15] The back surface of the heart lies near to the vertebral column, and the front surface sits deep to the sternum and costal cartilages.[7] Two of the great veins – the venae cavae, and the great arteries, the aorta and pulmonary artery, are attached to the upper part of the heart, called the base, which is located at the level of the third costal cartilage.[7] The lower tip of the heart, the apex, lies to the left of the sternum (8 to 9 cm from the midsternal line) between the junction of the fourth and fifth ribs near their articulation with the costal cartilages.[7] The right side of the heart is deflected forwards, and the left deflected to the back.[7]

The heart is cone-shaped, with its base positioned upwards and tapering down to the apex.[7] A stethoscope can be placed directly over the apex so that the heartbeats can be counted. The apex beat is the pulse felt at the point of maximal impulse, on the precordium near the apex. An adult heart has a mass of 250–350

Русиньскый
Русский
Саха тыла
संस्कृतम्
Sardu
Scots
Shqip
Sicilianu
සිංහල
Simple English
Slovenčina
Slovenščina
Ślůnski
Soomaaliga
کوردیی ناوەندی
Српски / srpski
Srpskohrvatski / српскохрватски
Basa Sunda
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Vepsän kel’
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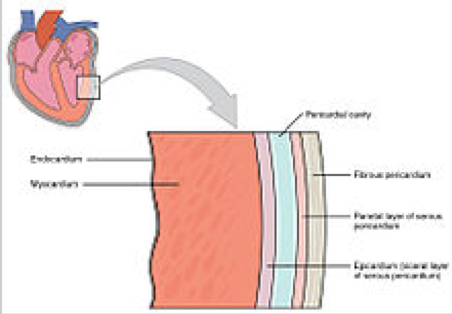
grams (9–12 oz).[16] The heart is typically the size of a fist: 12 cm (5 in) in length, 8 cm (3.5 in) wide, and 6 cm (2.5 in) in thickness.[7] Well-trained athletes can have much larger hearts due to the effects of exercise on the heart muscle, similar to the response of skeletal muscle.[7]

Heart wall

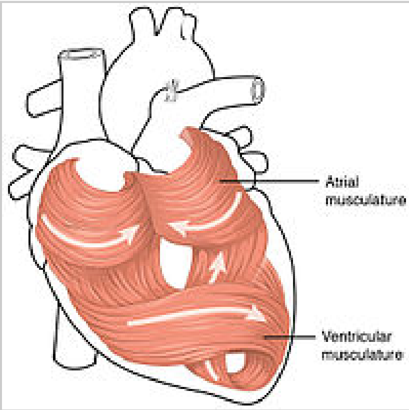
Main article: Cardiac muscle

The heart wall is made up of three layers: the inner endocardium, middle myocardium and outer epicardium. These are surrounded by a double-membraned sac called the pericardium.


Layers of the heart wall, including visceral and parietal pericardium.

The innermost layer of the heart is called the endocardium. It is made up of a lining of simple squamous epithelium, and covers heart chambers and valves. It is continuous with the endothelium of the veins and arteries of the heart, and is joined to the myocardium with a thin layer of connective tissue.[7] The endocardium, by secreting endothelins, may also play a role in regulating the contraction of the myocardium.[7]

The middle layer of the heart wall is the myocardium, which is the cardiac muscle– a layer of involuntary striated muscle tissue surrounded by a framework of collagen. The myocardium is also supplied with blood vessels, and nerve fibers by way of the epicardium that help to regulate the heart rate.[7] Cardiac muscle tissue has autorhythmicity, the unique ability to initiate a cardiac action potential at a fixed rate – spreading the impulse rapidly from cell to cell to trigger the contraction of the entire heart. This autorhythmicity is still modulated by the endocrine and nervous systems.[7]



The swirling pattern of myocardium helps the heart pump effectively

There are two types of cardiac muscle cell: cardiomyocytes which have the ability to contract easily, and modified cardiomyocytes the pacemaker cells of the conducting system. The cardiomyocytes make up the bulk (99%) of cells in the atria and ventricles. These contractile cells are connected by intercalated discs which allow a rapid response to impulses of action potential from the pacemaker cells. The intercalated discs allow the cells to act as a syncytium and enable the contractions that pump blood through the heart and into the major arteries.[7]

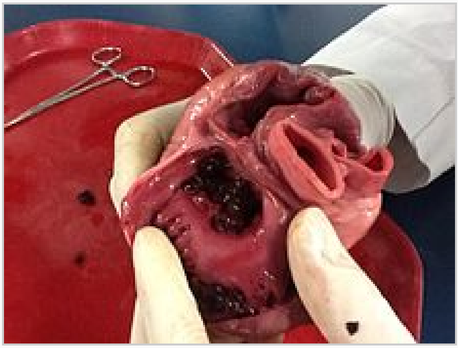
The pacemaker cells make up 1% of cells and form the conduction system of the heart. They are generally much smaller than the contractile cells and have few myofibrils which gives them limited contractibility. Their function is similar in many respects to neurons.[7]

The cardiac muscle pattern is elegant and complex, as the muscle cells swirl and spiral around the chambers of the heart.[7] They form a figure 8 pattern around the atria and around the bases of the great vessels.[7] Deeper ventricular muscles also form a figure 8 around the two ventricles and proceed toward the apex. More superficial layers of ventricular muscle wrap around both ventricles.[7] This complex swirling pattern allows the heart to pump blood more effectively than a simple linear pattern would.[7]

As with skeletal muscles the heart can increase in size and efficiency with exercise.[7] Thus endurance athletes such as marathon runners may have a heart that has increased in size by up to 40%.[17]

The pericardium surrounds the heart. It consists of two membranes: an inner serous membrane called the epicardium, and an outer fibrous membrane. These enclose the pericardial cavity which contains the pericardial fluid that lubricates the surface of the heart.[18]

Chambers

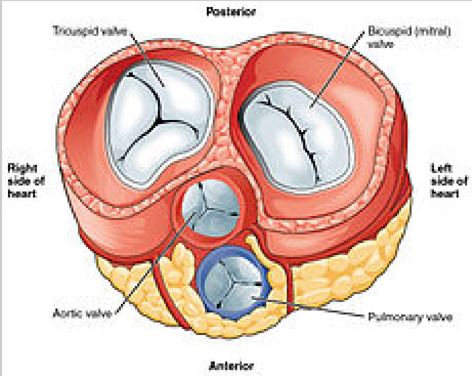

Heart being dissected showing right and left ventricles, from above

The heart has four chambers, two upper atria, the receiving chambers, and two lower ventricles, the discharging chambers. The atria open into the ventricles via the atrioventricular valves, present in the atrioventricular septum. This distinction is visible also on the surface of the heart as the coronary sulcus.[19] There is an ear-shaped structure in the upper right atrium called the right atrial appendage, or auricle, and another in the upper left atrium, the left atrial appendage.[20] The right atrium and the right ventricle together are sometimes referred to as the *right heart*. Similarly, the left atrium and the left ventricle together are sometimes referred to as the *left heart*.[6] The ventricles are separated from each other by the interventricular septum, visible on the surface of the heart as the anterior longitudinal sulcus and the posterior interventricular sulcus.[19]

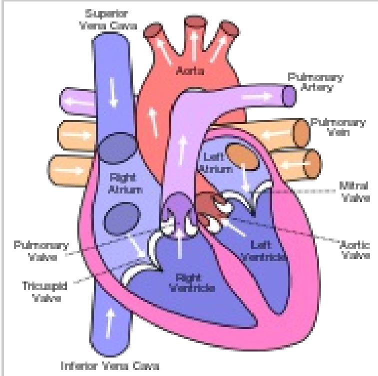
The cardiac skeleton is made of dense connective tissue and this gives structure to the heart. It forms the atrioventricular septum which separates the atria from the ventricles, and the fibrous rings which serve as bases for the four heart valves.[21] The cardiac skeleton also provides an important boundary in the heart's electrical conduction system since collagen cannot conduct electricity. The interatrial septum separates the atria and the interventricular septum separates the ventricles.[7] The interventricular septum is much thicker than the interatrial septum, since the ventricles need to generate greater pressure when they contract.[7]

Valves

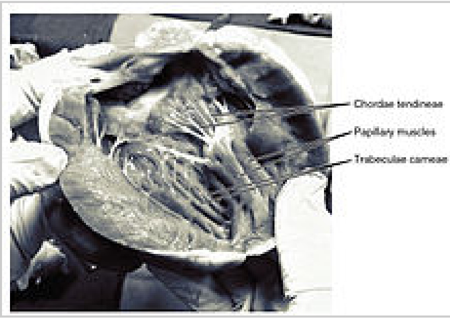
Main article: Heart valves



With the atria and major vessels removed, all four valves are clearly visible.[7]



The heart, showing valves, arteries and veins. The white arrows shows the normal direction of blood flow.



Frontal section showing papillary muscles attached to the tricuspid valve on the right and to the mitral valve on the left via chordae tendineae.[7]

The heart has four valves, which separate its chambers.[7] The valves ensure blood flows in the correct direction through the heart and prevents backflow. Between the right atrium and the right ventricle is the tricuspid valve. This consists of three cusps (flaps or leaflets), made of endocardium reinforced with additional connective tissue. Each of the three valve-cusps is attached to several strands of connective tissue, the chordae tendineae (tendinous cords).[22] They are composed of approximately 80 percent collagenous fibers with the remainder consisting of elastic fibers and endothelium.[*citation needed*] They connect each of the cusps to a papillary muscle that extends from the walls of the ventricle. These muscles prevent the valve from falling back into the atrium.[23][g] The three papillary muscles in the right ventricle are called the anterior, posterior, and septal muscles, which correspond to the three positions of the valve cusps.[22]

Between the left atrium and left ventricle is the mitral valve, also known as the bicuspid valve due to its having two cusps, an anterior and a posterior cusp. These cusps are also attached via chordae tendinae to two papillary muscles projecting from the ventricular wall.[24]

The tricuspid and the mitral valves are the atrioventricular valves. During the relaxation phase of the cardiac cycle, the papillary muscles are also relaxed and the tension on the chordae tendineae is slight. However, as the ventricle contracts, so do the papillary muscles. This creates tension on the chordae tendineae, helping to hold the cusps of the atrioventricular valves in place and preventing them from being blown back into the atria.[7]

The semilunar pulmonary valve is located at the base of the pulmonary artery. This has three cusps which are not attached to any papillary muscles. When the ventricle relaxes blood flows back into the ventricle from the artery and this flow of blood fills the pocket-like valve, pressing against the cusps which close to seal the valve. The semilunar aortic valve is at the base of the aorta and also is not attached to papillary muscles. This too has three cusps which close with the pressure of the blood flowing back from the aorta.[7]

Right heart

The two major systemic veins, the superior and inferior venae cavae, and the collection of veins that make up the coronary sinus which drains the myocardium, empty into the right atrium. The superior vena cava drains blood from above the diaphragm and empties into the upper back part of the right atrium. The inferior vena cava drains the blood from below the diaphragm and empties into the back part of the atrium below the opening for the superior vena cava. Immediately above and to the middle of the opening of the inferior vena cava is the opening of the thin-walled coronary sinus.[7]

In the wall of the right atrium is an oval-shaped depression known as the fossa ovalis, which is a remnant of an opening in the fetal heart known as the foramen ovale. The foramen ovale allowed blood in the fetal heart to pass directly from the right atrium to the left atrium, allowing some blood to bypass the pulmonary circuit. Within seconds after birth, a flap of tissue known as the septum primum that previously acted as a valve closes the foramen ovale and establishes the typical cardiac circulation pattern.[7] Most of the internal surface of the right atrium is smooth, the depression of the fossa ovalis is medial, and the anterior surface has prominent ridges of pectinate muscles, which are also present in the right atrial appendage.[7]

The atria receive venous blood on a nearly continuous basis, preventing venous flow from stopping while the ventricles are contracting. While most ventricular filling occurs while the atria are relaxed, they do demonstrate a contractile phase when they actively pump blood into the ventricles just prior to ventricular contraction. The right atrium is connected to the right ventricle by the tricuspid valve.[7]

When the myocardium of the ventricle contracts, pressure within the ventricular chamber rises. Blood, like any fluid, flows from higher pressure to lower pressure areas, in this case, toward the pulmonary artery and the atrium. To prevent any potential backflow, the papillary muscles also contract, generating tension on the chordae tendineae. This prevents the flaps of the valves from being forced into the atria and regurgitation of the blood back into the atria during ventricular contraction.[7]

The walls of the right ventricle are lined with trabeculae carneae, ridges of cardiac muscle covered by endocardium. In addition to these muscular ridges, a band of cardiac muscle, also covered by endocardium, known as the moderator band reinforces the thin walls of the right ventricle and plays a crucial role in cardiac conduction. It arises from the lower part of the interventricular septum and crosses the interior space of the right ventricle to connect with the inferior papillary muscle.[7]

When the right ventricle contracts, it ejects blood into the pulmonary artery, which branches into the left and right pulmonary arteries that carry it to each lung. The upper surface of the right ventricle begins to taper as it approaches the pulmonary artery. At the base of the pulmonary artery is the pulmonary semilunar valve that prevents backflow from the pulmonary artery.[7]

Left heart

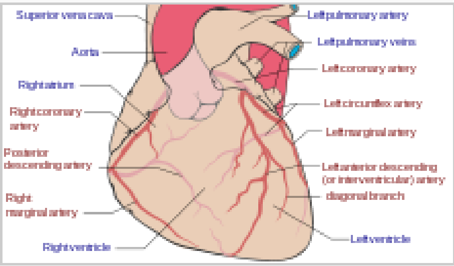
After gas exchange in the pulmonary capillaries, blood high in oxygen returns to the left atrium via one of the four pulmonary veins. Only the left atrial appendage contains pectinate muscles. Blood flows nearly continuously from the pulmonary veins back into the atrium, which acts as the receiving chamber, and from here through an opening into the left ventricle. Most blood flows passively into the heart while both the atria and ventricles are relaxed, but toward the end of the ventricular relaxation period, the left atrium will contract, pumping blood into the ventricle. This atrial contraction accounts for approximately 20 percent of ventricular filling. The left atrium is connected to the left ventricle by the mitral valve.[7]

Although both sides of the heart will pump the same amount of blood, the muscular layer is much thicker in the left ventricle compared to the right, due to the greater force needed here. Like the right ventricle, the left also has trabeculae carneae, but there is no moderator band. The left ventricle is the major pumping chamber for the systemic circuit; it ejects blood into the aorta through the aortic semilunar valve.[7]

Coronary circulation

Main article: Coronary circulation

Cardiomyocytes, like all other cells, need to be supplied with oxygen, nutrients and a way of removing metabolic wastes. This is achieved by the coronary circulation. The coronary circulation cycles in peaks and troughs correlating to the heart muscle's relaxation or contraction.[7]



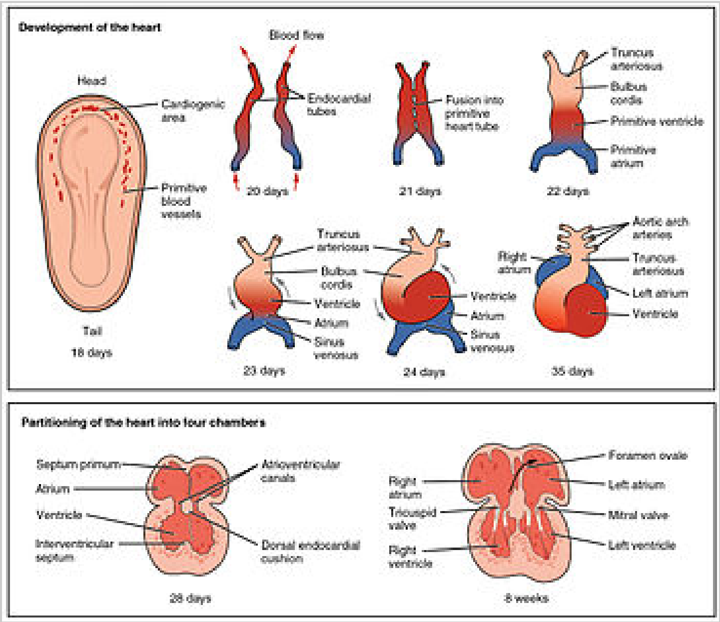
Arterial supply to the heart (red), with other areas labelled (blue).

Coronary arteries supply oxygen-rich blood to the heart and the coronary veins remove the deoxygenated blood. There is a left and a right coronary artery supplying the left and right hearts respectively, and the septa. Smaller branches of these arteries anastomose, which in other parts of the body serve to divert blood due to a blockage. In the heart these are very small and cannot form other interconnections with the result that a coronary artery blockage can cause a myocardial infarction and with it, tissue damage.[7]

The great cardiac vein receives the major branches of the posterior, middle, and small cardiac veins and drains into the coronary sinus, a large vein that empties into the right atrium. The anterior cardiac veins drain the front of the right ventricle and drain directly into the right atrium.[7]

Development

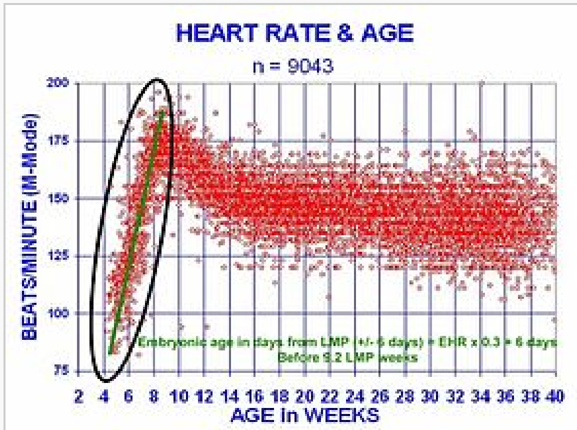
Main articles: Heart development and Human embryogenesis



Development of the human heart during the first eight weeks (top), and the formation of the heart chambers (bottom).[7]

The heart is the first functional organ to develop and starts to beat and pump blood at about three weeks into embryogenesis. This early start is crucial for subsequent embryonic and prenatal development.

The heart derives from splanchnopleuric mesenchyme in the neural plate which forms the cardiogenic region. Two endocardial tubes form here that fuse to form a primitive heart tube known as the tubular heart.[25] Between the third and fourth week, the heart tube lengthens, and begins to fold to form an S-shape within the pericardium. This places the chambers and major vessels into the correct alignment for the developed heart. Further development will include the septa and valves formation and remodelling of the heart chambers. By the end of the fifth week the septa are complete and the heart valves are completed by the ninth week.[7]



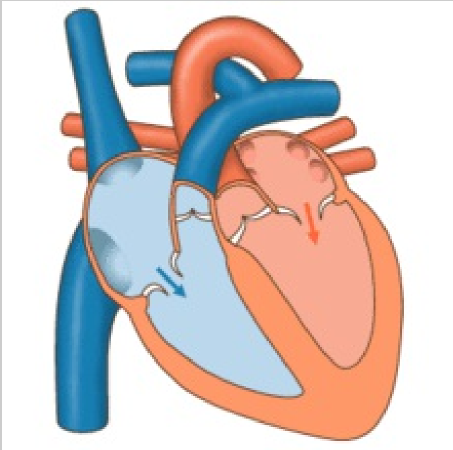
Embryo-fetal heart rates

The embryonic heart begins beating at around 22 days after conception (5 weeks after the last normal menstrual period, LMP). It starts to beat at a rate near to the mother's which is about 75–80 beats per minute (bpm). The embryonic heart rate then accelerates and reaches a peak rate of 165–185 bpm early in the early 7th week (early 9th week after the LMP).[26][27] After 9 weeks (start of the fetal stage) it starts to decelerate, slowing to around 145 (±25) bpm at birth. There is no difference in female and male heart rates before birth.[28]

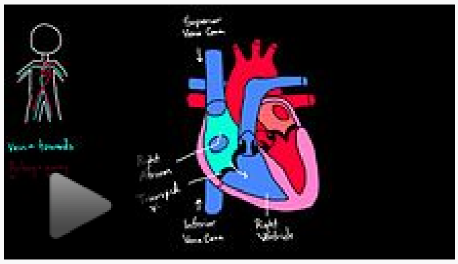
Physiology

Main article: Cardiac physiology

Blood flow



Blood flow through the valves



Blood flow through the heart from the Khan academy

The heart functions as a pump in the circulatory system to provide a continuous circulation of blood throughout the body. This circulation consists of the systemic circulation to and from the body and the pulmonary circulation to and from the lungs. Blood in the pulmonary circulation exchanges carbon dioxide for oxygen in the lungs through the process of respiration. The systemic circulation then transports oxygen to the body and returns carbon dioxide and relatively deoxygenated blood to the heart for transfer to the lungs.[7]

The **right heart** collects deoxygenated blood from two large veins, the superior and inferior venae cavae. Additionally, the coronary sinus returns deoxygenated blood from the myocardium to the right atrium. The blood collects in the right atrium and is pumped through the tricuspid valve into the right ventricle, where it is pumped into the pulmonary artery through the pulmonary valve. Here the blood enters the pulmonary circulation where carbon dioxide can be exchanged for oxygen in the lungs. This happens through the passive process of diffusion.

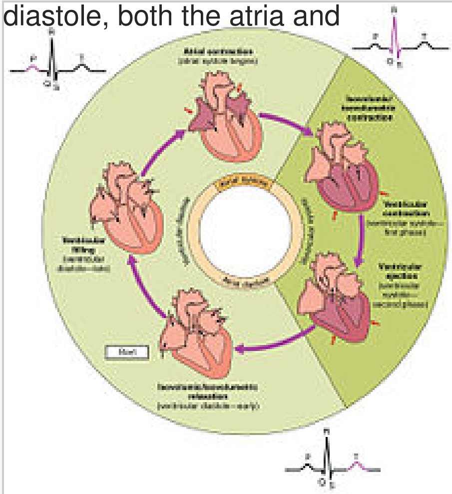
In the **left heart**, oxygenated blood is returned to the left atrium via the pulmonary veins. It is then pumped into the left ventricle through the mitral valve and into the aorta through the aortic valve for systemic circulation. The aorta is a large artery that branches into many smaller arteries, arterioles, and ultimately capillaries. In the capillaries, oxygen and nutrients from blood are supplied to body cells for metabolism, and exchanged for carbon dioxide and waste products.[7]

Cardiac cycle

Main articles: Cardiac cycle, Systole, and Diastole

The cardiac cycle refers to a complete heartbeat which includes systole and diastole and the intervening pause.[9] The cycle begins with contraction of the atria and ends with relaxation of the ventricles. Systole is when the ventricles of the heart contract to pump blood to the body. Diastole is when the ventricles relax and fill with blood. The atria and ventricles work in concert, so in systole when the ventricles are contracting, the atria are relaxed and collecting blood. When the ventricles are relaxed in diastole, the atria contract to pump blood to the ventricles. This coordination ensures blood is pumped efficiently to the body.[7]

At the beginning of the cardiac cycle, in early diastole, both the atria and ventricles are relaxed. Since blood moves from areas of high pressure to areas of low pressure, when the chambers are relaxed, blood will flow into the atria (through the coronary sinus and the pulmonary veins). As the atria begin to fill, the pressure will rise so that the blood will move from the atria into the ventricles. In late diastole the atria contract pumping more blood into the ventricles. This causes a rise in pressure in the ventricles, and in ventricular systole blood will be pumped into the pulmonary artery.[9]



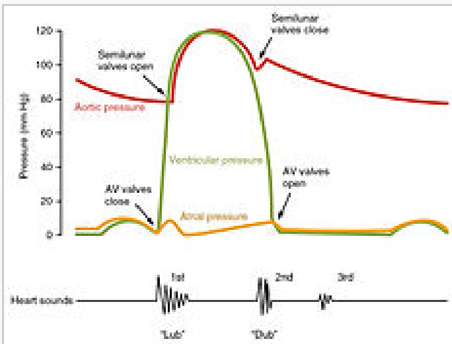
The cardiac cycle as correlated to the ECG

When the atrioventricular valves (tricuspid and mitral) are open, during blood flow to the ventricles, the semilunar valves are closed to prevent backflow into the ventricles. When the ventricular pressure is greater than the atrial pressure the tricuspid and mitral valves will shut. When the ventricles contract the pressure forces the semilunar aortic and pulmonary valves open. As the ventricles relax the semilunar valves will close in response to decreased pressure.[9]

Cardiac output

Main article: Cardiac output

Cardiac output (CO) is a measurement of the amount of blood pumped by each ventricle (stroke volume) in one minute. This is calculated by multiplying the stroke volume (SV) by the beats per minute of the heart rate (HR). So that: CO = SV x HR.[7] The cardiac output is normalized to body size through body surface area and is called the cardiac index.



The x-axis reflects time with a recording of the heart sounds. The y-axis represents pressure.[7]

The average cardiac output, using an average SV of about 70mL, is 5.25 L/min, with a range of 4.0–8.0 L/min.[7] The stroke volume is normally measured using an echocardiogram and can be influenced by the size of the heart, physical and mental condition of the individual, sex, contractility, duration of contraction, preload and afterload.[7]

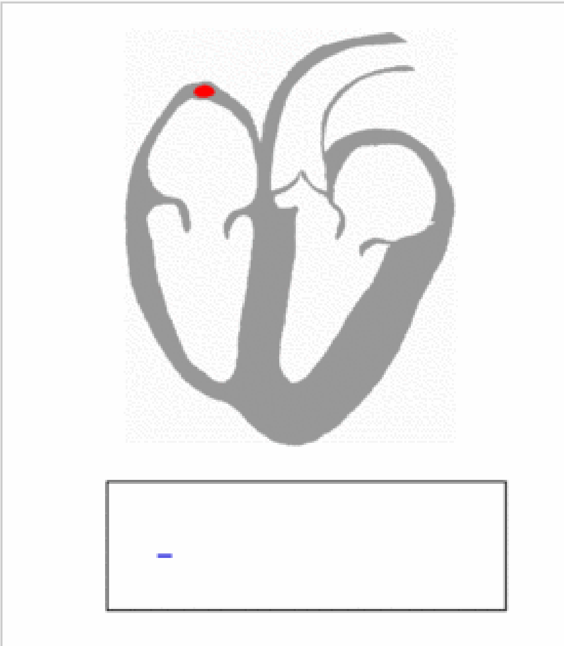
Preload refers to the filling pressure of the atria at the end of diastole, when they are at their fullest. A main factor is how long it takes the ventricles to fill—if the ventricles contract faster, then there is less time to fill and the preload will be less.[7] Preload can also be affected by a person's hydration status. The force of each contraction of the heart muscle is proportional to the preload, described as the Frank-Starling mechanism. This states that the force of contraction is directly proportional to the initial length of muscle fiber, meaning a ventricle will contract more forcefully, the more it is stretched.[7][29]

Afterload, or how much pressure the heart must generate to eject blood at systole, is influenced by vascular resistance. It can be influenced by narrowing of the heart valves (stenosis) or contraction or relaxation of the peripheral blood vessels.[7]

The strength of heart muscle contractions controls the stroke volume. This can be influenced positively or negatively by agents termed inotropes. These can be either conditions or drugs. Positive inotropes that cause stronger contractions include high blood calcium and drugs such as Digoxin, which will act to stimulate the sympathetic nerves in the fight-or-flight response. Negative inotropes causing weaker contractions include high blood potassium, hypoxia, acidosis, and drugs such as beta blockers and calcium channel blockers.

Electrical conduction

Main articles: Electrical conduction system of the heart and Heart rate

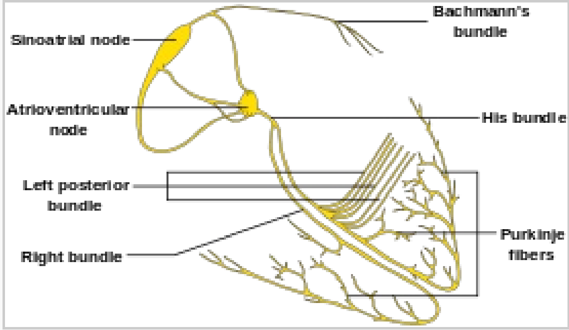


Transmission of a cardiac action potential through the heart's conduction system

The normal rhythmical heart beat, called sinus rhythm, is established by the sinoatrial node, the heart's pacemaker. Here an electrical signal is created that travels through the heart, causing the heart muscle to contract.

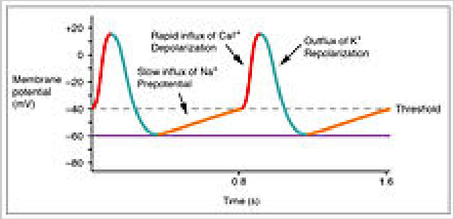
The sinoatrial node is found in the upper part of the right atrium near to the junction with the superior vena cava.[30] The electrical signal generated by the sinoatrial node travels through the right atrium in a radial way that is not completely understood. It travels to the left atrium via Bachmann's bundle, such that both left and right atria contract together.[31][32][33] The signal then travels to the atrioventricular node. This is found at the bottom of the right atrium in the atrioventricular septum—the boundary between the right atrium and the left ventricle. The septum is part of the cardiac skeleton, tissue within the heart that the electrical signal cannot pass through, which forces the signal to pass through the atrioventricular node only.[7] The signal then travels along the bundle of His to left and right bundle branches through to the ventricles of the heart. In the ventricles the signal is carried by specialized tissue called the Purkinje fibers which then transmit the electric charge to the cardiac muscle.[34]

Sinoatrial node



Conduction system of the heart

The sinoatrial node creates and sustains its own rhythm, the sinus rhythm. Cells in the sinoatrial node do this by creating an action potential. The cardiac action potential is created by the movement of specific electrolytes into and out of the pacemaker cells. The action potential then spreads to nearby cells.[35]



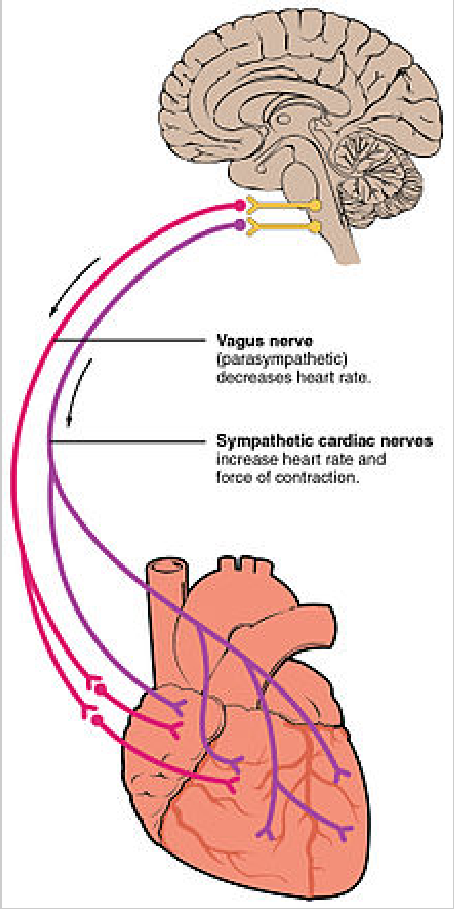
The prepotential is due to a slow influx of sodium ions until the threshold is reached followed by a rapid depolarization and repolarization. The prepotential accounts for the membrane reaching threshold and initiates the spontaneous depolarization and contraction of the cell; there is no resting potential.[7]

When the sinoatrial cells are resting, they have a negative charge on their membranes. However a rapid influx of sodium ions causes the membrane's charge to become positive. This is called depolarisation and occurs spontaneously.[7] Once the cell has a sufficiently high charge, the sodium channels close and calcium ions then begin to enter the cell, shortly after which potassium begins to leave it. All the ions travel through ion channels in the membrane of the sinoatrial cells. The potassium and calcium only start to move out of and into the cell once it has a sufficiently high charge, and so are called voltage-gated. Shortly after this, the calcium channels close and potassium channels open, allowing potassium to leave the cell. This causes the cell to have a negative resting charge and is called repolarization. When the membrane potential reaches approximately −60 mV, the potassium channels close and the process may begin again.[7]

The ions move from areas where they are concentrated to where they are not. For this reason sodium moves into the cell from outside, and potassium moves from within the cell to outside the cell. Calcium also plays a critical role. Their influx through slow channels means that the sinoatrial cells have a prolonged "plateau" phase when they have a positive charge. A part of this is called the absolute refractory period. Calcium ions also combine with the regulatory protein troponin C in the troponin complex to enable contraction of the cardiac muscle, and separate from the protein to allow relaxation.[36]

Influences

The normal sinus rhythm of the heart, giving the resting heart rate, is influenced by the autonomic nervous system through sympathetic and parasympathetic nerves.[37] These arise from two paired cardiovascular centres in the medulla oblongata.The vagus nerve of the parasympathetic nervous system acts to decrease the heart rate, and nerves from the sympathetic trunk act to increase the heart rate. These come together in the cardiac plexus near the base of the heart. Without parasympathetic input which normally predominates, the sinoatrial node would generate a heart rate of about 100 bpm.[7]



Autonomic innervation of the heart

The nerves from the sympathetic trunk emerge through the T1-T4 thoracic ganglia and travel to both the sinoatrial and atrioventricular nodes, as well as to the atria and ventricles. The ventricles are more richly innervated by sympathetic fibers than parasympathetic fibers. Sympathetic stimulation causes the release of the neurotransmitter norepinephrine (also known as noradrenaline) at the neuromuscular junction of the cardiac nerves. This shortens the repolarization period, thus speeding the rate of depolarization and contraction, which results in an increased heart rate. It opens chemical or ligand-gated sodium and calcium ion channels, allowing an influx of positively charged ions.[7] Norepinephrine binds to the beta–1 receptor. High blood pressure medications are used to block these receptors and so reduce the heart rate.[7]

The cardiovascular centres receive input from a series of receptors including proprioreceptors, baroreceptors, and chemoreceptors, plus stimuli from the limbic system. Through a series of reflexes these help regulate and sustain blood flow. For example, increased physical activity results in increased rates of firing by various proprioreceptors located in muscles, joint capsules, and tendons. With increased rates of firing, the parasympathetic stimulation may decrease or sympathetic stimulation may increase as needed in order to increase blood flow.[7]

Similarly, baroreceptors are stretch receptors located in the aortic sinus, carotid bodies, the venae cavae, and other locations, including pulmonary vessels and the right side of the heart itself. Rates of firing from the baroreceptors represent blood pressure, level of physical activity, and the relative distribution of blood. The cardiac centers monitor baroreceptor firing to maintain cardiac homeostasis, a mechanism called the baroreceptor reflex. With increased pressure and stretch, the rate of baroreceptor firing increases, and the cardiac centers decrease sympathetic stimulation and increase parasympathetic stimulation. As pressure and stretch decrease, the rate of baroreceptor firing decreases, and the cardiac centers increase sympathetic stimulation and decrease parasympathetic stimulation.[7]

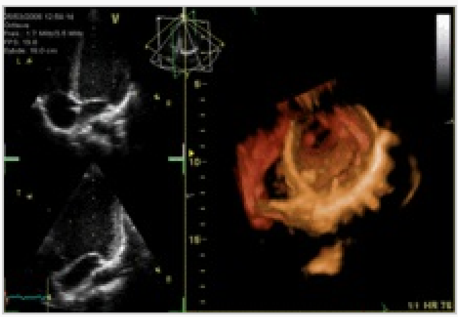
There is a similar reflex, called the atrial reflex or Bainbridge reflex, associated with varying rates of blood flow to the atria. Increased venous return stretches the walls of the atria where specialized baroreceptors are located. However, as the atrial baroreceptors increase their rate of firing and as they stretch due to the increased blood pressure, the cardiac center responds by increasing sympathetic stimulation and inhibiting parasympathetic stimulation to increase heart rate. The opposite is also true.[7]

In addition to the autonomic nervous system, other factors can impact on this. These include epinephrine, norepinephrine, and thyroid hormones; levels of various ions including calcium, potassium, and sodium; body temperature; hypoxia; and pH balance. Factors that increase the heart rate can include release of norepinephrine, hypoxemia, low blood pressure and dehydration, a strong emotional response, a higher body temperature, and metabolic and hormonal factors such as a low potassium or sodium level or stimulus from thyroid hormones.[7] Decreased body temperature, relaxation, and metabolic factors can also contribute to a decrease in heart rate.[7]

The resting heart rate of a newborn can be 129 beats per minute (bpm) and this gradually decreases until maturity.[38] The adult resting heart rate ranges from 60 to 100 bpm. Exercise and fitness levels, age and basal metabolic rate can all affect the heart rate. An athlete's heart rate can be lower than 60 bpm. During exercise the rate can be 150 bpm with maximum rates reaching from 200 to 220 bpm.[7]

Heart sounds

Main article: Heart sounds



3D echocardiogram showing the mitral valve (right), tricuspid and mitral valves (top left) and aortic valve (top right).
The closure of the heart valves causes the heart sounds.

One of the simplest methods of assessing the heart's condition is to listen to it using a stethoscope.[7] Typically, healthy hearts have only two audible heart sounds, called S1 and S2. The first heart sound S1, is the sound created by the closing of the atrioventricular valves during ventricular contraction and is normally described as "lub". The second heart sound, S2, is the sound of the semilunar valves closing during ventricular diastole and is described as "dub".[7] Each sound consists of two components, reflecting the slight difference in time as the two valves close.[39] S2 may split into two distinct sounds, either as a result of inspiration or different valvular or cardiac problems.[39] Additional heart sounds may also be present and these give rise to gallop rhythms. A third heart sound, S3 usually indicates an increase in ventricular blood volume. A fourth heart sound S4 is referred to as an atrial gallop and is produced by the sound of blood being forced into a stiff ventricle. The combined presence of S3 and S4 give a quadruple gallop.[7]

Heart murmurs are abnormal heart sounds which can be either pathological or benign.[40] One example of a murmur is Still's murmur, which presents a musical sound in children, has no symptoms and disappears in adolescence.[41]

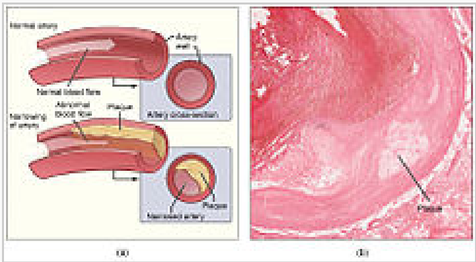
A different type of sound, a pericardial friction rub can be heard in cases of pericarditis where the inflamed membranes can rub together.[42]

Clinical significance

Disease

Cardiovascular diseases, which include diseases of the heart, are the leading cause of death worldwide.[43] The majority of cardiovascular disease is noncommunicable and related to lifestyle and other factors, becoming more prevalent with ageing.[43] Heart disease is a major cause of death, accounting for an average of 30% of all deaths in 2008, globally.[11] This rate varies from a lower 28% to a high 40% in high-income countries.[12] Doctors that specialise in the heart are called cardiologists. Many other medical professionals are involved in treating diseases of the heart, including doctors such as general practitioners, cardiothoracic surgeons and intensivists, and allied health practitioners including physiotherapists and dieticians.[44]

The stethoscope is used for auscultation of the heart, and is one of the most iconic symbols for medicine. A number of diseases can be detected primarily by listening for heart murmurs.



Atherosclerosis is a condition affecting the circulatory system. If the coronary arteries are affected angina pectoris may result or at worse a heart attack.

Coronary artery disease is also known as ischemic heart disease, is caused by atherosclerosis – a build-up of plaque along the inner walls of the arteries which narrows them, reducing the blood flow to the heart.[45] A stable plaque may cause chest pain (angina) or breathlessness during exercise or at rest, or no symptoms at all. A ruptured plaque can block a blood vessel and lead to ischaemia of the heart muscle, causing unstable angina or a heart attack.[46] In the worst case this may cause cardiac arrest, a sudden and utter loss of output from the heart.[47] Obesity, high blood pressure, uncontrolled diabetes, smoking and high cholesterol can all increase the risk of developing atherosclerosis and coronary artery disease.[43][45]

Heart failure is where the heart can't beat enough blood to meet the needs of the body.[45] It is generally a chronic condition, associated with age, that progresses gradually.[48]Each side of the heart can fail independently of the other, resulting in heart failure of the right heart or the left heart. Left heart failure can also lead to right heart failure by increasing strain on the right heart (called cor pulmonale). If the heart is unable to pump sufficient blood, it may accumulate throughout the body, causing breathlessness in the lungs (pulmonary congestion; pulmonary edema), swelling (edema) of the feet or other gravity-dependent areas, decrease exercise tolerance, or cause other clinical signs such as an enlarged liver, cardiac murmurs, or a raised jugular venous pressure. Common causes of heart failure include coronary artery disease, valve disorders and diseases of cardiac muscle.[49]

Cardiomyopathy is a noticeable deterioration of the heart muscle's ability to contract, which can lead to heart failure. The causes of many types of cardiomyopathy are poorly understood; some identified causes include alcohol, toxins, systemic disease such as sarcoidosis, and congenital conditions such as HOCM. The types of cardiomyopathy are described according to how they affect heart muscle. Cardiomyopathy can cause the heart to become enlarged (hypertrophic cardiomyopathy), constrict the outflow tracts of the heart (restrictive cardiomyopathy), or cause the heart to dilate and impact on the effiency of its beating (dilated cardiomyopathy).[50] HOCM is often undiagnosed and can cause sudden death in young athletes.[7]

Heart murmurs are abnormal heart sounds which can be either related to disease or benign, and there are several kinds.[51] There are normally two heart sounds, and abnormal heart sounds can either be extra sounds, or "murmurs" related to the flow of blood between the sounds. Murmurs are graded by volume, from 1) the quietest, to 6) the loudest, and evaluated by their relationship to the heart sounds, position in the cardiac cycle, and additional features such as their radiation to other sites, changes with a person's position, the frequency of the sound as determined by the side of the stethoscope by which they are heard, and site at which they are heard loudest.[51]Phonocardiograms can record these sounds,[7] and echocardiograms are generally required for their diagnosis.[51] Murmurs can result from valvular heart diseases due to narrowing (stenosis), or regurgitation of any of the main heart valves, such as aortic stenosis, mitral regurgitation or mitral valve prolapse. They can also result from a number of other disorders, including atrial and ventricular septal defects.[51] Two common and infective causes of heart murmurs, are infective endocarditis and rheumatic fever, particularly in developing countries. Infective endocarditis involves colonisation of a heart valve,[52] and rheumatic fever involves an initial bacterial infection by Group A streptococcus followed by a reaction against heart tissue that resembles the streptococcal antigen.[53]

Abnormalities in the normal sinus rhythm of the heart can prevent the heart from effectively pumping blood, and are generally identified by ECG. These cardiac arrhythmias can cause an abnormal but regular heart rhythm, such as a rapid heart rate (tachycardia, classified as arising from above the ventricles or from the ventricles) or a slow heart rate (bradycardia); or may result in irregular rhythms. Tachycardia is generally defined as a heart rate faster than 100 beats per minute, and bradycardia as a heart rate slower than 60.[54] Asystole is the cessation of heart rhythm. An irregular rhythm is classified as atrial or ventricular fibrillation depending if the electrical activity originates in the atria or the ventricles.[54] Abnormal conduction can cause a delay or unusual order of contraction of the heart muscle. This can be a result of a disease process, such as heart block, or congenital, such as Wolff-Parkinson-White syndrome.[54]

Diseases may also affect the pericardium which surrounds the heart, which when inflammed is called pericarditis. This may result from infective causes (such as glandular fever, cytomegalovirus, coxsackievirus, tuberculosis or Q fever), systemic disorders such as amyloidosis or sarcoidosis, tumours, high uric acid levels, and other causes. This inflammation affects the ability of the heart to pump effectively. When fluid builds up in the pericardium this is called pericardial effusion, which when it causes acute heart failure is called cardiac tamponade. This may be blood from a traumatic injury or fluid from an effusion.[55] This can compress the heart and adversely affect the function of the heart. The fluid can be removed from the pericardial sac using a syringe in a procedure called pericardiocentesis.[56]

The heart can be affected by congenital diseases. These include failure of the developmental foramen ovale to close, present in up to 25% of people; [57] ventricular or atrial septal defects, congenital diseases of the heart valves (e.g. congenital aortic stenosis) or disease relating to blood vessels or blood flow from the heart (such as a patent ductus arteriosus or aortic coarctation).;[58] Harrisons 1458–1465 These may cause symptoms at a variety of ages. If unoxygenated blood travels directly from the right to the left side of the heart, it may be noticed at birth, as it may cause a baby to become blue (cyanotic) such as Tetralogy of Fallot. A heart problem may impact a child's ability to grow.[58] Some causes rectify with time and are regarded as benign. Other causes may be incidentally detected on a cardiac examination. These disorders are often diagnosed on an echocardiogram.[59]

Diagnosis

Heart disease is diagnosed by the taking of a medical history, a cardiac examination, and further investigations, including blood tests, echocardiograms, ECGs and imaging. Other invasive procedures such as cardiac catheterisation can also play a role.[60]

Examination

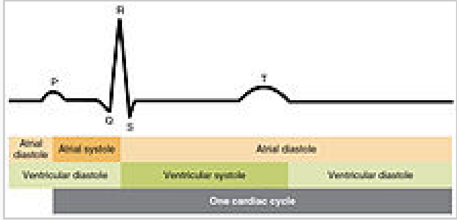
Main article: Cardiac examination

The cardiac examination includes inspection, palpation and listening with a stethoscope (auscultation).[61][62] It involves assessment of signs that may be visible on a person's hands (such as splinter haemorrhages), joints and other areas. A person's pulse is taken, usually at the radial artery near the wrist, in order to assess for the rhythm and strength of the pulse. The blood pressure is taken, either manually using a sphygmomanometer or an automatic blood pressure reader. Any elevation of the jugular venous pulse is noted. A person's chest is felt for any transmitted vibrations from the heart, and then listened to with a stethoscope, known as auscultation. A normal heart has two hearts sounds -

additional heart sounds or heart murmurs may also be able to be heard. Additional tests may be conducted to assess a person's heart murmurs if they are present, and signs of peripheral heart disease such as swollen feet or fluid in the lungs may be assessed.[62]

Electrocardiogram

Main article: Electrocardiography



Cardiac cycle shown against ECG

Using surface electrodes on the body, it is possible to record the complex electrical activity of the heart. This tracing of the electrical signal is the electrocardiogram (ECG) or (EKG). An ECG is a bedside test and usually requires the placement of nine leads on the body. This produces a "12 lead" ECG (three extra leads are calculated mathematically).[62]

There are five prominent points on the ECG: the P wave (atrial depolarisation), the QRS complex (atrial repolarisation and ventricular depolarisation) and the T wave (ventricular repolarisation).[7] These reflect the summed action potential of cardiac myocytes as they contract. A downward deflection on the ECG implies cells are becoming more negative in charge ("depolarising"), whereas an upward inflection implies cells are becoming more positive ("repolarising"). The ECG is a useful tool in detecting rhythm disturbances and in detecting insufficient blood supply to the heart.[61] Sometimes abnormalities are not immediately visible on the ECG. Testing when exercising can be used to provoke an abnormality, or an ECG can be worn for a longer period such as a 24-hour Holter monitor if a rhythm abnormality is suspected to be present but not present at the time of assessment.[62]

Imaging

Main article: Cardiac imaging

Several imaging methods can be used to assess the anatomy and function of the heart, including angiography, PET, CT, MRI and ultrasound (echocardiography). An echocardiogram is used to measure the heart's function, assess for valve disease, and look for any abnormalities. Echocardiography can be conducted by a probe on the chest ("transthoracic") or by a probe in the esophagus ("transoesophageal"). A typical echocardiography report will include information about the width of the valves noting any stenosis, whether there is any backflow of blood (regurgitation) and information about the blood volumes at the end of systole and diastole, including an ejection fraction, which describes how much blood is ejected from the left and right ventricles after systole. Ejection fraction can then be obtained by dividing the volume ejected by the heart (stroke volume) by the volume of the filled heart (end-diastolic volume).[63] Echocardiograms can also be conducted under circumstances when the body is more stressed, in order to examine for signs of lack of blood supply. This cardiac stress test involves either direct exercise, or where this is not possible, injection of a drug such as dobutamine.[62]

CT scans, chest X-rays and other forms of imaging can help evaluate the heart's size, evaluate for signs of pulmonary oedema, and indicate whether there is fluid around the heart. They are also useful for evaluating the aorta, the major blood vessel which leaves the heart.[62]

Treatment

A number of medications are used to treat diseases of the heart, or ameliorate symptoms.

For diseases of the heart rate or rhythm, a number of different antiarrhythmic agents are used. These may interfere with electrolyte channels and thus the cardiac action potential (such as calcium channel blockers, sodium channel blockers), interfere with stimulation of the heart by the sympathetic nervous system (beta blockers), or interfere in other ways, such as digoxin. Other examples include atropine for slow rhythms, and amiodarone for irregular rhythms. Such medications are not the only way of treating diseases of heart rate or rhythm. In the context of a new-onset irregular heart rhythm (atrial fibrillation), immediate electrical cardioversion may be attempted. For a slow heartbeat or heart block, a pacemaker or defibrillator may be inserted.[64] The acuity of onset often affects how a rhythm disturbance is managed, as does whether a rhythm causes hemodynamic instability, such as low blood pressure or symptoms. An instigating cause is investigated for, such as a heart attack, medication, or metabolic problem.[64]

For ischaemic heart disease, treatment also includes amelioration of symptoms. This includes GTN, beta blockers and, in the context of an acute event, stronger pain relief such as morphine and other opiates. Many of these drugs have additional protective benefits, by decreasing the sympathetic tone on the heart that occurs with the pain, or by dilating blood vessels (GTN).[64]

Treatment of heart disease includes primary and secondary prevention to prevent the occurrence or worsening of symptoms and atherosclerosis. This includes recommendations to cease smoking, decrease alcohol consumption, increase exercise, and make modifications to their diet to decrease the consumption of fats and sugars. Medications may also be given to help better control concurrent diabetes. Statins or other drugs such as fibrates may also be given to decrease a person's cholesterol levels. Blood pressure medication may also be commenced or modified.[64]

For many diseases of the heart, including atrial fibrillation and valvular disease, and after a heart operation, anticoagulation in the form of aspirin, warfarin, clopidogrel or novel oral anticoagulants is often given simultaneously, because of an increased risk of stroke or, in the context of a clotted heart vessel, rethrombosis.[64]

Surgery

Main articles: Cardiac surgery, Coronary artery bypass surgery, and Coronary stent

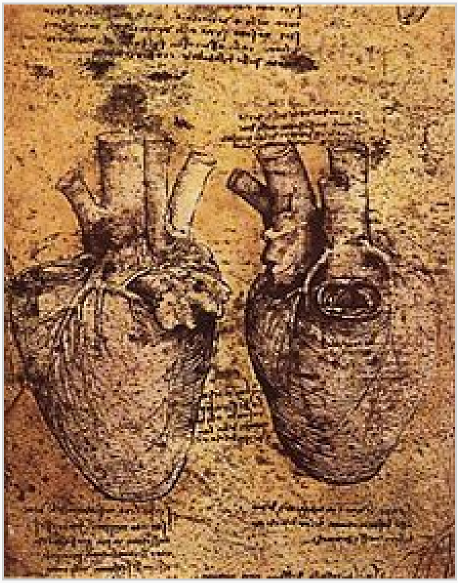
Surgery, when considered necessary for diseases of the heart, can take place via an open operation or via small guidewires inserted via peripheral arteries ("percutaneous coronary intervention"). Percutaneous coronary intervention is usually used in the context of an acute coronary syndrome, and may be used to insert a stent.[65]

Coronary artery bypass surgery is one such operation. In this operation, one or more arteries surrounding the heart that have becoming narrowed are bypassed. This is done by taking blood vessels harvested from another part of the body. Commonly harvested veins include the saphenous veins or the internal mammary artery. Because this operation involves the heart tissue, a machine is used so that blood can bypass the heart during the operation.[66]

Heart valve repair or valve replacement are options for diseases of the heart valves.[65]

History

Ancient



Heart and its blood vessels, by Leonardo da Vinci, 15th century

The valves of the heart were discovered by a physician of the Hippocratean school around the 4th century BC, although their function was not fully understood. On dissection, arteries are typically empty of blood because blood pools in the veins after death. It was subsequently assumed they were filled with air and served to transport air around the body.

Philosophers distinguished veins from arteries, but thought the pulse was a property of arteries. Erasistratos observed that arteries cut during life bleed. He ascribed the fact to the phenomenon that air escaping from an artery is replaced with blood which entered by very small vessels between veins and arteries. Thus he apparently postulated capillaries, but with reversed flow of blood.

The Greek physician Galen (2nd century AD) knew blood vessels carried blood and identified venous (dark red) and arterial (brighter and thinner) blood, each with distinct and separate functions. Growth and energy were derived from venous blood created in the liver from chyle, while arterial blood gave vitality by containing pneuma (air) and originated in the heart. Blood flowed from both creating organs to all parts of the body, where it was consumed and there was no return of blood to the heart or liver. The heart did not pump blood around, the heart's motion sucked blood in during diastole and the blood moved by the pulsation of the arteries themselves.

Galen believed the arterial blood was created by venous blood passing from the left ventricle to the right through 'pores' in the interventricular septum, while air passed from the lungs via the pulmonary artery to the left side of the heart. As the arterial blood was created, "sooty" vapors were created and passed to the lungs, also via the pulmonary artery, to be exhaled.

Pre-modern

The earliest descriptions of the coronary and pulmonary circulation systems can be found in the *Commentary on Anatomy in Avicenna's Canon*, published in 1242 by Ibn al-Nafis.[67] In his manuscript, al-Nafis wrote that blood passes through the pulmonary circulation instead of moving from the right to the left ventricle as previously believed by Galen.[68] His work was later translated into Latin by Andrea Alpago.[69]

In Europe, the teachings of Galen continued to dominate the academic community and his doctrines were adopted as the official canon of the Church. Andreas Vesalius questioned some of Galen's beliefs of the heart in *De humani corporis fabrica* (1543), but his magnum opus was interpreted as a challenge to the authorities and he was subjected to a number of attacks.[70] Michael Servetus wrote in *Christianismi Restitutio* (1553) that blood flows from one side of the heart to the other via the lungs.[70]

Modern

The breakthrough came with the publication of *De Motu Cordis* (1628) by the English physician William Harvey. Harvey's book completely describes the systemic circulation and the mechanical force of the heart, leading to an overhaul of the Galenic doctrines.[71] Otto Frank (1865–1944) was a German physiologist; among his many published works are detailed studies of this important heart relationship. Ernest Starling (1866–1927) was an important English physiologist who also studied the heart. Although they worked largely independently, their combined efforts and similar conclusions have been recognized in the name "Frank–Starling mechanism".[7]

Although Purkinje fibers and the bundle of His were discovered as early as the 19th century, their specific role in the electrical conduction system of the heart remained unknown until Sunao Tawara published his monograph, titled *Das Reizleitungssystem des Säugetierherzens*, in 1906. Tawara's discovery of the atrioventricular node prompted Arthur Keith and Martin Flack to look for similar structures in the heart, leading to their discovery of the sinoatrial node several months later. These structures form the anatomical basis of the electrocardiogram, whose inventor, Willem Einthoven, was awarded the Nobel Prize in Medicine or Physiology in 1924.[72]

The first successful heart transplantation was performed in 1967 by the South African surgeon Christiaan Barnard at Groote Schuur Hospital in Cape Town. This marked an important milestone in cardiac surgery, capturing the attention of both the medical profession and the world at large. However, long-term survival rates of patients were initially very low. Louis Washkansky, the first recipient of a donated heart, died 18 days after the operation while other patients did not survive for more than a few weeks.[73] The American surgeon Norman Shumway has been credited for his efforts to improve transplantation techniques, along with pioneers Richard Lower, Vladimir Demikhov and Adrian Kantrowitz. As of March 2000, more than 55,000 heart transplantations have been performed worldwide.[74]

By the middle of the 20th century, heart disease had surpassed infectious disease as the leading cause of death in the United States, and it is currently the leading cause of deaths worldwide. Since 1948, the ongoing Framingham Heart Study has shed light on the effects of various influences on the heart, including diet, exercise, and common medications such as aspirin. Although the introduction of ACE inhibitors and beta blockers has improved the management of chronic heart failure, the disease continues to be an enormous medical and societal burden, with 30 to 40% of patients dying within a year of receiving the diagnosis.[75]

Society and culture

Further information: Sacred Heart, Heart symbol, and Blood § Cultural and religious beliefs

Symbolism

***jb* (F34) "heart" in hieroglyphs**

As one of the vital organs, the heart was long identified as the center of the entire body, the seat of life, or emotion, or reason, will, intellect, purpose or the mind.[76] The heart is an emblematic symbol in many religions, signifying "truth, consience or moral courage in many religions - the temple or throne of God in Islamic and Judeo-Christian thought; the divine centre, or atman, and the third eye of transcendent wisdom in Hinduism; the diamond of purity and essence of the Buddha; the Taoist centre of understanding."[76]

Letter ღ of the Georgian script is often used as a "heart" symbol.

The seal script glyph for "heart" (Middle Chinese *sim*)

In the Hebrew Bible, the word for heart, *lev*, is used in these meanings, as the seat of emotion, the mind, and referring to the anatomical organ. It is also connected in function and symbolism to the stomach.[77]

An important part of the concept of the soul in Ancient Egyptian religion was thought to be the heart, or *ib*. The *ib* or metaphysical heart was believed to be formed from one drop of blood from the child's mother's heart, taken at conception.[78] To ancient Egyptians, the heart was the seat of emotion, thought, will, and intention. This is evidenced by Egyptian expressions which incorporate the word *ib*, such as *Awi-ib* for "happy" (literally, "long of heart"), *Xak-ib* for "estranged" (literally, "truncated of heart").[79] In Egyptian religion, the heart was the key to the afterlife. It was conceived as surviving death in the nether world, where it gave evidence for, or against, its possessor. It was thought that the heart was examined by Anubis and a variety of deities during the *Weighing of the Heart* ceremony. If the heart weighed more than the feather of Maat, which symbolized the ideal standard of behavior. If the scales balanced, it meant the heart's possessor had lived a just life and could enter the afterlife; if the heart was heavier, it would be devoured by the monster Ammit.[80]

The Chinese character for "heart", 心, derives from a comparatively realistic depiction of a heart (indicating the heart chambers) in seal script.[81] The Chinese word *xīn* also takes the metaphorical meanings of "mind", "intention", or "core".[82] In Chinese medicine, the heart is seen as the center of 神 *shén* "spirit, consciousness".[83] The heart is associated with the small intestine, tongue, governs the six organs and five viscera, and belongs to fire in the five elements.[84]

The Sanskrit word for heart is *hṛd* or *hṛdaya*, found in the oldest surviving Sanskrit text, the Rigveda. In Sanskrit, it may mean both the anatomical object and "mind" or "soul", representing the seat of emotion. *Hrd* may be a cognate of the word for heart in Greek, Latin, and English.[85][86]

Many classical philosophers and scientists, including Aristotle, considered the heart the seat of thought, reason, or emotion, often disregarding the brain as contributing to those functions.[87] The identification of the heart as the seat of emotions in particular is due to the Roman physician Galen, who also located the seat of the passions in the liver, and the seat of reason in the brain.[88]

The heart also played a role in the Aztec system of belief. The most common form of human sacrifice practiced by the Aztecs was heart-extraction. The Aztec believed that the heart (*tona*) was both the seat of the individual and a fragment of the Sun's heat (*istli*). To this day, the Nahua consider the Sun to be a heart-soul (*tona-tiuh*): "round, hot, pulsating".[89]

In Catholicism, there has been a long tradition of worship of the heart, stemming from worship of the wounds of Jesus Christ which gained prominence from the mid sixteenth century.[90] This tradition influenced the development of the medieval Christian devotion to the Sacred Heart of Jesus and the parallel worship of Immaculate Heart of Mary, made popular by John Eudes.[91]

The expression of a broken heart is a cross-cultural reference to grief for a lost one or to unfulfilled romantic love.

The notion of "Cupid's arrows" is ancient, due to Ovid, but while Ovid describes Cupid as wounding his victims with his arrows, it is not made explicit that it is the *heart* that is wounded. The familiar iconography of Cupid shooting little heart symbols is a Renaissance theme that became tied to Valentine's day.[76]

Food

Animal hearts are widely consumed as food. As they are almost entirely muscle, they are high in protein. They are often included in dishes with other offal, for example in the pan-Ottoman kokoretsi.

Chicken hearts are considered to be giblets, and are often grilled on skewers: Japanese *hāto yakitori*, Brazilian *churrasco de coração*, Indonesian chicken heart satay.[92] They can also be pan-fried, as in Jerusalem mixed grill. In Egyptian cuisine, they can be used, finely chopped, as part of stuffing for chicken.[93] Many recipes combined them with other giblets, such as the Mexican *pollo en menudencias*[94] and the Russian *ragu iz kurinyikh potrokhov*.[95]

The hearts of beef, pork, and mutton can generally be interchanged in recipes. As heart is a hard-working muscle, it makes for "firm and rather dry" meat,[96] so is generally slow-cooked. Another way of dealing with toughness is to julienne the meat, as in Chinese stir-fried heart.[97]

Beef heart may be grilled or braised.[96] In the Peruvian *anticuchos de corazón*, barbecued beef hearts are grilled after being tenderized through long marination in a spice and vinegar mixture. An Australian recipe for "mock goose" is actually braised stuffed beef heart.[98]

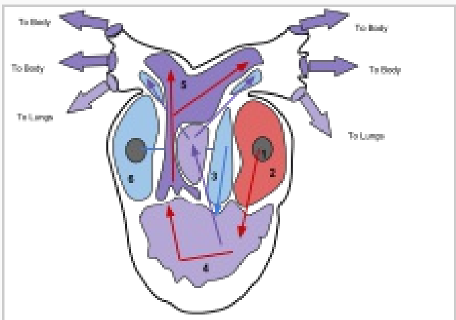
Pig heart is stewed, poached, braised,[99] or made into sausage. The Balinese *oret* is a sort of blood sausage made with pig heart and blood. A French recipe for *cœur de porc à l'orange* is made of braised heart with an orange sauce.

Other animals

The structure of the heart varies among the different animal groups. Cephalopods have two "gill hearts" also known as branchial hearts and one "systemic heart". The vertebrate heart lies in the front (ventral) part of the body cavity, dorsal to the gut. It is always surrounded by a pericardium, which is usually a distinct structure, but may be continuous with the peritoneum in jawless and cartilaginous fish.

The SA node is found in all amniotes but not in more primitive vertebrates. In these animals, the muscles of the heart are relatively continuous and the sinus venosus coordinates the beat which passes in a wave through the remaining chambers. Indeed, since the sinus venosus is incorporated into the right atrium in amniotes, it is likely homologous with the SA node. In teleosts, with their vestigial sinus venosus, the main centre of coordination is, instead, in the atrium. The rate of heartbeat varies enormously between different species, ranging from around 20 beats per minute in codfish to around 600 in hummingbirds[100] and up to 1200 bpm in the ruby-throated hummingbird.[101]

Double circulatory systems



A cross section of a three chambered

In the heart of lungfish, the septum extends part-way into the ventricle. This allows for some degree of separation between the de-oxygenated bloodstream destined for the lungs and the oxygenated stream that is delivered to the rest of the body. The absence of such a division in living amphibian species may be partly due to the amount of respiration that occurs through the skin; thus, the blood returned to the heart through the venae cavae is already partially oxygenated. As a result, there may be less need for a finer division between the two bloodstreams than in lungfish or other tetrapods. Nonetheless, in at least some species of amphibian, the spongy nature of the ventricle does seem to maintain more of a separation between the bloodstreams. Also, the original valves of the conus arteriosus have been replaced by a spiral valve that divides it into two parallel parts, thereby helping to keep the two bloodstreams separate.[100]

adult amphibian heart, note the single ventricle. The purple regions represent areas where mixing of oxygenated and de-oxygenated blood occurs.

1. Pulmonary Vein
2. Left Atrium
3. Right Atrium
4. Ventricle
5. Conus arteriosus
6. Sinus venosus

Adult amphibians and most reptiles have a double circulatory system but the heart is not separated into two pumps. The development of the double system is necessitated by the presence of lungs which deliver oxygenated blood directly to the heart.

In amphibians, the atrium is divided into two chambers by a muscular septum but there is only one ventricle. The sinus venosus, which remains large, connects only to the right atrium and receives blood from the venae cavae, with the pulmonary vein by-passing it to enter the left atrium.

The heart of most reptiles is similar in structure to that of lungfish but the septum is generally much larger. This divides the ventricle into two halves but the septum does not reach the whole length of the heart and there is a considerable gap near the pulmonary artery and aorta openings. In most reptilian species, there appears to be little, if any, mixing between the bloodstreams, so the aorta receives, essentially, only oxygenated blood.[100]

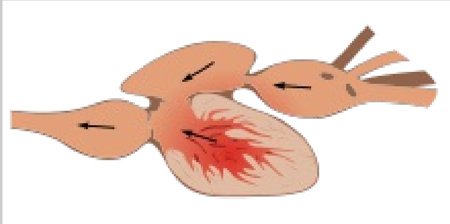
The fully divided heart

Archosaurs (crocodilians and birds) and mammals show complete separation of the heart into two pumps for a total of four heart chambers; it is thought that the four-chambered heart of archosaurs evolved independently from that of mammals. In crocodilians, there is a small opening, the foramen of Panizza, at the base of the arterial trunks and there is some degree of mixing between the blood in each side of the heart, during a dive underwater;[102][103] thus, only in birds and mammals are the two streams of blood – those to the pulmonary and systemic circulations – permanently kept entirely separate by a physical barrier.[100]

Fish

Main article: Fish anatomy § Heart

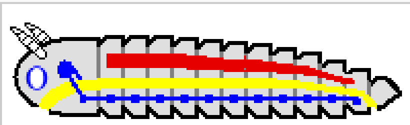
Primitive fish have a four-chambered heart, but the chambers are arranged sequentially so that this primitive heart is quite unlike the four-chambered hearts of mammals and birds. The first chamber is the sinus venosus, which collects deoxygenated blood, from the body, through the hepatic and cardinal veins. From here, blood flows into the atrium and then to the powerful muscular ventricle where the main pumping action will take place. The fourth and final chamber is the conus arteriosus which contains several valves and sends blood to the *ventral aorta*. The ventral aorta delivers blood to the gills where it is oxygenated and flows, through the dorsal aorta, into the rest of the body. (In tetrapods, the ventral aorta has divided in two; one half forms the ascending aorta, while the other forms the pulmonary artery).[100]



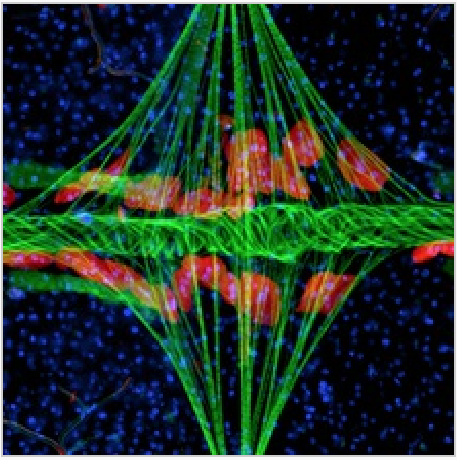
Blood flow through the fish heart: sinus venosus, atrium, ventricle, and outflow tract

In the adult fish, the four chambers are not arranged in a straight row but, instead form an S-shape with the latter two chambers lying above the former two. This relatively simpler pattern is found in cartilaginous fish and in the ray-finned fish. In teleosts, the conus arteriosus is very small and can more accurately be described as part of the aorta rather than of the heart proper. The conus arteriosus is not present in any amniotes, presumably having been absorbed into the ventricles over the course of evolution. Similarly, while the sinus venosus is present as a vestigial structure in some reptiles and birds, it is otherwise absorbed into the right atrium and is no longer distinguishable.[100]

Invertebrates



Basic arthropod body structure – heart shown in red

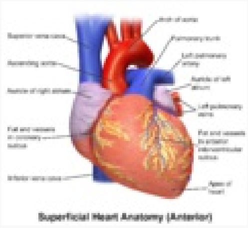


The tube-like heart (green) of the mosquito *Anopheles gambiae* extends horizontally across the body, interlinked with the diamond-shaped wing muscles (also green) and surrounded by pericardial cells (red). Blue depicts cell nuclei.

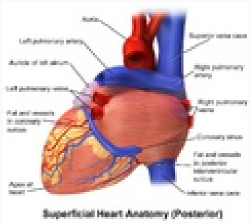
Arthropods have an open circulatory system, and often some short open-ended arteries.The arthropod heart is typically a muscular tube that runs the length of the body, under the back and from the base of the head. Instead of blood the circulatory fluid is haemolymph which carries the most commonly used respiratory pigment, copper-based haemocyanin as the oxygen transporter; iron-based haemoglobin is used by only a few arthropods. The heart contracts in ripples from the rear to the front of the animal transporting water and nutrients. Pairs of valves run alongside the heart, allowing fluid to enter whilst preventing backflow.

In insects, the circulatory system is not used to transport oxygen and so is much reduced, having no veins or arteries and consisting of a single perforated tube running dorsally which pumps peristaltically. The simpler unsegmented invertebrates have no body cavity, and oxygen and nutrients pass through their bodies by diffusion.

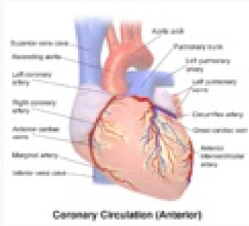
Additional images



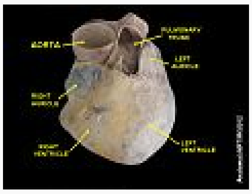
The human heart viewed from the front

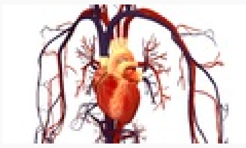


The human heart viewed from behind



The coronary circulation


An anatomical specimen of the heart


Heart Illustration with circulatory system

Notes

a. **^** From the heart to the body
b. **^** Arteries that contain deoxygenated blood, from the heart to the lungs
c. **^** Supplying blood to the heart itself
d. **^** From the body to the heart
e. **^** Veins containing oxygenated blood from the lungs to the heart
f. **^** Veins that drain blood from the cardiac tissue itself
g. **^** Note the muscles do **not** cause the valves to open. The pressure difference between the blood in the atria and the ventricles does this.

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V · T · E		Anatomy of the heart
General	Surface	base · apex · sulci (coronary · interatrial · anterior interventricular · posterior interventricular) · borders (right · left)
	Internal	atria (interatrial septum · pectinate muscles · terminal sulcus) · ventricles (interventricular septum · trabeculae carneae · chordae tendineae · papillary muscle) · valves · cusps · atrioventricular septum
		cardiac skeleton · intervenous tubercle
Chambers	Right heart	*(venae cavae, coronary sinus)* → right atrium (atrial appendage, fossa ovalis, limbus of fossa ovalis, crista terminalis, valve of inferior vena cava, valve of coronary sinus) → tricuspid valve → right ventricle (infundibulum, moderator band/septomarginal trabecula) → pulmonary valve → *(pulmonary artery and pulmonary circulation)*
	Left heart	*(pulmonary veins)* → left atrium (atrial appendage) → mitral valve → left ventricle → aortic valve (aortic sinus) → *(aorta and systemic circulation)*
Layers	Endocardium	heart valves
	Myocardium	Conduction system (cardiac pacemaker · SA node · AV node · bundle of His · bundle branches · Purkinje fibers)
	Pericardial cavity	pericardial sinus
	Pericardium	fibrous pericardium (sternopericardial ligaments) · serous pericardium (epicardium/visceral layer) · fold of left vena cava
Blood supply		Coronary circulation

V · T · E		Physiology of the cardiovascular system
	Cardiac output	Cardiac cycle · Cardiac output (Heart rate · Stroke volume) · Stroke volume (End-diastolic volume · End-systolic volume) · Afterload · Preload · Frank–Starling law of the heart · Cardiac function curve · Venous return curve · Wiggers diagram · Pressure volume diagram
	Ultrasound	Fractional shortening = (End-diastolic dimension · End-systolic dimension) / End-diastolic dimension · Aortic valve area calculation ·

Heart		Ejection fraction · Cardiac index
	Heart rate	Cardiac pacemaker · Chronotropic (Heart rate) · Dromotropic (Conduction velocity) · Inotropic (Contractility) · Bathmotropic (Excitability) · Lusitropic (Relaxation)
	Conduction	Conduction system · Cardiac electrophysiology · Action potential (cardiac · atrial · ventricular) · Effective refractory period · Pacemaker potential · Electrocardiography (P wave · PR interval · QRS complex · QT interval · ST segment · T wave · U wave) · Hexaxial reference system
	Chamber pressure	Central venous · Right (atrial · ventricular) · pulmonary artery (wedge) · Left (atrial · ventricular) · Aortic
	Other	Ventricular remodeling
Vascular system/ Hemodynamics	**Blood flow**	Compliance · Vascular resistance · Pulse · Perfusion
	Blood pressure	Pulse pressure (Systolic · Diastolic) · Mean arterial pressure · Jugular venous pressure · Portal venous pressure
	Regulation of BP	Baroreflex · Kinin–kallikrein system · Renin–angiotensin system · Vasoconstrictors · Vasodilators · Autoregulation (Myogenic mechanism · Tubuloglomerular feedback · Cerebral autoregulation) · Paraganglia (Aortic body · Carotid body · Glomus cell)
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