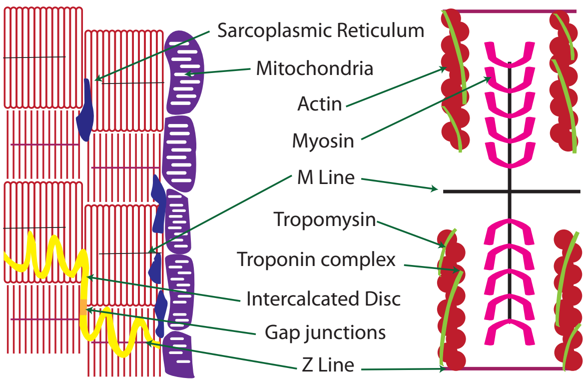
STRUCTURE AND FUNCTION OF THE HEART

Cardiac function The overall function of the cardiovascular system is to deliver oxygen and metabolic substrates to the to the tissues and to remove the products of metabolism.

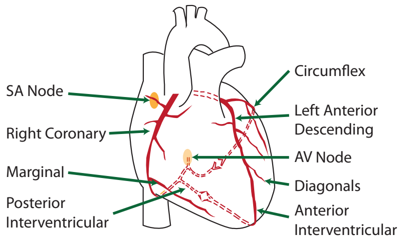


Cardiac Muscle is a unique type of involuntary striated muscle which resembles skeletal muscle in many of its features. Cardiac muscle has several structural and functional differences as compared to skeletal muscle.

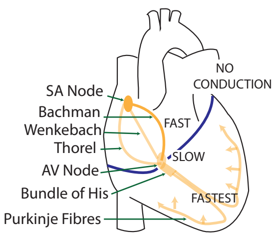
Structurally it is smaller, usually mononuclear, arranged more in series as opposed to parallel, it has a greater number of mitochondria (cardiac muscle is almost entirely aerobic), and has intercalcated discs separated by gap junctions (which bind the muscle cells together and permit electrical coupling).

Functionally all myocytes display five basic characteristics: rhythmicity (chronotropy), conductivity (dromotropy), excitiability (bathmotropy), contractility (inotropy) and relaxation (lusitropy). Cardiac muscle has automaticity which is the property of the heart to initiate its own heart beat. This occurs in specialised pacemaker cells of the SA and AV nodes as well as some ventricular cells. The resting membrane is not stable in phase 4 and the resting potential decreases towards to the threshold potential. This is intrinsic (not requiring external input) although catecholamines may increase pacemaker rates. Following depolarisation, the membrane repolarises and then the sequence of spontaneous depolarisation occurs again. This involves a period of absolute refractory period (where the muscle cannot contract again) and relative refractory period (where with a large enough stimulus the muscle may contract -although a reduced force). The predictable regularity of this sequence of events gives the heart a regular rhythm. This is known as the property of rhythmicity. The cardiac muscle enables improved conductivity due to specialised tracts known as the conducting system of the heart. It propogates through low resistance pathways alongside the intercalcated discs and easily crosses the gap junctions. The benefit of this system is improved coordination of each contraction and the heart has been described as a functional synctium due to this level of coordination. Cardiac muscle has increased excitability, that is it can respond to smaller stimulus than skeletal muscles. The steeper the slope of phase 0 the more excitable the myocyte. Contractility is an intrinsic property of cardiac muscle and refers to the ability of muscle to develop force at a given length. Finally cardiac myocytes demonstrate lusitropy which is an active phase of relaxation in the isovolaemic relaxation phase.

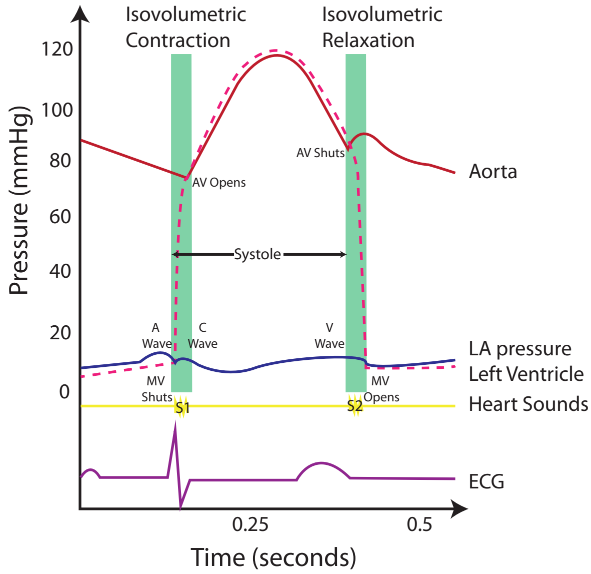
Cardiac Anatomy The left and right coronary arteries arise from the aortic root behind the cusps of the aortic valve. The right coronary artery perfuses the right ventricle and atrium. The left coronary artery divides into the anterior descending and circumflex branches and perfuses the left ventricle and atrium. There is considerable overlap between the left and right ateries and the right is more commonly predominant. Most venous blood drains into the right atrium via the coronary sinus although the thebsian circulation drains into the left side of the circulation and constitutes a physiological shunt.



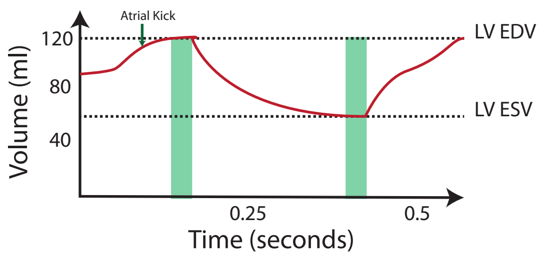
The heart has dual and opposing nerve supplies. Parasympathetic (acteylcholine - slows heart rate) and is supplied by the vagal nerve and sympathetic (catecholamine transmitter, increases heart rate and force of contraction). Sympathetic nerves originate from the intermediolateral columns of the upper thoracic spinal cord and synapse in the middle of stellate ganglia then form a complex plexus (incl. parasympathetic fibres) to innervate the heart. Embryologically the SA develops on the right side (hence right sided nerve supply) and the AV from the left with corresponding supply.



There are three bundles of atrial fibres that contain the Purkinje-type fibres and connect the SA to AV. Anteriorly it is the Bachmann tract, Wenkebach is in the middle and Thorel is posterior. Whilst the SA and AV have slow conduction speeds of 5cm/second, the atrial pathway, bundle of HIS and ventricular muscle conduct at 100cm/second and the purkinje system at the very fast rate of 400cm/second. Because the AV node is a gateway its reduced speed means that there is a AV nodal delay of 0.1 second.



Left Ventricle Pressure / Time Curve This curve is used in the context of discussing the cardiac cycle. The ECG and the heart sounds are used as the timing reference points. The QRS complex represents the electrical depolarisation of the ventricle. At this point the mitral valve is forced shut by the increase in LV pressure. There is then a period of isovolumetric contraction where pressure in the ventricle increases dramatically until it exceeds aortic pressure and the aortic valve is forced open. The pressure continues to exceed aortic pressure and blood is forced out of the ventricle. As the blood exits the LV the pressure drops and when it is less than the aortic pressure the aortic valve snaps shut. There is then a period of active relaxation (lusitropy) with both valves shut, called isovolumetric relaxation. When the pressure drops below CVP the mitral valve reopens and diastole occurs allowing the ventricle to refill (CVP>LVP).



Left Ventricular Volume / Time Curve This trace shows the volume of the left ventricle throughout the cycle. The important point is the atrial kick. Loss of this kick in atrial fibrillation and other conditions can adversely affect cardiac function through impaired LV filling. The maximal volume occurs at the end of diastolic filling and is labelled the left ventricular end-diastolic volume (LVEDV). In the same way, the minimum volume is the left ventricular end-systolic volume (LVESV). The difference between these two values must, therefore, be the stroke volume (SV), which is usually 70 ml as demonstrated above. The ejection fraction (EF) is the SV as a percentage of the LVEDV and is around 60% in the diagram adjacent.

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