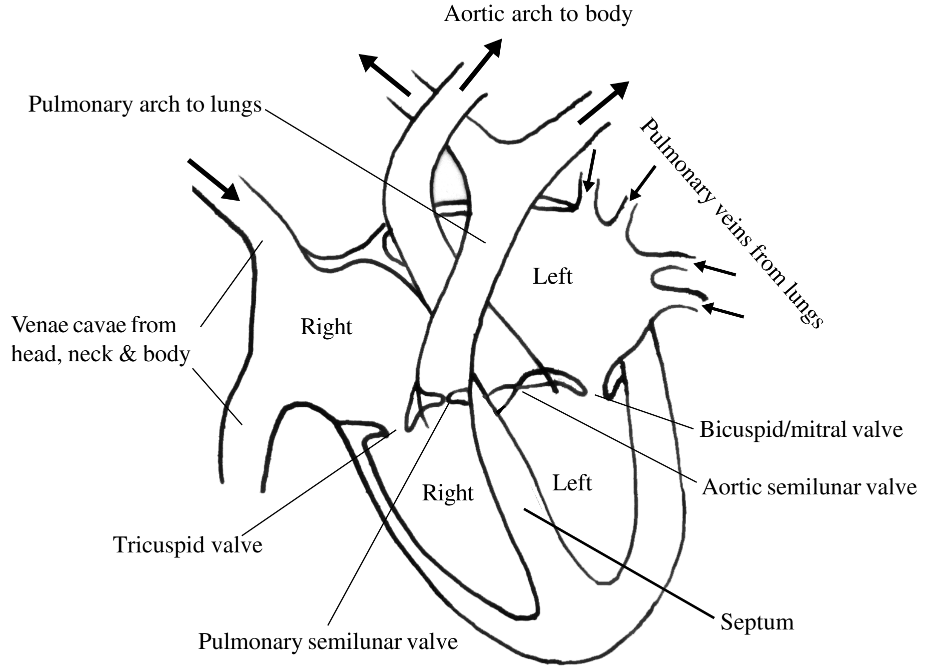
Bio Factsheet

www.curriculum-press.co.uk Number 139

Answering exam questions on the heart

When answering most exam questions on the heart it is essential that you know the basic anatomy of the heart, the cardiac cycle and how the heart beat is controlled. You will be able to interpret and analyse more complicated data interpretation questions only when you have this basic knowledge and understand it. Study the diagram below.

Fig 1. Section through human heart



Learn that:-

1 There are four chambers, **right atrium**, **left atrium**, **right ventricle** and **left ventricle**. *A very common error is that candidates confuse the left and right sides of the heart.*

2 There is a specific set of blood vessels associated with each heart chamber.
   * The right atrium receives deoxygenated blood from the body, (the venous return), via two veins called **venae cavae**. The superior/ anterior vena cava returns blood from the head and neck and the inferior/posterior vena cava returns blood from the rest of the body.
   * The left atrium receives oxygenated blood from the lungs via four **pulmonary veins**.
   * The right ventricle receives deoxygenated blood from the right atrium and pumps it to the lungs, for oxygenation, via the **pulmonary arch**. This divides into two pulmonary arteries, one to each lung.
   * The left ventricle receives oxygenated blood from the left atrium and pumps it to the body via the **aortic arch**. The aortic arch leads to the dorsal aorta which is the main artery to the body.

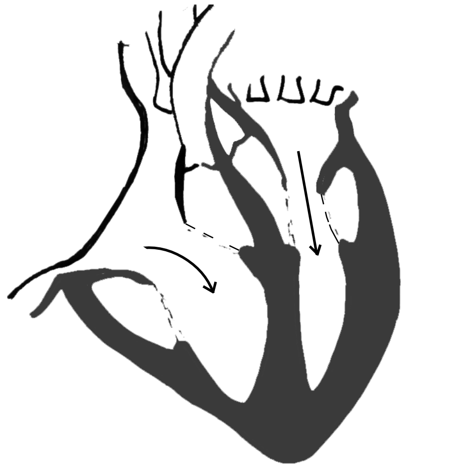
***Exam Hint:** - Candidates frequently err by associating the wrong vessels with specific heart chambers, or by reversing the blood flow in particular vessels or chambers, or by reversing the state of blood oxygenation in the left and right sides of the heart. Remember, the right side contains deoxygenated blood, the left side contains oxygenated blood.*

3 There are four valves in the heart whose job is to prevent backflow of blood in the heart.
   * The **tricuspid valve** is between the right atrium and right ventricle. It will be open when the heart relaxes and fills (diastole) and shut when the ventricle is contracting (systole).
   * The **bicuspid (mitral) valve** is between the left atrium and the left ventricle. It will be open when the heart relaxes and fills (diastole) and shut when the ventricle is contracting (systole).
   * The **pulmonary semilunar valve**, at the base of the pulmonary arch, is shut when the heart relaxes and fills, but opens when the right ventricle contracts to pump blood through the arch to the lungs.
   * The **aortic semilunar valve**, at the base of the aortic arch, is shut when the heart relaxes and fills, but opens when the left ventricle contracts to pump blood through the arch to the body.

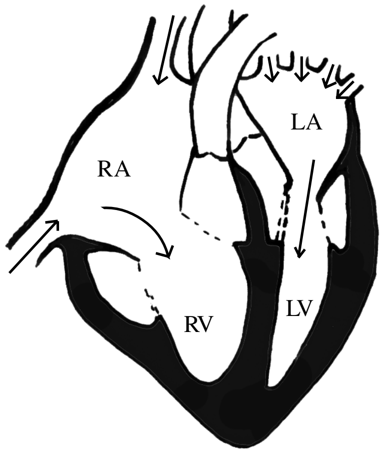
***Exam Hint:**- Students frequently mix the atrio-ventricular valves up by incorrectly placing the tricuspid valves on the left side and the bicuspid valves on the right side. Another common error is to have the valves open or shut at the wrong times in the cardiac cycle (heart beat cycle).*

Questions are frequently asked about the sequence of events that make up a **cardiac cycle** (one heart beat). Learn the following details of the cardiac cycle:-

Cardiac cycle



In **diastole**, the walls of the atria and the ventricles relax, the tricuspid and bicuspid valves are open but the semilunar valves at the bases of the aorta and pulmonary artery are closed. Thus blood flows into the heart, from the pulmonary veins and from the venae cavae, filling the atria and ventricles.



In **atrial systole**, the atria contract forcing blood from the atria into the relaxed ventricles. The blood cannot flow back up the veins because veins contain valves that prevent this. At this stage the tricuspid and bicuspid valves are open, but the semilunar valves are still closed. So blood cannot be pumped to the lungs or the body

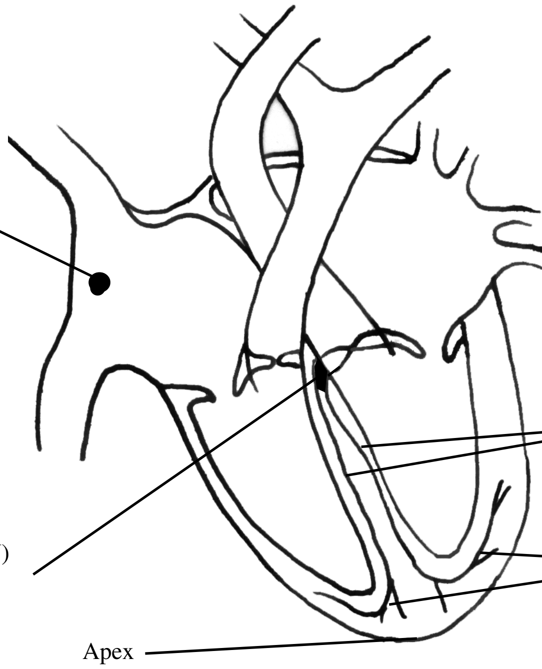
In **ventricular systole**, the tricuspid and bicuspid valves then close, preventing backflow of blood from ventricles to atria. The semilunar valves open so that blood can flow from the ventricles into the pulmonary artery and the aorta. The ventricles contract, forcing blood into the pulmonary artery to the lungs and into the aorta to the body. Atrial diastole starts while ventricular diastole is occurring.

Exam Hint:- *Candidates frequently mix up the stages of the cardiac cycle and the sequences of valve movements. A very common error is to describe diastole as blood just entering the atria with the tricuspid and bicuspid valves closed. Although this happens for a small fraction of a second during ventricular systole, in full diastole the whole heart relaxes and both atria and ventricles fill with blood, with the tricuspid and bicuspid valves open.*

Another common error made by candidates is to have blood passing across the heart from left to right or vice versa. Remember blood can only get from one side of the heart to the other side through the circulation, because the septum of the heart prevents passage from side to side.

The diagram below gives details that you need to know to answer questions on the control of the heart beat. Remember that the heart co-ordinates its own cardiac cycle.

Fig 2. Section of heart showing its conducting system



- Cardiac (heart) muscle is **myogenic**. This means it will contract and relax **rhythmically** of its own accord. The mean inherent rhythm rate of ventricular muscle is 72 contractions minute^{-1}. This gives the mean heart beat rate.

> ***Exam Hint**: - When answering questions about the control of the heart beat these facts should start the account. However, many candidates forget to include these facts but start their answers by describing the SAN/pacemaker.*

- The SAN generates impulses which spread through and depolarize the cardiac muscle causing contraction. Thus the right atrium receives impulses before the left atrium and so the right atrium contracts before the left atrium.

> ***Exam Hint:** - Candidates often mix up the sides of the heart here by putting the SAN in the left atrium.*

Where the atria and ventricles join is a thick ring of fibrous connective tissue which is the 'skeleton' to which the cardiac muscle is attached. The impulse from the SAN cannot pass this and can only pass to the ventricles via the AVN.

> ***Exam Hint:**- Few candidates remember this and most neglect to explain why the impulses can only be routed via the AVN.*

- The AVN has fairly high electrical resistance and delays the impulse passage by about 0.1 second. The impulses are then very rapidly shunted through the bundles of His to the apex of the heart and are dispersed through the ventricular muscle, causing depolarization and contraction.

> ***Exam Hint:** - Many candidates forget to refer to the AVN-delay which is responsible for delaying ventricular contraction until the atria are starting relaxation. Candidates frequently forget to point out that the ventricles contract from the apex upwards – a fact linked to the rapid shunt of the bundles of His and the branching out of the Purkyne fibres from the apex upwards.*

- After the cardiac muscle fibres have depolarized and contracted they then repolarise and relax.

> ***Exam Hint:**- Candidates often forget to mention this, or make the point that the repolarisation sequence of the parts of the heart will follow the depolarization sequence, - right atrium, left atrium, ventricles from apex.*

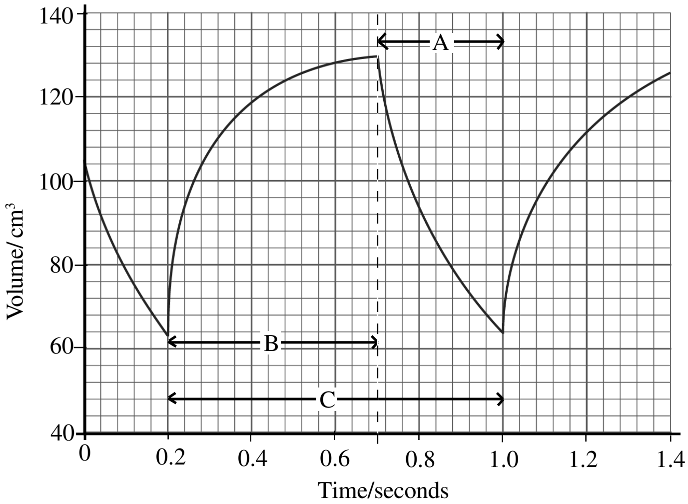
Though the heart co-ordinates its own beat, at a mean frequency of 72 beats minute^{-1}, (the inherent frequency of ventricular cardiac muscle and also the mean impulse generation rate of the SAN), the frequency and force of the heart beat is modified by the autonomic nervous system.

- The **sympathetic nerves** to the heart go directly to the SAN/AVN and to cardiac muscle. Increased stimulation of the sympathetic nerves (and stimulation by adrenaline/nor-adrenaline) accelerates the heart – it increases the frequency and force of the heart beat. Decreased stimulation has the reverse effects.

- The **parasympathetic nerves** to the heart (branches of the vagus nerve) go to the SAN and AVN. Increase in parasympathetic stimulation decreases the impulse frequency of the SAN and increases the delay time at the AVN thus slowing the heart beat. A decrease in parasympathetic stimulation increases the impulse frequency of the SAN and decreases the delay time at the AVN, thus complementing the effects of sympathetic stimulation.

> ***Exam Hint:**- When describing the control of the heart beat candidates often forget to include the role of the nervous system, or if they do they often get the sympathetic and parasympathetic systems confused. Few candidates make the point that the heart rate is a result of **balance**between sympathetic and parasympathetic stimulation.*

The following graph shows changes in the volume of blood in the right ventricle as the heart beats.



The line A shows when blood is leaving the ventricle. Explain, in terms of blood pressure, why blood does not flow back into the atrium at this time.

Answer:
ventricle will be contracting thus raising the pressure to force blood out;
thus ventricular pressure is higher than in the atrium;
this will force the tricuspid valves shut, closing the passage from RV to RA;

> *The commonest error by candidates is to refer to the wrong valve – in this case they may refer incorrectly to the bicuspid valve or to an arch semilunar valve. Some candidates tend to give too much detail – details of the actions of valve tendons (chordae tendinae) and valve muscles (papillary muscles) are not relevant because the question specified 'in terms of blood pressure'. To do this is poor exam technique because it wastes time and cannot score extra marks.*

Candidates were asked to draw a horizontal line on the graph to show the period in one cardiac cycle when the muscle in the wall of the ventricle is relaxed. Candidates should have drawn line B having realized that this is when the complete heart is filling (diastole) and so the ventricles (and atria) would be relaxed.

The line must be horizontal, not wobbly, and run from 0.2 to 0.7 seconds exactly. Candidates who lacked this precision would not score. Candidates who drew a line from 1.0 to 1.4 would not score because it was not a completes diastolic phase.

Candidates were asked to draw a horizontal line on the graph to show one complete cardiac cycle. Candidates should have drawn line C, realizing that this included both diastole and systole. Diastole started at 0.2 seconds and then at 1.0 seconds so the line should stretch from 0.2 to 1.0 seconds.

Candidates whose lines were not horizontal, or were wobbly or did not run exactly from 0,2 to 1.0 seconds would not score.

Candidates were asked to use line C to calculate the number of times the heart would beat in one minute and to show their working.

Answer
1 beat (line C) = 0.8 sec
number of beats per minute = 60 ÷ 0.8 ; = 75 beats minute^{-1} ;

Candidates were then asked to calculate the volume of blood pumped out by the heart in dm^3 minute^{-1}, (this is the cardiac output), and to show their working.

Answer:
from graph, volume of blood pumped out per beat = 130 - 64 = 66 cm^3 ;
cardiac output = 66 x 75 ÷ 1000 = 4.95 dm^3 minute^{-1} ;

> *In each of these calculations, candidates who failed to show their working would lose the first mark. (Remember – semicolons indicate marking points). Candidates who failed to give the units could lose the second mark.*

In conditions of hard physical work the cardiac output could increase to as much as 20 dm^3 minute^{-1}. Describe the role of the autonomic nervous system in achieving this rise.

Answer:
decrease in parasympathetic stimulation allows SAN/pacemaker to increase its impulse frequency;
also shortens the delay time for impulses to pass the AVN;
increase in sympathetic stimulation will increase the frequency and force of contraction of cardiac muscle;

> *Weaker candidates usually omit details of the parasympathetic functions, assuming that increase in cardiac output just relates to the sympathetic system. To make answers clear, candidates should refer to decreased parasympathetic stimulation and to increased sympathetic stimulation. There is always a balanced measure of both sympathetic and parasympathetic stimulation to the heart, to adjust the cardiac output according to bodily requirements.*

During the cardiac cycle the heart fills with blood and then the ventricles contract. The table below gives the filling time and the contraction time at different heart rates.

Heart rate /beats minute^{-1}	Filling time /seconds	Contraction time/seconds
40	0.38	1.15
50	0.39	0.85
71	0.39	0.47
81	0.39	0.36
88	0.40	0.32

Candidates were asked to describe two observations from the figures in the table.

Answer:
as the heart rate increases the filling time remains more or less constant/ only increases slightly;
but the contraction time decreases as the heart rate increases;

> *Candidates should direct their observations to the changes in the variables in the table (columns 2 and 3). Candidates who try to explain the observations instead of describing them as asked in the question would lose marks.*

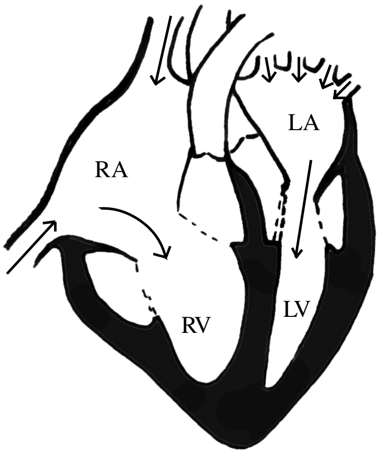
Candidates were then asked to explain how they would use the figures in the table to calculate the contraction time at a heart rate of 60 beats per minute.

Answer: Candidates may have suggested:
drawing a graph of contraction time plotted against rate;
reading off the value for 60 beats per minute;

Other candidates may have suggested:
one heart beat would take 1 second (60 seconds per minute);
subtract the filling time/0.39 seconds which is constant at middle range rates;

> *Candidates were not asked to do the calculation but to explain how to do it. Thus candidates who just gave an answer (0.61 seconds) would not score.*

Study the following diagram of the heart.

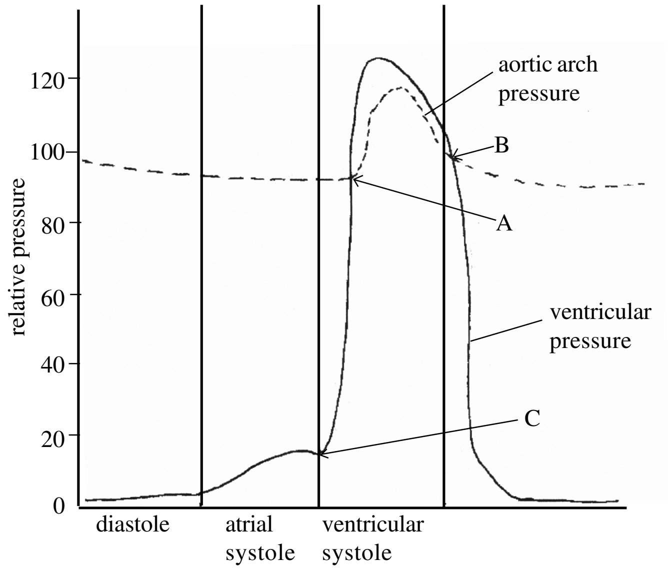


Candidates were asked which stage of the cardiac cycle the heart was showing and to explain why.

Answer:
diastole/filling/relaxation stage;
blood is entering from all the veins and filling all chambers/atria and ventricles;
the tricuspid and bicuspid valves are wide open but the arch semilunar valves are closed;

> *Many candidates failed to refer to the states of the valves. Some candidates just referred to the entry of blood into the atria and did not notice that the ventricles also fill.*

Candidates were then asked to study the following graph which indicates the pressure changes in the left ventricle and aortic arch during a cardiac cycle.



Candidates were asked to state and explain the changes to heart valves which occurred at A, B and C.

Answer:
aortic semilunar valves open at A because left ventricular blood pressure exceeds aortic blood pressure;
thus blood flows from left ventricle to aortic arch;
aortic semilunar valves close at B because aortic blood pressure exceeds left ventricular blood pressure;
prevents backflow/ventricle has emptied and its pressure is falling;
bicuspid/mitral valves forced closed at C by increasing ventricular blood pressure;
prevents backflow from left ventricle to left atrium;

> *It is always important for candidates to read questions carefully because some candidates failed to note that the question referred specifically to the left side of the heart and consequently got the valves wrong. The question shows the need for good knowledge – with a sound knowledge and understanding of the cardiac cycle it is easy to answer. If that knowledge and understanding is deficient it becomes very difficult to give a correct answer.*

Acknowledgements:
This Factsheet was researched and written by Martin Griffin.
Curriculum Press, Bank House, 105 King Street, Wellington, Shropshire, TF1 1NU.
 ISSN 1351-5136