

Topic 5 - Transport in Humans

1. Heart

2. Blood Vessel

3. Blood

Heart

5-1

- The human circulatory system consists of 3 main components:
 - Heart
 - Blood vessels
 - Blood
- In mammals, there is a **double circulation** (i.e. blood passes through the heart twice in one complete circuit):
 - Pulmonary circulation** – blood flows from the heart to the lungs and back to the heart
 - Blood enters the lungs at low pressure, allowing for blood to be well oxygenated before it is returned to the heart during pulmonary circulation.
 - Systemic circulation** – blood flows from the heart to the rest of the body and back to the heart.
 - Blood leaves the heart for the systemic circulation at high pressure, ensuring that oxygenated blood is distributed to the body tissues faster.

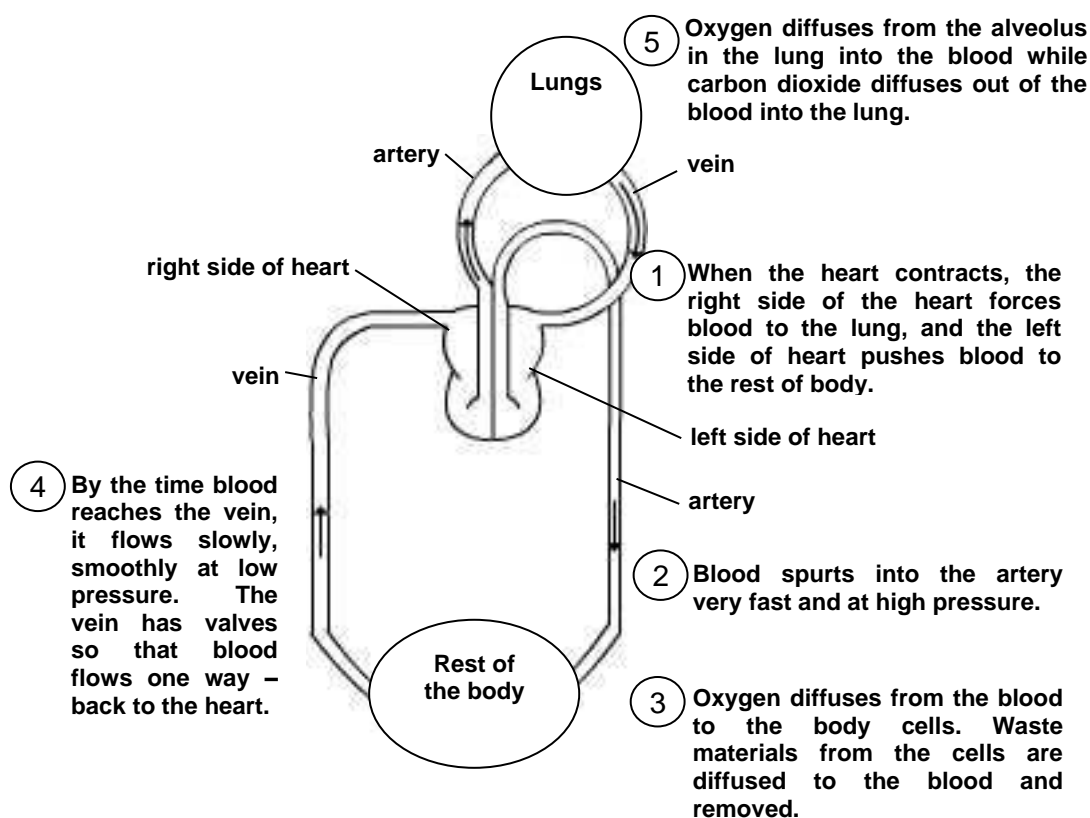


Figure 7-1: Simple diagram on blood flow around the human body

3. The **heart** is a muscular organ/'pump' that pumps blood/maintains blood pressure in **blood vessels**; this allows blood to circulate within the body.
- The heart is made up of a special type of muscle cell called the **cardiac muscle**, and these cells contract and relax non-stop throughout life, circulating blood in the body.
 - Each muscle fibre contains one or more nuclei and numerous mitochondria. The large number of mitochondria is present to produce ATP required for the contraction of the muscles.
 - There is a period of respite, called the refractory period, in between heart beats. This allows the muscle cells to clear the **oxygen debt** built in the contraction of the cells.

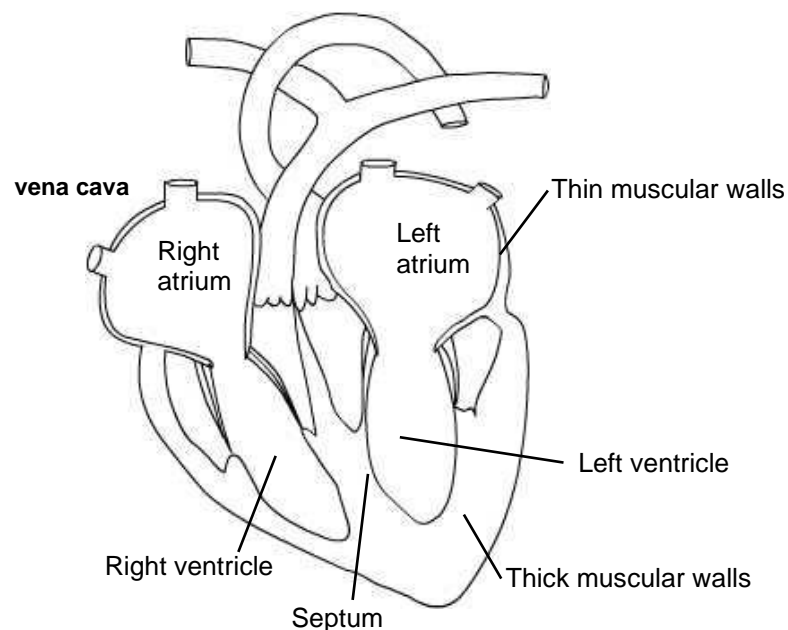


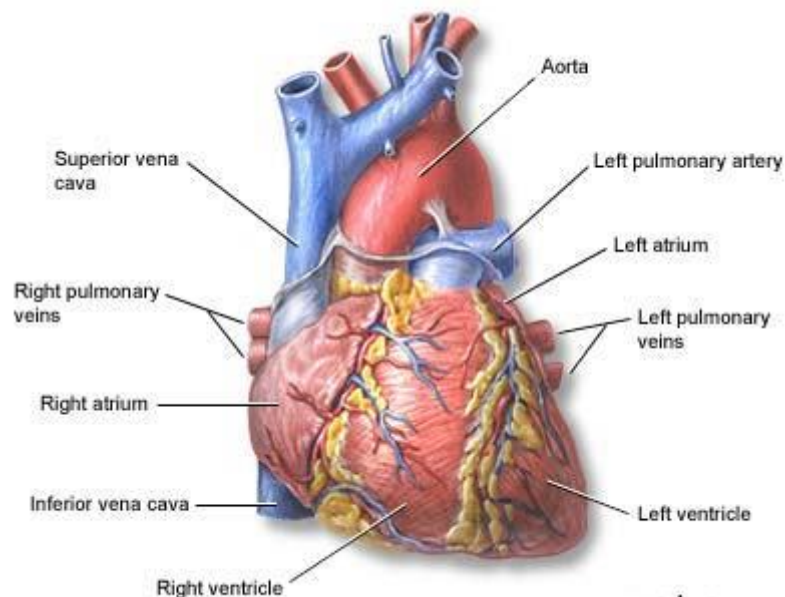
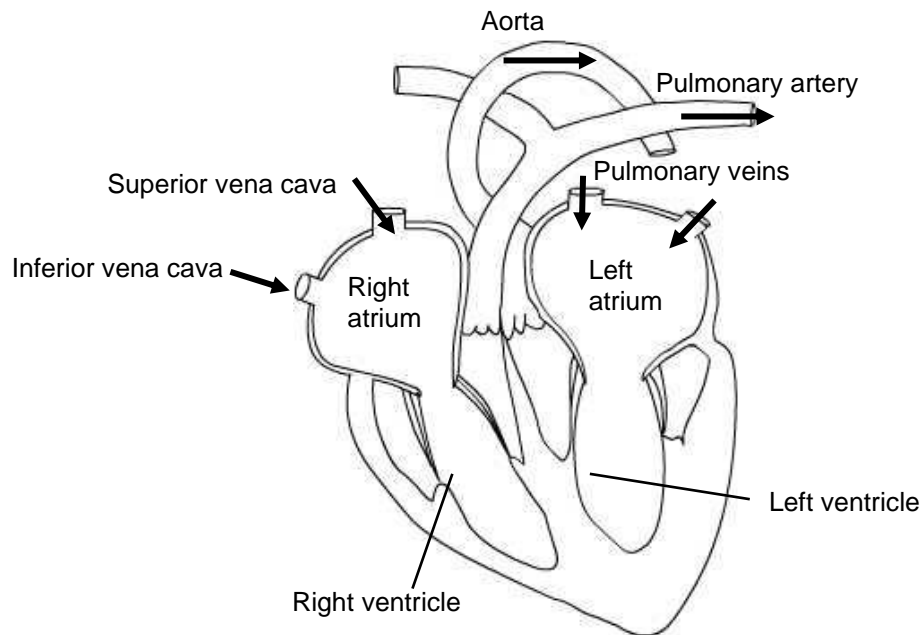
Figure 7-4: Structure of the Heart

Right atrium Receives deoxygenated blood from the <i>rest of the body</i>	S E P T U M	Left atrium Receives oxygenated blood from the <i>lungs</i>
Right ventricle Pumps deoxygenated blood to the <i>lungs</i>		Left ventricle Pumps oxygenated blood to the <i>rest of body</i>

- The heart has 4 separate chambers: 2 upper chambers with thin walls called the **atria** and 2 lower chambers with thick walls called the **ventricles**. The left and right chambers are separated by a septum.
- Median septum serves as a dividing wall that separates the heart into two partitions – right side and left side of the heart. These two sides of the heart are completely separated, so the deoxygenated blood and the oxygenated blood do not mix together in the heart.

LORD – left oxygenated; right deoxygenated

4. The **blood vessels** connected to the heart and the presence of **valves** control the efficient flow of blood in and out of the heart as it pumps.
- Blood vessels connected to the heart are as shown in figure below



ADAM.

Figure 7-5: Blood vessels connected to the Heart

Blood vessel	Function	From	To
Pulmonary artery	Carries deoxygenated blood to the lung away from the heart	Right ventricle	Lung
Pulmonary Vein	Carries oxygenated blood to the heart from the lung	Lung	Left atrium
Aorta	Carries oxygenated blood to other parts of the body	Left ventricle	Other parts of body
Superior vena cava	Carries deoxygenated blood to the heart	Brain and arms	Right atrium
Inferior vena cava	Carries deoxygenated blood to the heart	Other parts of body	Right atrium

5. There are 4 valves in the heart and they ensure a one-way flow of blood.

atrio-ventricular (AV) valves		semilunar valves	
tricuspid valve	mitral/bicuspid valve	pulmonary valve	aortic valve
operate together to allow blood flow into the ventricles while preventing backflow into atria		operate together to allow blood flow out of the ventricles into the arteries and aorta while preventing backflow into ventricles	

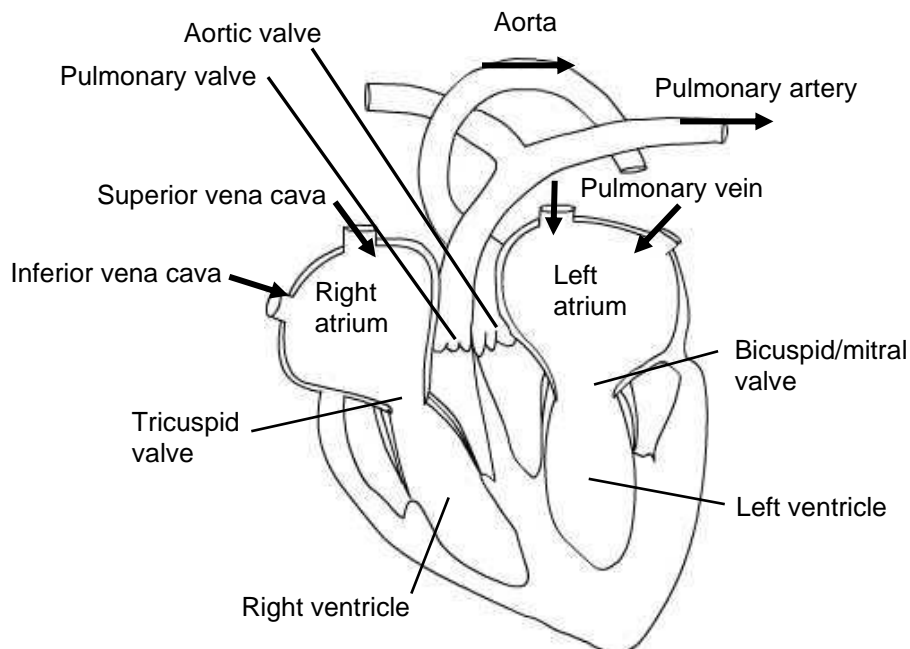


Figure 7-6: Valves in the Heart

- An example of a tricuspid (having 3 flaps/cusps) valve is sketched below.



Figure 7-7: Tricuspid Valve

Students are to be clear about the chambers of the heart and the various valves found in the heart, as well as how they are connected to the blood vessels.

- Blood flow in **Right** side of heart passes through **T**ricuspid valve then **P**ulmonary valve. (RTP)
- Deoxygenated blood flows into **Right** side of heart from the superior/inferior **v**ena cava to the right atrium and through **T**ricuspid valve to the ventricle. **P**ulmonary valve links to the pulmonary artery bringing deoxygenated blood to the lungs. (RvTP)
- Blood flow in **Left** side of heart passes through **M**itral valve then **A**ortic valve. (LMA)
- Oxygenated blood flows into **Left** side of heart from the pulmonary vein to the left atrium and through **M**itral valve to the ventricle. **A**ortic valve links to the **a**orta where oxygenated blood is circulated to the various parts of the body. (LvMA)

The cardiac cycle

6. The heart beats about 70 times per minute. Each cardiac cycle consists of 2 parts: **systole** (contraction of the heart) and **diastole** (relaxation of the heart). Systole is divided into **atrial systole** and **ventricular systole**.

- During Diastole, the heart enlarges as it relaxes and blood is drawn into the atria.

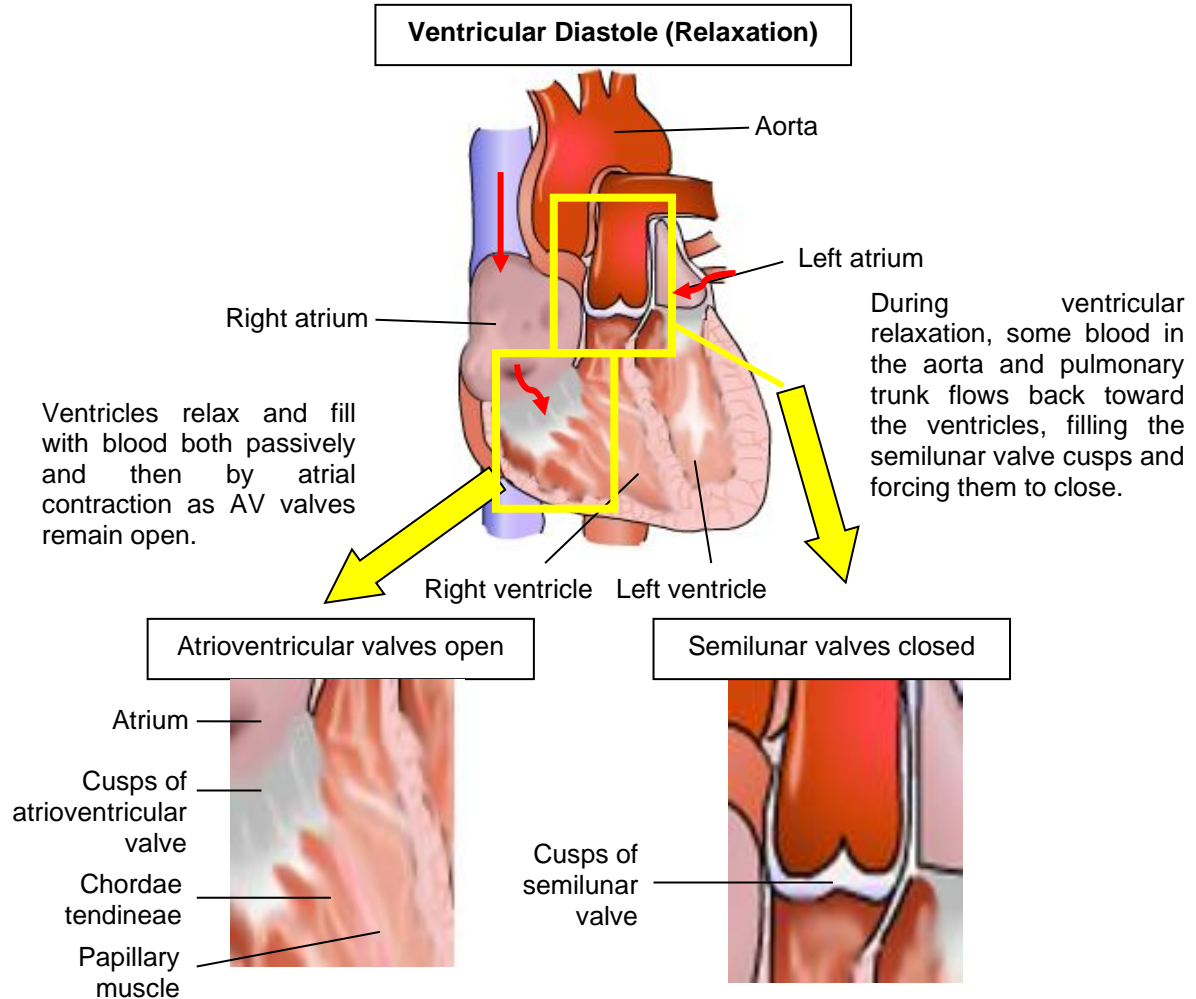


Figure 7-8: Diastole

- During Systole, blood is pushed from the atria into the ventricles and forced out of the ventricles into the arteries.

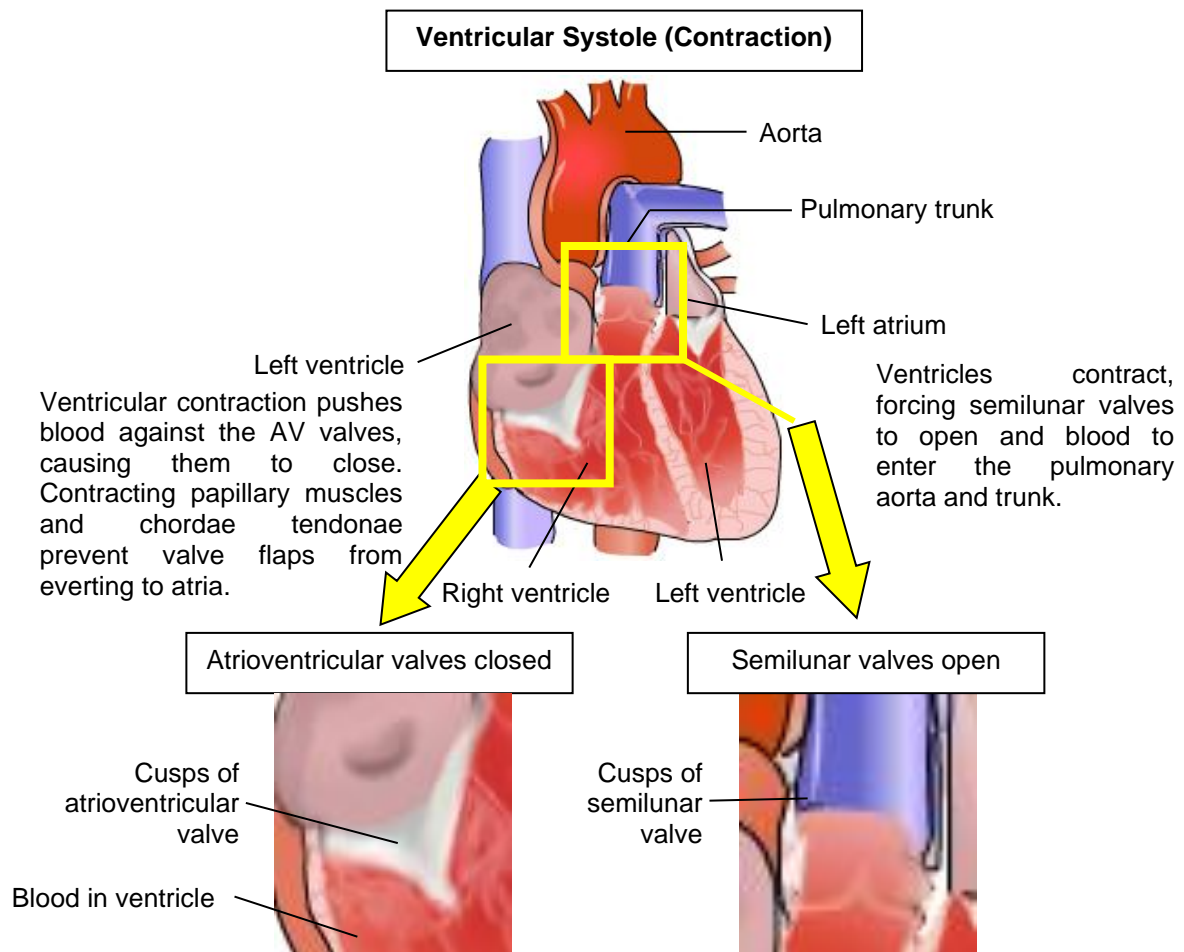


Figure 7-9: Systole

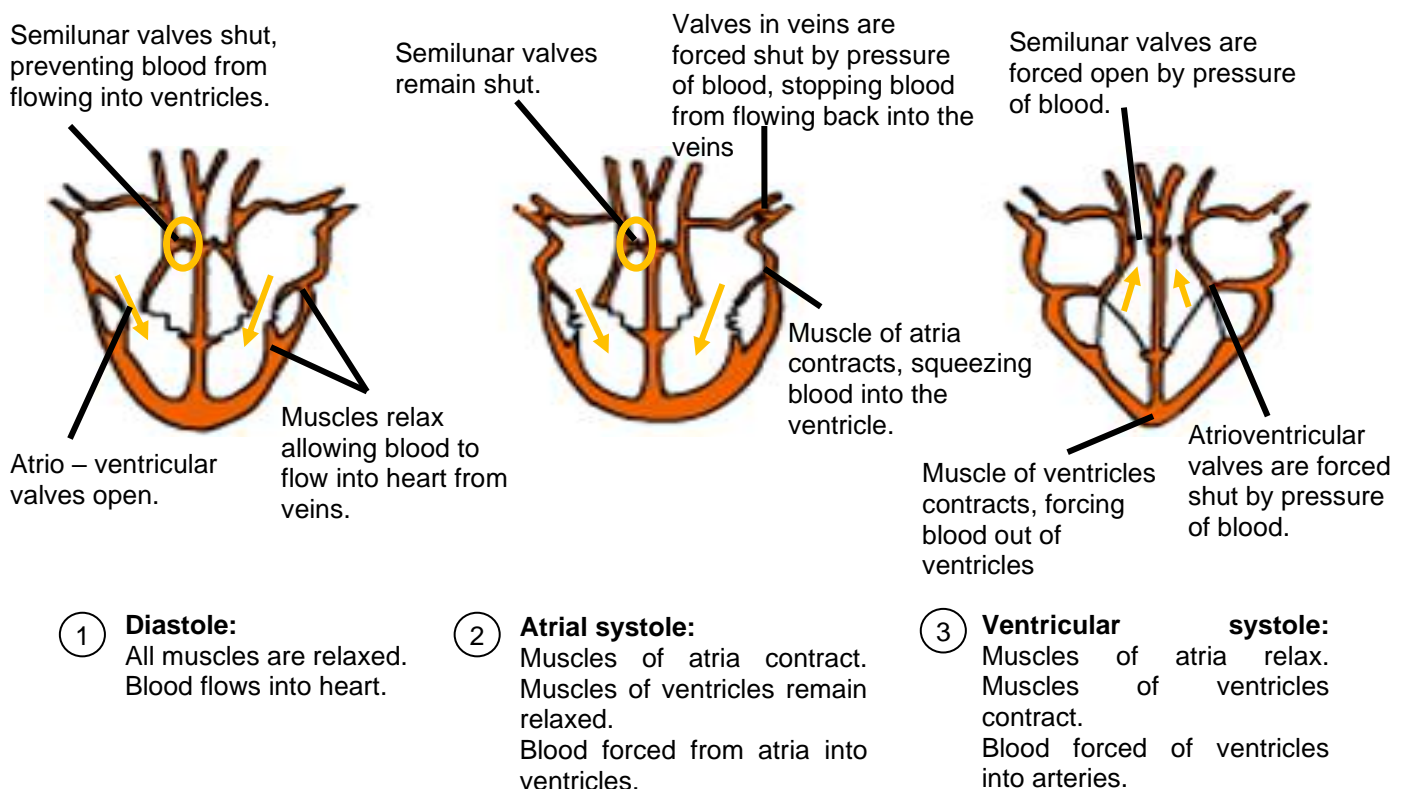
- The valves ensure that blood flows in one way as summarized in table.

Process	Function	Right Side of Heart (RTP)		Left side of Heart (LMA)	
		Tricuspid valve	Pulmonary valve	Mitral/bicuspid valve	Aortic valve
Diastole	Muscles relax to draw in blood from the veins to fill the atria	Shut subsequently Open*	Shut	Shut subsequently Open*	Shut
Atrial Systole	Muscles of atria contract and push blood from atria into ventricles	Open#	Shut	Open#	Shut
Ventricular Systole	Muscles of ventricle contract and push blood from ventricles into arteries	Shut	Open (push by high pressure)^	Shut	Open (push by high pressure)^

* Tricuspid and mitral/bicuspid valves open since the pressure in atria builds with blood filling them. They are held by papillary muscles that prevent them from flapping into the atria.

^ Pulmonary and aortic valves are semilunar valves which prevent backflow of blood into heart.

#The tricuspid and mitral/bicuspid valves are already open when the atria start to contract. They open due to the higher blood pressure in the atria as compared to the ventricles which is caused by the filling of blood in the atria.



Semilunar valves are the pulmonary valve and aortic valve.

Atrio-ventricular (AV) valves are the tricuspid valve and mitral/bicuspid valve.

Figure 7-10: Diastole and Systole

7. Diastole is the filling of the ventricles with blood. Ventricular systole opens the **semilunar valves**, forcing blood out of the ventricles through the pulmonary artery or aorta. The sound of the heart contracting and the valves opening and closing produces a characteristic "lub-dub" sound. "Lub" is associated with closure of the **atrio-ventricular valves**; "dub" is the closing of the **semilunar valves**.

	Atrial Systole	Ventricular Systole	Diastole
Blood flow	from atria to ventricle	from ventricles into pulmonary artery and aorta	from other parts of body into atrium
Muscles of atria	contracting	relaxing	relaxed
Muscles of ventricles	relaxed	contracting	relaxing
Atrio-ventricular valves	open	closing (Lub sound)	closed and subsequently open
Semi-lunar valves	closed	open	closing (Dub sound)

Phase	Atrial Systole	Early ventricular systole ↔ Late ventricular systole	Early ventricular diastole ↔ Late ventricular diastole
Structure	Atrial Systole	Early ventricular systole ↔ Late ventricular systole	Early ventricular diastole ↔ Late ventricular diastole
Atria	Contract	Relax	Relax
Ventricle	Relax	Contract	Relax
AV valves	Open	Closed	Open
Semilunar valves	Closed	Open	Closed

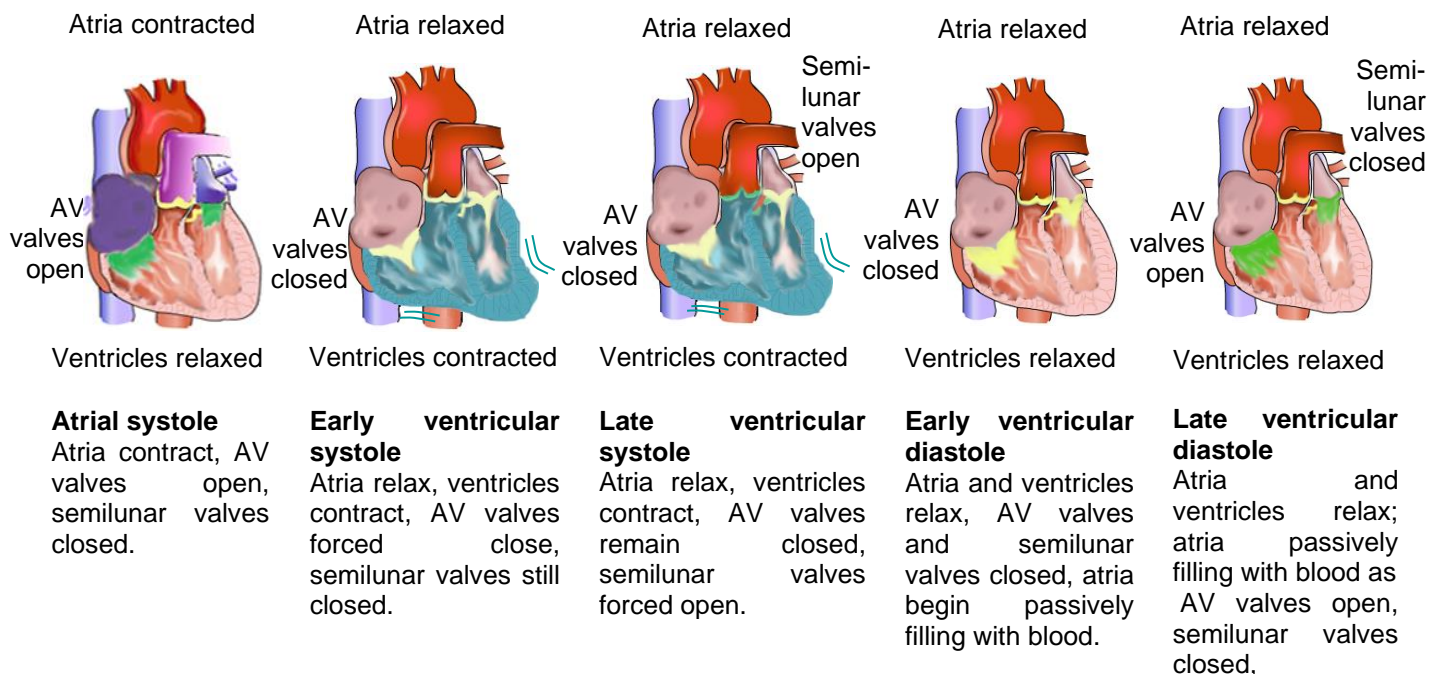
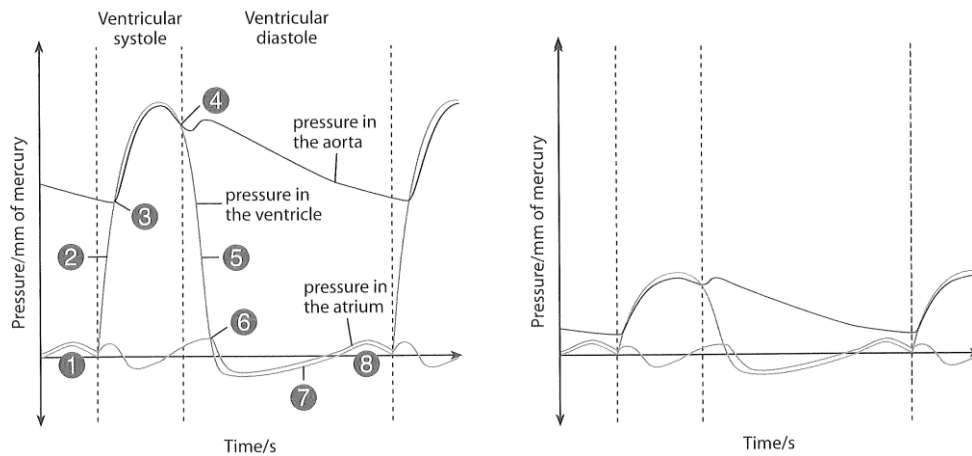


Figure 7-12: Details of the stages of Systole and Diastole



In the picture above, the graph on the right shows similar changes in the pressure in the right side of the heart (the graph on the left represents the left side of the heart). Pressure changes are similar to that in the left side of the heart except that the pressure increase in the right ventricle is lower than that of the left ventricle.

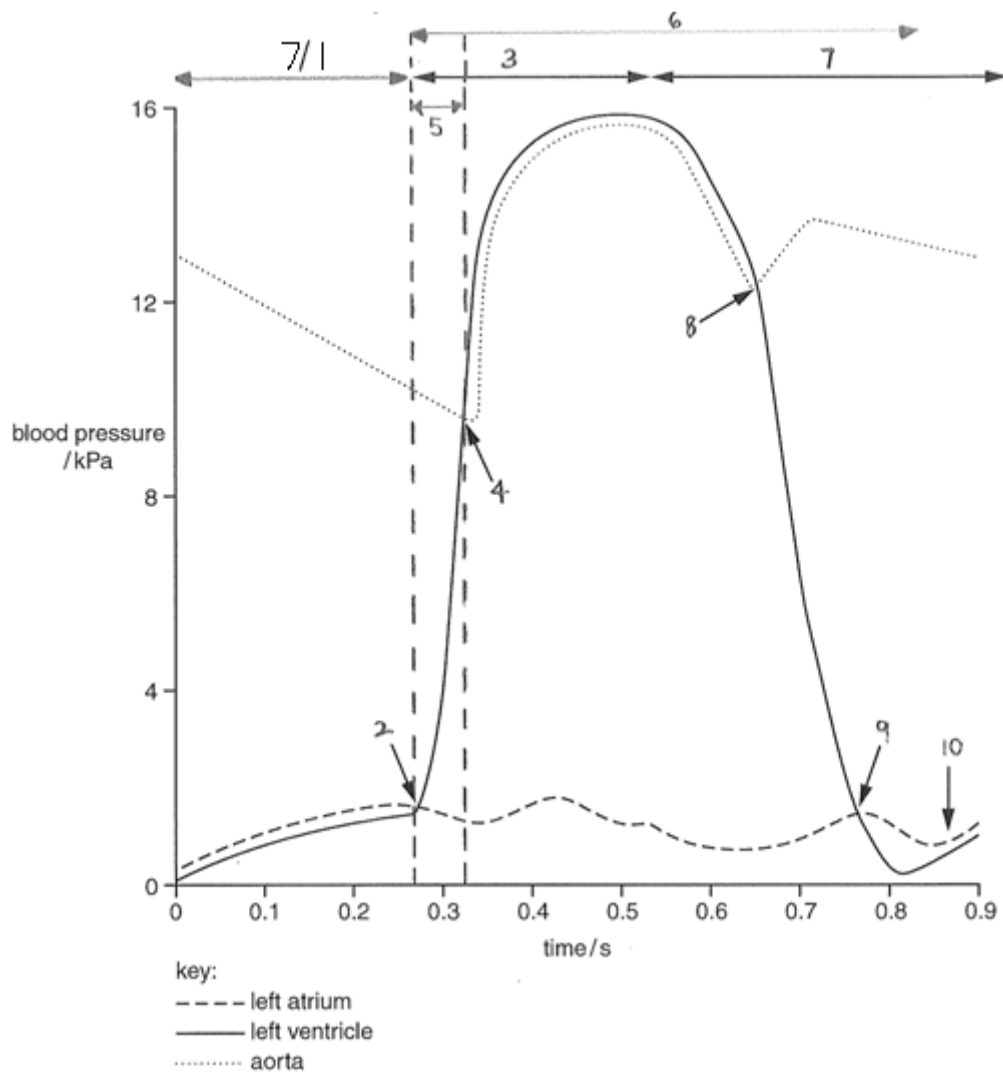


Figure 7-11: Changing blood pressure in left ventricle and aorta during diastole and systole

Number	Event
	Atrial systole
1	<ul style="list-style-type: none"> - Atrium contracts - Blood pressure in the atrium increases - Blood is forced from the atrium to the ventricle - NOTE: bicuspid valve is already open (see No. 9)
2	Bicuspid valve closes because of No. 3 (see below) <ul style="list-style-type: none"> - Ventricular pressure is higher than atrial pressure - Blood is being forced back into the atrium - Bicuspid valve closes to prevent backflow of blood from the ventricle to the atrium
	Ventricular systole
3	<ul style="list-style-type: none"> - Ventricle contracts - Blood pressure in the ventricle increases - Blood is forced from the ventricle to the aorta
4	Semi-lunar valve opens <ul style="list-style-type: none"> - To allow blood to exit the heart to the rest of the body through the aorta
5	All 4 valves in the heart are closed during this period
	Atrial diastole
6	<ul style="list-style-type: none"> - Atrium relaxes - Blood pressure in the atrium is low - Blood fills the atrium from the lungs via the pulmonary vein
	Ventricular diastole
7	<ul style="list-style-type: none"> - Ventricle relaxes - Blood pressure in the ventricle decreases
8	Semi-lunar valve closes because of No. 7 <ul style="list-style-type: none"> - Ventricular pressure is lower than aortic pressure - Blood moves back into the ventricle from the aorta - Semi-lunar valve closes to prevent backflow of blood
	Bicuspid valve opens
9	<ul style="list-style-type: none"> - Atrial pressure is higher than ventricular pressure - To allow blood to move from the atrium to the ventricle - NOTE: not due to contraction of atrium but the fact that the atrium is already completely filled with blood
10	Atrial systole of the next cycle The cardiac cycle repeats

★The atrioventricular valves (bicuspid and tricuspid) first open **BEFORE** atrial systole!
They open during ventricular diastole.
Blood flows passively from the atria into the ventricles at this time.

Students are to be clear of the following:

During Systole, the muscles of the ventricles and atria are antagonistic. i.e. when one contracts the other relaxes, and vice versa during systole. (Sc)

- Atrial systole, atrium contracts. Ventricle relaxes.
- Ventricular systole, ventricle contracts. Atrium relaxes.

During Diastole, all muscles are relaxed. (Dr)

Semilunar valves follow the pressure in the ventricle; i.e. if the ventricles contract then they would open. Atrio-ventricular valves are generally opposite of semilunar valves; i.e. when one is opened, the other is closed.

Classroom Worksheet

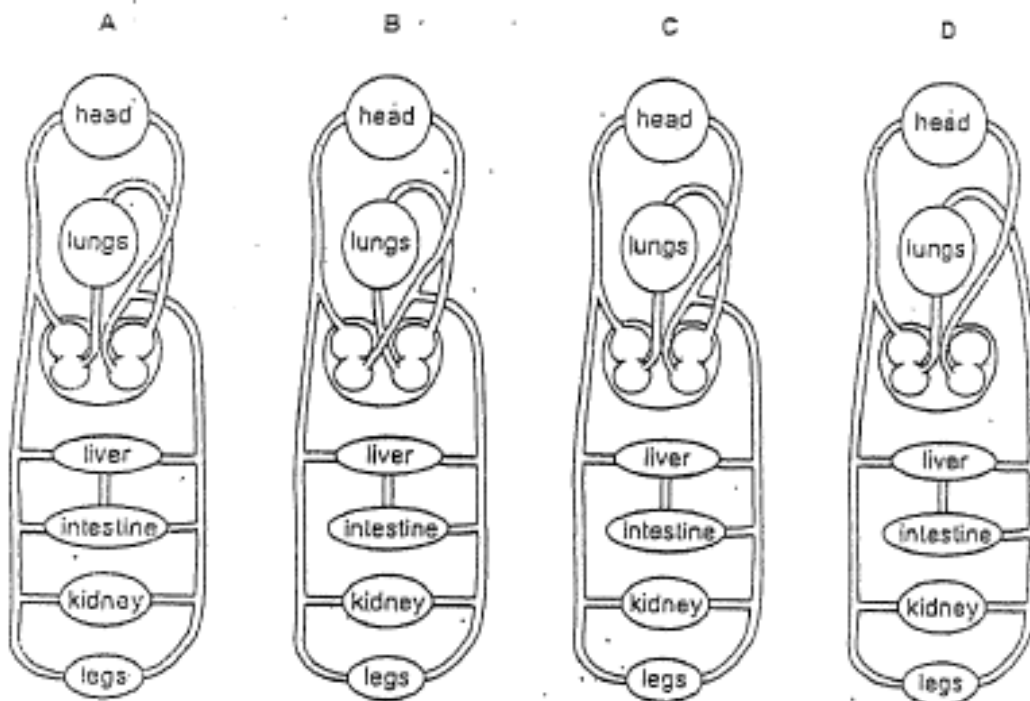
1 The following five events occur during the cardiac cycle (one heart beat) in humans.

- 1 ventricular diastole (relaxation)
- 2 bicuspid and tricuspid valves forced open
- 3 blood forced back against bicuspid and tricuspid valves
- 4 blood forced back against semi-lunar valves
- 5 atrial systole (contraction)

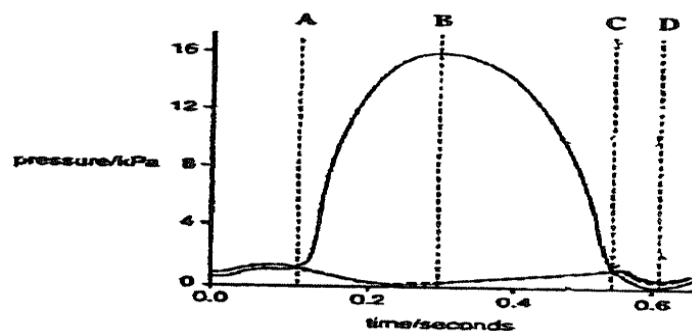
What is the correct sequence of these events?

- A 2 → 5 → 3 → 4 → 1
- B 3 → 2 → 4 → 5 → 1
- C 4 → 1 → 2 → 3 → 5
- D 5 → 2 → 3 → 1 → 4

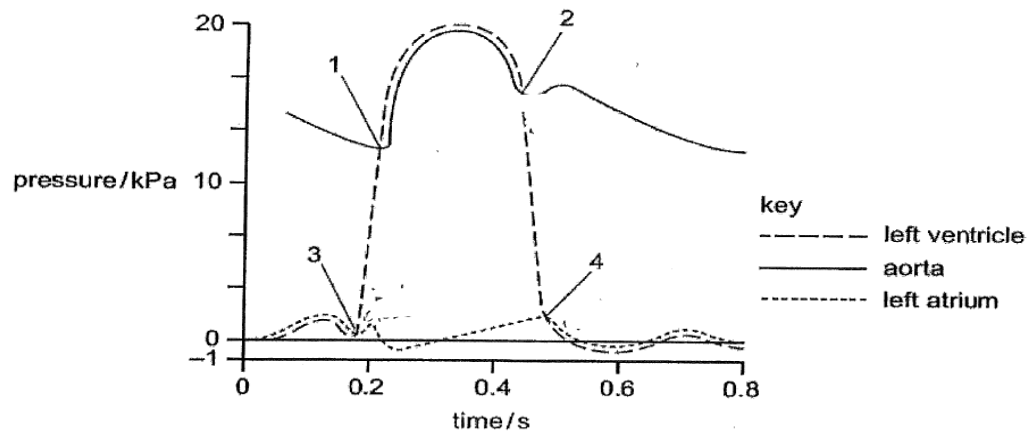
2 The diagrams represent the circulatory system. Which diagram is correct for a human adult?



3 The graph below shows pressure changes in the left side of the heart, during a single heart beat. At which point does the mitral valve open, allowing blood to flow from the atrium to the ventricle?



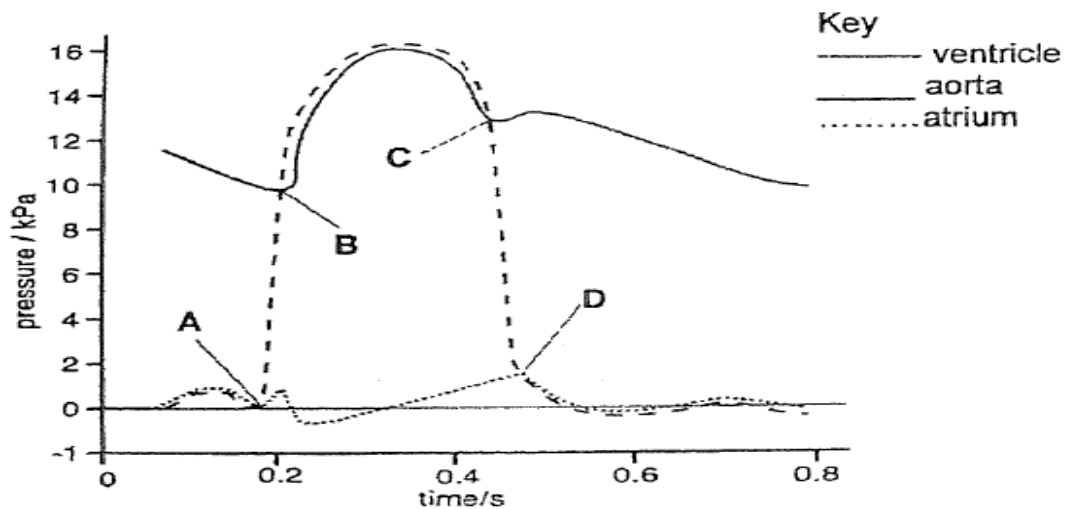
- 4 The following graph shows the pressure changes in the left atrium, left ventricle and aorta during a cardiac cycle.



With reference to the semi-lunar and bicuspid valves, what is happening at points 1, 2, 3 and 4?

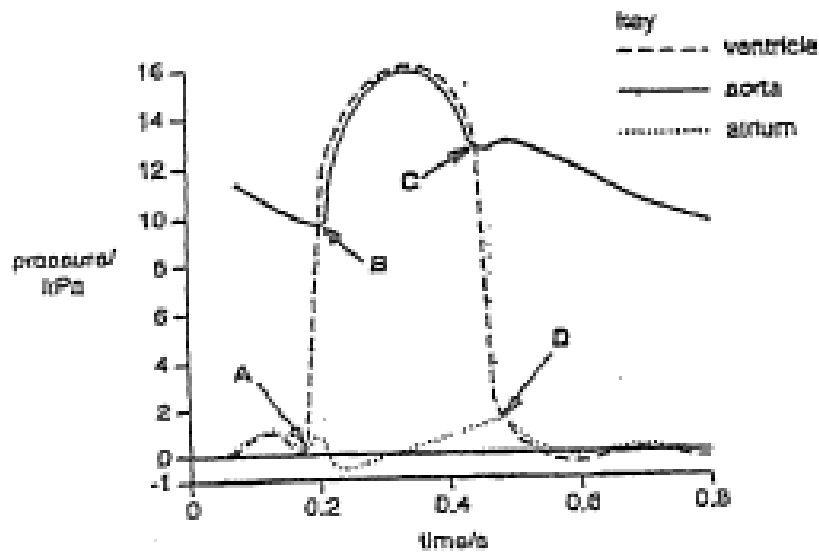
	semi-lunar valve		bicuspid valve	
	opens	closes	opens	closes
A	1	2	3	4
B	1	2	4	3
C	2	3	1	4
D	2	3	4	1

- 5 The diagram below shows pressure changes in the left side of the heart during part of the human cardiac cycle. At which point do the semi-lunar valves at the base of the aorta close?



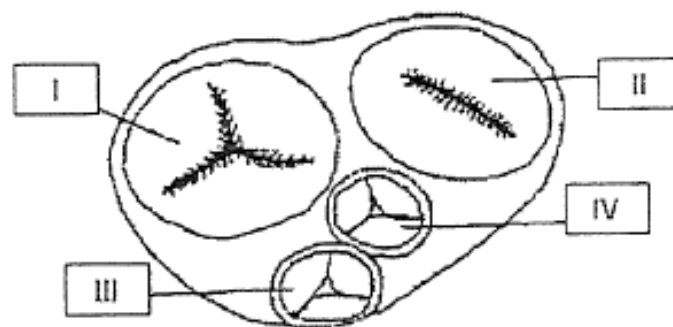
6

The diagram below shows pressure changes in the left side of the heart during part of the human cardiac cycle. At which point does the atrioventricular valve open?



7

The diagram below shows a cross-section of a mammalian heart with the structures of the various valves.

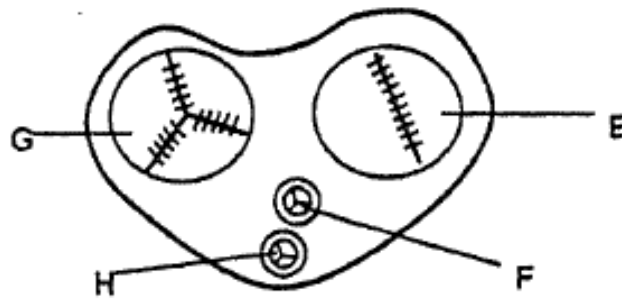


Which of the following valves close when the ventricles are contracting?

- A Valves I and III
- B Valves II and IV
- C Valves I and II
- D Valves III and IV

8

The diagram below shows the transverse section of a mammalian heart.

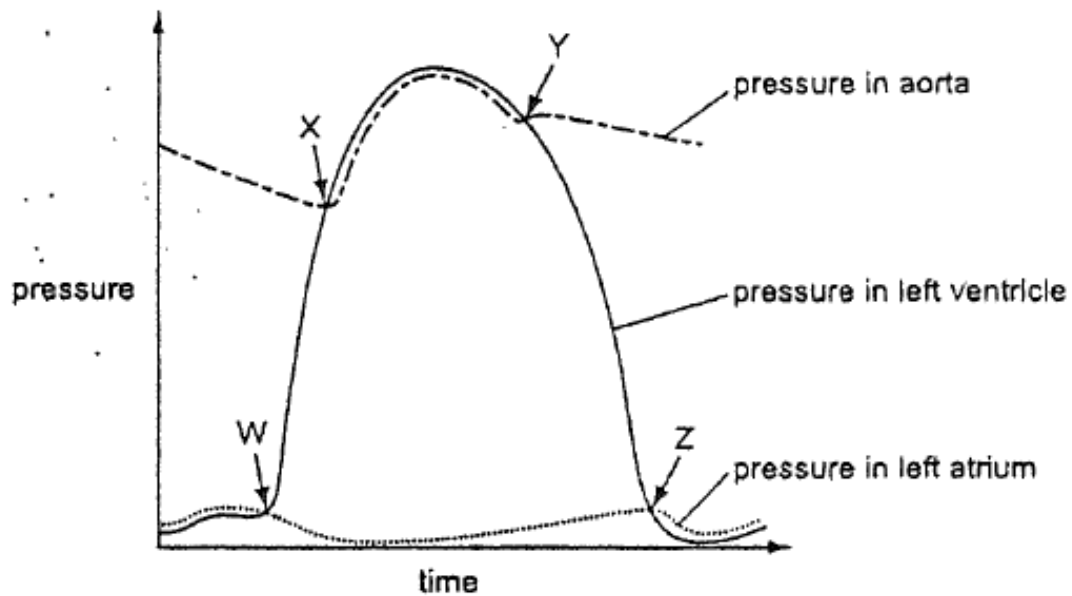


Which valves will open and close during ventricular systole?

	open	close
A	E and F	F and H
B	E and G	F and G
C	F and G	E and F
D	F and H	E and G

9

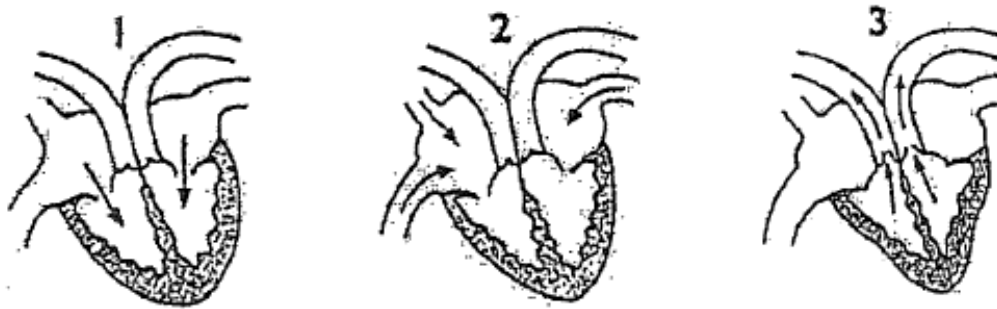
The graph shows the pressure changes in the aorta and the left side of the heart during one cardiac cycle.



At which points do the bicuspid and aortic valves close respectively?

- | | | | |
|---|---------|---|---------|
| A | W and Y | C | X and Y |
| B | W and Z | D | X and Z |

- 10 The diagram below shows three stages in the cardiac cycle.



Which of the following sequences is correct?

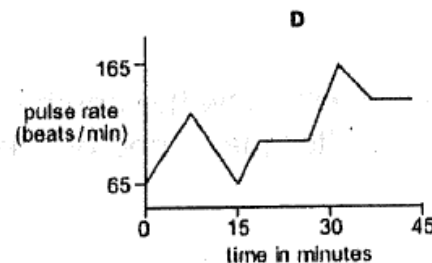
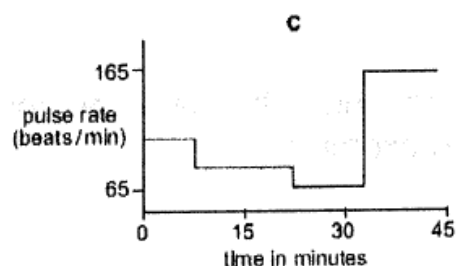
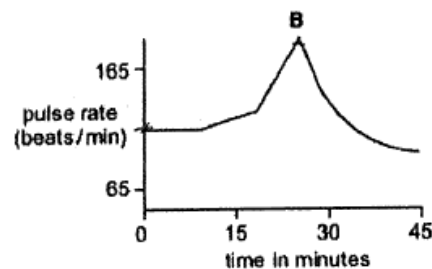
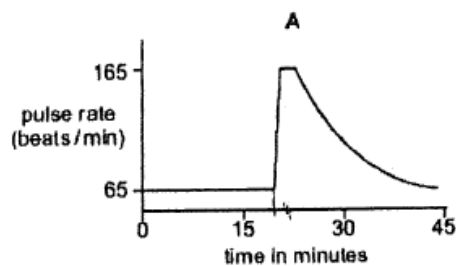
- A 2, 3, 1
B 1, 2, 3
C 2, 1, 3
D 3, 1, 2

- 11 A graph shows changes in a person's heart rate over a period of 45 minutes.

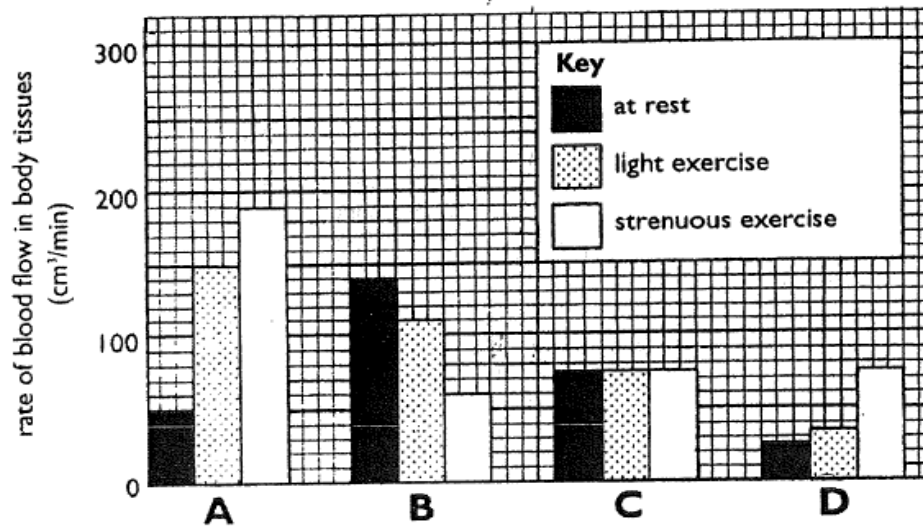
The sequence of events involves:

- waiting in a queue
- entering a sports stadium
- seeing a goal scored
- relaxing during half time

Which graph shows this sequence of events?



For questions 12 and 13, refer to the bar graph below which shows the rate of blood flow in four parts of the body when the body is in different states of activity.



- 12 Which group of bars represents the small intestines?
- 13 The group of bars labelled A may possibly represent all of the following **EXCEPT** _____.
- A. heart
 - B. muscles
 - C. lungs
 - D. bladder

Fig. a shows a graph of the pressure changes that occur during a single heart beat and Fig. b shows the sectional top view of the heart.

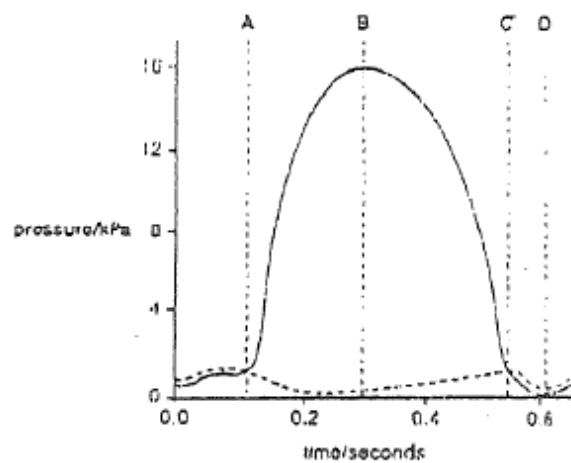


Fig. a

Key ——— ventricle - - - - - atrium

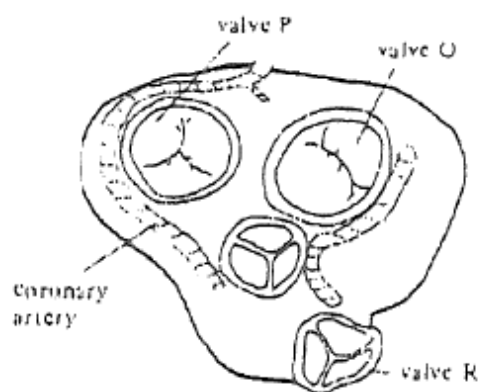
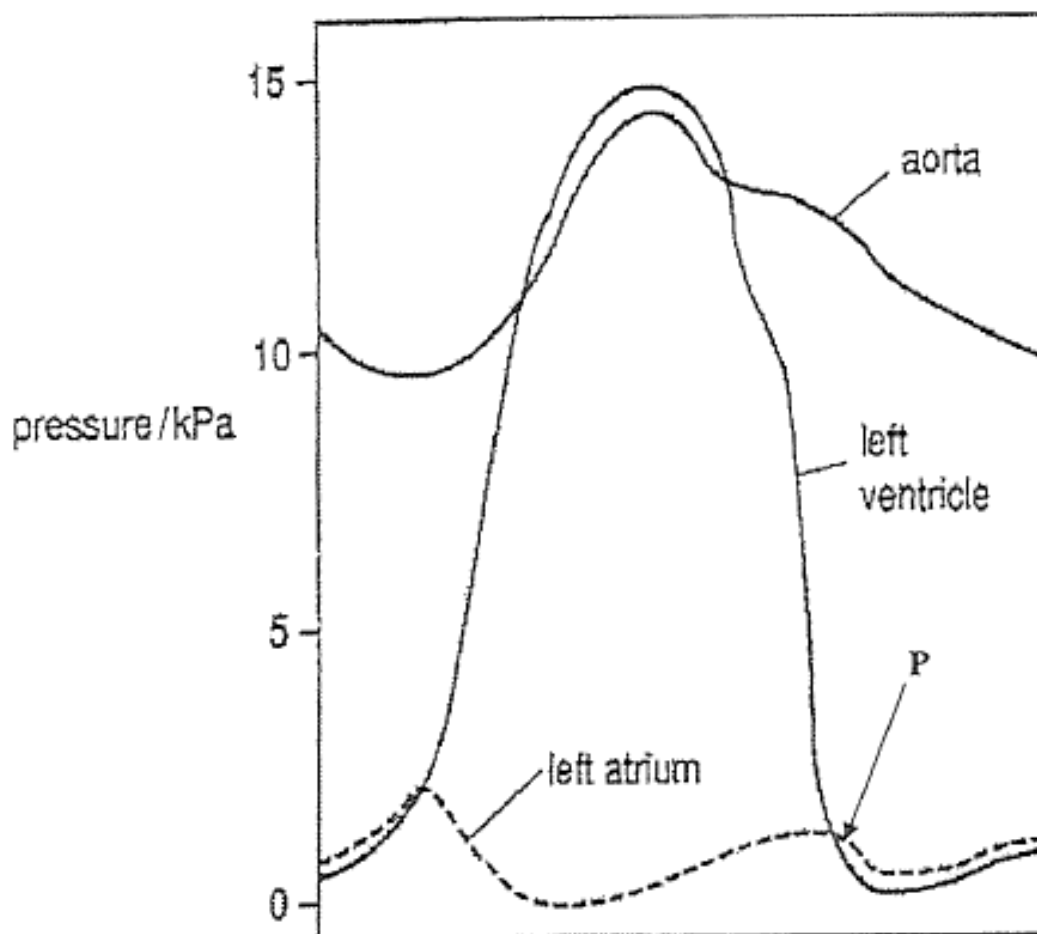


Fig. b

At which points do valves P and Q close?

The graph shows the pressure changes that occur in the left side of the mammalian heart during one cardiac cycle.



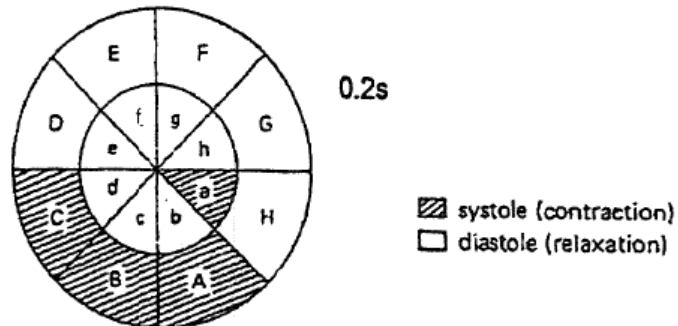
What caused the decrease in pressure in the left atrium at point P?

- A The opening of bicuspid valves.
- B The opening of tricuspid valves.
- C The closing of bicuspid valves.
- D The closing of tricuspid valves.

Homework

Structured

- 16 The figure below shows the series of events in a cardiac cycle of a man. The outer ring of the circle (A-H) represents the sequence of events in the ventricles, while the inner ring (a-h) represents the sequence of events in the atria.



- (a) What is the heart rate of man? Show all working.

- (b) Name the period (A-H), at which
(i) blood flows from the atria into the ventricles.

[2]

- (ii) the semi-lunar valves close.

[1]

- (c) Describe the events that occur during the period A to C.

[1]

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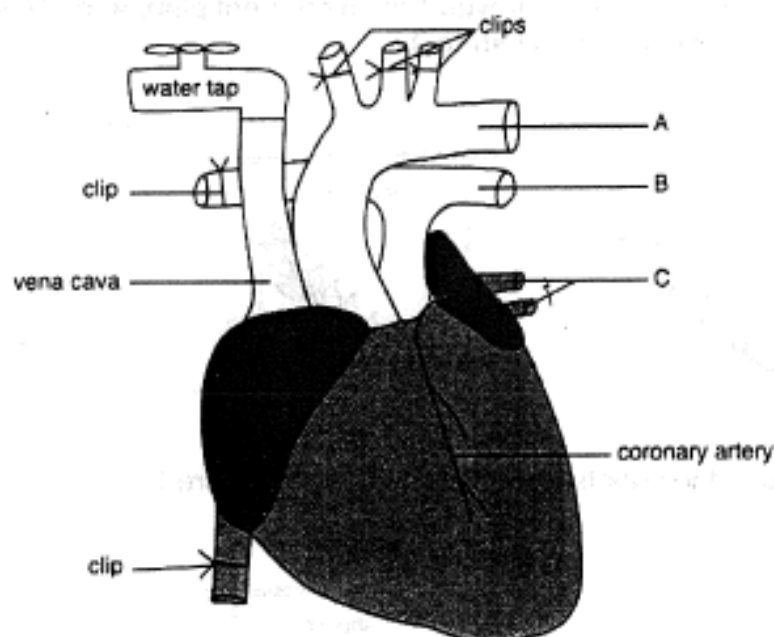
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[5]

6. The diagram below shows a pig's heart connected to a water tap.



- a If the water tap is turned on, water will come out from which vessel (s)? [1]

- b Name the vessels labelled A, B and C. [3]

A	
B	
C	

- c When the heart is disconnected from the water tap, can the water inside the heart flow back to the vena cava? Explain why. [2]

Diagram A5.1 below shows three stages in a cardiac cycle.

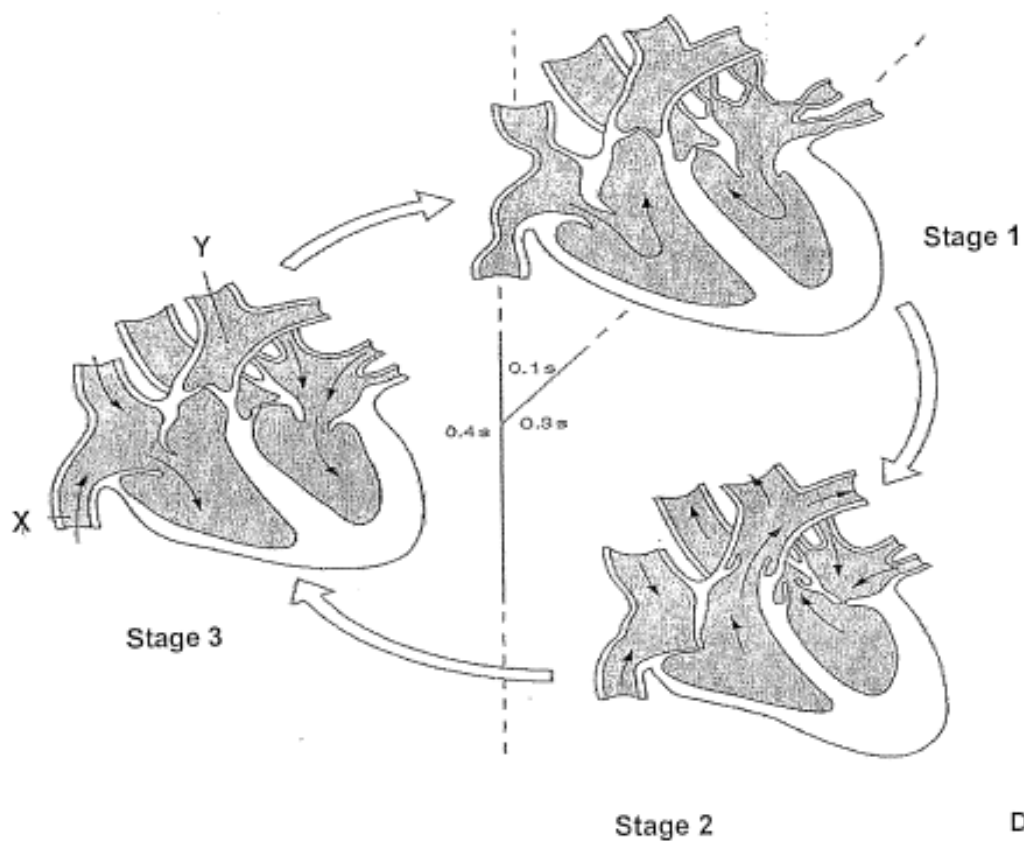


Diagram A5.1

- a) Name the blood vessels labelled X and Y:

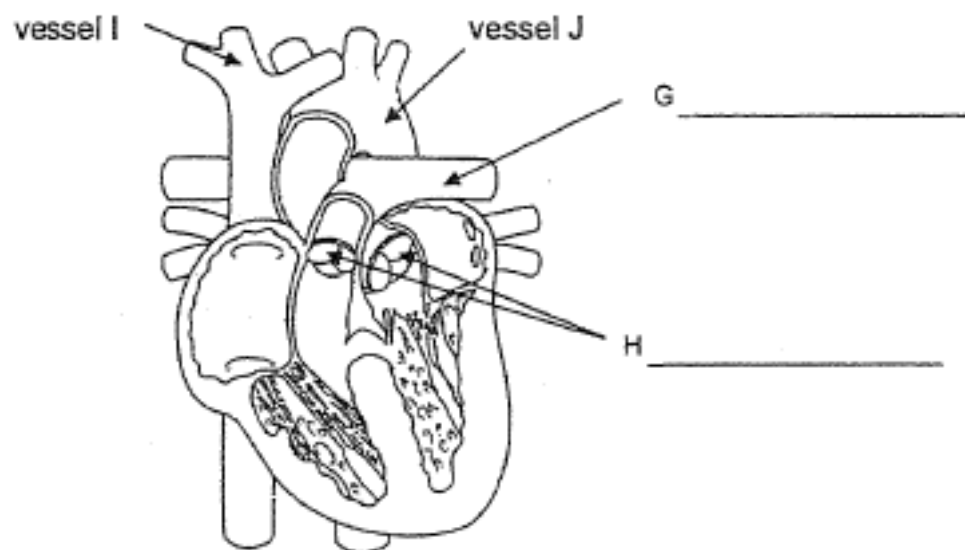
[2]

X: _____

Y: _____

- b) Describe what is happening at the left side of the heart at Stage 2 of the cardiac cycle. . . [4]

The diagram below shows the structure of the heart of a cardiac patient.



(a) Label the parts G and H. [2]

(b) By means of arrows, show clearly the direction of blood flow in vessels I and J. [1]

(c) Study this heart carefully. State the structural anomaly of this heart. [1]

(d) What are the consequences of such an anomaly? [2]

Essay

20

- 8(a) Mammals have a double circulation. What are the advantages of having a double circulation? [3]

- (b) Explain why the left ventricle has thicker wall than the right ventricle. [4]

- (c) Sometimes babies are born with a hole between the left and right sides of the heart, through which blood can pass. Explain the effect this has on the double circulation system of the baby's body. [3]
