

## Secondary School Learners Conceptions of the Structure and Function of the Human Circulatory System

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**Abstract:** Students possess their own conceptions when they start to learn science in their classrooms. Students' conceptions which are normally incongruent with the scientists are called misconceptions and they are one of the key factors in learning science. The objective of this study was to find out 10th grade students' misconceptions on the function and the structure of the human circulatory system with the use of a two-tier multiple-choice test. The procedure adopted to construct the two-tier test had three main phases; defining the content boundaries of the test, collecting information on student misconceptions and the instrument development stage. Two-tier test was constructed with eight test items and it was administered to 195, 10th grade students. Test items were planned to examine the students' conceptual understanding on blood pathway, structure of the human circulatory system, gas exchange and function of red blood cells. Analysis of students' responses revealed that students possessed 08 misconceptions and the highest number of misconceptions recorded in blood pathway. The highest percentage of students, nearly 44% had a misconception related to function of red blood cells. The next highest valve (24%) was recorded in relation to gas exchange.

**Key words:** Misconceptions, Learning, Science, Two-tier test, Human Circulatory System

### 1. INTRODUCTION

In the process of teaching learning science students' understanding of scientific concepts and phenomena is a vital component in any science curriculum. A large number of researches have been conducted over the years to find out students' conceptions related to different science concepts. Many researchers agree that students bring with them their own conceptions to the science classroom which are inconsistent with the views of scientists [1, 2]. These conceptions have been defined in the literature by number of terms such as, 'alternative conceptions', conceptual difficulties, misconceptions, informal ideas, naïve beliefs, erroneous ideas, alternative framework and naïve conceptions. The most commonly used terminology, misconception is used throughout in this article. Misconceptions are students' ideas from life experience or informal education, which are not structured well and resulting in the incorrect meaning according to scientific concepts' (248) [3]. Children understand the world through their everyday experiences which gain through number of sources including teachers [4, 5], textbooks [6], family members ([5], student personal experiences, cultural beliefs and media [7].

Misconceptions are strongly held and resistant to change [8, 9] and students in all age groups possess misconceptions [10]. According to the literature misconceptions hinder student learning at any stage of education. Therefore, in order to facilitate effective science learning teachers need to identify students misconceptions and plan lessons accordingly.

Literature reveals number of methods to diagnose students' misconceptions related to science concepts. The most common out of those is the diagnostic test which includes open-ended tests, simple multiple-choice tests, two-tier, three -tier and four-tier multiple choice tests. In addition, naturalistic settings [11], interviews[12],concept maps [13], concept cartoons [14] and student drawings [15] have been used to identify students' misconceptions in several science disciplines.

Two-tier multiple choice tests have been widely used to identify students misconceptions in biological science concepts which includes; photosynthesis and respiration [16], Photosynthesis [17], diffusion

and osmosis [18], breathing and respiration [19], internal transport in plants and human circulatory system [20], plant transport [15].

Some studies have been conducted to find out students' misconceptions on human circulatory system using open-ended questions [21] and three-tier test [22]. Although numerous research have been conducted in other countries relating to students' misconceptions in Biology and especially human circulatory system hardly any [15] have been reported in Sri Lanka. The objective of this study was to identify 10<sup>th</sup> grade students' misconceptions on Human circulatory system with the use of a two-tier test.

## 2. METHOD

The study was conducted in two main phases; construction of two-tier test and implementation of the test. The two-tier diagnostic instrument described by Treagust (1995), to identify students' misconceptions in specific science areas was used in this research. The design of the diagnostic instrument was based on the procedure described by Treagust (1995) that included three broad phases, (a) defining the content in terms of propositional knowledge statements and concept map for the specified concept. (b) obtaining information about students' conceptions, and (c) developing a diagnostic instrument.

In the two-tier diagnostic instrument, the first tier of each item in the test is a multiple-choice content question providing several distracters along with the correct answer, the second tier is composed of a multiple choice set of reasons for the answer to the first tier. The reasons provided for student contain the correct answer and possible misconceptions identified in questionnaires and interviews.

### 2.1. Defining the Content

This broad step consisted of four specific steps as, identifying propositional knowledge statements, developing concept maps, relating propositional knowledge statements to the concept map and the validating the content. During the first step 16 propositional knowledge statements given below were identified for the content area human circulatory system by reviewing the grade 10 science syllabus, teacher instructional manual and text books. Then a concept map for human circulation was developed (Figure 1) to the content area of human circulatory system and propositional knowledge statements were related to concept map. Next propositional knowledge statements were content validated by three experienced science graduate teachers. Discrepancies identified in the test items were corrected and modified.

1. Human circulatory system is composed of heart and specialized vessels called arteries and veins for blood transportation. Human circulation is a double circulation
2. Heart consists of four chambers: two atria and two ventricles and the walls of ventricles are thicker than walls of atria.
3. Walls of arteries are thicker than walls of veins
4. Deoxygenated blood from the body enters the right atrium
5. Blood from the right atrium flows through the tricuspid valve into the right ventricle
6. Contraction of the right ventricle closes the tricuspid valve and blood flows into the pulmonary artery.
7. Deoxygenated blood is carried to the right and left lungs.
8. The capillary beds of the lungs are drained into venules and form pulmonary veins
9. Four pulmonary veins, two draining from each lung carry oxygenated blood into the left atrium of the heart.
10. Gas exchange takes place between air sacs and blood vessels. Blood gives up carbon dioxide and takes on fresh supply of oxygen.
11. Blood flows through the bicuspid valve into the left ventricle.
12. Contraction of the left ventricle closes the bicuspid valve and blood flows to the aorta.
13. Oxygen rich blood enters arteries through aorta and runs throughout the body.

14. Blood consists of blood cells and plasma and Blood cells contain red blood cells, white blood cells and platelets.
15. Function of red blood cells is the transportation of respiratory gases. And the white blood cells are responsible for destroying pathogens.
16. Function of platelets is the blood clotting.

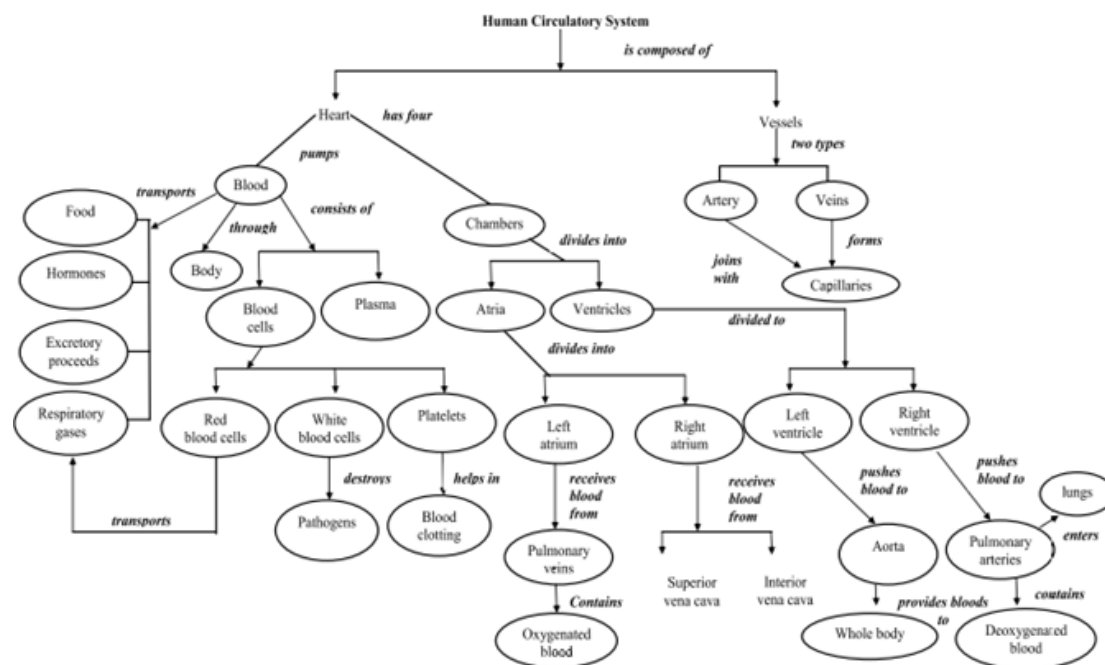


Figure1. Concept map of Human Circulatory System

## 2.2. Obtaining Information About Students’ Conceptions

The second broad area of obtaining information about student conceptions involved three steps; examining related research literature, conducting unstructured student interviews and developing multiple choice content items with free responses. As the first step of this phase, the related literature was examined in order to get an understanding of the student misconceptions on the human circulatory system [20, 21, 22].

During the next step unstructured interviews were conducted with 25 grade 10 students in order to gain a broad perspective of students’ understanding of human circulation. All the interviews were audiotape recorded and interview transcripts were prepared for each interview. Example of an open-ended question used in interview is, “*Explain what happens when atrial systole occurs in the functioning of heart?*”? A list of students’ misconceptions was prepared by examining interview transcripts.

The next step was developing multiple-choice items with free responses. Each multiple-choice item was based on limited no. of propositional knowledge statements. Multiple choice items were designed to address students’ conceptions and misconceptions encountered in the literature and the interview. Each item was followed by a space for the student to complete the reason why particular option of the multiple choices was selected. Open-ended multiple choice test instrument was administered to 25 students and the free responses were examined to collect misconceptions of human circulatory system.

## 2.3. Construction of Two-Tier Diagnostic Instrument

Two-tier diagnostic instrument was constructed with the use of group of misconceptions obtained from each item in the multiple-choice test with free responses and interviews. Each test item in the instrument consisted of a stem followed by two-tier questions. The first-tier of each item provided a selection of possible distractions related to the students’ misconceptions in addition to the correct answer. The second tier consisted of four possible reasons for the first tier: three alternative reasons and one scientifically accepted reason. A pilot study was conducted to refine the item on the test.

The final version of the human circulatory system consisted of 08 items (Annex 01). The conceptual areas covered by the test were: structure of circulatory system, blood pathway, gas exchange and functions of blood cells. The content area addressed by each question and the relevant propositional statement is given in Table 1.

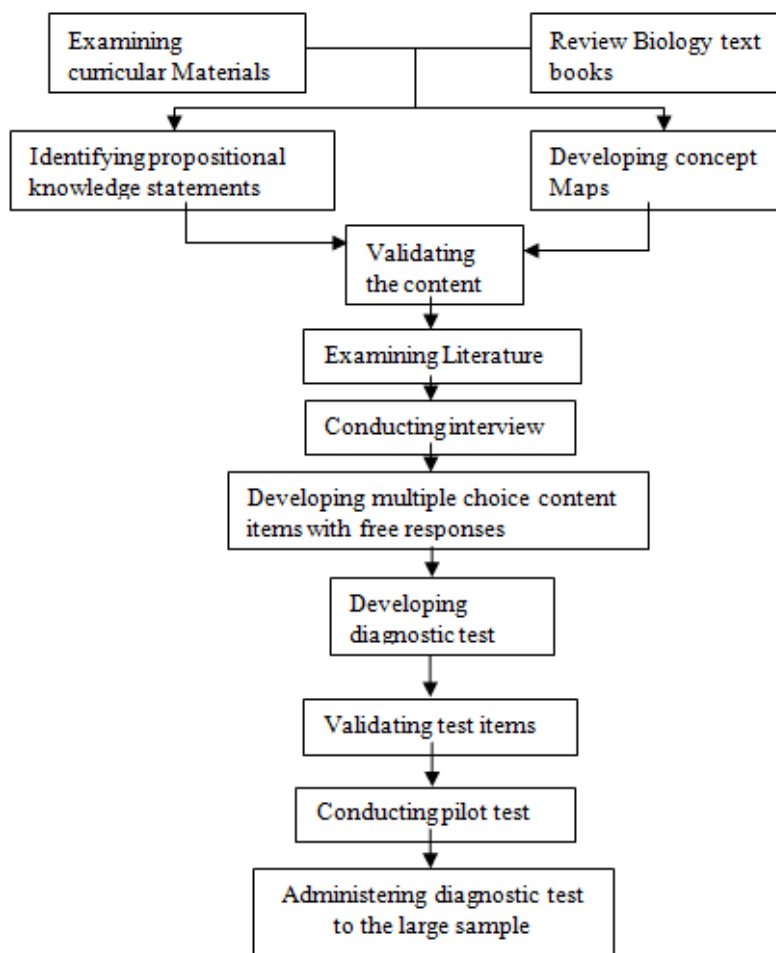
**Table1.** The content area and the relevant propositional statement in each of the test item

Item Number	Topic Area	Propositional Statements
1	Blood pathway	1
2	Structure of circulatory system	2
3	Structure of circulatory system	3
4	Blood pathway	4
5	Blood pathway	5, 6, 11, 12, 13,
6	Blood pathway	7, 8, 9
7	Gas exchange	10
8	Functions of blood cells	14, 15, 16

### 2.4. Sample of Population

The human circulatory system diagnostic test was administrated to 195 grade ten students those who learnt human circulation. The convenience sampling was used in this research and total number of 6 schools form two districts, Kandy and Kegalle were selected.

The procedure adopted in the research is shown in Figure 2



**Figure2.** Flow chart showing research procedure

### 2.5. Scoring the Items

An item was scored as correct on the Two-tier diagnostic test when both the tiers (content and reason) were selected, and students were offered two marks for each item. As there were 08 items students were given marks out of 16 for the whole test. Percentage of student responses in each response category (content and combination) was calculated.

3. RESULTS AND DISCUSSION

The characteristics of Human Circulatory System Diagnostic Test (Annex 01) summarizes in Table 2. Percentage of students with correct content choice and combination: content and reason are given in Table 3

**Table2.** Characteristics of the Human Circulatory System diagnostics test

Characteristic	Description
Areas evaluated	Blood pathway: items 1, 4, 5, 6, Structure of circulatory system: items 2,3 Gas exchange: item 07 Functions of blood cells: item 08
Content based on	Validated propositional knowledge statements and concept map
Number of items	08
Recommended grade level	10 <sup>th</sup> grade (Grade 10)
Time to complete the test	15-20 minutes

**Table3.** Percentage of students selecting the correct content and combination

Item	Content Choice	Combination
1	97.2	66.1
2	83.8	60.0
3	73.3	43.8
4	62.7	53.3
5	56.1	35.5
6	68.8	38.3
7	77.7	45.0
8	75.5	27.2

The percentage of correct answers for the content choice (first tier) varied form 56.1% to 97.2% while combination varied form 27.2% to 66.1%. In considering the first-tier of the items the results show that there is a higher percentage of correct response choice exceeding 56%.However,the percentages for the combination choice including students’ reasoning for their choice in the first-tier of the item, are lower in all items. The highest percentage of correct content choice was recorded form items no. 1 which was based on double circulation of human circulatory system. The lowest percentage of correct content was shown in item no. 5 based on blood pathway

It was able to identify 12 misconceptions by analyzing the responses of human circulatory system as given in Table 4.

**Table4.** Student misconceptions of human circulatory system identified by the two -tiered test

Item	Area	Misconception’ Identified	Percentage
(1)	Blood pathway	Human circulation is a double circulation since there are left and right sides in the heart.	10.5
		Human circulation is a double circulation since there are arteries and veins	13.3
(2)	Structure of circulatory system	The walls of arteries are thicker than walls of veins because arteries transport oxygenated blood and veins transport deoxygenated blood	8.8
(3)	Structure of circulatory system	The walls of ventricles are thicker than walls of atria because there is larger amount of blood in the ventricles	12.2
		The walls of the ventricles are thicker than walls of atria to withstand the pressure exerted by atria	13.8
(4)	Blood pathway	Deoxygenated blood form the body enters the left atrium	13.8
(5)	Blood pathway	During atrial systole, semi-lunar valves open and blood flows into aorta and pulmonary artery	5.5
		During atrial systole bicuspid valve and tricuspid valve open and blood flows into aorta and pulmonary artery	9.4
(6)	Blood pathway	Blood in the left side of the heart is different form blood in the right side since it contains deoxygenated blood brought form pulmonary veins	8.8

		Blood in the left side of the heart is different form blood in the right side since it contains deoxygenated blood coming form pulmonary arteries	21.6
(7)	Gas exchange	In the process of gas exchange between alveolar sac and blood capillaries, CO <sub>2</sub> diffuses form alveolar sacs to blood capillaries, and O <sub>2</sub> diffuse form blood capillaries to alveolar sacs	24.4
(8)	Function of blood cells	The function of red blood cells is to transport only the oxygen gas	43.8

As it is evident in Table 4 students had misconceptions related to each item of the diagnostic test and it was able to identify 12 misconceptions. The highest number of misconceptions (7) were recorded in the area of blood pathway while the lowest form gas exchange and functions of blood cells. When the human circulation was concerned the highest percentage (43.8%) of students had the misconception that ‘Function of red blood cells is transporting only oxygen’

### 3.1. Blood Pathway

This concept was examined through items 1, 4, 5, 6. Analysis of students’ responses to these items are given in Table 5.

**Table5.** Percentage of students responses item no.1, 4, 5, and 6

Item	Content choice	Reason choice					Total
		a	b	c	d	No reason	
1	a	0.5	1.1	0.6	-	-	2.2
	b	10.6	13.3	*66.1	4.4	2.8	97.2
4	a	3.3	1.7	13.9	7.2	0.5	26.6
	b	5.5	*53.3	1.7	1.7	0.5	62.7
	c	-	-	2.8	1.6	-	4.4
	d	-	0.5	1.1	1.1	-	2.7
5	a	2.8	-	2.2	5.5	-	10.5
	b	1.7	3.9	3.9	2.7	-	12.2
	c	*35.6	9.4	5.5	5.6	-	56.1
	d	5.0	5.6	3.9	1.6	0.5	16.6
6	a	21.6	*38.3	7.8	1.1	-	68.8
	b	3.3	8.9	7.2	6.7	-	26.6

\*the correct choice and reason response

- No response in this category

In item 1, students were asked to determine the type of blood circulation in human being. Nearly 100% of students responded (97.2%) first-tier of the diagnostic test. Out of these students only 66.1% of students have understood the concept “double circulation” correctly. However, more than 10 % of students have understood “double circulation as having left and right sides in circulation”. Another 13.3% had the misconception “double circulation means blood flow through veins and arteries” students have understood the word ‘double’ as having two as right and left or ‘arteries and veins’. According to the study conducted by Pelaez et al., (2005) with the elementary prospective teachers, even with them 70% had not understand the dual blood circulation pathway.

In item 4, more than 50% of students (53.3%) responded desired content choice “the blood carries form different parts of the heart enters right atrium through superior vena cava and inferior vena cava”. More than 28% of student had the misconception that blood form different parts of the body enters left atrium as superior vena cave and inferior vena cave enters. Students may have this misconception due to the difficulties identifying left and right side of heart.

Students’ understanding of cardiac cycle was assessed in item 5. Only 35.6% students selected desired content and reason choice. Analysis of responses revealed that more than 40% students possessed misconceptions of cardiac cycle. Item 6 was based on pulmonary circulation. Nearly 40% of students selected correct content (38.3%) and reason choice. The most common misconception identified was “Blood in the left side of the heart is oxygenated because pulmonary arteries carry blood to the left side of the heart”

### 3.2. Gas Exchange

Item 7 assessed students understanding of gas exchange in the lungs. Percentage of students' responses to each response is given in Table 6. Out of 195 students in the sample 07 did not respond both 1<sup>st</sup> and 2<sup>nd</sup> tiers of this item. The most prominent misconception was "Diffusion of CO<sub>2</sub> form air sacs to blood vessels and, O<sub>2</sub> form blood vessels of air sacs". Nearly 20% of students had this misconception. Another misconception revealed form the result was "Only oxygen diffusion takes place form air sacs to blood vessels" This was further evident form responses to first content choice 15% students responded that only oxygen diffusion takes place between air sacs and blood vessels. Pelaez et al., (2005) in their study with prospective elementary teachers reveal that 55% had misconceptions about gas exchange.

**Table6.** Percentage of students responses item no.7

Item	Content choice	Reason choice					Total
		a	b	c	d	No reason	
(7)	a	2.8	4.4	5.5	1.7	0.5	15.0
	b	2.2	-	-	2.2	-	4.4
	c	19.4	*45.0	10.0	2.7	0.5	77.7

*\*the correct choice and reason response*

- No response in this category

### 3.3. Structure of Circulatory System

Items 2 and 3 assessed students understanding of structure of blood vessels and heart respectively. Percentage of students' responses is given below. (Table 7). In item 2, students were asked to determine the structure of blood vessels. Nearly 4% did not respond both tiers. 60% of students were capable of selecting correct content and response. However, nearly 10% of students possessed the misconception that "Walls of arteries are thicker than walls of veins because rate of blood flow is higher in arteries". Another 10% responded, "walls of arteries are thicker than veins as arteries carry oxygenated blood while veins carry deoxygenated blood".

**Table7.** Percentage of students responses to item no.2 and 3

Item	Content choice	Reason choice					Total
		a	b	c	d	No reason	
(2)	a	8.9	9.4	*60.0	5.0	0.5	83.8
	b	4.4	2.2	5.0	2.2	-	13.8
(3)	a	2.2	12.2	13.9	*43.9	1.1	73.3
	b	9.4	1.7	5.5	7.2	-	23.7

*\*the correct choice and reason response*

- No response in this category

Students understanding of structure of chambers of heart was assessed form item 3, Although 73.3% of students selected desired content, only 43.9% were capable of determining correct reason. Nearly 15% of students had the misconception that "Walls of ventricles are thicker than walls of atria to resist to the pressure exerted by atria". Another 12% possessed the misconception that "Walls of ventricles are thicker than walls of atria as the large amount of blood contains in the ventricles".

### 3.4. Function of Blood Cells

This was examined through item 8 and the analyses of responses are given in Table 8. Nearly 3% of students did not respond to this question. The most common misconception of this item was "Hemoglobin in the red blood cells transports only oxygen" Students may have misunderstood that respiratory gases refers only to oxygen.

**Table8.** Percentage of students responses item no.8

Item	Content choice	Reason choice					Total
		a	b	c	d	No reason	
(8)	a	0.5	7.8	7.8	-	0.5	16.6
	b	*27.2	43.9	2.2	1.1	1.1	75.5
	c	0.5	0.6	-	3.3	-	4.4

*\*the correct choice and reason response*

- No response in this category

#### 4. CONCLUSION

It is evident from this study that grade ten students have several misconceptions of human circulatory system even after the instruction. The results of the study conducted by [21](2013) shows that misconceptions about the human circulatory system prevails in different grade levels and it shows a decreasing trend from elementary school students to university students. The results further reveal that although high percentages of students select correct content choice, considerable number of students fail to select correct reason for their content choice response. Therefore, it is apparent that students learn the content without having a correct conceptual understanding of the concepts. The results of the study were supported by other studies in the literature [20, 22, 24]. The findings of the study showed that the two-tier diagnostic test is an effective instrument to assess students' conceptual understanding of science concepts rather than simple multiple-choice questions alone.

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**Annex 01**

**Plant Transport and Human Circulatory System Diagnostic Test**

Instruction: This test consists of 16 pairs of questions that examine your knowledge of Plant Transport and Human Circulatory System. Each question has two parts: a multiple choice response followed by a multiple choice reason. On the answer sheet provided, please circle one answer form both response and reason sections of each question.

(1)	a.	Human circulation belongs :
		a. Single circulation b. Double circulation
	b.	The reason for my answer is :
		a. Having left and right sides in blood circulation b. Blood circulation through arteries and veins c. Circulation of blood twice through the heart when the blood once circulates through the body d. Circulation of blood twice through the heart when the blood circulates twice through the heart
(2)	a.	Walls of arteries are :
		a. Thicker than walls of veins b. Thinner than walls of veins
	b.	The reason for my answer is :
		a. Arteries carry oxygenated blood and veins carry deoxygenated blood b. Rate of blood flow is higher in arteries c. Blood flows through arteries in high pressure d. Arteries carry blood form heart
(3)	a.	Thickness of walls of ventricles are :
		a. Higher than atria b. Lower than atria
	b.	The reason for my answer is :
		a. Rate of blood flow is lower in ventricles b. Ventricles consists large volume of blood c. Resist to pressure exerted by atria d. Ventricles pump blood
(4)	a.	Deoxygenated blood form the body enters the :
		a. Left atrium b. Right atrium c. Left ventricle d. Right ventricle
	b.	The reason for my answer is :
		a. Superior vena cava enters the right atrium b. Superior and inferior venae cavae enter right atrium c. Superior and inferior venae cavae enter left atrium d. Pulmonary veins enter left atrium
(5)	a.	When the atrial systole occurs
		a. Only bicuspid valve opens b. Only tricuspid valve opens

		c. bicuspid and tricuspid valve open d. semi lunar valves open
	b.	The reason for my answer is :
		a. Blood flows form atria to ventricles b. Blood in the atria flows to aorta and pulmonary artery c. Blood in the left ventricles flows to left atrium d. Blood form right atrium flows to right ventricles
(6)	a.	Left side of the blood in the heart is different form blood in the right side because of :
		a. Having oxygenated blood b. Having deoxygenated blood
	b.	The reason for my answer is :
		a. Pulmonary arteries form lungs enters the left side b. Pulmonary veins form lungs enters the left side c. Superior vena cave carrying form all parts of the body enters d. Inferior vena cave carrying blood form all parts of the body enters
(7)	a.	Which one of the following gases exchange between air sacs of lungs and blood vessels :
		a. Only oxygen b. Only Carbon dioxide c. Oxygen and Carbon dioxide
	b.	The reason for my answer is :
		a. CO <sub>2</sub> diffuses form air sacs to blood vessels and O <sub>2</sub> diffuses form blood vessels to air sacs b. CO <sub>2</sub> diffuses form blood vessels to air sacs and O <sub>2</sub> form air sacs to blood vessels c. Only O <sub>2</sub> diffusion occurs form air sacs to blood vessels as the oxygen concentration is higher in air sacs d. Only CO <sub>2</sub> diffusion takes place form blood vessels to air sacs as the CO <sub>2</sub> concentration is higher
(8)	a.	The function of red blood cells is :
		a. Contribution to blood clotting b. Transportation of respiratory gases c. Destroy pathogens
	b.	The reason for my answer :
		a. Haemoglobin in the red blood cells transport respiratory gases b. Haemoglobin in the red blood cells transport oxygen c. Chemicals of red blood cells involve in blood clotting d. Produce antibodies form red blood cells

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