CHAPTER 4: *The cardiovascular system*

Question - text book page 52

Why does the human body need a double circulatory system?

Answer:
- *There are two circulatory systems with quite distinct functions.*
- *The pulmonary system provides deoxidised blood to the lungs.*
- *Where carbon dioxide (carried by the blood) is expelled into the lungs.*
- *And oxygen from the air in the lungs is transferred into the blood*
- *So that blood arriving at the heart from the lungs has very little* CO_2*, but is full of* O_2.

- *The systemic system then takes this oxygenated blood and carries it out to the rest of the body.*
- *Including muscle, liver, kidneys, stomach, brain.*
- *Where the* O_2 *in the blood is transferred to the tissue.*
- *And* CO_2 *produced by the energy creating process in the tissue is picked up and transferred back into the blood.*
- *Which is then carried in the blood back to the heart ready to be taken to the lungs - and so on.*

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1) Figure 4.23 shows a diagrammatic picture of the cardiac impulse. Using the information in this diagram, describe the flow of blood during the specific stages of the cardiac cycle in relation to the cardiac impulse. In your answer explain how the heart valves help control the direction of blood flow. 8 marks

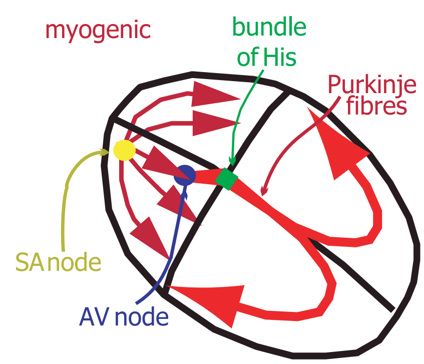
Answer:

Atrial and ventricular diastole:
- *During atrial and ventricular diastole there is no electrical impulse from the SA node.*
- *And so relaxed heart muscle chambers (atria and ventricles) fill with blood.*
- *From the venae cavae (on the right hand side of the heart).*
- *And the pulmonary veins (on the left hand side of the heart).*
- *As the cuspid valves open and the semi-lunar valves close.*

Diastole is followed by systole consisting of two distinct phases:

Atrial systole:
- *The SA node creates an electrical impulse.*
- *This causes a wave-like contraction over the atria myocardium.*
- *Forcing the remaining blood from the atrial chambers.*
- *Past the cuspid valves.*
- *Into the ventricles.*

figure 4.23 – the cardiac impulse



Ventricular systole:
- *The impulse reaches the AV node.*
- *The cuspid valves close during ventricular systole.*
- *The impulse travels down the bundle of His to the Purkinje fibres.*
- *Across ventricular myocardium.*
- *Which then contracts as the semi-lunar valves open.*
- *Blood is forced out of the ventricles.*
- *Into the aorta (left hand side).*
- *And the pulmonary arteries (right hand side).*
- *Myocardial contractions, during systole, are said to be myogenic or under involuntary nervous control.*

2) $\dot{Q}$ = SV x HR. Explain the meaning of this equation and give typical resting values that you would expect in an endurance-based athlete. 6 marks

Answer:

- *$\dot{Q}$ represents cardiac output – is defined as the volume of blood pumped by the left ventricle in one minute.*
- *And is a combination of SV – stroke volume is defined as the volume of blood pumped by the left ventricle of the heart per beat.*
- *x HR – heart rate is defined as the number of beats of the heart per minute (bpm).*
- *Typical resting values for an endurance-based athlete:*

$$\dot{Q} = SV \times HR$$

$$5.6 \text{ litres min}^{-1} = 110\text{ml} \times 51 \text{ (or same values in dm}^3\text{ min}^{-1}).$$

3) A fit 18 year old female student performs a 400m time trial in one minute.

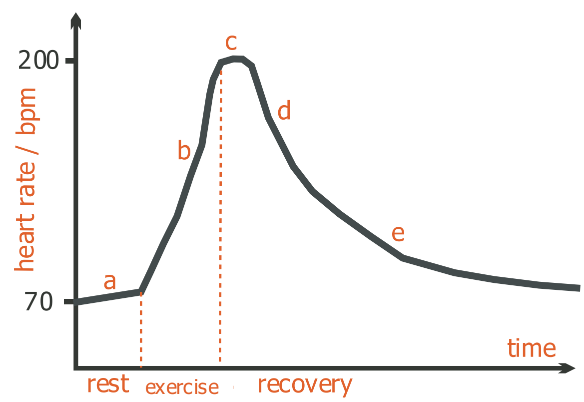
a) Sketch and label a graph to show a typical heart rate response from a point 5 minutes before the start of the run, during the time trial, and over the 20 minute recovery period. 4 marks

Answer:

See graph in figure 4.24.

- *a Anticipatory rise just before start of exercise.*
- *b Initial rapid increase in HR.*
- *c To reach HR_{max} at end of time trial.*
- *d Recovery initially rapid.*
- *e Tapering off slowly towards resting values.*

figure 4.24 – heart rate during a time trial



b) Explain why heart rate takes some time to return to its resting value following the exercise period. 2 marks

Answer:

2 marks for 2 of:

- *There is a raised O_2 demand of active muscle tissue.*
- *There are raised levels of CO_2.*
- *And a build up of lactic acid during high intensity work which takes time to clear.*
- *Body organs such as the heart, need additional O_2 above resting O_2 consumption.*
- *This reflects the size of EPOC or oxygen debt.*
- *Hence HR values stay elevated above resting values until the oxygen debt is purged.*

c) Identify a hormone that is responsible for heart rate increases prior to and during an exercise period. 1 mark

Answer:

- *Adrenaline or noradrenaline.*

d) Heart rate is regulated by neural, hormonal and intrinsic factors. How does the nervous system detect and respond to changes in heart rate during an exercise period? 4 marks

Answer:

4 marks for 4 of:

- *The cardiac control centre (CCC) responds to neural information.*
- *This is supplied by proprioceptors and other reflexes.*
- *Such as the baroreceptor reflex, sensitive to changes in blood pressure.*
- *And the chemoreceptor reflex, sensitive to changes in CO_2 and pH levels.*
- *For example, a decrease in pH and an increase in CO_2 levels increase the action of the sympathetic nervous system (SNS), via the accelerator nerve.*
- *To increase stimulation of the SA node.*
- *Thereby increasing heart rate.*

4) Jodie Swallow is a top class female British Triathlete, and has a resting heart rate of 36 bpm. Give reasons why such an athlete might have a low resting heart rate. 4 marks

Answer:

4 marks for 4 of:

- *Due to bradycardia or slow heart beat.*
- *Effects of an aerobic endurance-based triathlete training programme is to produce cardiac hypertrophy i.e. heart becomes bigger and stronger (mainly left ventricle).*
- *Producing an increase in stroke volume (SV).*
- *And decrease in resting heart rate (HR_{rest}).*
- *A reduced resting heart rate allows for an increase in diastolic filling time.*
- *The net effect is that the heart does not have to pump as frequently for the same given resting oxygen consumption.*

5) Table 4.4 shows the rate of blood flow (in cm^3 per minute) to different parts of the body in a trained male athlete, at rest and while exercising at maximum effort on a cycle ergometer.

Table 4.4 – **estimated blood flow at rest and during maximum effort**

organ or system	estimated blood flow in cm^3 min^{-1}	
	at rest	during max effort
skeletal muscle	1000	26400
coronary vessels	250	1200
skin	500	750
kidneys	1000	300
liver & gut	1250	375
other organs	1000	975

Study the data carefully before answering the following questions.

a) The rate of blood flow to the 'entire body' increases significantly during exercise. Explain briefly how the heart achieves this. 2 marks

Answer:

- *Increased heart rate.*
- *Increased stroke volume.*
- *Therefore increased cardiac output.*

b) What percentage of the total blood flow is directed to the skeletal muscle at rest and during maximum effort? Show your calculations. 3 marks

Answer:

The percentage of total blood flow directed to skeletal muscle at rest is:

- $\frac{1000 \times 100}{5000} = 20\%.$

The percentage of total blood flow directed to skeletal muscle during maximal effort is:

- $\frac{264000 \times 100}{30000} = 88\%.$

c) How is blood flow to various regions of the body controlled? 4 marks

Answer:

- *Achieved through vasomotor control.*
- *Which creates the vascular shunt.*
- *This is vasodilation, which is the expansion of arteries and arterioles, and relaxation of pre-capillary sphincters to increase blood flow to active muscle tissue.*
- *This is in response to a cessation of neural signals to the smooth muscle walls of these blood vessels.*
- *Also vasoconstriction, which is the restriction of arteries and arterioles, and contraction of pre-capillary sphincters to decrease blood flow to non-active tissue.*
- *This is a response to increased neural signals from baroreceptors which detect changes in cardiac output.*
- *These neural signals go to the smooth muscle walls of these particular blood vessels.*

6) a) What is meant by the concept 'venous return mechanism'? 2 marks

Answer:

- *Venous return is the transport of blood from the capillaries, through venules, veins and venae cavae to the right atrium of the heart.*

b) Describe how it is aided during physical activity when a person is exercising in an upright position. 3 marks

Answer:

- *Venous return is aided by exercise due to increased actions of skeletal muscle and respiratory and cardiac pumps and limited action of venoconstriction of veins.*
- *Increased activity in skeletal muscle results from contracting and relaxing squeezing sections of veins.*
- *Therefore causing increased blood flow back towards the heart.*
- *Blood cannot flow the opposite way because of pocket valves placed every so often in each vein.*

c) Explain the importance of the skeletal muscle pump mechanism during an active cool-down. 2 marks

Answer:

- *Skeletal muscles continue to contract to squeeze vein walls, forcing blood back towards the heart.*
- *Thereby preventing blood pooling and an associated sudden drop in blood pressure.*
- *And removing of waste products such as carbon dioxide and lactic acid.*

d) What effect does enhanced venous return have upon cardiac output and stroke volume? 3 marks

Answer:

- *Stroke volume is dependent on the amount of venous return.*
- *Up to 70% of the total volume of blood is contained in the veins at rest.*
- *Increased venous return will cause myocardial tissue to be stretched even further.*
- *And so contract more forcibly.*
- *To increase stroke volume (Starling's Law of the heart).*
- *Cardiac output is a combination of SV and HR.*
- *Therefore an increased stroke volume will create an increased cardiac output.*

7) a) How is oxygen transported by the blood? 2 marks

Answer:

O_2 transport:

- *Via attachment with haemoglobin $Hb + 4O_2 \rightarrow Hb(O_2)_4$.*
- *Transported as oxyhaemoglobin (97%).*
- *Dissolved in plasma (3%).*

b) Identify the main method whereby carbon dioxide is transported in venous blood. 1 mark

Answer:

CO_2 main transporter:

- *Carbonic acid – 70% (which dissociates into H^+ and HCO_3^-).*

c) Explain how increased levels of carbon dioxide levels affect performance during physical activity. 3 marks

Answer:

- *Chemoreceptors are sensitive to changes in carbon dioxide levels.*
- *When carbon dioxide levels increase the cardiac control centre (CCC in medulla oblongata) is alerted.*
- *CCC sends neural impulses to pacemaker.*
- *To increase heart rate, stroke volume and hence cardiac output.*
- *And increase rate and depth of breathing (f and TV) and hence minute ventilation ($\dot{V}E$).*
- *And stimulating redistribution of blood – blood shunting mechanism.*
- *To transport more oxygenated blood to active tissues.*
- *At tissue cell site increased carbon dioxide production causes more unloading of oxygen from haemoglobin (Böhr effect).*

8) A simple equation for the calculation of blood pressure can be written as:
Blood Pressure = Cardiac Output x Resistance to blood flow

a) Identify **one** factor that affects resistance to the flow of blood within systemic blood vessels. 1 mark

Answer

One from the following list:

- *Friction between moving blood and the walls of blood vessels.*
- *Length of blood vessels.*
- *Diameter or lumen width of blood vessels.*
- *Viscosity of blood.*

b) Blood pressure is quoted as two numbers. An example would be resting values of 120/80 mmHg. Explain what each of these numbers refer to. 2 marks

Answer

- *The first number (120 mmHg) refers to systolic blood pressure or blood pressure when heart (ventricles) is (are) contracting.*
- *The second number (80 mmHg) refers to diastolic blood pressure or blood pressure when heart (ventricles) is (are) relaxing.*

c) How would these blood pressure values change during a game of football and a rugby scrum lasting 6 seconds? Give a reason for each of your answers. 3 marks

Answer

- *During dynamic exercise such as a football game, an active player's systolic blood pressure would rise.*
- *As a result of increased cardiac output.*
- *And diastolic blood pressure would remain at the same resting value.*
- *A 6 second isometric maximal exertion rugby scrum raises both systolic and diastolic blood pressures to force blood into the capillary bed.*

A reason for each of your answers:

- *Because this isometric position reduces the actions of the skeletal muscle and respiratory pumps.*
- *Which in turn reduces venous return, cardiac output, blood pressure and capillary blood flow.*
- *Therefore both systolic and diastolic pressures increase to force more blood through the capillaries of working muscles.*

9) Table 4.5 identifies differences in total blood volume, plasma volume, and blood cell volume between untrained and highly trained endurance males (same age, height and body mass). Comment on the data that is presented in table 4.4 and suggest how the trained athlete would benefit from these increased volumes. 4 marks

Table 4.5 – **blood volumes in trained and untrained males**

subjects	total blood volume (dm^3)	plasma volume (dm^3)	blood cell volume (dm^3)
trained male	7	4.2	2.8
untrained male	5.6	3.2	2.4

Answer

- *One of the effects of endurance training is to increase blood volume, resulting primarily from an increase in plasma volume, but there is also a small increase in red blood cells as observed in the figures in table 2.10.*

Benefits:

- *A bigger plasma volume reduces blood viscosity and improves circulation and oxygen availability.*
- *A bigger red blood cell count, with increased levels of haemoglobin, is available in blood for increased oxygen transport and hence an increase in $\dot{V}O_{2max}$.*

10) An unhealthy lifestyle is likely to lead to risky behaviours. Describe how smoking adversely affects the respiratory system. 6 marks

Answer:

6 marks from 6 of:

- *Sticky mucus in the lungs traps pathogens, which is normally swept out of the lungs by cilia cells lining the respiratory tract.*
- *Cigarette smoke contains harmful chemicals that damage these cells, leading to a build-up of mucus and a smoker's cough.*
- *Smoke irritates the bronchi, causing bronchitis.*
- *Smoke damages the walls of the alveoli walls, forming larger air spaces than normal.*
- *This reduces the efficiency of gas exchange, so people with the lung disease emphysema (a type of COPD or chronic obstructive pulmonary disease) carry less oxygen in their blood and find even mild exercise difficult.*
- *Carbon monoxide combines with haemoglobin in red blood cells.*
- *This reduces the ability of the blood to carry oxygen, putting strain on the circulatory system.*
- *And increasing the risk of coronary heart disease and strokes.*
- *Carcinogens are substances that cause cancer.*
- *Tobacco smoke contains many carcinogens, including tar.*
- *Smoking increases the risk of lung cancer, and cancer of the mouth, throat and oesophagus.*

11) Identify three healthy lifestyle changes to reduce diabetes risk. 3 marks

Answer:

3 marks from 3 of:

There are many other acceptable answers.

- *Engage in 30 to 60 mins or more of daily exercise.*
- *Keep alcohol consumption at the light to moderate level.*
- *Consume a healthy diet.*
- *Maintain a body mass index (BMI) of less than 25.*

12) A Level. Discuss the following statement: 'An unhealthy lifestyle has a detrimental effect on the cardiovascular and respiratory systems'. 15 marks

Answer:

Note: In your answer try and get a balance of points for both cardiovascular and respiratory systems.

1 mark for a definition:

- *An unhealthy lifestyle is defined as a lifestyle where a person engages in activities that are known to be detrimental to one's health.*

- *Such as smoking, not exercising regularly or enough, eating unhealthy foods on a regular basis, and not maintaining a healthy weight.*
- *Smoking has a severe effect on the respiratory system. Sticky mucus in the lungs traps pathogens, which is normally swept out of the lungs by cilia cells lining the respiratory tract.*
- *Cigarette smoke contains harmful chemicals that damage these cells, leading to a build-up of mucus and a smoker's cough.*
- *Smoke irritates the bronchi, causing bronchitis.*
- *Smoke damages the walls of the alveoli walls, forming larger air spaces than normal.*
- *This reduces the efficiency of gas exchange, so people with the lung disease emphysema (a type of COPD or chronic obstructive pulmonary disease) carry less oxygen in their blood and find even mild exercise difficult.*
- *Carbon monoxide combines with haemoglobin in red blood cells.*
- *This reduces the ability of the blood to carry oxygen, putting strain on the circulatory system.*
- *And increasing the risk of coronary heart disease and strokes.*
- *Smokers are more likely to suffer from blood clots. Platelets regulate clot formation, which are a primary cause of heart attacks.*
- *Carcinogens are substances that cause cancer.*

12) (continued)

- *Tobacco smoke contains many carcinogens, including tar.*
- *Smoking increases the risk of lung cancer, and cancer of the mouth, throat and oesophagus.*
- *Not exercising regularly or enough (ie a sedentary lifestyle), reduces the efficiency of the lungs and heart.*
- *Thus increasing the likelihood of coronary heart diseases, such as heart attacks and cardiovascular diseases associated with obesity.*
- *Eating unhealthy foods has had a major impact on the increase in diabetes – a condition that occurs when a person's body cannot regulate blood glucose levels.*
- *And is strongly associated with diet, obesity and inactivity.*
- *Type 2 diabetes is linked to obesity. A positive energy balance gives the body more calories than it needs, and sugary foods and drinks contain a lot of calories and so contribute to obesity.*
- *Excessive weight gain is associated with coronary heart disease and hypertension (high blood pressure).*
- *And high cholesterol which results from eating a diet high in saturated fats found in animal products.*
- *Resulting in an increase in low-density lipoproteins.*
- *That can lodge in arterial walls in the form of plaques causing the arteries to become narrower with blood pressure increasing.*
- *A disease known as atherosclerosis.*
- *Unhealthy pathways lead to long-term respiratory and circulatory problems in older people.*
- *And a combination of cardiovascular diseases can develop into irreversible diseases such as metabolic syndrome.*