CHAPTER 2: The cardiovascular system

Practice questions - pages 46 - 47

1) Heart rate is controlled by the cardiac conduction system.
Which one of the following is the order of the cardiac conduction system?
   a. atrioventricular node, sinoatrial node, bundle of His, Purkinje fibres.
   b. atrioventricular node, sinoatrial node, Purkinje fibres, bundle of His.
   c. sinoatrial node, atrioventricular node, bundle of His, Purkinje fibres.
   d. sinoatrial node, atrioventricular node, Purkinje fibres, bundle of His.

Answer: c.
Explanation:
- *The sinoatrial node (SA node) is the pacemaker located in the right atrial wall just inferior to the entrance of the superior vena cava.*
- *The SA node generates impulses which travel across the atria (followed by atrial systole) and then pause (0.1s) at the atrioventricular node (AV node, sited at the superior part of the inter-ventricular septum) and then to the bundle of His located between the ventricles, splitting into right and left branches down the inter-ventricular septum towards the heart apex, and out to the Purkinje fibres which turn superiorly into the ventricular walls (followed by ventricular systole).*

2) The pulse is a wave of pressure produced by:
   a. the contraction of the right atrium.
   b. the contraction of the left ventricle.
   c. the contraction of the left atrium.
   d. the contraction of the right ventricle.

Answer: b.
Explanation:
- *This is the throbbing pulsation produced as the contraction of the left ventricle forces blood into the elastic arteries and expands them.*

3) Which statement does not accurately describe veins?
   a. have less elastic tissue and smooth muscle than arteries.
   b. contain more fibrous tissue than arteries.
   c. most veins in the extremities have valves.
   d. always carry deoxygenated blood.

Answer: d.
Explanation:
- *This is because the pulmonary vein carries oxygenated blood from the lungs to the left ventricle.*

4) Which one of the following statements is false?
   a. most of the total blood volume is contained in veins.
   b. capillaries have a greater total surface area than any other type of vessel.
   c. gas exchange between blood and tissue fluid occur across the walls of venules.
   d. small arteries and arterioles present great resistance to blood flow.

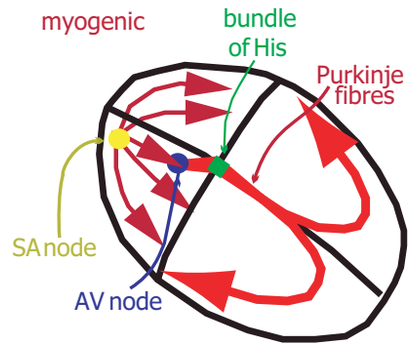
Answer: c.
Explanation:
- *Gaseous exchange occurs across the capillary walls and at the venous end of the capillary bed, blood enters venules which transport blood to veins.*

5) Which one of the following would not result in dilation of the feeder arterioles and opening of the precapillary sphincters in systemic capillary beds?
   a. a decrease in local tissue O_2.
   b. an increase in local tissue O_2.
   c. a local increase in CO_2.
   d. a local increase in pH.

Answer: d.
Explanation:
- *pH is a measure of the relative acidity or alkalinity of a solution whereas other 3 choices are all vasodilators.*

6) Figure 2.15 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

figure 2.15 – the cardiac impulse



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.*

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.*

7) $\dot{Q}$ = 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 x HR

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

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

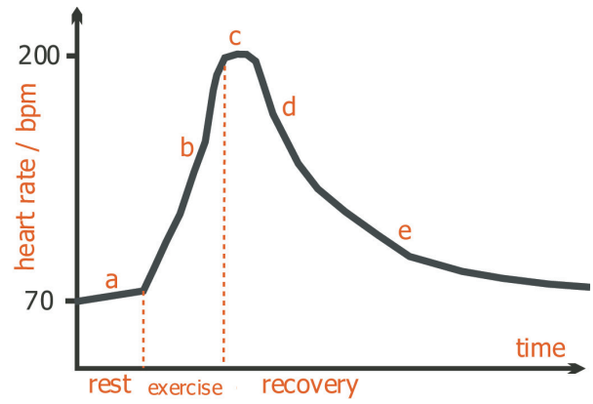
a) Sketch and label a graph to show a typical heart rate response from a point 5 minutes before the start of the run, during the time trial, and over the 20 minute recovery period. 4 marks

Answer:

See graph in figure 2.11.

- *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 2.11 – heart rate response to exercise



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.*

9) Table 2.3 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 2.3 – **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 precapillary 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 precapillary 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.*

10) 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.*

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

12) Table 2.4 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 2.4 and suggest how the trained athlete would benefit from these increased volumes. 4 marks

Table 2.4 – **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 2.4.*

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* $\dot{V}O_{2max}$.