

## CHAPTER 1: THE CARDIOVASCULAR SYSTEM

### Practice questions - text book pages 26 - 27

- 1) Heart rate is controlled by the cardiac conduction system. Which one of the following is the order of the cardiac conduction system?
- atrioventricular node, sinoatrial node, bundle of His, Purkinje fibres.
  - atrioventricular node, sinoatrial node, Purkinje fibres, bundle of His.
  - sinoatrial node, atrioventricular node, bundle of His, Purkinje fibres.
  - 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) According to the Frank-Starling law, stroke volume increases as a function of:
- increasing heart rate.
  - decreasing heart rate.
  - increasing end-diastolic volume.
  - increasing venous return.

**Answer:** c.

**Explanation:**

- Frank–Starling law states that the stroke volume of the heart increases in response to an increase in the volume of blood filling the heart (the end diastolic volume) when all other factors remain constant.*

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

**Answer:** d.

**Explanation:**

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

- 4) The amount of blood pumped by one ventricle in one minute is called:
- stroke volume.
  - end-diastolic volume.
  - ejection fraction.
  - cardiac output

**Answer:** d.

**Explanation:**

- Cardiac output is a combination of stroke volume and heart rate. Stroke volume is the volume of blood pumped by the left ventricle of the heart per beat. Heart rate is the number of beats of the heart per minute (bpm).*

- 5) Why is atherosclerosis especially dangerous when found in coronary arteries?
- it can cause a heart attack.
  - it can restrict blood flow to the heart muscle.
  - It can lead to coronary heart disease.
  - all of the above options are correct.

**Answer:** d.

**Explanation:**

- Atherosclerosis is a disease of the arteries characterised by the deposition of fatty material on their inner walls that can lead to a. b. and c.*

- 6) Figure 1.18 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:*

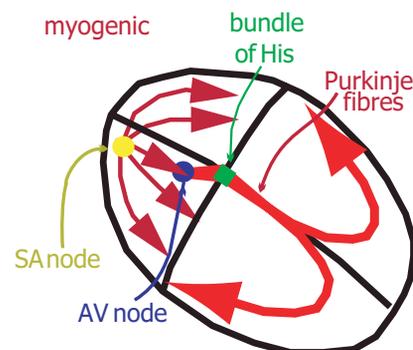
*Atrial systole:*

- 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.

*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.

figure 1.18 – the cardiac impulse



- 7)  $\dot{Q} = SV \times HR$ . 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:

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

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

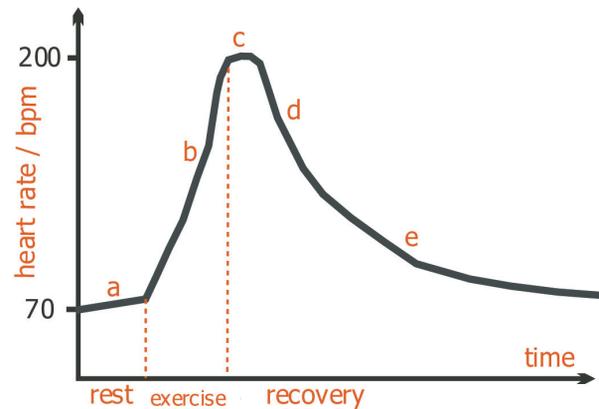
- 8) A fit 18 year old female student performs a 400m time trial in one minute.  
 a) Sketch and label a graph to show a typical heart rate response from a point 5 minutes before the start of the run, during the time trial, and over the 20 minute recovery period. 4 marks

**Answer:**

See graph in figure 1.5.

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

**figure 1.5 – heart rate response to exercise**



**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) 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:**

- 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.

10) Explain what is meant by the term 'cardiovascular drift'.

3 marks

**Answer:**

- Cardiovascular drift is characterised by a *decrease in stroke volume* and a parallel increase in heart rate to maintain a constant cardiac output.
- This results in a *decrease in pulmonary arterial pressure and reduced stroke volume*.
- And an *increase in heart rate*.

11) **A Level** Regular aerobic exercise results in significant benefits to the heart and vascular system.

What are these benefits and how do they contribute to a 'healthier lifestyle'?

15 marks

**Answer:**

- Stamina-building activities such as jogging, cycling and swimming will improve the efficiency of cardiac tissue and blood circulation.
- Resting heart rate reduces as stroke volume increases to give the same resting cardiac output.
- This is because the heart becomes bigger and stronger.
- Improved coronary blood flow will reduce myocardial demands as the heart becomes more efficient.
- Therefore less likely to suffer angina and/or coronary heart disease.
- **Resting blood pressure** is lowered and the balance of **cholesterol** and **triglycerides** (can create fatty deposits that obstruct arteries) is improved.
- Thereby reducing the risks of hypertension and atherosclerosis respectively.
- There is an increase in blood volume and blood cell count.
- Hence an **increase in  $\dot{V}O_{2max}$** .
- Increased elasticity and thickness of smooth walls of arterial muscle makes walls tougher and less likely to stretch under pressure.
- Thereby reducing arteriosclerosis and hypertension.
- Regular exercise will reduce the risk of potential blood clots.
- Thereby reducing risk of coronary thrombosis.
- All these aerobic adaptive responses will enable the individual to sustain physical activity for longer and be able to increase work load intensities.
- Within an ageing population,  $\dot{V}O_{2max}$  and physical strength can be maintained at a much higher level.
- Therefore greater and better life expectancy.
- **Reduction in obesity**, as weight decreases due to regular aerobic exercise, puts less strain on the heart and so benefits from decreased risk of cardiovascular for all age groups.
- The impact of a fitter population reduces the strain on NHS.
- A physically active population has long-term mental and social well-being as individual fitness copes with the demands of everyday life.

- 12) Regular exercise can positively influence several health risks.  
Identify two cardiovascular diseases and briefly explain their health risks on the human body.  
Explain how regular aerobic exercise might reduce these risks.

8 marks

**Answer:**

Select two from the following:

- **Hypertension** is a condition that occurs when a person's blood pressure is continually high..
- Hypertension causes the heart to work harder than normal because it has to expel blood from the left ventricle against a greater resistance.
- It also places great strain on systemic arteries and arterioles, and so it is a major contributing factor in atherosclerosis, coronary heart disease (CHD), strokes and kidney failure.
- **Atherosclerosis**, commonly described as furring up of the arteries, is caused by lipid (fat) deposits accumulating in the inner lining of arteries, resulting in a narrowing of the arterial lumen, thereby impeding blood flow.
- When the deposits obstruct one of the coronary arteries, a coronary heart attack (CHD) results.
- **Angina** refers to a painful constriction or tightness somewhere in the body, characterised in the chest by increased heart rate caused by physical exertion or excitement and heavy and cramp-like chest pains. These chest pains are due to ischemia (a lack of blood and hence oxygen supply) to the heart muscle.
- **Coronary thrombosis** or heart attack is a sudden severe blockage in one of the coronary arteries, cutting off the blood supply to the myocardial tissue. This blockage is often caused by a **blood clot** formed within slowly moving blood in an already damaged, furred-up coronary artery.

Explain how regular aerobic exercise might reduce these risks:

- Stamina-building activities such as jogging, cycling and swimming will improve the efficiency of cardiac tissue and blood circulation.
- Resting heart rate reduces as stroke volume increases to give the same resting cardiac output.
- This is because the heart becomes bigger and stronger.
- Improved coronary blood flow will reduce myocardial demands as the heart becomes more efficient.
- Therefore less likely to suffer angina and/or coronary heart disease.
- **Resting blood pressure** is lowered and the balance of **cholesterol** and **triglycerides** (can create fatty deposits that obstruct arteries) is improved.
- Thereby reducing the risks of hypertension and atherosclerosis respectively.
- There is an increase in blood volume and blood cell count.
- Hence an increase in  $\dot{V}O_{2max}$ .
- Increased elasticity and thickness of smooth walls of arterial muscle makes walls tougher and less likely to stretch under pressure.
- Thereby reducing arteriosclerosis and hypertension.
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- Thereby reducing risk of coronary thrombosis.
- All these aerobic adaptive responses will enable the individual to sustain physical activity for longer and be able to increase work load intensities.

13) Table 1.4 shows the rate of blood flow (in cm<sup>3</sup> 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 1.4 – estimated blood flow at rest and during maximum effort

organ or system	estimated blood flow in cm <sup>3</sup> min <sup>-1</sup>	
	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:

- $\frac{26400 \times 100}{30000} = 88\%$ .

- 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.

14) 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**.

15) A simple equation for the calculation of blood pressure can be written as:

$$\text{Blood Pressure} = \text{Cardiac Output} \times \text{Resistance to blood flow}$$

- 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.

- 16) Table 1.5 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 1.5 and suggest how the trained athlete would benefit from these increased volumes. 4 marks

**Table 1.5 – blood volumes in trained and untrained males**

subjects	total blood volume (dm <sup>3</sup> )	plasma volume (dm <sup>3</sup> )	blood cell volume (dm <sup>3</sup> )
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 1.5.

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