SUGGESTED TEXTBOOK ANSWERS

# Chapter 8 Homeostasis of blood sugar and gas concentrations

The following are suggested answers only. Other answers to the same questions may also be correct.
*Note*: Activity 8.2 would be an ideal open investigation assessment task.

## Science inquiry

### Activity 8.1 Breathing rate

### Studying your results

**1** How did your breathing rate change after holding your breath and after breathing into the paper bag?

*Answer*: After holding the breath the breathing rate would be expected to be higher than when breathing normally.

After breathing into a paper bag the breathing rate would be expected to be higher than when breathing normally.

**2** Suggest reasons for the changes in breathing rate.

*Answer*: While the breath is being held the level of carbon dioxide in the blood will slowly rise because no exchange of gases is taking place.

While breathing into a paper bag the level of carbon dioxide in the blood will also rise because the subject is re-breathing the same expired air, which will contain higher and higher levels of carbon dioxide.

In both cases the increased concentration of carbon dioxide in the blood stimulates chemoreceptors, which send impulses to the respiratory centre which increases breathing rate.

**3** What could be the stimulus that regulates a person's rate of breathing?

*Answer*: Possible stimuli involved in regulation of breathing rate include the following (these are possibilities only and are not necessarily involved):

- Oxygen concentration in the blood
- pH of the blood/concentration of hydrogen ions
- Carbon dioxide concentration in the blood
- Anxiety
- Anger
- Conscious control of breathing rate

**4** How does the evidence from the activity you have just done support your answer to Question 3?

*Answer*: Responses will vary, but you would expect students to suggest that carbon dioxide concentration and possibly oxygen concentration could be involved and they may be able to offer plausible reasons.

Some students may say that the results of the activity do not enable one to say what stimulus is involved in regulation of breathing rate.

## **Activity 8.2** Investigating behaviour and homeostatic mechanisms

Design an investigation to test links between one type of behaviour and one aspect of homeostasis.

### Planning your investigation

Some of the questions that you will need to answer in your planning are as follows.

- What hypothesis will you test? The hypothesis should link the behaviour you are going to test with the aspect of homeostasis that you are going to investigate. Make sure that your investigation really will test your hypothesis.

  *Answer*: The student's hypothesis should be brief, a definite statement, have a single idea that can be tested and it should link behaviour with the aspect of homeostasis to be investigated.

- How will you make your observations objective? Measurement is the best option, if it is possible.

  *Answer*: Students responses will vary; however, teachers should ensure that the responses are practical and achievable.

- What variables will you control and how you will go about controlling them?

  *Answer*: Students should devise ways of controlling all factors that could possibly affect the aspect of heomeostasis being tested (except the behaviour under investigation).

- How will you make sure that your results are valid and reliable? How many repetitions will you perform?

  *Answer*: The proposed experiment will be valid if it tests what it is supposed to test.

  The experiment will be reliable if it gives the same result each time it is carried out. Students should have sufficient repetitions of their experiment to determine reliability.

- How will you record your results? Will it be possible to present the results as a table and/or a graph?

  *Answer*: Answers will depend on the actual results to be measured or observed. Students may suggest drawing up a table to record their results. If the results are in a tabular form, a graph should be able to be drawn.

# Review questions

**1** What is the role of the liver in regulating blood sugar concentration?

*Answer*: The liver is able to convert glucose to glycogen for storage, or glycogen to glucose for release into the blood. The liver stores glucose as glycogen, so the liver can either take up glucose from the blood or can add glucose to the blood according to the body's needs.

**2** Distinguish between glycogenesis, glycogenolysis and gluconeogenesis.

*Answer*:

- Glycogenesis is where glucose molecules are chemically combined in long chains to form glycogen molecules.
- Glycogenolysis is the process of converting glycogen to glucose.
- Gluconeogenesis is the production of glucose molecules from fats or amino acids.

See also Table 8.1 on page 107 of the textbook.

**3 a** Which gland is involved in the secretion of insulin and glucagon? Identify the location of the gland.

*Answer*: The islets of Langerhans of the pancreas (pancreatic islets) secrete insulin and glucagon. These are small islands of tissue within the pancreas – a pale grey gland that lies partly in the curve of the duodenum.

**b** Describe how insulin and glucagon regulate the concentration of glucose in the blood.

*Answer*: When blood glucose levels rise, insulin is secreted from beta cells in the pancreatic islets. Insulin decreases blood sugar levels in the following ways:

- It speeds up the transport of glucose from the blood into the cells, especially those of the skeletal muscles.
- It accelerates the conversion of glucose into glycogen.
- It stimulates the conversion of glucose to fat which is stored in adipose tissue (fat storage tissue).
- It causes an increase in protein synthesis in some cells.

When blood glucose levels fall, glucagon is secreted from alpha cells in the pancreatic islets. Glucagon causes an increase in blood sugar levels by:

- stimulating the conversion of glycogen to glucose (glycogenolysis) in the liver. The glucose formed is then released into the blood
- stimulating the liver to produce new glucose molecules from fats and amino acids (gluconeogenesis).

**c** How are the levels of these hormones in the blood determined?

*Answer*: The secretion of both glucagon and insulin is directly determined by the level of glucose in the blood. Secretion is controlled by a negative feedback system. When the blood sugar falls below normal, chemical sensors in the alpha cells of the islets of Langerhans stimulate those cells to secrete glucagon. As the level of blood sugar increases, the cells are no longer stimulated and secretion is reduced. In a similar way, as blood glucose rises, beta cells in the islets of Langerhans are stimulated to secrete insulin. Due to the action of insulin blood glucose then falls until the beta cells are no longer stimulated.

**4** Describe the influence of the hormones of the adrenal glands on blood sugar concentration.

*Answer*: The hormones secreted by the adrenal cortex are glucocorticoids. These hormones ensure that enough energy is provided to the cells by stimulating the conversion of glycogen to glucose. They also increase the rate at which amino acids are removed from cells (mainly muscle cells) and are transported to the liver. Some of these amino acids may be converted to glucose by the liver if glycogen levels are low, a process called gluconeogenesis.

The adrenal medulla synthesises adrenaline and noradrenaline. These hormones prepare the body for increased physical activity. In particular, adrenaline brings about a rise in blood glucose levels and, in so doing, counteracts the effects of insulin. It stimulates breakdown of glycogen in the liver and the release into the blood of the glucose that is formed.

**5** After a meal, the blood sugar level often rises well beyond the normal level. Explain why this occurs.

*Answer*: After consuming a meal, especially one containing a high proportion of carbohydrates, the breakdown products of carbohydrate digestion, mainly glucose, are absorbed into the blood capillaries of the villi of the small intestine. Thus, blood glucose concentration following a meal may rise sharply until homeostatic mechanisms take effect and return blood sugar to normal levels.

**6** Describe the effects of the following factors on breathing rate.

**a** Concentration of oxygen in the blood

*Answer*: Oxygen normally plays little part in the regulation of breathing. The concentration of oxygen has to fall to very low levels before it has a major stimulatory effect on the rate of breathing.

**b** Concentration of carbon dioxide in the blood

*Answer*: The concentration of carbon dioxide in the plasma is very important in the regulation of breathing rate. Any increase in the concentration of $CO_2$ in the blood results in the stimulation of the central and peripheral chemoreceptors. These send nerve impulses to the respiratory centre, which increases breathing rate.

**c** Hydrogen ion concentration (pH) in the blood

*Answer*: Carbon dioxide in the blood plasma combines with water to form carbonic acid, which dissociates into hydrogen ions and bicarbonate ions. Thus any increase in carbon dioxide in the plasma will result in an increase in hydrogen ion concentration. The increase in $CO_2$ concentration and hydrogen ion concentration in the blood stimulates the central and peripheral chemoreceptors. These send nerve impulses to the respiratory centre in the medulla oblongata, which increases breathing rate.

**7** Explain how the respiratory centre controls the rate of breathing.

*Answer*: The respiratory centre in the medulla oblongata of the brain receives information about the carbon dioxide concentration of the blood from the aortic and carotid bodies and from receptors in the medulla itself. The aortic and carotid bodies are sensitive to increases in the concentration of hydrogen ions and $CO_2$. They stimulate the respiratory centre to bring about an increase in breathing rate if $CO_2$ levels rise. Negative feedback occurs as $CO_2$ levels fall due to the increase in breathing rate.

**8** Describe the role of the aortic and carotid bodies in regulating breathing rate.

*Answer*: The aortic and carotid bodies contain chemoreceptors that are sensitive to the concentration of $CO_2$ and hydrogen ions in the blood plasma. When stimulated by rising concentrations of these substances, the bodies send messages to the respiratory centre in the medulla oblongata, which in turn increases breathing rate.

**9** Why is it dangerous to hyperventilate before swimming under water?

*Answer*: Hyperventilation is rapid, deep breathing. It has the effect of removing much of the $CO_2$ from the blood. When a person swims under water after hyperventilating there is no urge to breathe because the $CO_2$ concentration is very low. Oxygen concentration could become so low that the person lose consciousness.

**10** Define 'cardiac output'.

*Answer*: Cardiac output is the amount of blood leaving the heart every minute. Thus:

cardiac output (mL/min) = heart rate (beats/min) × stroke volume (mL)

**11** Describe how the autonomic nervous system influences cardiac output.

*Answer*: Impulses from the sympathetic division of the autonomic nervous system speed up the heart rate while impulses from the parasympathetic division slow it down. The balance between these two sets of opposing impulses determines the heart rate at any time. At rest, parasympathetic impulses dominate, while during exercise, sympathetic impulses become dominant.

**12** Describe the roles of the sinoatrial (SA) and atrioventricular (AV) nodes in regulating heart rate.

*Answer*: The SA node brings about the rhythmical contractions of the heart. It begins each heart beat with an impulse that spreads out over the atria, causing them both to contract. The impulse eventually reaches the AV node between the two atria. The AV node then sends out impulses which are carried along fibres that run through the septum between the two ventricles. From the fibres in the septum impulses spread through the muscle of the ventricles causing them to contract. Although the SA node can stimulate heartbeat on its own, its activity is influenced by the autonomic nervous system. (See also the answer to Question 11.)

# Apply your knowledge

**1** Apply the stimulus–response–feedback model (Figure 6.5 on page 77) to the response of the pancreas to rising blood sugar.

*Answer*:

- Stimulus = blood sugar levels rise above normal
- Receptors = chemical sensors in the beta cells of the islets of Langerhans
- Modulator = beta cells of the islets of Langerhans secrete insulin
- Effectors = liver, muscles
- Response = liver and muscles take up glucose from the blood and convert it into glycogen
- Feedback = the level of blood sugar decreases so that the beta cells are no longer stimulated and production of insulin is reduced.

**2** Compile a table that summarises the role of each of the following systems in regulating blood sugar level: nervous system, digestive system, endocrine system, circulatory system, muscular system, excretory system.

*Answer*:

| System | Role in regulating blood sugar |
|---|---|
| Nervous system | Regulates food intake through control of appetite |
| Digestive system | Responsible for the breakdown of food, especially carbohydrates to glucose; absorbs glucose and supplies the blood and hence cells with glucose |
| Endocrine system | Alpha and beta cells in pancreas monitor glucose level in blood<br>Produces and secretes the hormones insulin and glucagon; cortisol and adrenaline |
| Circulatory system | Transports glucose from digestive system to liver, and the rest of the body where glucose is taken up by cells for respiration or stored as glycogen. Transports the hormones involved in blood sugar regulation around the body |
| Muscular system | Cells use glucose to release energy; stores glucose as glycogen. |
| Excretory system | Kidneys reabsorb filtered glucose to maintain levels. Excretion of hormone molecules |

**3** We cannot voluntarily control heart rate or blood sugar level, yet we can voluntarily control our breathing.

**a** Explain why it is important for us to be able to voluntarily decide when to take a breath and how deep the breath should be.

*Answer*: Voluntary control of breathing is essential for speech. It is also a protective device to prevent food, water or irritating gases from entering the lungs. Voluntary control is also important in activities like blowing up a balloon, blowing out candles, swimming and many other actions.

**b** We cannot voluntarily stop breathing indefinitely. Explain why.

*Answer*: If we stop breathing, the build-up of carbon dioxide in the plasma stimulates the inspiratory centre to send impulses to the inspiratory muscles. The reflex contraction of the inspiratory muscles due to carbon dioxide build-up eventually overcomes any voluntary effort and we are forced to take a breath – whether we want to or not.

**4** People sometimes hyperventilate in stressful situations. The hyperventilation may cause dizziness and tingling of the fingers and toes. In such cases, the person may be advised to breathe into a paper bag and re-breathe the same air that was breathed out. How would such a procedure help to overcome the problems of hyperventilation?

*Answer*: Rapid, deep breathing can provide more oxygen than required and remove more carbon dioxide than necessary. By breathing in air that has been breathed out (into a paper bag), the person is breathing air that has a higher concentration of $CO_2$ than atmospheric air. As $CO_2$ in the blood builds up, the chemoreceptors will be stimulated and a normal breathing pattern should resume.

**5** Calculate the cardiac output for an individual with a heart rate of 75 beats per minute and a stroke volume of 70 mL per beat.

*Answer*:

Cardiac output = heart rate × stroke volume

Thus:

75 × 70 = 5250 mL/min, or 5.25 L/minute

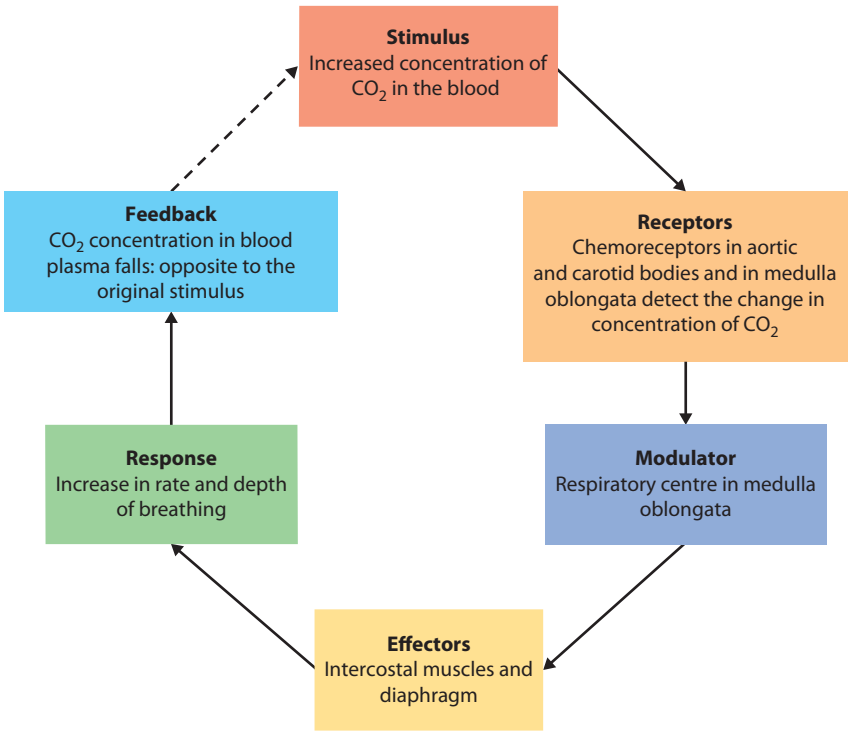
**6** Explain why an increase in cardiac output is an advantage during exercise.

*Answer*: Increased cardiac output means increased supply of oxygen and glucose-rich blood to muscles and increased rate of re-oxygenation of blood as it flows through the lungs. The increased blood that is pumped by the heart results in increased blood flow to muscles and thus increased delivery of oxygen and glucose for cellular respiration and increased removal of cell wastes such as $CO_2$.

**7** Draw a stimulus–response–feedback diagram to show what happens to breathing rate when:

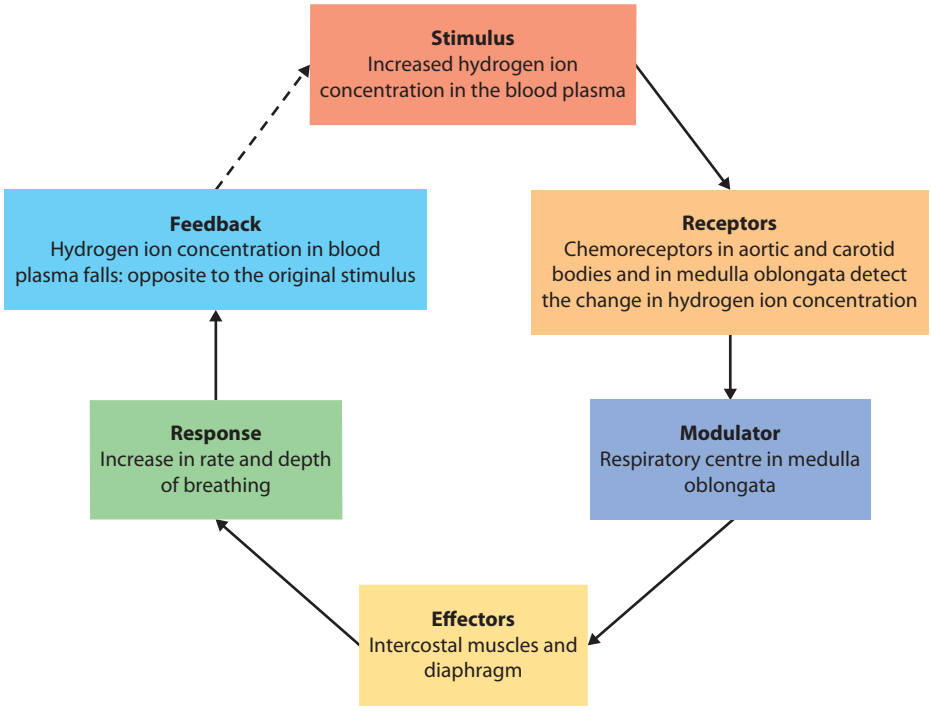
**a** the concentration of carbon dioxide in the blood increases

*Answer*:




**b** the hydrogen ion concentration of the blood increases.

*Answer*:




**8** What do you think would happen to heart rate and stroke volume during prolonged, strenuous exercise?

*Answer*: Both heart rate and stroke volume would increase to supply more blood (with oxygen and glucose) to the contracting muscles. Since the exercise is prolonged, the heart rate and stroke volume would stabilise at a higher level than when the person was at rest.