SUGGESTED TEXTBOOK ANSWERS

Chapter 7 Homeostasis of body temperature and body fluids

The following are suggested answers only. Other answers to the same questions may also be correct.

Science inquiry

Activity 7.1 Investigating thermoregulation

Working with a partner or in a small group, design an investigation to answer a question, or questions, about thermoregulation.

Answer: Students could plan and carry out investigations to find out the answers to their chosen questions. It could be used as an open investigation assessment, where students choose one independent variable to test at different environmental temperatures.
Three different environments could be arranged in the laboratory, as such:

- cool temperatures, which could be achieved using air conditioners, fans, wet towels, cold packs, removing some clothing, sitting with feet in cold water, and so on
- normal room temperature
- warm temperatures, which could be achieved using heaters, blankets, hot water bottles, heat packs and so on.

1 What changes occur in core body temperature when the skin temperature is changed?

Answer: Students should find that when skin temperature changes, the core body temperature stays the same (due to the adjustments made by the hypothalamus to maintain homeostasis).

2 What changes are evident at the surface of the body when the environment is very hot or very cold?

Answer: Students should be able to demonstrate that in very hot conditions the skin becomes red and sweat is secreted.

In very cold conditions the skin should become pale, or even bluish, and no sweat is secreted. Goosebumps may appear as the hairs on the arms and legs are raised in an attempt to trap an insulating layer of air above the surface of the skin.

3 Do changes in environmental temperature affect breathing rate, heart rate or blood pressure?

Answer: Results will depend on how carefully students do the experiments. At the temperatures achievable in a school laboratory one would not expect any effect on breathing rate, heart rate or blood pressure.

Activity 7.2 Experiments in a heated room

1 Beef is muscle from a cow or a bull. Explain how the men's muscles were unharmed after 45 minutes in the hot chamber, while the muscle in the beef was cooked.

Answer: Humans have mechanisms, controlled by the hypothalamus, that maintain body temperature so that their muscles do not 'cook'. Skin vasodilation and sweating occur to keep the body temperature as close to normal as possible (approximately 37°C). Beef has no such mechanisms for maintaining its temperature.

2 Would you expect to see any changes in the appearance of the men after they had been in the hot chamber? Explain your answer.

Answer: The men would look very red, due to the vasodilation of blood vessels in their skin, and they would be dripping with sweat.

3 The men were in the hot chamber for 45 minutes. Do you think they would be able to survive for a much longer period? Explain.

Answer: It is unlikely that at such a high temperature the men would survive for much longer. There would be a limit to the amount of sweat they could produce and limited air circulation would reduce evaporation.

4 Do you think the men (and the dog) would have had anything to drink while in the chamber? Explain.

Answer: It is very likely that they would have had a drink, because the amount of sweat being secreted would have been very high, and the water lost would have to be replaced – otherwise their core temperature would have increased more rapidly.

5 A sauna is a small room where people can experience heating in dry or humid conditions. The temperature in the room can vary from 60°C up to 120°C. High humidity is used at lower temperatures but at higher temperatures only dry heat is used. Explain why a high-humidity sauna should not be set to a high temperature.

Answer: High humidity would decrease the effectiveness of sweating. Sweating is only effective if there is high evaporation, because heat is removed from the skin when the liquid changes into a vapour. If humidity is high, there is too much water in the air for evaporation to be effective, and heat stroke could occur.

6 Suggest some precautions that should be taken when using a sauna.

Answer: The environmental temperature inside the sauna should be monitored at all times. The humidity should be decreased if the person is sweating, but not being cooled. Minimal clothes should be worn, so that the maximum surface area of skin can be exposed to air for cooling. Water should be consumed.

Activity 7.3 Effect of drinking on urine production

Studying your results

1 What was your rate of urine production (in mL per hour) before drinking the litre of water?

Answer: Rate will depend on the individual.

2 What was your rate of urine production (in mL per hour) after drinking the litre of water?

Answer: Rate will depend on the individual but should be greater than before drinking.

3 What proportion of the litre of water that you drank was excreted in 90 minutes?

Answer: Proportion will depend on the individual.

4 Was there any difference in the colour of the urine before and after you drank the litre of water? If so, how can you explain the difference in colour?

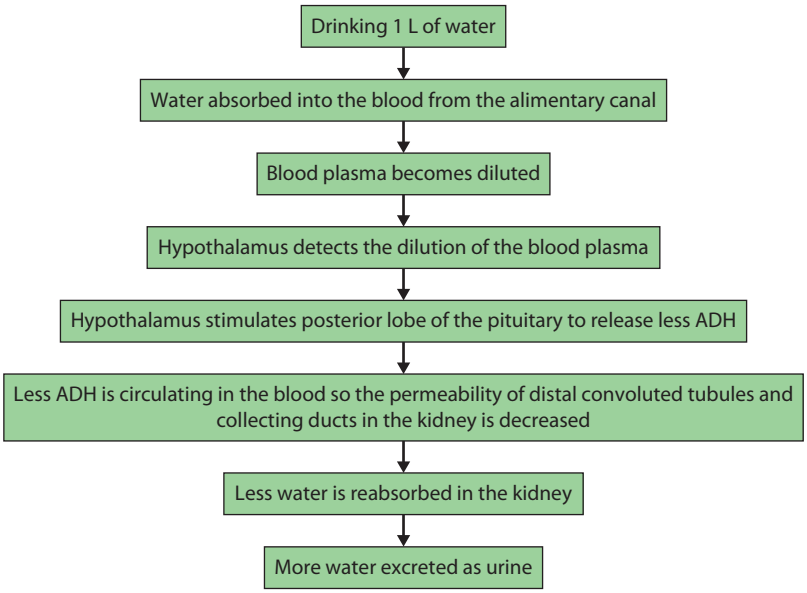
Answer: Colour before and immediately after drinking the water should be approximately the same.

5 Was there any change in the colour of the urine as the investigation progressed? If so, how can you explain the change in colour?

Answer: Colour should become lighter as the investigation proceeds and urine becomes more dilute. More water is being excreted to maintain homeostasis.

6 Draw a flow chart to show the sequence of events that would have occurred from the time you drank the water to the time your kidneys began to increase water excretion.

Answer: Flow chart could look something like the one shown below. Students may omit or combine some of the steps and may present it as a feedback loop.



7 Explain why the changes in urine production were necessary to maintain a constant level of water in the body.

Answer: Fluid gain must equal fluid loss if the composition of body fluids is to be kept fairly constant. Thus, if there is a large fluid input (as in drinking large amounts of water), then fluid output must increase accordingly. This occurs through increased urine production unless a lot of water is lost by sweating.

Review questions

1 Why must heat loss equal heat gain?

Answer: A balance between heat gain and heat loss results in a relatively constant body temperature. If heat loss was more than heat gain, body temperature would fall; if heat loss was less than heat gain, body temperature would rise.

2 Describe the ways in which the body can gain heat.

Answer: The body can gain heat by:

- shivering (skeletal muscle contraction produces heat)
- increased metabolic rate (a long term response)
- absorption of heat radiation (for example, from a heater or the sun)
- conduction from hot surrounding air
- consumption of hot food or drink.

3 What are the two types of thermoreceptors and in what parts of the body are they located?

Answer: Thermoreceptors in the skin and in some mucous membranes are called peripheral thermoreceptors. Those located in the hypothalamus are called central thermoreceptors.

Some students may say (but in doing so, have not answered the question): There are two types of peripheral thermoreceptors. Cold receptors are stimulated by environmental temperatures lower than normal, and heat receptors detect temperatures higher than normal.

4 Describe the role of the skin in regulating body temperature.

Answer: The skin helps to regulate body temperature in two ways:

- Blood vessels near the surface of the skin can constrict or dilate to control the amount of blood flowing near the surface. The more blood flowing near the skin's surface, the more heat is lost by conduction, convection and radiation (provided environmental temperature is lower than body temperature).
- Heat loss is regulated by increasing or decreasing the amount of sweat secreted by the skin.

5 a What responses are likely to occur if core body temperature begins to fall?

Answer: If the core temperature falls, the following responses may occur:

- vasoconstriction in the skin
- reduction in sweating
- increase in cellular metabolism that leads to an increase in heat production (a long-term response)
- shivering
- increase in voluntary activity
- conscious behaviour, such as putting on a jumper or turning on a heater
- reducing surface area from which heat can be lost.

b What responses are likely to occur if core body temperature begins to rise?

Answer: If body temperature tends to rise, the following responses may occur:

- vasodilation of skin blood vessels to increase blood flow through the skin
- sweating
- a decrease in metabolic rate (in the longer term)
- behavioural responses such as turning on a fan or air conditioner, removing external clothing and reducing physical activity
- increasing surface area
- decreasing voluntary activity.

6 Explain the difference between heat stroke and heat exhaustion.

Answer: Heat exhaustion occurs due to extreme sweating and vasodilation in the skin. The reduction in blood volume and the decreased resistance to blood flow (due to vasodilation) results in a drop in blood pressure, which may cause the person to collapse. Body temperature remains fairly normal.

Heat stroke occurs when the body is unable to maintain a normal core temperature because heat loss mechanisms are inadequate. Body temperature rises above normal.

7 Describe the different types of body fluid.

Answer: The types of body fluid are:

- the fluid inside the cells – the intracellular fluid or cytosol
- the fluid outside the cells – the extracellular fluid
- the blood plasma – part of the extracellular fluid
- the intercellular fluid – the fluid between the cells, which is also part of the extracellular fluid.

8 Define 'metabolic water'.

Answer: Metabolic water is a small amount of water produced as a by-product of chemical processes occurring within the cells. For example, cellular respiration uses oxygen and glucose and releases carbon dioxide and water.

9 a What are nephrons?

Answer: Nephrons are the functional units of the kidney; they carry out the kidney's role in excretion and water regulation.

b Draw a diagram of a nephron and label the places where filtration, reabsorption and secretion occur.

Answer: See Figure 7.11 on page 94. Filtration occurs between the capillaries of the glomerulus and the capsule that surrounds it. Reabsorption takes place along the length of the tubule and in the collecting duct. Secretion occurs from the kidney tubule into the peritubular capillaries.

10 Describe the role of antidiuretic hormone (ADH) in regulating water output.

Answer: The permeability of the walls of the distal convoluted tubules and collecting ducts of the kidney nephrons are controlled by ADH. When the concentration of ADH in the blood plasma is high, the tubules are very permeable to water, and water leaves the tubule and enters the surrounding capillary network. On the other hand, when the concentration of ADH in the plasma is low, the tubules are not very permeable to water, and little water is reabsorbed into the plasma of the blood.

11 How does the thirst reflex regulate water intake?

Answer: As cells become dehydrated, the events that take place to bring about intake of water and restoration of the water balance include the following:

- Osmoreceptors in the thirst centre in the hypothalamus detect any rise in osmotic concentration of the blood. Such a rise is caused by decreased concentration of water in the blood. Other stimuli (such as a dry mouth) may also be involved.
- Stimulation of the thirst centre makes the person feel thirsty.
- Awareness of thirst stimulates the person to drink.
- The fluid that is drunk is absorbed into the blood plasma from the alimentary canal.
- The extra water absorbed into the blood returns the osmotic concentration of the blood to normal so that the thirst centre is no longer stimulated and the feeling of thirst no longer occurs.

12 How much water would a person lose before symptoms of dehydration became evident?

Answer: When a person has lost about 2% of normal body water, symptoms of dehydration become evident.

13 Aldosterone regulates the amount of sodium in the blood. Explain why:

a aldosterone influences the amount of water excreted from the body

Answer: Aldosterone is a hormone that increases the amount of sodium reabsorbed into the kidney tubules. Water is reabsorbed with the sodium so aldosterone indirectly affects the amount of water excreted.

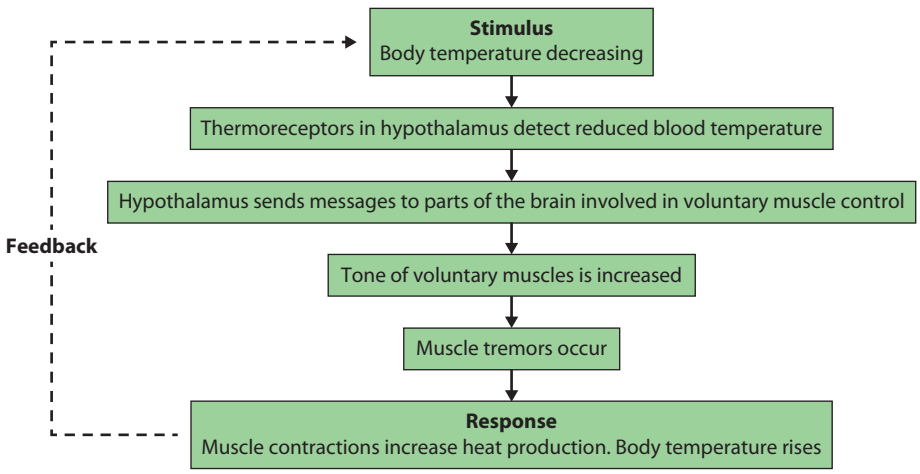
b aldosterone affects blood pressure.

Answer: When aldosterone increases sodium reabsorption it also increases water reabsorption. The increase in water reabsorption increases blood volume which in turn increases blood pressure.

Apply your knowledge

1 Using shivering as an example, draw a stimulus–response model to show the processes involved. Make sure you include the effect of the feedback on the original stimulus.

Answer:



Students may combine some of the above points.

2 In very cold weather it is our fingers and toes that often feel coldest.

a Why are fingers and toes affected by cold more than other parts of the body?

Answer: Fingers and toes have a higher surface area-to-volume ratio and therefore tend to lose heat more quickly than the torso and therefore feel colder. They are also more likely to be in contact with cold surfaces than are other parts of the body.

b The fingers and toes may appear white when very cold. Explain why.

Answer: Fingers and toes have a higher surface to volume ratio than other parts of the body and therefore tend to lose heat more rapidly. To reduce heat loss, vasoconstriction (to restrict blood flow through arterioles) occurs in fingers and toes. Heat loss is then minimised. Because there is little blood flowing through the skin of the fingers and toes, they appear white.

c When very cold, people sometimes appear to be 'blue with cold'. What makes the skin appear blue?

Answer: Vasoconstriction of skin blood vessels may cause the blood to stagnate in the skin. As the blood loses its oxygen, oxyhaemoglobin breaks down to haemoglobin. Oxyhaemoglobin is bright red, but haemoglobin is bluish-purple. The skin appears blue because the stagnant blood has lost its oxygen and thus contains haemoglobin.

3 Alcohol increases blood flow through the skin. What advice would you give to a person who recommended 'a stiff drink to warm you up'? Explain.

Answer: Increasing blood flow through the skin will allow more heat to be transferred from the body to the environment by radiation and conduction. An alcoholic drink would not be useful if a person is feeling cold, because it will increase heat loss and make the person feel even colder.

4 Vasoconstriction in the skin occurs when a person's body temperature is low, or when a person is very scared or very angry (we say someone is 'white with fear' or 'white with anger').

a Apply the feedback model shown in Figure 6.5 on page 77 to each of these responses. Do they both fit the model? Explain your answer.

Answer: Stimulus = decreased body (blood) temperature; receptor = thermoreceptors in hypothalamus; modulator = hypothalamus; effector = arterioles in skin; response = vasoconstriction in skin so that skin appears pale; feedback = increased body temperature

Stimulus = scary event; receptor = senses such as eyes (photoreceptors) and hearing; modulator = cerebral cortex; effector = arterioles in skin; response = vasoconstriction in skin and increased blood flow to vital organs; feedback = the person either confronts the threat or removes themselves from the threatening situation (fight or flight) and so the stimulus is decreased

b What is the advantage to a person of vasoconstriction in the skin:

i when body temperature is tending to fall

Answer: Vasoconstriction causes the skin to retain heat because with less warm blood flowing near the surface heat loss by radiation is reduced.

ii when the person is scared or angry?

Answer: Vasoconstriction in the skin allows for blood to be redirected to the muscles and organs that will be needed for a fight-or-flight response.

5 A thermograph shows the temperature at the surface of an object or body. Examine the thermograph of the ballerina shown in Figure 7.1 (page 85).

a What parts of the ballerina's skin are the hottest? What parts are the coolest?

Answer: The hottest parts are the head and neck, the shoulders and arms and the lower legs.

The coolest parts are the fingers, toes and soles of the feet.

b Explain the reasons for the differences in skin temperature that you have described in your answer to part **a** of this question.

Answer: The hottest parts are where muscles are actively contracting. Muscle contraction requires energy, which comes from cellular respiration and some of the energy released in respiration is in the form of heat.

The coolest parts are where muscles are not contracting so actively and, where there is a large surface to volume ratio, which allows more heat loss.

6 Explain why excretion is closely related to maintaining fluid balance.

Answer: Wastes excreted by the kidneys must be dissolved in water, so that removal of wastes inevitably involves loss of water. By regulating the amount of water reabsorbed, and thus the concentration of wastes in the urine, fluid balance can be maintained.

7 Examine Figure 7.12 on page 95 and identify the stimulus, receptor, modulator, effector, response and feedback.

Answer:

- Stimulus = osmotic pressure of the blood is raised (decreased amount of water in the blood).
- Receptor = osmoreceptors in the hypothalamus.
- Modulator = hypothalamus (stimulates posterior lobe of the pituitary gland to release ADH into the bloodstream).
- Effector = nephron tubules and collecting ducts in the kidney respond to ADH in the blood stream.
- Response = permeability to water of the distal convoluted tubules and the collecting ducts is increased; more water is then reabsorbed into the blood plasma from the tubules and ducts.
- Feedback = increased water reabsorption decreases osmotic pressure of the blood, which is opposite to the original stimulus (increasing osmotic pressure of the blood) so negative feedback has occurred.

8 A person lost in the desert would suffer extreme dehydration. Although the thirst receptors would try to initiate drinking behaviour, the lack of available water would not allow this requirement to be met. Describe the mechanisms the body would employ to conserve water while getting rid of metabolic wastes.

Answer: The person would be losing water through sweating but would be unable to replace that water. This means that the osmotic pressure of the blood would be raised. Osmoreceptors in the hypothalamus detect the increased osmotic pressure of the blood. The hypothalamus stimulates the posterior lobe of the pituitary gland to release ADH into the bloodstream. ADH affects its target organs, which are the nephron tubules in the kidney. The permeability to water of the distal convoluted tubules and the collecting ducts is increased. More water is then reabsorbed into the blood plasma from the tubules and ducts. This response will cause a dramatic decrease in the volume of urine produced and an increase in the concentration as less water is available to dilute the salts/wastes being excreted. Small quantities of highly concentrated urine will be produced.

9 A student made the following observations. On a very hot day, little urine was produced and it was dark in colour. On a cold day, urination occurred more frequently and the urine was pale in colour. Explain these observations.

Answer: On a very hot day, the student will sweat in order to cool the body and maintain homeostasis. This results in an increase in water loss from the body, which raises the osmotic pressure of the blood. More ADH will be released from the posterior pituitary. This causes the nephron to become more permeable to water, so water is retained in the blood and only small quantities of urine are produced. The urine would be dark in colour because the metabolic wastes are concentrated due to the excretion of less water.

On a cold day, the opposite occurs. The student will not lose as much fluid through sweat. Less ADH will be released from the posterior pituitary. This causes the nephron to become less permeable to water, so water is retained in the collecting tubule and is lost as urine. It is light or pale in colour because the metabolic wastes are diluted by the larger volume of water being lost.

10 An athlete had blood samples taken before and after a vigorous training session on a hot, dry day. The sample taken after training had a much higher concentration of ADH than the sample taken before training. Explain why there would be a difference in concentrations.

Answer: A vigorous training session on a hot, dry day will result in the athlete sweating profusely to maintain homeostasis of body temperature. Thus, if there is a decreased amount of water in the blood, the water concentration of the blood plasma would decrease. This means that the osmotic pressure of the blood is raised. Osmoreceptors in the hypothalamus detect this and stimulate the posterior lobe of the pituitary gland to release ADH into the bloodstream. ADH causes permeability to water of the distal convoluted tubules and the collecting ducts to increase. Thus, less water is lost in the urine to compensate for the increased loss of water through sweating.

11 For the regulation of the following, draw up a table listing the body systems that are involved in the regulation in one column and a brief statement of the role of each system in a second column.

a Body temperature

Answer:

Body systems	Role of system
Central nervous system	Hypothalamus is the major integrating area for thermoregulation
Endocrine system	Increase or decrease metabolic rate, thus creating or decreasing the production of heat
Skin (integumentary system)	Insulates the body; contains sweat glands to assist with heat loss; contains blood vessels able to dilate or constrict
Muscular system	Skeletal muscles may 'shiver' to produce heat
Circulatory system	Arterioles in the skin respond to the autonomic nervous system, causing vasoconstriction for heat retention, or vasodilation to increase heat loss. Circulation distributes heat to all parts of the body from heat-producing organs like the liver and skeletal muscles

b Body fluid balance

Answer:

Body systems	Role of system
Central nervous system	Hypothalamus is the major integrating area for fluid regulation
Endocrine system	Increase or decrease of ADH secretion increases or decreases fluid loss from kidneys
Skin (integumentary system)	Contains sweat glands through which water is lost
Excretory system	Filter, reabsorb water and control water levels in the blood

12 Table 7.2 shows the water loss from a person's skin and kidneys under different conditions. Use the data in the table to explain the relationship between the regulation of body temperature and regulation of fluid content of the body.

Table 7.2 Water loss in differing conditions

	Water lost (mL/hour)		
Organ	**At room temperature**	**In hot weather**	**With lengthy vigorous exercise**
Skin	19	73	225
Kidneys	58	50	20

Answer: At room temperature a person sweats very little, so only a small volume of water is lost from the skin as sweat. This means that more water circulates in the plasma to the kidneys and, with less ADH released from the pituitary gland, more water will be lost as urine.

In hot weather, a person sweats to help cool the body, so a larger volume of water is lost from the skin as sweat. This means that less water circulates in the plasma to the kidneys and, with more ADH released from the pituitary gland, smaller amounts of water will be lost as urine.

With lengthy vigorous exercise, a person sweats profusely, so a large volume of water is lost from the skin as sweat. This means that osmotic pressure of the blood is raised significantly. Greater amounts of ADH will be released from the pituitary gland, so that as much water as possible will be retained by the kidneys. This results in a very small volume of urine being formed.