SUGGESTED TEXTBOOK ANSWERS

Chapter 2 Chemical messengers

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

Science inquiry

Activity 2.1 Endocrine dysfunction

Write a brief report on the disorder that you chose. The report should be in a format that could be presented to the rest of your class.

Answer:

Disorder	Cause	Symptoms	Treatment
Acromegaly	Oversecretion of growth hormone after most skeletal growth has stopped; usually due to a tumour of the pituitary gland	Large hands, feet and jaw due to overgrowth of bones in these areas	Removal of the tumour or reducing activity of the tumour using drugs and/or radiation
Addison's disease	Undersecretion of cortisol and sometimes aldosterone. Usually caused by an auto-immune response that attacks the adrenal cortex. May be an infection or tumour	Low blood pressure, loss of appetite, weight loss, muscle weakness, chronic fatigue, nausea, vomiting, diarrhoea	Daily consumption of cortisol (and possibly aldosterone) tablets to replace the missing hormones
Androgen insensitivity syndrome	An inherited (sex-linked) condition in which males with normal X and Y chromosomes are resistant to male hormones (androgens)	The patient, although genetically male, develops some or all of the physical characteristics of a female	Depends on severity of symptoms. May involve removal of testes, sex re-assignment, hormone replacement therapy
Cushing's syndrome	Oversecretion of ACTH from the pituitary, which results in oversecretion of cortisol from the adrenal cortex. May also be caused by overconsumption of cortisol or other steroid hormones	Weight gain in the upper body, moon face, thirst, high blood pressure, purple marks on the skin, muscular weakness, bone pain, rib and spine fractures	Surgical removal of pituitary or adrenal tumours. Reduction in drug dose if caused by overconsumption of steroids
Exophthalmia (also called exophthalmos)	The most common cause is oversecretion of the thyroid. It is often one of the symptoms of Graves' disease	Marked protrusion of the eyeballs	Drugs to reduce thyroid secretions or radioactive iodine to kill some of the thyroid cells
Gigantism	Oversecretion of growth hormone during childhood, often due to a benign tumour of the pituitary	Excessive growth in height, as well as abnormally large muscles and other organs	Surgery to remove tumour or medications that reduce release of growth hormone

Disorder	Cause	Symptoms	Treatment
Goitre	Can be caused by both oversecretion and undersecretion of the thyroid gland. Oversecretion may be caused by Graves' disease (see below); undersecretion may be caused by dietary iodine deficiency, autoimmune disease or dysfunction of the pituitary	Enlargement of the neck due to swelling of the thyroid gland. If the thyroid becomes large enough it may press on the windpipe and impair breathing or press on the oesophagus and cause difficulty swallowing	If caused by iodine deficiency – consumption of iodine rich foods. If caused by hyperthyroidism – drugs can be used to slow activity of the thyroid. If caused by hypothyroidism – hormone replacement therapy can be used
Graves' disease	Abnormal immune system response where the patient's immune system attacks the thyroid gland, leading to oversecretion of the thyroid	Tiredness, irregular or accelerated heart beat, sleeplessness, anxiety, weight loss, trembling and muscle weakness, protruding eyes	There is no cure, but management of the condition may include drugs to reduce thyroid secretions, radioactive iodine to kill some of the thyroid cells, surgery to remove all or part of the thyroid
Myxoedema	Underactivity of the thyroid gland	Swelling of the face and hands, dry skin, slow reflexes, impaired mental ability, inability to tolerate cold weather	Treatment of the underlying cause of hypothyroidism accompanied by medication to replace thyroid hormones
Phaeochromocytoma	A tumour (usually benign) of the adrenal medulla that results in oversecretion of adrenaline and noradrenaline	High blood pressure, rapid and strong heartbeat, sweating, anxiety, weight loss, abdominal and/or chest pain	Medication to reduce high blood pressure, followed by surgical removal of the tumour. If the tumour is inoperable, drugs are used to control the effects of excessive hormones

Activity 2.2 The discovery of insulin

1 Use the Internet to research the story of insulin's discovery. There are websites with biographies of the four researchers involved – Frederick Banting, Charles Best, J. J. R. Macleod and James Collip – and descriptions of the methods used to isolate insulin. Research into insulin continues to the present day. In the 1950s the full sequence of amino acids in the insulin molecule was determined, and in 1969 scientists worked out its three-dimensional structure.

Answer: Suitable websites include the following.

- http://www.medicalnewstoday.com/info/diabetes/discoveryofinsulin.php
- http://www.nobelprize.org/educational/medicine/insulin/discovery-insulin.html
- http://link.library.utoronto.ca/insulin

Student responses should include some of the following key points.

- Before insulin was discovered, diabetes was an incurable disease that led to death.
- In 1921 Frederick Banting and his assistant, Charles Best, removed the pancreas from a dog and demonstrated that the dog developed diabetes.
- Banting and Best removed the pancreas from another dog, ground it up, filtered it and injected the solution into the diabetic dog. By giving the diabetic dog regular injections, they were able to prevent the symptoms of diabetes.

- Professor John Macleod, who had provided Banting and Best with the finance and a laboratory for their experiments, insisted on more tests to confirm that pancreatic extract relieved the symptoms of diabetes. He suggested that they should call their extract insulin.
- Using pancreases from cattle, Banting and Best were able to keep several diabetic dogs alive.
- Bertram Collip joined Banting and Best and was given the task of purifying the pancreatic extract so that it could be tested on humans.
- Early in 1922 a 14-year-old boy who was near death with diabetes was given injections of insulin. He rapidly recovered.

2 In 2006 a research team at the CSIRO in Australia made another important discovery in the quest for a full understanding of how insulin works. Find out what the discovery was and its implications for the understanding of insulin.

Answer: Suitable websites include the following.

- http://www.csiro.au/Outcomes/Health-and-Wellbeing/Technologies/Landmark-insulin-discovery.aspx
- http://www.csiro.au/Organisation-Structure/Divisions/CMSE/Insulin-Breakthrough.aspx

Students may make the following points.

- In 2006 CSIRO scientists worked out most of the three-dimensional structure of the insulin receptor – that is, the protein on the cell membrane that detects the presence of the insulin molecule.
- In 2011 researchers at the Walter and Eliza Hall Institute in Melbourne determined the structure of the part of the receptor where the insulin molecule binds.
- In 2012 CSIRO was developing a new therapy, which would mean that daily insulin injections were no longer required by people suffering from insulin dependant diabetes. The new technique involved transplanting, into diabetics, insulin-producing tissue derived from stem cells.

Review questions

1 a What is a feedback system?

Answer: A feedback system is a situation where the response of the body to a stimulus is such that it changes the original stimulus.

b Define 'negative feedback'.

Answer: Negative feedback occurs when the system responds in an opposite direction to that of the original stimulus.

2 Explain the difference between endocrine and exocrine glands and give five examples of each.

Answer: Endocrine glands are sometimes called ductless glands, because they secrete substances (hormones) into the extracellular fluid that surrounds the cells making up the gland, rather than through a duct. The secretion then usually passes into the capillaries to be transported by the blood. Examples of endocrine glands include the pituitary gland, the thyroid gland, the ovaries, the testes, the adrenal glands, the thymus, the pineal gland, the parathyroid glands and the pancreatic islets.

Exocrine glands secrete substances into a duct, which then carries the secretion to the body surface or to one of the body cavities. Examples of exocrine glands include the sweat glands, the mucous glands, the salivary glands, the part of the pancreas that secretes pancreatic juice, the gastric glands, the sebaceous glands, the tear glands, the milk glands, the bulbourethral glands, the seminal vesicles and the prostate gland.

3 a What is a hormone?

Answer: Hormones are substances that affect the functioning of cells. They are secreted by endocrine glands. Hormones may be proteins, steroids or amines. Most are transported throughout the body in the blood. A hormone may affect particular groups of cells, or one or more organs, or it may affect all the cells of the body.

b Explain the difference between a hormone and a paracrine.

Answer: Paracrines, or local hormones, are secretions of cells that diffuse into adjacent or nearby cells. This allows for communication between cells in localised areas. Hormones are transported throughout the body by the blood and affect target cells or organs. All cells secrete paracrines; only specialised cells secrete hormones.

4 Explain how hormones change the functioning of cells.

Answer: Hormones change the functioning of cells by attaching to receptor molecules on the cell membrane or by entering a cell and attaching to a receptor molecule inside the cell. Hormones change the type, activities or quantities of proteins the cell produces. Often hormones exert their influence by changing the activity of enzymes or by changing the concentration of enzymes.

This may be done by:

- activating certain genes in the nucleus so that a particular enzyme or structural protein is produced
- changing the shape or structure of an enzyme so that it is turned 'on' or 'off'
- changing the rate of production of an enzyme or structural protein by changing the rate of transcription or translation during protein production.

5 Hormones that are steroids work in a different way from those that are proteins or amines. Explain the difference.

Answer: Protein and amine hormones attach to receptor molecules on the surface of the target cell. When the hormone combines with the receptor on the cell membrane it stimulates a secondary messenger substance to diffuse through the cell and activate particular enzymes.

Steroid hormones diffuse into the target cell and combine with a receptor protein, which may be on the mitochondria, on other organelles or in the nucleus. The complex formed by the hormone and receptor activates genes controlling the formation of particular proteins.

6 Describe 'enzyme amplification'.

Answer: Enzyme amplification is the process whereby thousands of enzyme molecules are activated by one hormone molecule. The hormone triggers a cascading effect so that the number of reacting molecules involved is increased hundreds or thousands of times for each step in the metabolic pathway. It is possible for one hormone molecule to trigger the production of more than a billion enzyme molecules. In this way, a very small stimulus can produce a very large response.

7 The hypothalamus and the pituitary gland are closely related. Describe their relationship in terms of:

a their location in the body

Answer: Both organs are located very close together: the hypothalamus is a part of the brain and the pituitary lies just underneath it. They are joined by a stalk called the infundibulum.

b the ways in which they function.

Answer: The hypothalamus controls the release of many hormones from the pituitary gland.

- The hypothalamus produces releasing or inhibiting hormones, such as ACTH and TSH, that regulate secretion of hormones from the anterior lobe of the pituitary.
- The hypothalamus produces the hormones oxytocin and ADH, which travel by way of nerve fibres to the posterior lobe of the pituitary. Secretion of these hormones from the posterior lobe is stimulated by nerve impulses from the hypothalamus.

8 The pituitary gland is sometimes described as the 'master gland' because it secretes hormones that regulate the activity of other endocrine glands. Describe the pituitary hormones that are involved in the control of other endocrine glands.

Answer: Pituitary hormones that regulate other endocrine glands include:

- Gonadotropins: Follicle stimulating hormone (FSH) stimulates development of the follicles in the ovary, thus stimulating the production of oestrogen. Luteinising hormone (LH) works with FSH in the female to bring about ovulation and to form the corpus luteum after ovulation. The corpus luteum then produces oestrogen and progesterone. In males, LH stimulates interstitial cells in the testes to secrete male sex hormones.
- Thyroid stimulating hormone (TSH) stimulates production and release of hormones from the thyroid gland.
- Adrenocorticotropic hormone (ACTH) controls production and release of some of the hormones from the cortex of the adrenal glands.

9 Hormones secreted by the posterior lobe of the pituitary are not actually made in the posterior lobe. Describe the origin of these hormones and explain how they get to the posterior lobe of the pituitary gland.

Answer: The hormones oxytocin and antidiuretic hormone are both produced in special nerve cells in the hypothalamus of the brain. These cells have long extensions that pass through the infundibulum to the posterior lobe. Hormones manufactured in the cells move along the extensions and are stored in the posterior lobe ready for release into the bloodstream. Nerve impulses initiated in the hypothalamus and conducted along the cell extensions stimulate release of the hormones.

10 a What is a target organ?

Answer: A target organ for a particular hormone is the organ that responds to stimulation by that hormone.

b How do hormones get from their source to the target organ?

Answer: They are transported throughout the body in the blood.

c Describe target organ/cells and the role of the following hormones.

i Oxytocin

ii Antidiuretic hormone

iii Adrenaline

iv Parathyroid hormone

v Insulin

vi Glucagon

vii Thyroxine.

Answer:

Hormone	Target organ/cell	Role
Oxytocin	The target organs for oxytocin are the muscles of the uterus and the mammary glands	Oxytocin is released in large quantities during labour. It stimulates contraction of the muscles of the uterus. Oxytocin also stimulates contraction of cells in the mammary glands, resulting in release of milk during breastfeeding
Antidiuretic hormone	The target organs for ADH are the (collecting ducts of) kidney tubules	Antidiuretic hormone (ADH) causes the kidneys to remove water from urine that is forming
Adrenaline	The target cells occur throughout the body, including in the heart, iris of the eye, and the alimentary canal	Adrenaline, also called epinephrine, has an effect similar to that of the sympathetic division of the autonomic nervous system. Adrenaline helps to prepare the body for reaction to a threatening situation; that is, it is concerned with fight-or-flight responses
Parathyroid hormone	The bones and the kidneys	Parathyroid hormone (PTH or parathormone) controls calcium and phosphate levels in the blood
Insulin	Target organs/cells for insulin are the liver, skeletal muscles, fat storage cells and body cells in general	Insulin has the effect of reducing the amount of glucose in the blood, and this is achieved by promoting the uptake of glucose from the blood by the cells of the body. In the liver, insulin causes the conversion of glucose to glycogen and fat; in the skeletal muscles it causes formation of glycogen from glucose; in fat storage tissue it causes glucose to be converted into fat
Glucagon	The targets for glucagon are the liver and fat storage tissue	Glucagon acts in the opposite way to insulin. It works to increase blood sugar level, mainly by promoting the breakdown of glycogen to glucose in the liver. Glucagon also stimulates breakdown of fat in the liver and fat storage tissues
Thyroxine	All cells in the body are targeted by thyroxine	Thyroxine controls body metabolism by regulating reactions in which complex molecules are broken down to release energy and in which complex molecules are synthesised from simple ones. The overall effect of thyroxine is to bring about release of energy and, since some of the energy released is in the form of heat, to maintain body temperature

11 a Which gland produces thymosins and what is the function of these hormones?

Answer: Thymosins are secreted by the thymus. They bring about the maturation of T lymphocytes.

b Which gland secretes melatonin? What is the role of melatonin?

Answer: Melatonin is secreted by the pineal gland. It is involved in the regulation of sleep patterns.

Apply your knowledge

1 Explain why endocrine glands are sometimes called ductless glands or glands of internal secretion.

Answer: Endocrine glands secrete hormones directly into extracellular fluid. The hormones then diffuse through capillary walls into the blood to be transported throughout the body. There are no ducts into which the hormones are released, and they are not released into a body cavity or onto the surface of the body.

2 Hormones are specific. What does this mean and how is specificity achieved?

Answer: Hormones are only able to influence cells that have the correct receptor for the hormone. That is, hormone receptors are specific. The receptors consist of chemical structures that only allow specific hormones with specific chemical structures to interact with them.

3 Hormones affect the activity of their target cells. Explain why the addition of more and more hormone does not continue to increase the intensity or rate of the response.

Answer: Once all the receptor molecules of a cell are combined with hormone molecules, the addition of more hormone cannot produce any greater effect. This is called saturation.

4 Athletes have sometimes taken (illegally) the hormone erythropoietin in an effort to improve their performance. In what ways would this hormone improve sporting performance?

Answer: Erythropoietin stimulates the production of red blood cells in the bone marrow. This hormone would improve performance because more red blood cells circulating throughout the body results in greater uptake and carriage of oxygen to cells. Aerobic respiration, which uses oxygen to provide the energy for muscle contraction, is therefore enhanced.

5 Many famous people have suffered from endocrine disorders.

a John F. Kennedy, President of the United States from 1960 until his assassination in 1963, suffered from Addison's disease. Consult references to see if you can find out some of Kennedy's medical history. How was he able to be President of the United States despite having such a serious illness?

Answer: Addison's disease is an endocrine or hormonal disorder that occurs in all age groups and affects men and women equally. The disease is characterised by weight loss, muscle weakness, fatigue, low blood pressure, and sometimes darkening of the skin in both exposed and non-exposed parts of the body. Addison's disease occurs when the adrenal glands do not produce enough of the hormone cortisol and, in some cases, the hormone aldosterone. President Kennedy had Addison's disease, which is incurable. However, the disease can be treated by daily cortisol tablets (and perhaps aldosterone as well), so Kennedy was able to function normally.

b Napoleon Bonaparte is believed to have suffered from a disease of the hypothalamus that caused the pituitary gland to function abnormally. Because the anterior pituitary regulates the functioning of the gonads and the adrenal and thyroid glands, these organs were also affected. See if you can find out the symptoms of Napoleon's disorder.

Answer: It is likely that Napoleon suffered from an underactive thyroid gland, and some reports suggest that this may have been due to a deficiency of the pituitary, a condition known as Froehlich's syndrome. Evidence for the condition is given as a big increase in weight, slow deliberate movements, tiredness and drowsiness, failing judgement and occasional bursts of phrenetic energy. These are symptoms of a combined decrease in secretions of the pituitary, thyroid and adrenal glands.

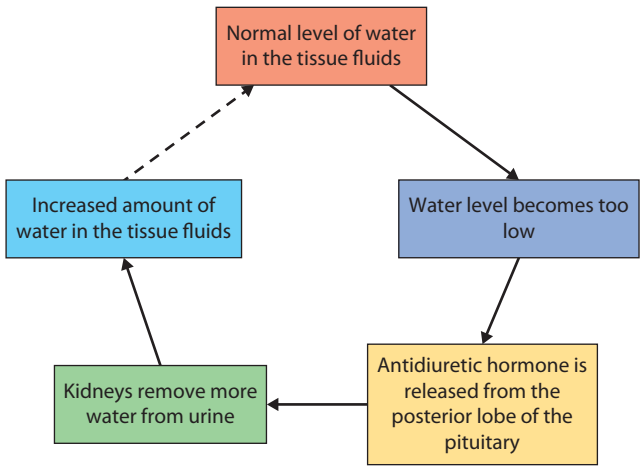
There is considerable doubt and dispute about the accuracy of the above diagnosis, because Napoleon suffered from a multitude of illnesses – what one author described as a hypochondriac's wish list. His ailments included skin problems, stomach ulcer, piles, epilepsy, migraine, underactive thyroid, pneumonia, insomnia, bladder stones and a relapsing fever, which was probably malaria.

c Akhenaton, an Egyptian Pharaoh who lived 3500 years ago, is portrayed in statues made later in his life with feminine features – prominent breasts, hips wider than the shoulders, and a large amount of fat on the buttocks and thighs. It has been suggested that Akhenaton may have been afflicted with a disorder of one of the endocrine glands. Which gland, or glands, could it have been and what hormones could have been involved?

Answer: It is most likely to have been the testes not producing testosterone or the anterior pituitary gland failing to produce/release luteinising hormone that would normally stimulate the testes to produce testosterone. Another possibility is that it may have been the hypothalamus not secreting gonadotropin releasing factors.

6 Construct a diagram similar to Figure 2.8 on page 28 using the hormone ADH and its role in water balance as the example. Be sure to include the role of feedback systems in your diagram.

Answer:



7 Thyroid-stimulating hormone (TSH) is secreted by the anterior lobe of the pituitary gland. If a cancer patient had the thyroid gland removed, would you expect the level of TSH in the person's blood to rise or fall? Explain your answer.

Answer: The levels of TSH would rise, because the levels of thyroxine would fall without an intact thyroid. The decrease in thyroxine, through a negative feedback mechanism, will stimulate the pituitary gland to secrete more TSH, such that the thyroid will produce more thyroxine. If the thyroid is removed, this cannot be achieved, so the pituitary does not receive any negative feedback; thus it continues to secrete TSH. The patient would need to have supplements of thyroxine to cause a decline in TSH levels.