2 HORMONES HELP CONTROL THE BODY

UNIT 3 CONTENT

SCIENCE INQUIRY SKILLS

» select, use and/or construct appropriate representations, including diagrams, models and flow charts, to communicate conceptual understanding, solve problems and make predictions

SCIENCE UNDERSTANDING

Endocrine system

» hormones can be lipid soluble and able to cross cell membranes to bind with and activate intracellular receptors, or water soluble and able to bind with and activate receptors on cell membranes, and require secondary messengers to affect cell functioning

» the hypothalamus, pituitary, thyroid, parathyroid, pancreas, thymus, gonads, pineal and adrenal glands are endocrine glands found in the human body

» hormones secreted from the hypothalamus, pituitary, thyroid, parathyroid, pancreas and adrenal glands are involved in homeostasis by affecting specific target organs

» the secretions of the pituitary gland are controlled by the hypothalamus through transport of hormones, either via nerve cells or the vascular link between them

Source: School Curriculum and Standards Authority, Government of Western Australia

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The body is composed of trillions of cells that are organised into tissues, organs and systems. All these structures must work together in a coordinated way. This coordination is achieved through the activities of the nervous system and the endocrine system.

- The nervous system exerts control by the transmission of nerve impulses to and from the various tissues.
- The endocrine system influences the activity of cells by the release of chemical messengers known as hormones.

Much of the work of the endocrine system is concerned with keeping the environment inside the body fairly constant. Maintaining a stable internal environment is known as **homeostasis**. In this chapter, we will discuss how the endocrine system maintains homeostasis and controls cellular activities through chemical messengers.

2.1 ENDOCRINE SYSTEM

The endocrine system is made up of the endocrine glands, which secrete hormones.

Endocrine glands

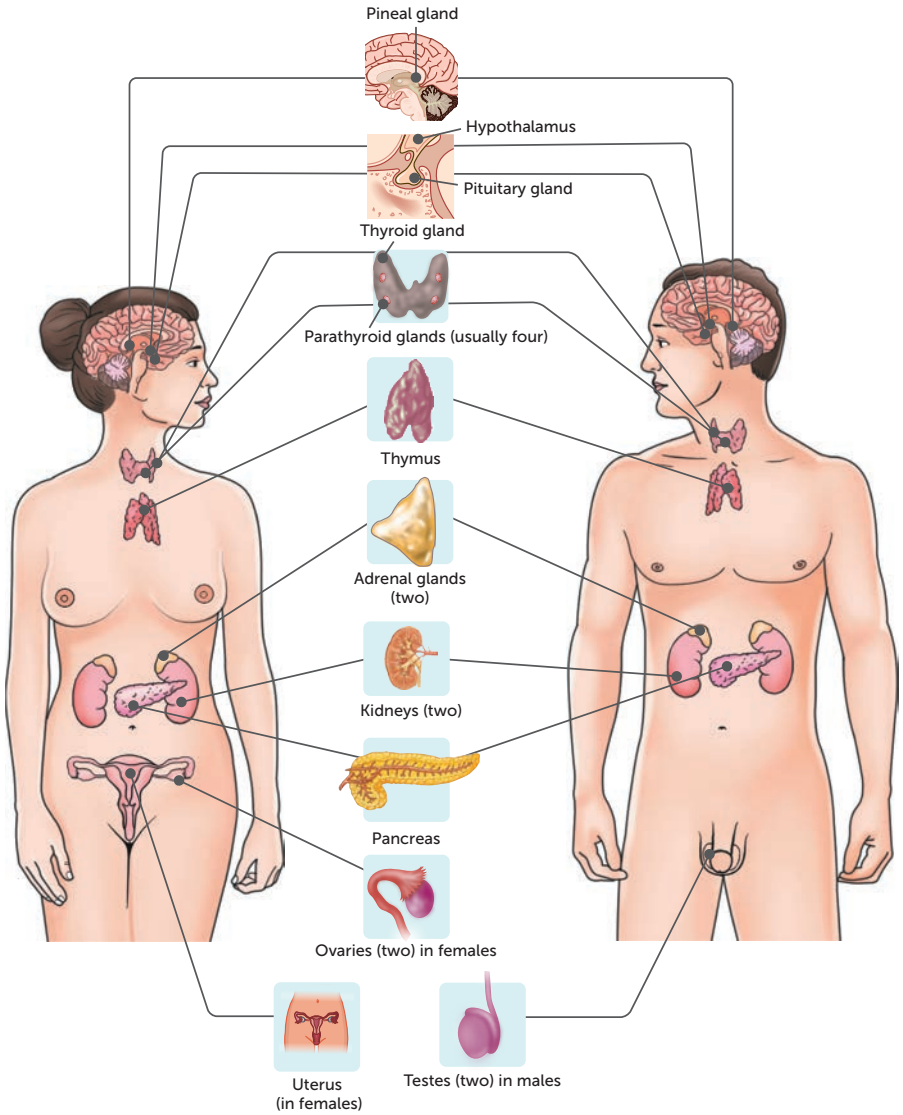

FIGURE 2.1
Endocrine glands

Endocrine system
This website contains more information about the endocrine system, the endocrine glands and hormones.

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There are two types of glands in the body.

- **Exocrine glands secrete** into a duct that carries the secretion to the body surface or to one of the body cavities. Sweat glands, mucous glands, salivary glands and the glands of the alimentary canal are examples of exocrine glands.
- **Endocrine glands** secrete hormones into the extracellular fluid that surrounds the cells that make up the gland. The secretion then usually passes into the capillaries to be transported by the blood. Endocrine glands are sometimes called ductless glands.

Hormones

Hormones are chemicals, secreted by endocrine glands, that are transported throughout the body in the blood. They change the functioning of cells by changing the type, activities or quantities of proteins produced. They are *not* enzymes; however, in many cases, hormones exert their influence by changing the activity of enzymes or their concentration. Hormones may:

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

Hormones are only able to influence cells that have the correct receptor for the hormone. Therefore, a hormone may affect:

- all the cells of the body
- only particular groups of cells, **target cells**
- only particular organs, **target organs**.

Hormones may be steroids, proteins or amines.

Steroid hormones

Steroid hormones, such as oestrogen, progesterone, cortisol and aldosterone, are lipid-soluble, meaning they do not dissolve in water. Once they are released into the blood, the hormones bind to transport proteins, enabling them to travel in the bloodstream. When they reach the target cells, the steroid hormones separate from the transport proteins and diffuse across the cell membrane. Inside the cell they work by combining with a receptor protein in the cytoplasm or nucleus. The hormone–receptor complex activates the genes controlling the formation of particular proteins. It does this by binding to the promoter section of a certain gene, stimulating (or inhibiting) transcription and, therefore, protein synthesis. Steroid hormones are slow to have an effect, but the effect is long lasting.

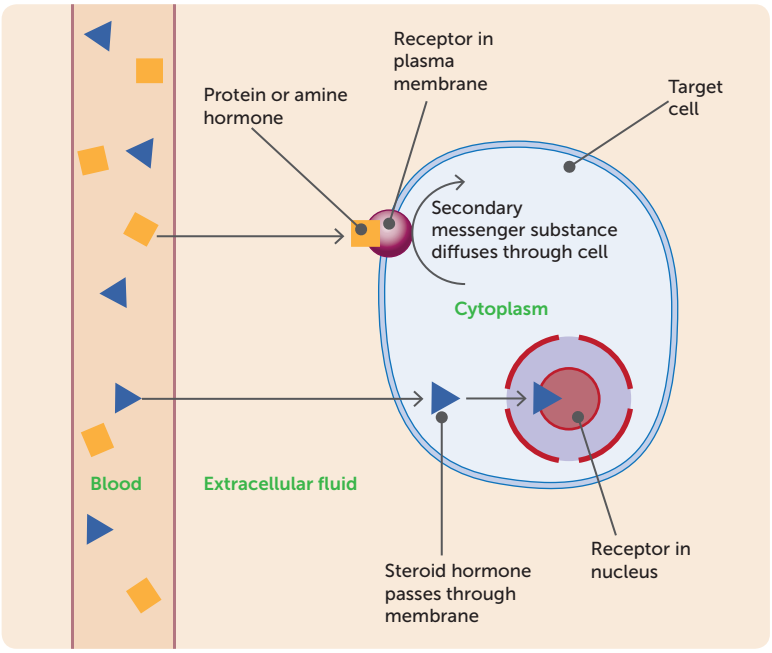


FIGURE 2.2 Hormones combine with receptors on the cell membrane or with receptors inside the cell

Protein and amine hormones

Protein and **amine hormones** are water-soluble. Because they are not lipid soluble, they are unable to diffuse across the cell membrane. Instead, they work by attaching to receptor proteins in the membrane of the target cell. The combination of the hormone with the receptor causes a secondary messenger substance to diffuse through the cell and activate particular enzymes. For example, the hormone insulin binds to a receptor protein and this leads to an increase in glucose absorption by the cell. Protein and amine hormones tend to be quick to cause a response; however, the effect is short lasting.

Hormone receptors

Receptor proteins are *specific*. Each type of receptor will bind with only one specific molecule. The lock and key analogy can be used to describe this interaction. The lock, the receptor protein, will only work with the correct key, the binding molecule.

There are a limited number of receptor proteins in the membrane of each cell. When each receptor is bound to a molecule, there can be no further increase in the rate of the cell's activity. For example, when each insulin receptor in the cell membrane is bound to insulin, the cell's rate of glucose uptake cannot increase any further, even if the amount of insulin increases. This means that *saturation* can occur; once all the receptor molecules are occupied by hormone molecules, the addition of more hormones does not produce any greater effect.

Different cells have different types and numbers of receptor proteins. This is why there is variation in the sensitivities of cells to hormones and other substances.

Steroid hormones
This website provides an animation of the way steroid hormones work.

Enzyme amplification

One hormone molecule does not cause the manufacture or activation of just one molecule of an enzyme – it activates thousands of molecules. This is achieved through a process called **enzyme amplification**. The hormone triggers a cascading effect in which the number of reacting molecules involved is increased hundreds or thousands of times for each step along the metabolic pathway. One hormone molecule could trigger the production of more than a billion enzyme molecules. Thus, a very small stimulus can produce a very large effect.

Hormone clearance

Once a hormone has produced the required effect, it must be turned off. This is done by breaking down the hormone molecules. Some hormones are broken down in the target cells, but most are broken down in the liver and the kidneys. The degraded hormones are then excreted in either the bile or the urine.

Control of hormone secretions

To maintain homeostasis, the amount of hormone produced by an endocrine gland must be very closely regulated. Any oversecretion or undersecretion of a hormone will cause the body to function abnormally.

Hormonal secretions are generally regulated by **negative feedback** systems whereby the response produced by the secretion of the hormone is the opposite of the stimulus that caused the secretion. Negative feedback systems will be covered in more detail in Chapter 5.

Key concept

The endocrine system is made up of the endocrine glands, which secrete steroid, protein or amine hormones that affect the functioning of the cell.

Questions 2.1

RECALL KNOWLEDGE

1. Where do exocrine glands secrete their products?
2. How do the products of endocrine glands move to their target cells?
3. List the three ways that hormones are able to change the functioning of cells.
4. Use a flow chart to show what happens to protein and amine hormones after they are secreted from the endocrine gland.

5 Describe the following properties of hormone receptors:
   a specific
   b saturation.

APPLY KNOWLEDGE

6 Explain why the receptors for steroid hormones are located inside the cell.
7 Predict what would happen if hormone clearance were unable to occur.

2.2 HYPOTHALAMUS AND PITUITARY GLAND

The hypothalamus and pituitary gland work together to control the functioning of many of the other glands. For this reason, the pituitary gland is often called the master gland. Combined, they can be thought of as the command centre for the body.

Hypothalamus

The **hypothalamus** has roles in both the nervous and endocrine systems and serves as a connection between the two systems. It regulates many of the basic functions of the body, such as body temperature, water balance and heart rate, in addition to increasing or decreasing the secretions of other glands.

The hypothalamus is located at the base of the brain, below the thalamus and above the pituitary gland. It is about the size of an almond.

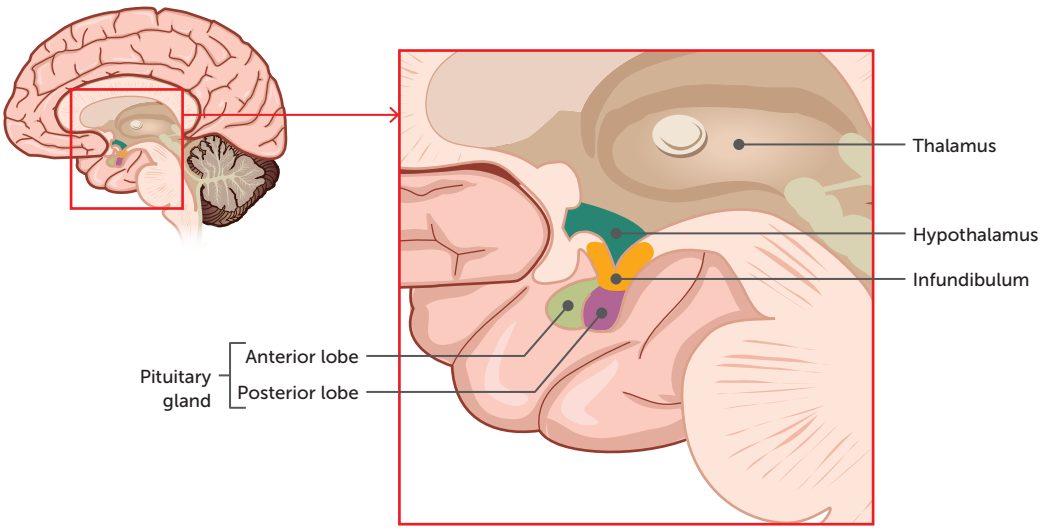


FIGURE 2.3 Location of the hypothalamus and the lobes of the pituitary gland

Hypothalamus and pituitary gland
This website provides more information on the relationship between the hypothalamus and the pituitary gland.

Pituitary gland and hypothalamus
This website gives more detailed information about the hypothalamus and pituitary glands.

Many of the functions of the hypothalamus are carried out through the pituitary gland.

- The hypothalamus secretes **releasing factors**, which stimulate the secretion of a hormone, or **inhibiting factors**, which slow down the secretion of a hormone. These factors travel through blood vessels to the anterior lobe of the pituitary gland, affecting the secretion of its hormones.
- Other hormones are produced by the hypothalamus and pass along the nerve fibres to the posterior lobe of the pituitary gland where they are then released.

Pituitary gland

The **pituitary gland**, or **hypophysis**, lies just under the hypothalamus and is joined to the hypothalamus by a stalk called the **infundibulum**. It is not much bigger than a large pea, about 13 mm in diameter, but it is absolutely vital to the normal functioning of the body.

The pituitary gland consists of an anterior lobe and a posterior lobe, each of which functions separately. The anterior (front) lobe has no nerves connecting it to the hypothalamus; rather, they are connected by a complex network of blood vessels lying in the infundibulum. The posterior (rear) lobe is joined to the hypothalamus by nerve fibres that come from nerve cell bodies in the hypothalamus and pass through the infundibulum to the posterior lobe. It is not a true endocrine gland because it does not secrete substances. Instead, it simply stores and releases hormones.

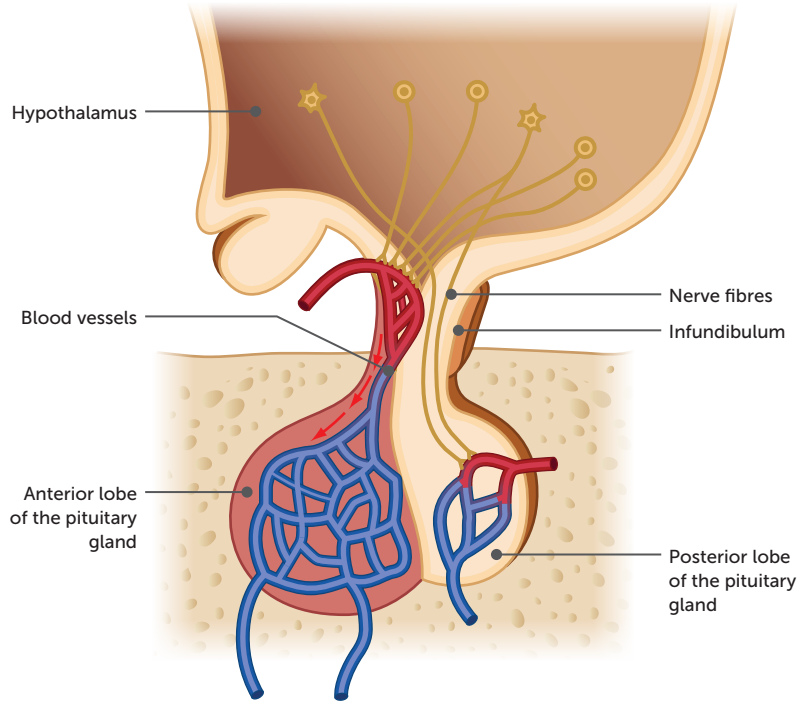


FIGURE 2.4 Blood vessels and nerves run through the infundibulum, connecting the hypothalamus to the lobes of the pituitary gland

Anterior lobe of the pituitary gland

The anterior lobe of the pituitary gland (the adenohypophysis) releases a number of hormones that regulate a great range of bodily activities. Secretions of the anterior lobe are in turn controlled by releasing and inhibiting factors secreted by the hypothalamus.

The following hormones are released by the anterior lobe of the pituitary gland:

- **Gonadotropins** are hormones that affect the gonads, the ovaries and testes. **Follicle-stimulating hormone (FSH)** stimulates development of the follicles that contain eggs in the ovary of the female. In the male, FSH stimulates the production and maturation of sperm in the testes. **Luteinising hormone (LH)** works with FSH in the female to bring about ovulation and to form a structure called the corpus luteum after ovulation. In the male, LH stimulates interstitial cells in the testes to secrete male sex hormones.
- **Growth hormone (GH)**, or somatotropin, stimulates body growth, particularly growth of the skeleton. It increases the rate at which amino acids are taken up by cells and built into proteins. GH is secreted throughout life as it helps to maintain the size of organs once maturity is reached.
- **Thyroid-stimulating hormone (TSH)**, or thyrotropin, stimulates production and release of hormones from the thyroid gland.
- **Adrenocorticotropic hormone (ACTH)**, or adrenocorticotropin, controls production and release of some of the hormones from the cortex of the adrenal glands.
- **Prolactin (PRL)**, or lactogenic hormone, works with other hormones to initiate and maintain milk production in females.

Posterior lobe of the pituitary gland

The posterior lobe of the pituitary gland (the neurohypophysis) releases the hormones oxytocin and antidiuretic hormone, but neither is manufactured in the posterior lobe. Both hormones are 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 down the extensions and are stored ready for release into the bloodstream. The release of the hormones is triggered by nerve impulses initiated in the hypothalamus and conducted along the cell extensions.

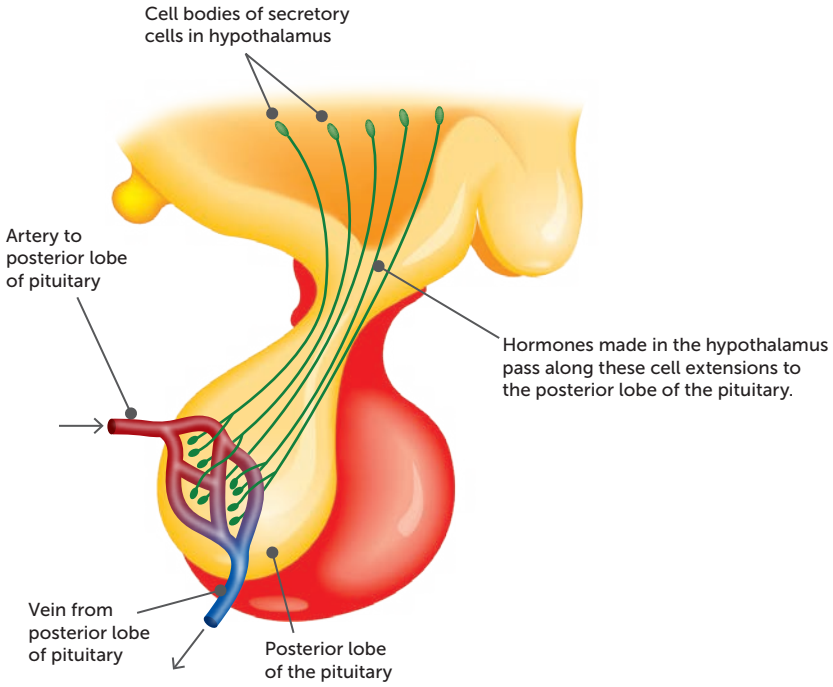


FIGURE 2.5 Hormones made in the hypothalamus are transported to the posterior lobe of the pituitary gland and can then be released into the bloodstream

Oxytocin (OT) stimulates contraction of the muscles of the uterus. It is released in large quantities during labour. Oxytocin also stimulates contraction of cells in the mammary glands, resulting in release of milk during breastfeeding.

Antidiuretic hormone (ADH), or **vasopressin**, causes the kidneys to remove water from urine that is forming. This water is returned to the bloodstream. In this way, ADH helps to retain fluid within the body. At higher concentrations, ADH can also cause constriction of small arteries, the arterioles. This is why its alternative name is vasopressin.

TABLE 2.1 Hormones released by the pituitary gland

HORMONE	TARGET ORGAN	MAIN EFFECTS
Anterior lobe of the pituitary gland		
Follicle-stimulating hormone (FSH)	Ovaries (females) Testes (males)	Growth of follicles Production of sperm
Luteinising hormone (LH)	Ovaries (females) Testes (males)	Ovulation and maintenance of corpus luteum Secretion of testosterone
Growth hormone (GH)	All cells	Growth and protein synthesis
Thyroid-stimulating hormone (TSH)	Thyroid gland	Secretion of hormones from the thyroid
Adrenocorticotropic hormone (ACTH)	Adrenal cortex	Secretion of hormones from the adrenal cortex
Prolactin (PRL)	Mammary glands	Milk production

HORMONE	TARGET ORGAN	MAIN EFFECTS
Posterior lobe of the pituitary gland		
Antidiuretic hormone (ADH)	Kidneys	Reabsorption of water
Oxytocin (OT)	Uterus Mammary glands	Contractions of uterus during childbirth Release of milk

Key concept

The hypothalamus is connected to the pituitary gland through nerves and blood vessels in the infundibulum. The hypothalamus communicates to the pituitary gland through these structures, influencing the release of hormones.

Questions 2.2

RECALL KNOWLEDGE

1. Describe the location of the hypothalamus.
2. One of the types of hormones that the hypothalamus secretes is releasing factors.
   - a. How do releasing factors reach their target cells?
   - b. What are the target cells of releasing factors?
   - c. What is the function of releasing factors?
3. What is the alternative name for the neurohypophysis?
4. Compare and contrast the anterior and posterior lobes of the pituitary gland.
5. List the gonadotrophins secreted by the anterior lobe of the pituitary gland and explain why they are classified as gonadotrophins.
6. List the hormones released from the posterior lobe of the pituitary gland.
7. Describe the target cells and function of each of the following hormones:
   - a. adrenocorticotropic hormone
   - b. prolactin
   - c. growth hormone
   - d. oxytocin
   - e. luteinising hormone
   - f. antidiuretic hormone
   - g. thyroid-stimulating hormone
   - h. follicle-stimulating hormone.

APPLY KNOWLEDGE

8. Explain why the pituitary gland is known as the master gland.
9. Predict what would happen if the infundibulum was severed.
10. Explain why the posterior lobe of the pituitary gland is technically not an endocrine gland.

2.3 OTHER ENDOCRINE GLANDS

Pineal gland

The **pineal gland** is found deep inside the brain. In children it is about the size of a pea. After puberty it gradually decreases in size. Its role remains something of a mystery, but it is known that it secretes the hormone **melatonin**, which is involved in the regulation of sleep patterns. Production of melatonin by the pineal gland is stimulated by darkness and inhibited by light.

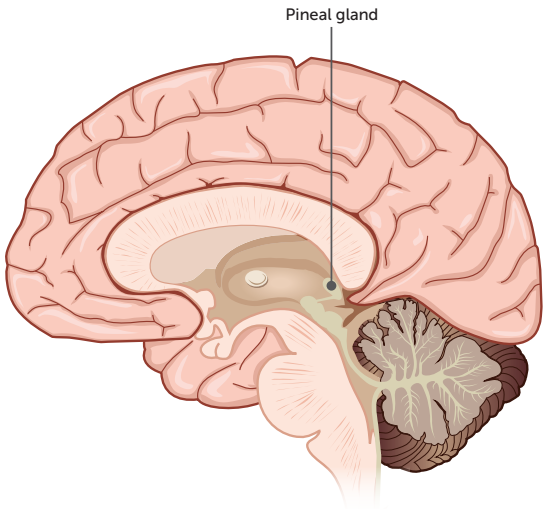


FIGURE 2.6 The pineal gland is located deep in the brain

Thyroid gland

The **thyroid gland** is located in the neck, just below the larynx. It consists of two lobes that lie on either side of the trachea and are joined by a narrow piece of tissue that lies across the front of the trachea.

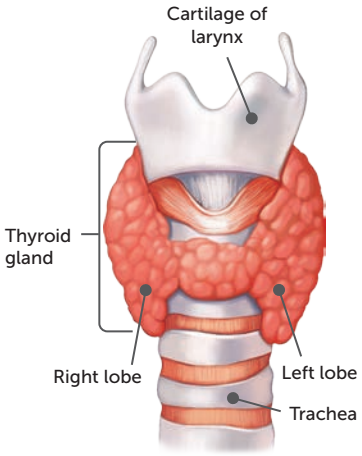
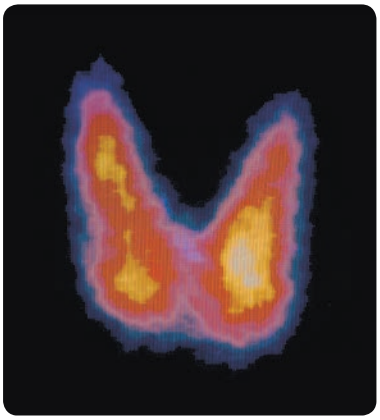


FIGURE 2.7 Location of the thyroid gland



Science Photo Library/Chris Priest

FIGURE 2.8 Scan of the thyroid gland, an endocrine gland in the neck. A radioactive tracer has been used to show the most active areas of the gland. These areas appear as yellow patches on the scan

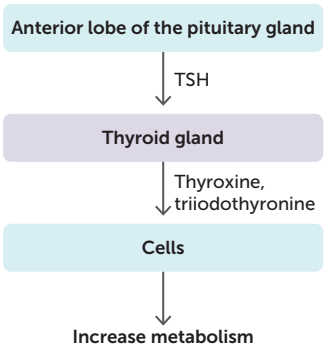


FIGURE 2.9 Thyroxine production

The follicular cells in the thyroid gland secrete two hormones in response to thyroid stimulating hormone: **thyroxine** (or T4) and **triiodothyronine** (or T3). The structure of both T3 and T4 is based on two molecules of the amino acid tyrosine. T3 has three iodine atoms attached while T4 has four iodine atoms attached. Thyroxine is much less active than triiodothyronine but lasts a lot longer. Approximately 80% of the thyroid hormones produced are thyroxine and only 20% are triiodothyronine. Once released, enzymes convert T4 into T3.

Thyroxine controls body metabolism by regulating reactions in which complex molecules are broken down to release energy, and other reactions in which complex molecules are synthesised from simple ones. The overall effect of thyroxine is to bring about the release of energy and, because some of the energy released is in the form of heat, to maintain body temperature.

The thyroid gland also plays a role in regulating the levels of calcium and phosphate in the blood through the release of **calcitonin** by C-cells. When the concentration of calcium in the blood increases, the thyroid gland releases calcitonin, which reduces the reabsorption of calcium by the kidneys and the breakdown of bone. If the concentration of phosphate in the blood becomes too high, calcitonin acts to move phosphate into bone and reduces its reabsorption by the kidneys. These actions allow calcium and phosphate concentrations to decrease.

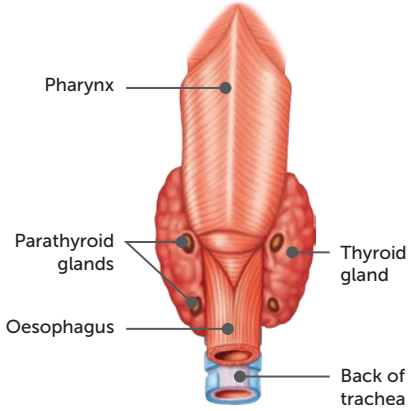


FIGURE 2.10 Location of the parathyroid glands (as seen from the rear of the body)

Parathyroid glands

The **parathyroid glands** are located in the rear surface of the lobes of the thyroid gland. There are usually four parathyroid glands, although some people have more. Each is about the size of a small pea.

The parathyroid glands secrete **parathyroid hormone** (**PTH**, or **parathormone**), which increases calcium levels in the blood and phosphate excretion in the urine.

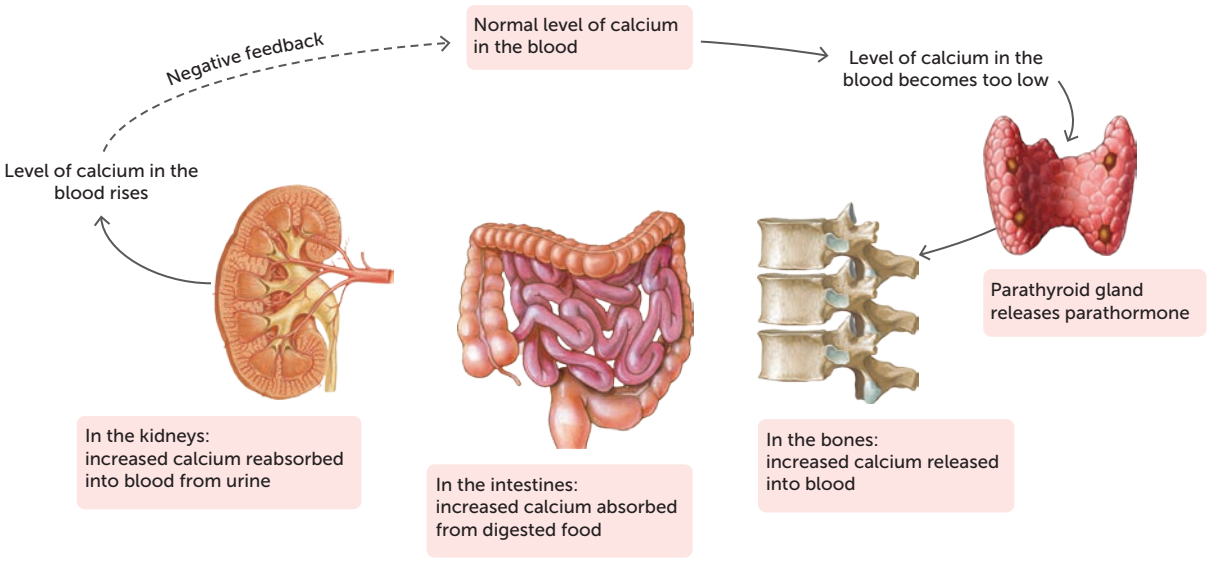


FIGURE 2.11 The regulation of blood calcium level by parathyroid hormone is a good example of negative feedback

Thymus

The **thymus** is located in the chest just above the heart and just behind the sternum. Like the pineal gland, the thymus is largest in infants and children, and begins to shrink after puberty. The thymus secretes a group of hormones called **thymosins**. These hormones influence the maturation of disease-fighting cells called T-lymphocytes. The role of T-lymphocytes will be discussed in Chapter 7.

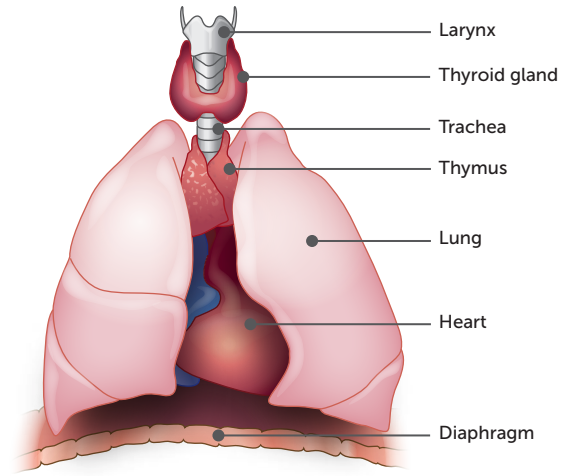


FIGURE 2.12 Location of the thymus

Adrenal glands

There are two **adrenal glands**, one immediately above each kidney. Each adrenal gland has an inner **adrenal medulla** and an outer **adrenal cortex**. These two parts are quite different in their structure and function. Thus, each adrenal gland is really two separate endocrine glands.

Adrenal medulla

The hormones produced by the adrenal medulla are adrenaline and noradrenaline.

- **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

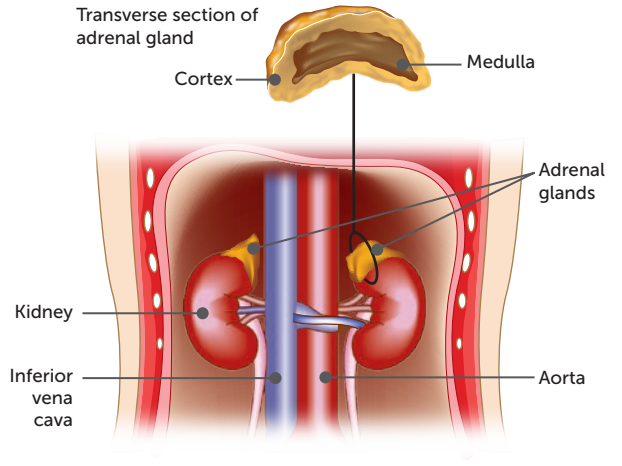


FIGURE 2.13 Location of the adrenal glands

threatening situation; that is, it is concerned with fight-or-flight responses. These responses will be discussed in more detail in Chapter 4.

- **Noradrenaline**, also called **norepinephrine**, has effects similar to those of adrenaline. In particular, it increases the rate and force of the heartbeat.

Adrenal cortex

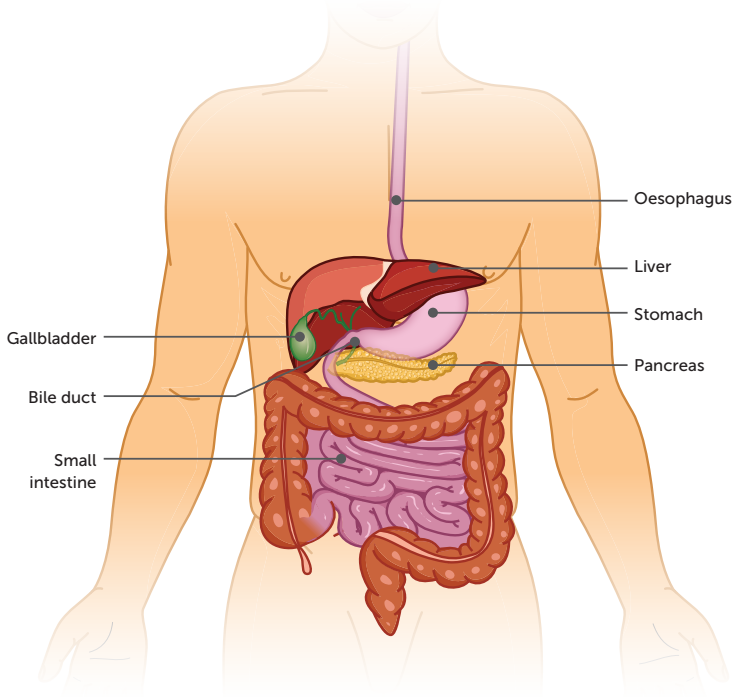
More than 20 different hormones are produced in the adrenal cortex and they are known collectively as **corticosteroids**. The two main ones are:

- **aldosterone**, which acts on the kidney to reduce the amount of sodium and increase the amount of potassium in the urine
- **cortisol**, which, with related hormones, promotes normal metabolism, helping the body to withstand stress and to repair damaged tissues.

Pancreas

The **pancreas** is a soft organ approximately 15 cm long. It lies just below the stomach and alongside the duodenum, the first part of the small intestine.

FIGURE 2.14
Location of the pancreas



The pancreas is both an exocrine gland and an endocrine gland. The exocrine part secretes digestive enzymes into the small intestine through the pancreatic duct. The endocrine part is made up of clusters of special cells called **islets of Langerhans** (also called **pancreatic islets**). These cells secrete two important hormones.

- **Insulin** is secreted by the beta cells of the islets of Langerhans. It reduces the amount of glucose in the blood (the blood sugar level). It does this 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 skeletal muscles, it causes formation of glycogen from glucose; and in fat storage tissue, it causes glucose to be converted into fat. The level of secretion of insulin by the pancreas is determined by the amount of glucose in the blood and is controlled through a negative feedback system. This will be covered in more detail in Chapter 5.

Activity 2.1
Researching the discovery of insulin

- **Glucagon**, secreted by the alpha cells of the islets of Langerhans, acts in the opposite way to insulin. It works to increase the blood glucose level, mainly by promoting the breakdown of glycogen to glucose in the liver. Glucagon also stimulates the breakdown of fat in the liver and in fat storage tissues.

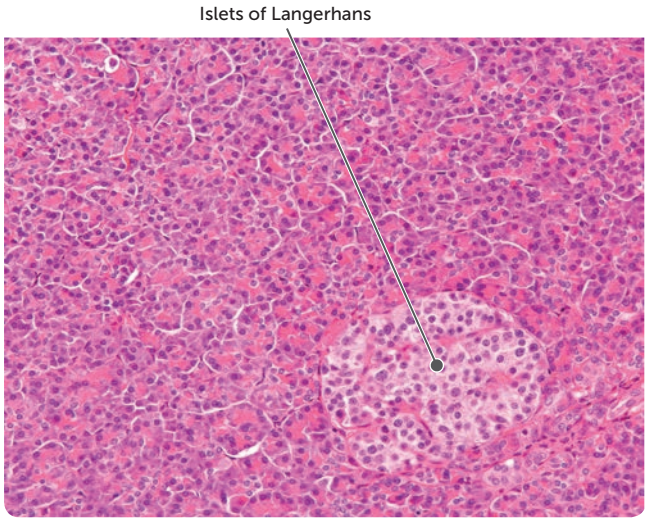


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FIGURE 2.15 Micrograph of islets of Langerhans within the pancreas

Gonads

The **gonads** are the testes and the ovaries. In Units 1 & 2, you learnt about their role in the reproductive system, with their production of sperm and eggs. They are also a part of the endocrine glands due to their production of hormones.

Androgens – for example, testosterone – are known as the male sex hormones. They are responsible for the development and maintenance of the male sex characteristics. In males, androgens are produced by the testes. Females also produce androgens in the ovaries, adrenal glands and fat cells. However, the levels produced in females are much lower than in males.

Oestrogens and **progesterone** are the female sex hormones produced by the ovaries. They stimulate the development and maintenance of the female sex characteristics. Together with the gonadotropic hormones of the pituitary, they also regulate the menstrual cycle and are involved in changes that occur during pregnancy.

Other endocrine tissues

In addition to the major endocrine glands discussed above, there are other tissues, many of which are not called endocrine glands, that secrete hormones. For example:

- The stomach and small intestine both secrete hormones that coordinate the exocrine glands of the digestive system.
- The kidneys secrete hormones, including **erythropoietin (EPO)** – a hormone that stimulates production of red blood cells by the bone marrow.
- The heart secretes a hormone that helps to reduce blood pressure.
- The **placenta** secretes a number of hormones during pregnancy that help to maintain the pregnancy, stimulate development of the foetus and stimulate the mother's mammary glands.

Major endocrine glands
This website provides further discussion of the major endocrine glands.

TABLE 2.2 Hormones produced by endocrine glands other than the pituitary gland

GLAND	HORMONE	TARGET CELLS	MAIN EFFECTS
Thyroid	Thyroxine and triiodothyronine Calcitonin	Most body cells Bones, kidney	Increases metabolic rate and therefore oxygen consumption and heat production Decreases calcium and phosphate levels in the blood
Parathyroid	Parathyroid hormone	Bones Kidneys	Increases level of calcium in blood
Thymus	Thymosins	T-lymphocytes	Stimulates development and maturation of T-lymphocytes

GLAND	HORMONE	TARGET CELLS	MAIN EFFECTS
Adrenal cortex	Corticosteroids, including:		
	Aldosterone	Kidneys	Increases reabsorption of sodium ions and excretion of potassium ions
	Cortisol	Most body cells	Promotes normal metabolism; helps the body deal with stress; promotes repair of damaged tissues
Adrenal medulla	Adrenaline and noradrenaline	Most body tissues	Prepares the body for fight-or-flight responses; reinforces the effects of the sympathetic nervous system
Pancreas	Insulin	Most body cells	Stimulates uptake of glucose; lowers blood glucose level
	Glucagon	Liver and fat storage tissues	Stimulates breakdown of glycogen and fat; increases blood glucose level
Testes	Androgens; e.g. testosterone	Many tissues	Stimulate sperm production, growth of skeleton and muscles, and development of male sexual characteristics
Ovaries	Oestrogens	Many tissues	Stimulate development of female sexual characteristics; regulate the menstrual cycle
	Progesterone	Uterus and mammary glands	Regulates menstrual cycle and pregnancy; prepares mammary glands for milk secretion

2.1 Chemical messengers

Activity 2.2
Understanding endocrine dysfunction

Questions 2.3

RECALL KNOWLEDGE

1. Which endocrine gland secretes melatonin?
2. Describe the location of the thyroid gland.
3. Name the hormone secreted by the parathyroid gland and describe its function.
4. Name two endocrine glands that decrease in size with age.
5. Describe the location of the adrenal glands, and the arrangement of the adrenal medulla and adrenal cortex.
6. Match the hormone in the following table with the gland that produces it.

HORMONE	ENDOCRINE GLAND
adrenaline	adrenal cortex
thyroxine	pancreas
aldosterone	adrenal medulla
cortisol	ovaries
testosterone	testes
insulin	adrenal cortex
oestrogen	thyroid gland

APPLY KNOWLEDGE

7. Explain why people who suffer from hyperthyroidism (overactive thyroid) experience weight loss.
8. Explain how insulin and glucagon are able to keep blood glucose at the correct level.
9. Explain why oestrogen and progesterone are called the female hormones when they exist in both males and females.
10. Explain how the body is able to maintain a consistent level of calcium in the blood.

CHAPTER 2 ACTIVITIES

ACTIVITY 2.1 Researching the discovery of insulin

Insulin, a hormone secreted by the islets of Langerhans in the pancreas, was discovered in 1921–22 by researchers at the University of Toronto in Canada. The discovery is recognised as one of the greatest medical breakthroughs of all time.

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.

Your task

1. Use the Internet to research the story of insulin's discovery by:
   - Frederick Banting
   - Charles Best
   - JJR Macleod
   - James Collip.

   For each scientist, include the method they used to isolate insulin.
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.

ACTIVITY 2.2 Understanding endocrine dysfunction

Many disorders can be caused by an oversecretion or undersecretion from one or more of the endocrine glands. Some of these disorders are listed below.

- Acromegaly
- Addison's disease
- Androgen insensitivity syndrome
- Cushing's syndrome
- Exophthalmia
- Gigantism
- Goitre
- Graves' disease
- Myxoedema
- Phaeochromocytoma

Select one of these hormonal problems and use references to learn about:

- the endocrine gland and hormone involved
- the symptoms of the disorder
- whether the disorder is caused by an oversecretion or undersecretion of the hormone
- the treatment that is available for the disorder.

Write a short essay to show the cause-and-effect relationship between the information that you researched.

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CHAPTER 2 SUMMARY

- The nervous and endocrine systems are responsible for maintaining homeostasis.
- Endocrine glands secrete hormones into the extracellular fluid, where they diffuse into capillaries to be transported in the blood vessels.
- Hormones change the functioning of cells by altering the type, activity or quantity of proteins produced.
- Hormones affect target cells, which have specific receptors for the hormone.
- Lipid-soluble hormones (steroid hormones) diffuse through the cell membrane to bind to receptors inside the cell.
- Water-soluble hormones (protein and amine hormones) bind to receptors on the cell membrane. This triggers a secondary messenger in the cell.
- Hormone receptors are specific and can become saturated.
- One hormone can lead to the production of many enzyme molecules. This is known as enzyme amplification.
- Negative feedback systems control the secretion of hormones.
- The hypothalamus and pituitary gland work together, and control many other endocrine glands.
- Secretions from the anterior lobe of the pituitary gland are controlled by releasing and inhibiting factors from the hypothalamus. These secretions travel to the anterior lobe through blood vessels in the infundibulum.
- The anterior lobe of the pituitary gland secretes follicle-stimulating hormone, luteinising hormone, growth hormone, thyroid-stimulating hormone, adrenocorticotropic hormone and prolactin.
- The posterior lobe of the pituitary gland stores and releases hormones that are produced by the hypothalamus. They travel to the posterior lobe along nerve fibres in the infundibulum and are released due to nerve impulses from the hypothalamus.
- The posterior lobe of the pituitary gland releases oxytocin and antidiuretic hormone.
- The pineal gland secretes melatonin, which regulates sleep patterns.
- The thyroid gland releases thyroxine and triiodothyronine, which increase metabolism to release energy, including heat. It also secretes calcitonin, which decreases the level of calcium and phosphate in the blood.
- The parathyroid glands release parathyroid hormone, which increases the calcium level in the blood and phosphate excretion in the urine.
- The thymus secretes thymosins, which play a role in the maturation of T-lymphocytes.
- The adrenal medulla is the inner part of the adrenal gland. It secretes adrenaline and noradrenaline, which play a role in the fight-or-flight response.
- The adrenal cortex is the outer part of the adrenal gland. It secretes aldosterone, which regulates sodium and potassium excretion, and cortisol, which protects the body from stress.
- The endocrine cells in the pancreas form the islets of Langerhans. They secrete insulin, which decreases blood glucose levels, and glucagon, which increases blood glucose levels.
- Androgens, such as testosterone, are produced by the testes and are responsible for the male sex characteristics.
- Oestrogens and progesterone are produced by the ovaries. They are responsible for the female sex characteristics and help to regulate the menstrual and ovarian cycles.
- The stomach, kidneys, heart and placenta are also considered endocrine glands as they produce hormones.

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CHAPTER 2 GLOSSARY

Adrenal cortex The outer portion of an adrenal gland; secretes the hormones aldosterone and cortisol

Adrenal glands Two endocrine glands, one immediately above each kidney; each consists of an inner adrenal medulla and an outer adrenal cortex

Adrenal medulla The inner portion of an adrenal gland; secretes the hormones adrenaline and noradrenaline

Adrenaline A hormone secreted from the adrenal medulla that prepares the body for the fight-or-flight responses; also called epinephrine

Adrenocorticotropic hormone (ACTH) A hormone that controls the production and release of some of the hormones from the cortex of the adrenal glands

Aldosterone A hormone that acts on the kidney to reduce the amount of sodium in the urine and increase the amount of potassium

Amine hormone A hormone composed of an amino acid with modified groups

Androgen Any of the male sex hormones produced by the testes; responsible for the development and maintenance of the male sex characteristics

Antidiuretic hormone (ADH) A hormone produced by the hypothalamus and released by the posterior lobe of the pituitary gland that stimulates the kidneys to remove water from urine, thus reducing urine production; also known as vasopressin

Calcitonin A hormone secreted by the C-cells of the thyroid gland that decreases the concentrations of calcium and phosphate

Corticosteroid Any of a group of more than 20 hormones secreted by the adrenal cortex; the two main hormones are aldosterone and cortisol

Cortisol A hormone that, along with related hormones, promotes normal metabolism

Endocrine gland A gland that secretes hormones directly into adjacent tissue; also called a ductless gland

Enzyme amplification A series of chemical reactions in which the product of one step is an enzyme that produces an even greater number of product molecules at the next step

Epinephrine *see* adrenaline

Erythropoietin (EPO) A hormone that stimulates production of red blood cells by the bone marrow

Exocrine gland A gland that secretes into a duct that carries the secretion to the surface of the body cavities

Follicle-stimulating hormone (FSH) A hormone that stimulates the development of a follicle in the ovary

Glucagon A hormone secreted by the pancreas that increases blood sugar level

Gonadotropin A hormone that affects the sex organs

Gonads The testes and ovaries

Growth hormone (GH) A hormone that stimulates body cells to grow and multiply, especially the skeleton and skeletal muscles

Homeostasis The maintenance of a relatively constant internal environment despite fluctuations in the external environment

Hormone A chemical that is secreted by an endocrine gland and that affects the functioning of a cell or organ; often carried in the blood

Hypophysis An alternative name for the pituitary gland

Hypothalamus The part of the brain lying just below the thalamus and above the pituitary gland; controls many homeostatic mechanisms, such as body temperature, water balance and heart rate

Infundibulum The stalk-like structure that joins the pituitary gland to the hypothalamus

Inhibiting factor A hormone that slows the release of another hormone

Insulin A hormone, secreted by the pancreas, that decreases blood sugar level

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Islets of Langerhans Clusters of endocrine cells in the pancreas; secrete the hormones insulin and glucagon

Luteinising hormone (LH) A hormone that promotes final maturation of the ovarian follicle and the formation of the corpus luteum

Melatonin A hormone secreted by the pineal gland that regulates sleep patterns

Negative feedback Feedback that reduces the effect of, or eliminates, the original stimulus

Noradrenaline A hormone secreted from the adrenal medulla that has effects similar to that of adrenaline; in particular, it increases the rate and force of the heartbeat; also called norepinephrine

Norepinephrine *see* noradrenaline

Oestrogen A female sex hormone; develops or maintains female reproductive structures and regulates the menstrual cycle and pregnancy

Oxytocin The hormone that stimulates contraction of the muscles of the uterus

Pancreas A gland that lies just below the stomach; both an endocrine and exocrine gland; secretes digestive enzymes from the exocrine cells, and the hormones insulin and glucagon from endocrine cells

Pancreatic islet *see* islets of Langerhans

Parathormone *see* parathyroid hormone

Parathyroid gland One of four (usually) small glands about the size of a small pea embedded in the rear surface of the thyroid gland; secretes parathyroid hormone (PTH)

Parathyroid hormone (PTH) A hormone that controls calcium and phosphate levels in the blood; also known as parathormone

Pineal gland A small gland, about the size of a pea in children, found deep inside the brain; in adults it is just a tiny lump of fibrous tissue; the functions of the hormones it secretes have still not been identified

Pituitary gland An endocrine gland located below the brain; joined to the hypothalamus by a stalk called the infundibulum

Placenta The organ that supplies nutrients to, and removes wastes from, the foetus; also produces a number of hormones, including oestrogens and progesterone

Progesterone A female sex hormone produced by the ovaries; helps prepare the uterine lining for a fertilised egg; also prepares the mammary glands for milk secretion

Prolactin (PRL) A hormone that promotes milk production during and after pregnancy

Protein hormone A hormone consisting of a long chain of amino acids (a protein)

Releasing factor A hormone whose purpose is to control the release of another hormone

Secretion A useful substance produced and released by a gland or cell (noun); the process of producing and releasing a useful substance (verb)

Steroid hormone A hormone derived from the lipid cholesterol

Target cell A cell whose activity is affected by a particular hormone

Target organ An organ whose activity is affected by a particular hormone

Thymosin Any of a group of hormones secreted by the thymus that stimulate the immune system by helping the maturation of T-lymphocytes

Thymus An endocrine gland located in the chest just above the heart and behind the sternum; secretes a group of hormones called thymosins

Thyroid gland An endocrine gland, consisting of two lobes, located in the neck just below the larynx; secretes the hormone thyroxine

Thyroid-stimulating hormone (TSH) A pituitary hormone that stimulates production and release of hormones from the thyroid gland; also known as thyrotropin

Thyroxine A hormone secreted by the thyroid gland that regulates metabolism, growth and development

Triiodothyronine The more active thyroid hormone that increases the rate of metabolism, also known as T3

Vasopressin *see* antidiuretic hormone

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CHAPTER 2 REVIEW QUESTIONS

Recall

1 a Describe the endocrine system.
b Describe the relationship between endocrine glands and hormones.

2 a Define 'hormone'.
b List the different types of hormones.

3 Describe enzyme amplification and state why it is important.

4 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.

5 a What is a target organ?
b How do hormones get from their source to the target organ?
c Describe target organs/cells and the role of the following hormones.
i Oxytocin
ii Antidiuretic hormone
iii Adrenaline
iv Parathyroid hormone
v Insulin
vi Glucagon
vii Thyroxine

6 a Which gland produces thymosins, and what is the function of these hormones?
b Which gland secretes melatonin? What is the role of melatonin?

Explain

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

8 Hormones are specific. Explain what this means and how it is achieved.

9 The hypothalamus and the pituitary gland are closely related. Describe their relationship in terms of:
a their location in the body
b the ways in which they function.

10 Hormones act by changing the functioning of a cell. Explain how they are able to do this.

11 Hormones that are lipid-soluble work in a different way from those that are water-soluble. Explain the difference and why it occurs.

12 Hormones secreted by the posterior lobe of the pituitary are not actually made in the posterior lobe. Explain the process of producing and releasing these hormones.

Apply

13 Explain why endocrine glands are sometimes called ductless glands.

14 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.

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

16 Construct a flow diagram similar to Figure 2.11 for the hormone ADH and its role in water balance. Include the role of feedback in your diagram.

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

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Extend

18 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 carry out his duties as President of the United States while having such a serious illness?
- **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 lobe 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.
- **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 had a disorder of one of the endocrine glands. Which gland, or glands, could it have been, and what hormones could have been involved?

19 In an average person the thymus weighs about 35 g just before puberty, but by age 50 it has shrunk to around 12 g and by 75 to about 6 g. It has been suggested that this decline in size may be responsible for elderly people becoming more susceptible to disease. Research the thymus to find out:

- **a** how the role of the thymus was discovered
- **b** the role of the thymus in providing defence against disease.

20 New hormones are still being identified. One well-known example is the hormone leptin, discovered in 1994 through the study of obese mice. Leptin is secreted by fat storage tissues (adipose tissues). Find out:

- **a** how leptin was discovered
- **b** the target cells for leptin
- **c** the effect of the hormone.

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