3.6 The endocrine system is slower but more sensitive to change

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The endocrine system is much slower than the nervous system. It uses chemical messengers called hormones to maintain control and to regulate growth. These chemical messengers act more slowly than the nerve impulses sent around by the nervous system, but their effects often last for a lot longer.

The **endocrine system** is a collection of glands that secrete (release) **hormones**. The hormones are secreted directly into the bloodstream and then travel around the body through the blood. Some cells in the body have receptors that match the hormone like a lock to a key. These cells are called **target cells.** It only takes one hormone to cause a change in the target cell.

The glands and organs of the endocrine system are spread throughout the body (Table 3.1).

Table 3.1 Some organs and hormones of the endocrine system

ORGAN	HORMONE	TARGET TISSUE	MAIN EFFECTS
Hypothalamus	Wide range of neurohormones	Pituitary gland	Links nervous system to endocrine system via pituitary gland to control many homeostatic functions such as body temperature, hunger, thirst and sleep patterns
Ovaries	Progesterone	Uterus	Thickens wall of uterus
	Oestrogen	Body cells	Development of female sexual characteristics; aspects of pregnancy and foetal development
Testes	Testosterone, progesterone and oestrogen	Male reproductive system, body cells	Development and control of male sexual characteristics; production of sperm
Pancreas	Insulin	Liver, most cells	Lowers blood glucose level
	Glucagon	Liver	Raises blood glucose level
Pituitary gland	Thyroid-stimulating hormone	Thyroid	Changes the rate of thyroxine release from the thyroid
	Antidiuretic hormone	Kidneys	Reduces the amount of water reabsorbed from the kidneys
	Pituitary growth hormone	Bones, muscles	Stimulates muscle growth; controls the size of bones
Thyroid gland	Thyroxine	Body cells	Affects rate of metabolism, and physical and mental development
	Calcitonin	Blood	Decreases the amount of calcium in the blood
Parathyroid glands	Parathyroid hormone	Blood	Regulates the amount of calcium in the blood
Adrenal glands	Adrenalin	Body cells	Increases body metabolism in 'fight or flight' response
	Progesterone	Body cells	Important for calcium in bones
	Oestrogen	Body cells	Development of certain sexual characteristics
Pineal gland	Melatonin	Skin cells	Whitening of skin; involved in daily biological rhythms

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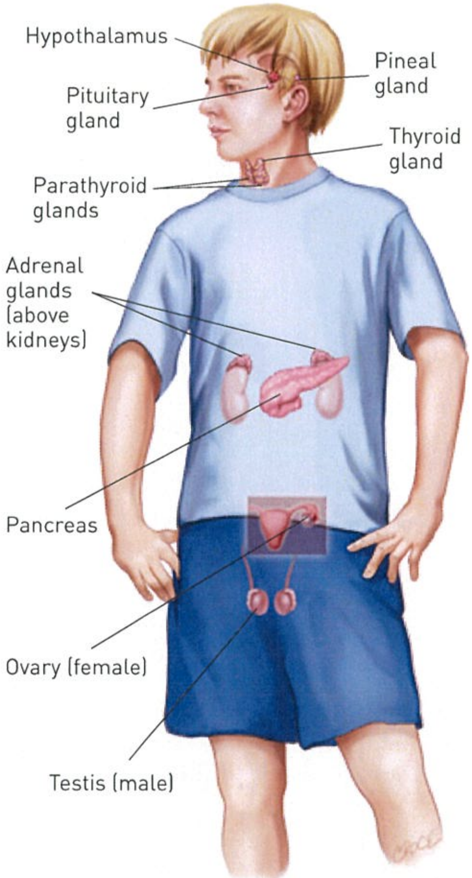

Figure 3.29 The human endocrine system.

Fight or flight?

If you are ever in a dangerous or frightening situation, you may experience a 'fight or flight' response. You break out in a cold sweat, your heart beats wildly, everything around you seems to slow down and your senses bombard you with information.

Most of the symptoms are triggered by the release of the hormone adrenalin (also called epinephrine). Adrenalin is constantly produced by the adrenal glands in small doses. The adrenal glands are located above the kidneys. The usual function of this hormone is stimulating heart rate and enlarging blood vessels. However, when you are in danger, adrenalin takes on another role. It floods into your system, causing an increase in the strength and rate of the heartbeat, raising your blood pressure and speeding up the conversion of glycogen into glucose, which provides energy to the muscles. In this way, adrenalin prepares your body for the extra effort required should you need to defend yourself (fight) or run away (flight).

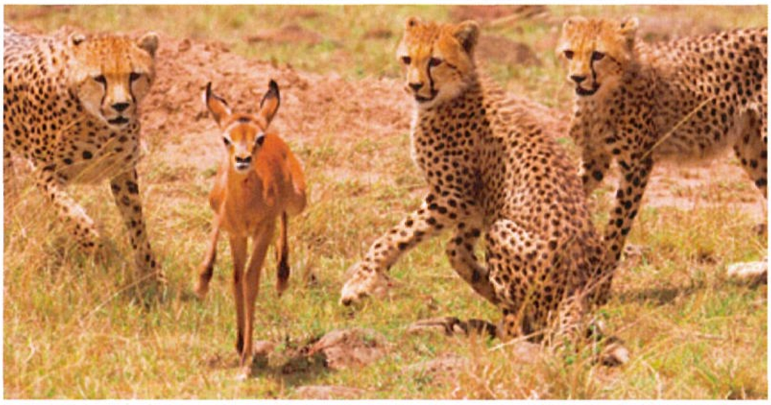

Figure 3.30 Adrenalin is responsible for the fight or flight response in mammals.

Types of hormone

Hormones are classified into two types on the basis of their chemical structure: peptide hormones and steroid hormones. Most hormones are peptides. Peptide hormones are made from proteins and produced by the anterior pituitary, parathyroid gland, placenta, thyroid gland and pancreas. Peptides travel through the bloodstream until they find and interact with specific receptors on the surface of their target cells. This causes the target cells to respond.

Steroid hormones include those hormones secreted by the adrenal glands and the ovaries (women) and testes (men). Steroid hormones are produced from cholesterol.

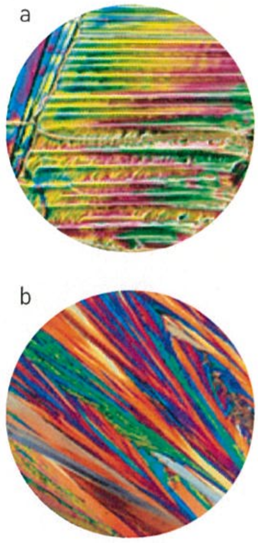

Figure 3.31 Crystal structures (as seen under a microscope) of (a) the peptide hormone calcitonin and (b) the steroid hormone testosterone.

Check your learning 3.6

Remember and understand

1 What is the name of the system in your body responsible for hormones?
2 What is meant by the phrase 'fight or flight' and how does it relate to hormones?
3 Describe the two different types of hormone.
4 Why is the endocrine system referred to as a communications system?

Apply and analyse

5 How is a hormonal response different to a nervous response? Name one advantage for each system.

3.7 Homeostasis regulates through negative feedback

Your body works to maintain constant levels of important nutrients and water and temperature in order to stay healthy. The process of regulating the internal conditions of the body is called homeostasis. Negative feedback occurs when the body responds in a way that removes the initial stimulus.

Figure 3.32 Homeostasis is your body's ability to regulate and maintain a stable condition inside your body, regardless of changes to the external environment.

So far, scientists have been unable to discover another planet that humans could inhabit. The reality is that humans can only survive in very specific environments. Our bodies are quite fussy and need to have access to the right amount of food and water, oxygen and carbon dioxide. If you were lost in a desert or in freezing temperatures, your body would try to maintain a temperature of about 37°C at all times to keep cells working efficiently. This 'business as usual' that is maintained by your body is called **homeostasis**.

Homeostasis

To maintain homeostasis, your body uses a mechanism a bit like a thermostat on a heater. When temperature receptors on your skin and in the hypothalamus of your brain detect cooling down (stimulus), then a message gets sent to a variety of effectors around your body. This may include muscles to make you shiver (to warm up) or blood vessels to redirect the warm blood flow to the important organs in your body (your heart liver and brain).

If the temperature receptors detect that you are too hot (stimulus), then the effectors include your sweat glands and blood vessels. This causes your body to respond by the blood carrying heat to your skin so that sweat evaporates and cools you. This a negative feedback mechanism system – the effectors respond by removing the stimulus. If you are too hot, then your body tries to cool you down. If you are too cold, then your body works to warm you up.

Figure 3.33 When your body is stimulated by heat, homeostasis ensures you cool down by sweating.

Hormones at work

The rate of hormone production and secretion is often regulated by the negative feedback mechanism. This means that if a stimulus is received that indicates something in the body is happening 'too much', the response would be to produce a hormone to remove it.

Blood glucose

As you eat, food gets broken down into smaller nutrients. All carbohydrates get broken down into simple sugars, including glucose. These glucose molecules travel through your blood and provide the energy for cellular respiration (the reaction of glucose with oxygen to produce carbon dioxide, water and ATP). Too much glucose in the blood is not healthy because it causes water to be lost from cells through osmosis. Your body tries to control the amount of glucose in your blood. If the concentration

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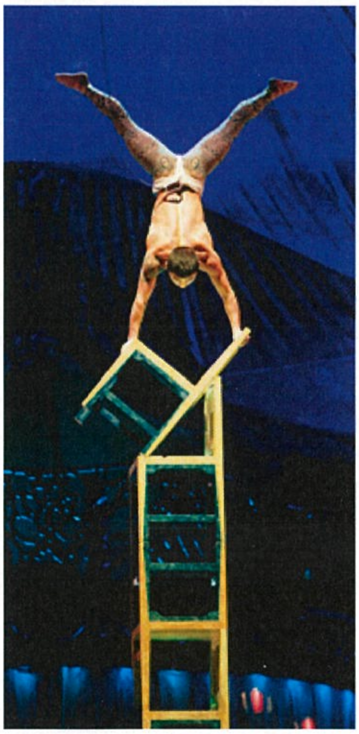

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of glucose in your blood is too high (stimulus), then receptors in the pancreas will detect it. They will then release the hormone insulin into the blood. Insulin will travel throughout the body to the insulin receptors on muscle and liver cells. These cells will then act as effectors and remove the glucose from the blood. This causes the blood glucose to decrease, removing the original stimuli. This is an example of negative feedback.

If blood glucose levels are too low, then your body will use negative feedback to restore the levels to a homeostatic state. The low glucose levels are detected by receptors in the pancreas (stimulus). This time, the hormone glucagon is release into the blood. Receptors for glucagon are also found on the effector cells in the liver and muscle. Glucagon binding to the receptors causes the muscle and liver cells to release the stored glucose into the blood (response), increasing the amount of blood glucose once again.

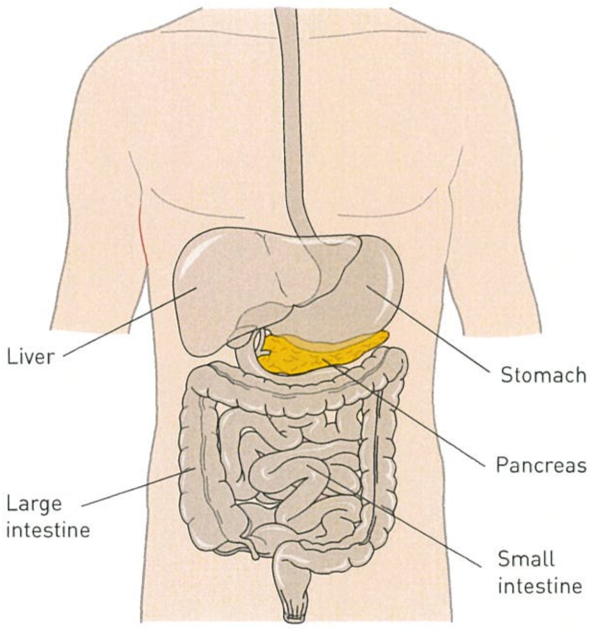

Figure 3.34 The pancreas is the endocrine organ responsible for the regulation of blood glucose levels.

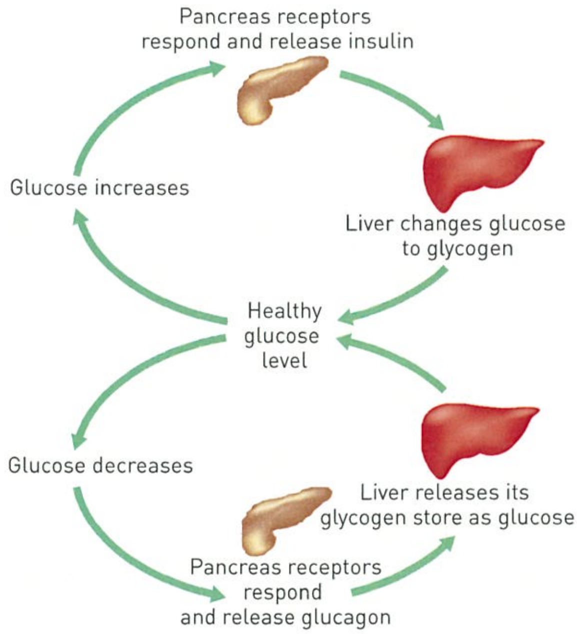

Figure 3.35 The pancreas and the liver work together to maintain healthy glucose levels in the body.

Check your learning 3.7

Remember and understand

1 What is homeostasis?

2 How does your body respond to cold weather?

3 What happens to your blood sugar levels when you eat?

4 How does your body respond to low blood sugar levels?

Apply and analyse

5 How is the stimulus response model similar to or different from the negative feedback mechanism?

6 If a negative feedback loop reduces the effect of a hormone, what would a positive feedback loop do?

Evaluate and create

7 In type I diabetes, cells in the pancreas are unable to produce insulin. Suggest what effect this would have on blood glucose levels. Research how people with type I diabetes ensure that their blood glucose levels remain at the homeostatic level.

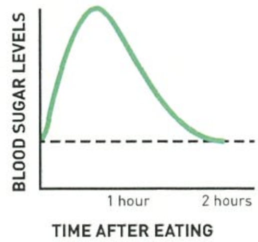

Figure 3.36 After eating, blood glucose levels increase. The body's response is to release insulin, which causes the muscle and liver effectors to remove the glucose and restore homeostasis.

//SCIENCE AS A HUMAN ENDEAVOUR//

3.8 Hormones are used in sport

Erythropoietin is a hormone normally produced by the kidneys to increase the number of red blood cells in the body. Athletes can use this version of negative feedback mechanism naturally or artificially to increase their performance on the sporting field.

Many athletes and sporting clubs spend months training high in the mountains to help their performance in competitions. The air in the mountains is much thinner. Although it is still 21% oxygen, it is harder for a person to fill their lungs as the particles in the air are spread out further. As a result, when a person first arrives at high altitude, their body struggles to get enough oxygen. This can make the person feel tired as they are unable to burn the glucose in aerobic cellular respiration.

Negative feedback in action

The body normally produces just enough red blood cells to carry oxygen around the body. When red blood cells die, a hormone called erythropoietin is produced by the kidneys. The erythropoietin travels through the blood to receptors in the bone marrow. The effector bone marrow cells then produce more red blood cells to replace those lost.

Figure 3.38 Erythropoietin increases the production of red blood cells.

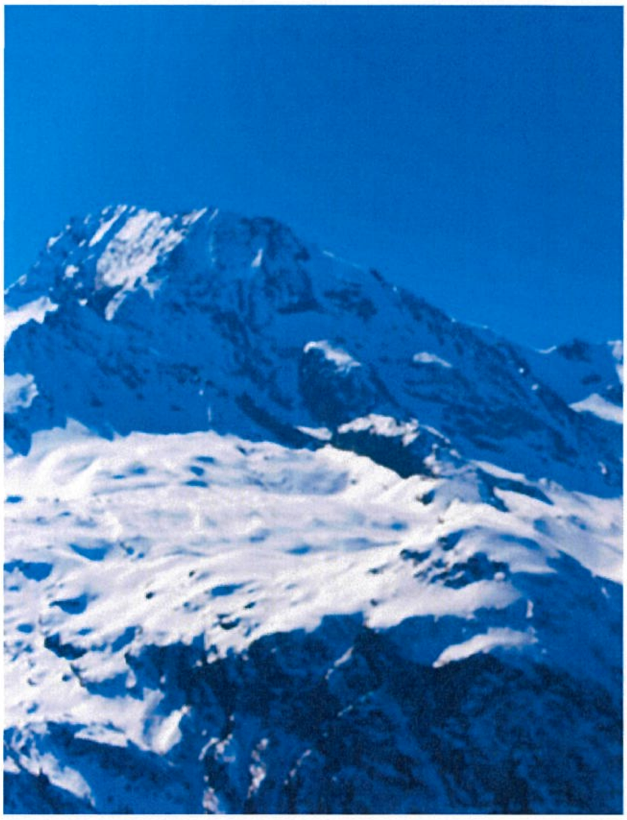

Figure 3.37 Training at high altitude can increase an athlete's performance.

Exercising at high altitude stimulates the body to react as though there are not enough red blood cells to carry oxygen to the muscles. Erythropoietin is produced, causing the bone marrow to make extra red blood cells. It takes about three weeks for the extra cells to start being noticeable. When the athlete returns to compete at sea level, the red blood cells remain active for up to a month. This means the athlete's blood is more efficient at carrying oxygen to muscles, making the athlete less likely to become fatigued (tired). Training at high altitude uses the negative feedback mechanism to the athlete's advantage.

Some athletes bypass the high-altitude training and inject erythropoietin directly into their blood. This is called blood doping. However, the amounts of hormone introduced into the blood are not controlled. This can cause an over-production of red blood cells, which strains the heart. The athlete is at risk of a heart attack or stroke.

Medical uses of erythropoietin

Erythropoietin is produced in the kidneys. Any disease that affects kidney function will also affect the production of erythropoietin. As a result, a person suffering kidney disease will also have low red blood cell levels. This is called anaemia. Symptoms of anaemia are a pale appearance and feeling tired when doing exercise. Regular injections of erythropoietin will increase the production of the red blood cells and improve the person's health.

Drug testing

Erythropoietin started being synthesised in the laboratory in the 1990s. Unfortunately, it was 10 years before drug testing could distinguish the artificial hormone from naturally occurring erythropoietin. In 2002, at the Winter Olympic Games in Salt Lake City, USA, the first athlete was identified as having a version of erythropoietin in their urine and blood.

Figure 3.39 In 2013 Lance Armstrong admitted to injecting erythropoietin to help him win world cycling events.

Extend your understanding 3.8

1. Is erythropoietin part of the nervous system or endocrine system? Explain your answer.
2. What symptoms will an athlete have when they first start training at high altitude?
3. List the stimulus, location of the receptor, effector and response in the negative feedback mechanism of erythropoietin.
4. What are the symptoms of anaemia?
5. 'The only way to create a level playing field in sport is for all athletes to be able to use performance enhancing drugs.' Do you agree or disagree? Provide at least three forms of evidence to support your view.

Figure 3.40 Testing for erythropoietin is part of the routine tests that professional athletes undergo.