7 Body coordination

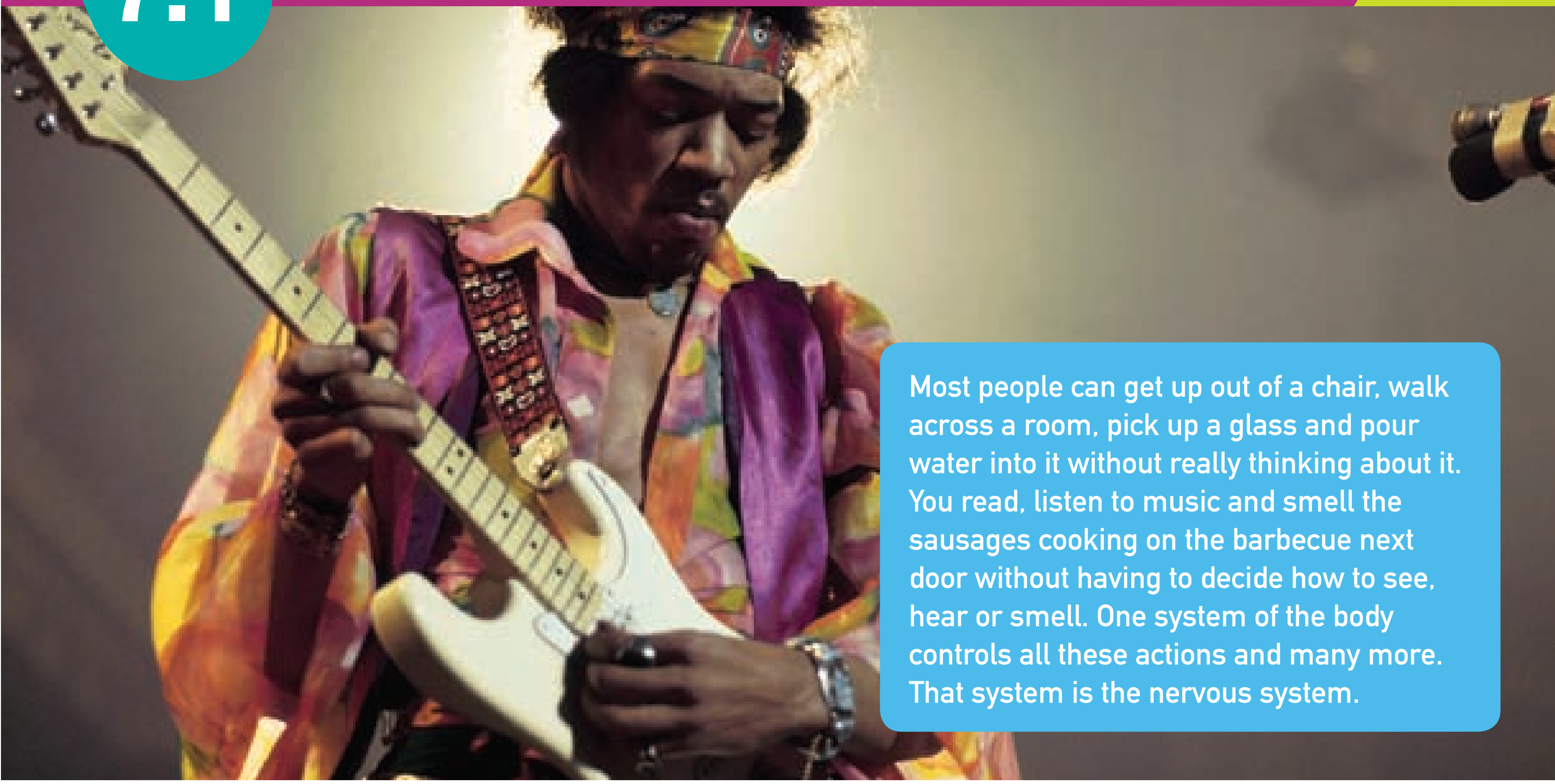
HAVE YOU EVER WONDERED ...

- what makes you shiver when cold and sweat when hot?
- why you are able to act quickly in response to sharp or hot objects?
- why you get ‘butterflies’ in your stomach when you are nervous or feel shaky when frightened?

After completing this chapter students should be able to:

- explain the role of the nervous system in controlling and coordinating the functioning body
- explain the role of the endocrine system, including its role in coordinating body functioning
- discuss the interaction of the nervous and endocrine systems in coordinating the body’s response to changes in the internal and external environments
- demonstrate the use of models to explain how body systems work together
- explain how all the body systems work together to provide the needs of the body and maintain an internal environment that supports the functioning cells.

7.1 Nervous control



Most people can get up out of a chair, walk across a room, pick up a glass and pour water into it without really thinking about it. You read, listen to music and smell the sausages cooking on the barbecue next door without having to decide how to see, hear or smell. One system of the body controls all these actions and many more. That system is the nervous system.

INQUIRY science 4 fun

Pupils change

What changes occur in the eyes in the light and dark?

Yes

Collect this ...

- mirror
- strip of dark cloth

Do this ...

1. Stand in front of the mirror in a room with good light.
2. Look at your eyes—especially notice the size of the pupils.
3. Close your eyes and cover them gently with the dark cloth. Do not press on your eyes.
4. Keep your eyes closed for two minutes.
5. Remove the cloth and open your eyes. Look in the mirror immediately.
6. Observe the pupils of your eyes.

Record this ...

Describe what happened.

Explain why this happened.

Human nervous system

The nervous system is a communication system that controls all parts of your body. The human nervous system has two main parts, as shown in Figure 7.1.1.

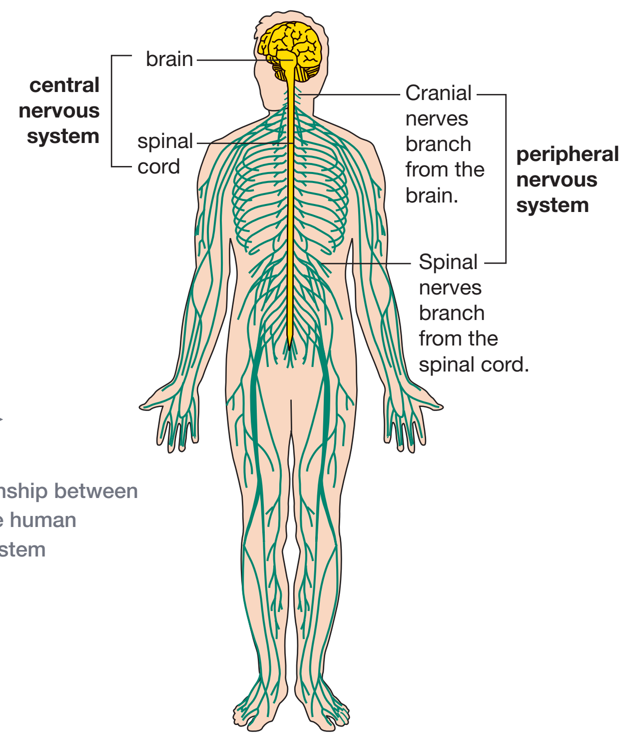


Figure 7.1.1 The relationship between parts of the human nervous system

The two parts of the nervous system are:

- the **central nervous system** (CNS), made up of your brain and your spinal cord
- the **peripheral nervous system** (PNS), made up of the nerves that carry messages to and from the CNS and other parts of your body.

The CNS receives information from all over the body, processes that information, and then sends out messages telling the body how to respond.

Nerve cells

The nervous system is made up of trillions of nerve cells or **neurones**. Neurones carry electrical messages, called **nerve impulses**, from one part of your body to another at very high speed. These nerve impulses can travel in only one direction.

As you can see in Figure 7.1.2, a neurone has four main parts: a cell body, dendrites, knobs and an axon. The **cell body** contains the nucleus, which is the control centre of the cell. The **dendrites** branch out from the cell body and receive messages from other nerve cells, which are then sent on to the cell body. The **axon** or nerve fibre sends nerve impulses in only one direction—away from the cell body. The knobs pass the message on to the next neurone. Two common types of neurones are:

- **motor neurones**—these carry messages from the CNS to **effectors**. Effectors are muscles or glands (tissues that secrete chemicals) that put the messages into effect
- **sensory neurones**—these carry messages from cells in the sense organs (such as your eyes, ears, tongue and skin) to the brain and spinal cord.

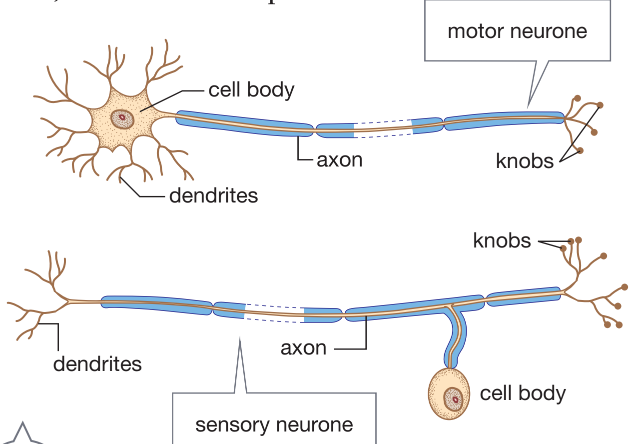


Figure 7.1.2 Two types of neurone

The messages sent along the neurone are electrical. If all the neurones in your body touched one another, stimulating one nerve ending would be like turning on one switch in your house and having all the lights and appliances come on. Your body needs to control which nerves 'fire' at a certain time.

When the nerve impulse reaches the knobs at the end of an axon, a chemical called a **neurotransmitter** is released into the space between the neurones (**synapse**). You can see this in Figure 7.1.3. The neurotransmitter carries the message from the axon of one neurone to the dendrite of the next neurone. The dendrite receives the chemical message and sends off an electrical signal.

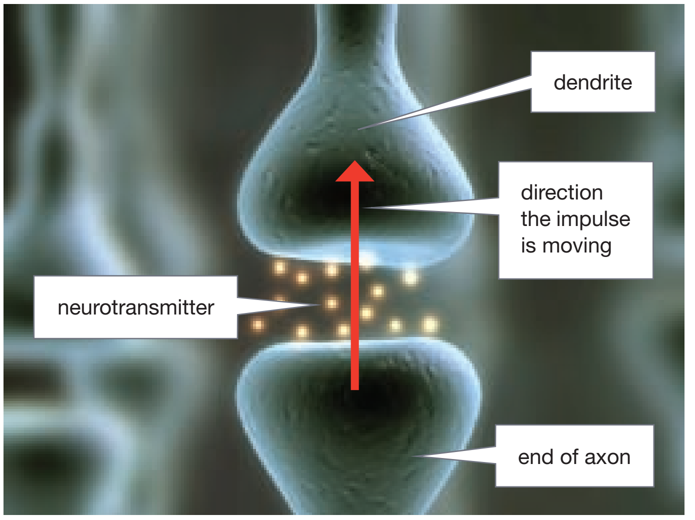


Figure 7.1.3 At the synapse, the electrical signal of the nerve is converted into a chemical signal and then back into an electrical signal again.

About 50 different neurotransmitters have been found that carry electrical impulses across these gaps. These neurotransmitters control which nerves fire and when.

In your body, the neurones are bundled together to form nerves, as shown in Figure 7.1.4. Neurones are covered with an insulating layer called a **myelin sheath**. The myelin sheath electrically insulates the neurones from each other and increases the speed of the nerve impulse.

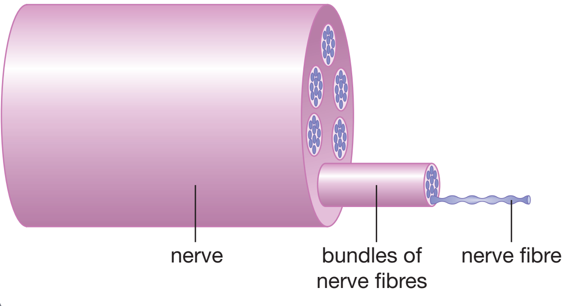


Figure 7.1.4 A nerve is made up of a large number or neurones, each of which is surrounded by a myelin sheath.

The parts of the CNS that contain neurones covered in myelin are called white matter. The parts that contain mainly cell bodies are called grey matter. The outer parts of the brain are made up mainly of grey matter.

7.1

What a nerve!

The longest neurone in your body extends from your big toe to the middle part of your spine and is about a metre long. A giraffe's longest nerve is at least two metres long!

SciFile

The brain: communication centre

Humans have a very large brain for their body size, compared with other animals. The human brain contains about 100 billion neurones, and has an average volume of 1200–1400 mL.

The brain controls and regulates body functions. Without it you cannot survive. Amazing new medical imaging techniques can now look inside a living brain. MRI (magnetic resonance imaging), for example, uses strong magnetic fields to distinguish different types of body tissue (Figure 7.1.5). This is useful in diagnosing brain tumours and finding areas of brain injury. Damage to the brain is repaired slowly. Sometimes other parts of the brain take over the function of the damaged parts, but there are situations where brain damage is permanent.

The cerebrum

When you think of what a human brain looks like, you are probably thinking of the **cerebrum**. It occupies more than 80% of the brain and contains over 10 billion neurones. Its many folds increase its surface area by three times. It is here that the higher intellectual functions of humans take place. The cerebrum controls your conscious thoughts and the intentional (voluntary) movement of every body part. It also receives sensory messages from all body parts.

The cerebrum is made up of two parts, called the right and left cerebral hemispheres. When it comes to intended actions such as walking or hitting a ball, the right hemisphere controls the left side of your body and the left hemisphere controls the right side of your body (Figure 7.1.6). Each half of the brain can work independently, but you use both cerebral hemispheres for most activities. One side usually dominates in a particular task. For example, in most people the left side has more control over language and logical thinking, such as mathematical ability. The right side is the more creative and emotional side. Musical and artistic ability depends on the right side of the brain.

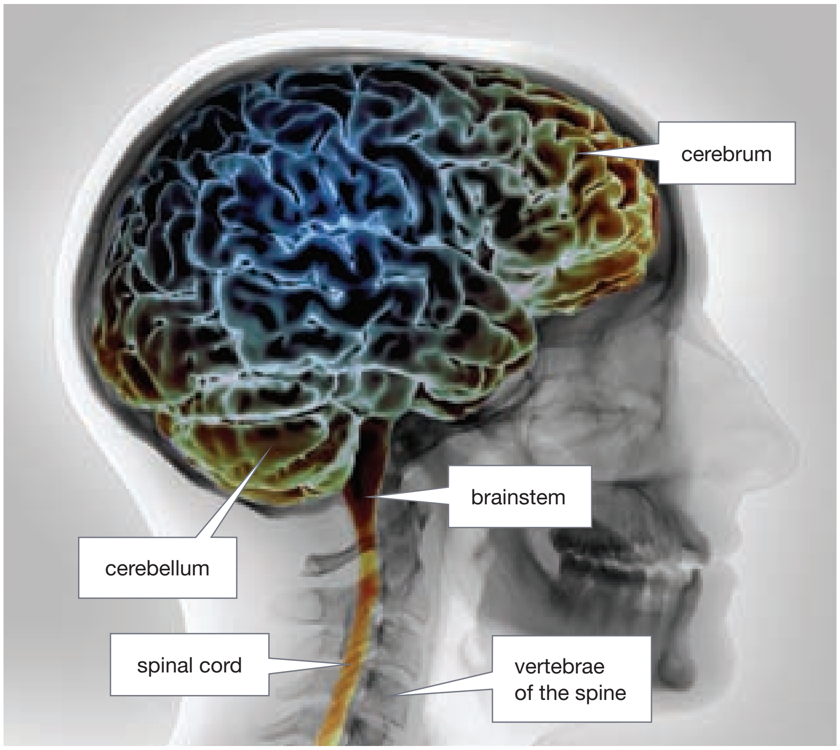


Figure 7.1.5 Computer-enhanced X-ray showing the external structure of a human brain.

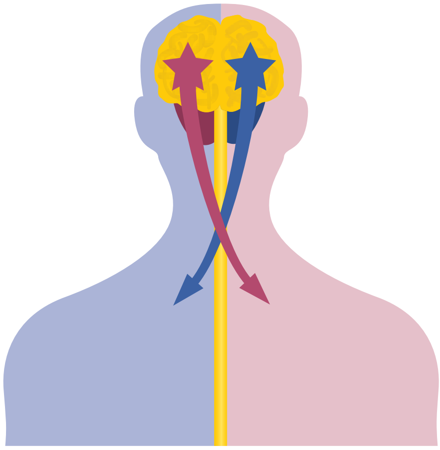


Figure 7.1.6 The right and left sides of the brain control the opposite sides of the body.

Figure 7.1.7 uses images of the brain created using both MRI and PET (positron emission topography). Together these scans reveal the parts of the brain that are active during various activities. They show that the left-hand side of the brain is active during activities that involve language. They also show that different parts are active when listening, speaking, reading or just thinking about words.

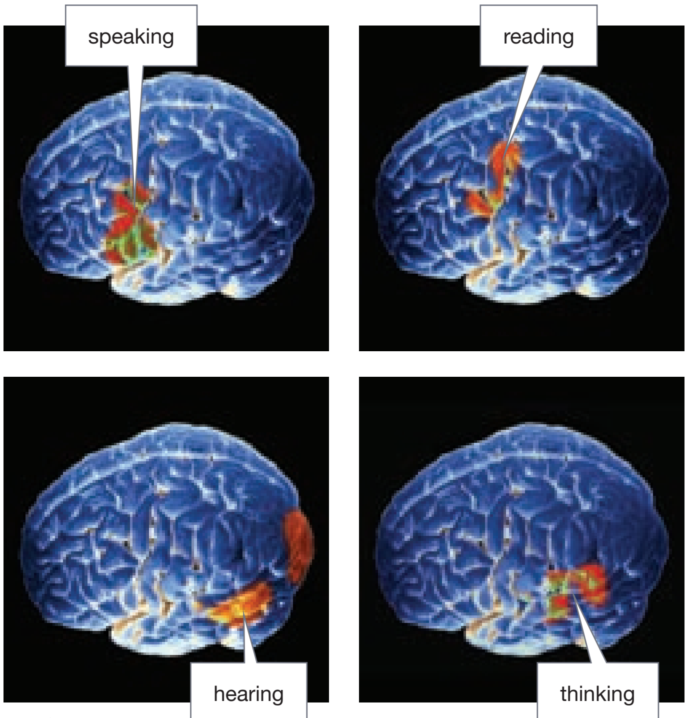


Figure 7.1.7 The red and green areas in these images show the areas of your brain that are active during various activities.

At the base of the cerebrum, where you can feel your skull curve inwards, is the **cerebellum**. Its position is shown in Figure 7.1.8. The cerebellum is responsible for coordination and balance. Without it, walking would be impossible.

The lower part of the **brain stem** or **medulla** can be seen where the spinal cord widens just after it passes into the skull. It controls the body's vital functions, such as breathing, blood pressure and heart rate. Damage to this area can be fatal.

Peripheral nervous system

The PNS has two separate parts: the somatic nervous system and the autonomic nervous system.

Somatic nervous system

All animals including humans need information about their surroundings. The **somatic nervous system** collects this information through sensory organs such as the eyes and ears. The somatic nervous system also coordinates movement of the body.

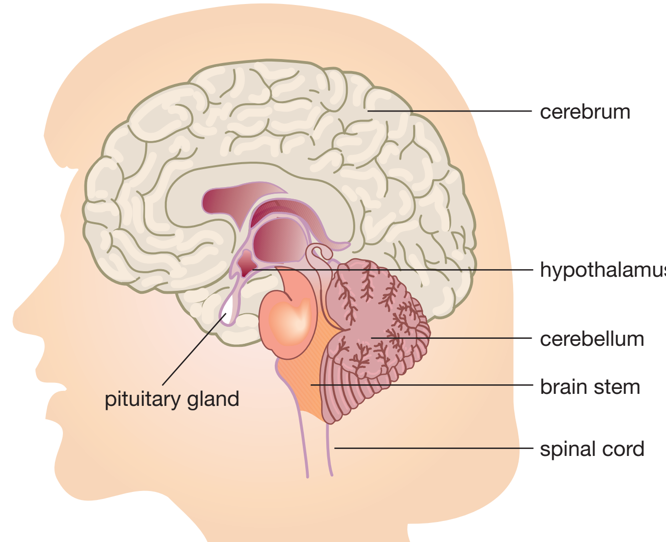


Figure 7.1.8 Vertical section through the brain

The somatic nervous system's sensory organs are **receptors**—special organs or tissues that have nerve endings that detect changes in the environment. The changes stimulate the nerve endings to send messages to your brain. Something that you can detect using your sense organs is a **stimulus**. Stimuli in your environment include temperature, light, touch, smell and sound.

In your body there are different types of receptors. Mechanoreceptors are sensitive to stimuli such as touch. They also make you aware of muscles being stretched, for example when your bladder becomes full. Photoreceptors in the eye are sensitive to light. Thermoreceptors respond to changes in temperature. Chemoreceptors are sensitive to chemicals, such as those found in food. Chemoreceptors tell you if food is sweet or bitter.

The sensitive skin

The skin responds to many different sensations, such as touch, pain and temperature. One of the ways that your body protects itself from the outside world is by being very sensitive to touch. Receptors in your skin alert you to a hot surface or a biting mosquito. You can see these receptors in Figure 7.1.9.

1 p235

The sense of hearing

Sometimes receptors are grouped together to form a sense organ. An example is the receptors in the ear. The ear not only senses sound, but also helps you to keep your balance.

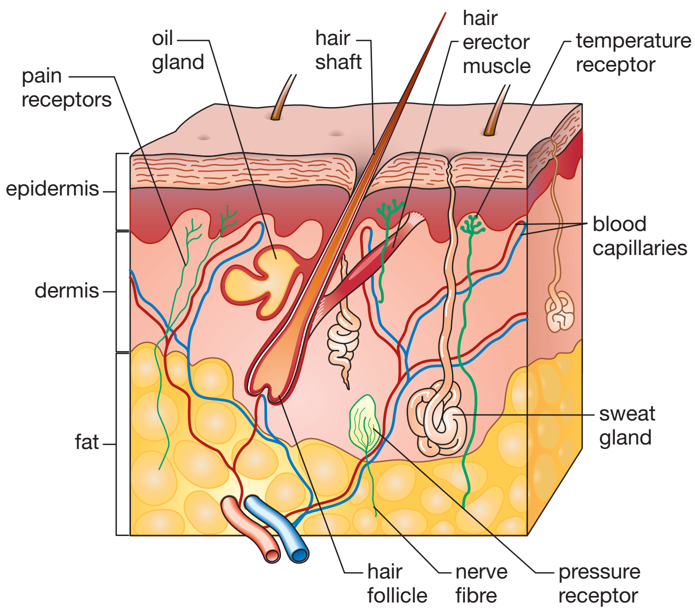


Figure 7.1.9 The skin has many receptors and provides you with a lot of information about your surroundings.

In your inner ear are fluid-filled semicircular canals. These are shown in Figure 7.1.10. If you suddenly lean in one direction, the fluid in one of the canals moves against tiny sensory hairs in the canal lining. A nerve impulse is sent to the brain, and the brain then sends messages to the muscles to help you balance.

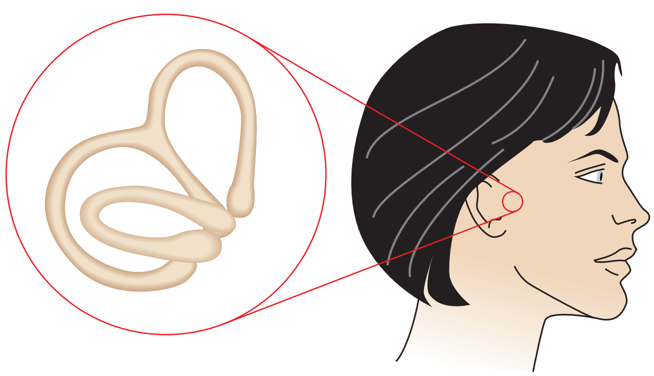


Figure 7.1.10 Nerves in the semicircular canals of the inner ear respond to gravity and help you maintain your balance.

SciFile

You spoke?

Have you ever heard girls complain that boys do not listen to them? There is a scientific basis for this. Researchers in the United Kingdom have found that male and female voices stimulate different parts of the brain and that deciphering a female voice is a more complex process.

The sense of sight

Only about one-sixth of the eye is visible. Most of it is protected within the skull. The pupil is an opening that allows light to pass through the lens and into your eye (Figure 7.1.11). The lens bends (refracts) light to help focus the light rays onto the photoreceptors in the retina at the back of the eye. Messages are sent from the photoreceptors via the **optic nerve** to the brain for interpretation, and this is what is called vision.

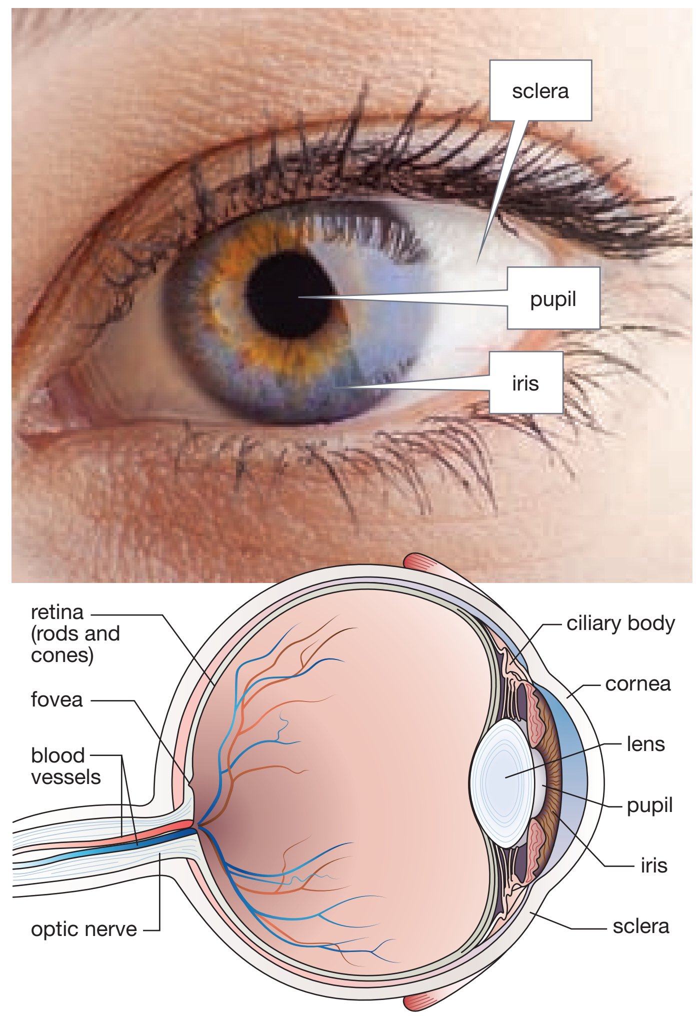


Figure 7.1.11 The structure of the human eye

In the retina there are two types of photoreceptors: rods and cones. Rods work in dim light and are responsible for night vision. Cones work in bright light and are responsible for colour vision. People with colour blindness have difficulty distinguishing between certain colours because they have fewer cones than normal.

A sense of smell and taste

The chemoreceptors for taste and smell work together. Food never tastes as good when you cannot smell it. The receptor cells for taste are taste buds. You have about 10 000 taste buds (shown in Figure 7.1.12) scattered on the surface of your tongue.

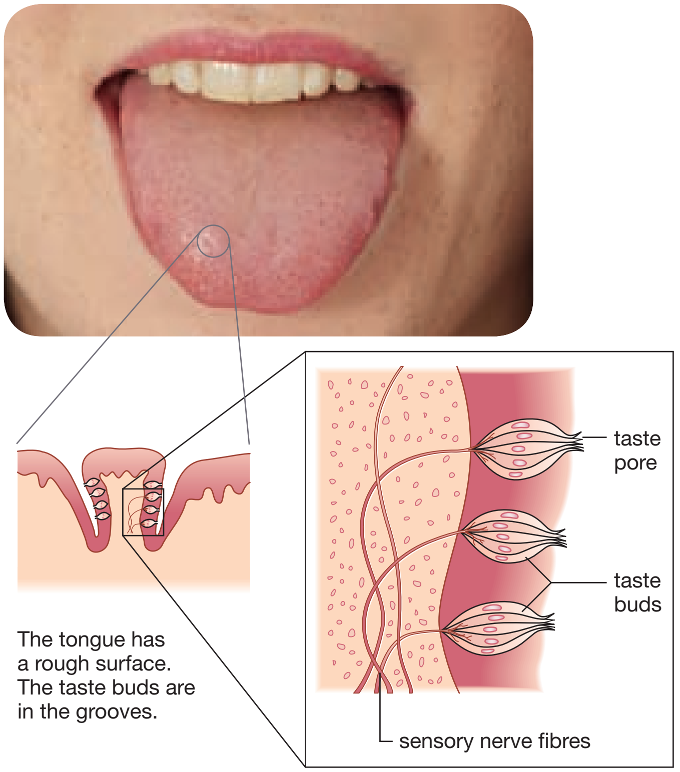


Figure 7.1.12 Taste buds are arranged in groups to form a taste pore, through which taste receptors extend. Chemicals bind to the taste receptors and stimulate sensory nerves. Messages sent to the brain give the sensation of taste.

SciFile

Tastes good

Humans can distinguish sweet, sour, salty and bitter tastes. In 2002, umami (savoury) was added as a fifth sense. In 2010, researchers from Deakin University, Australia, discovered that humans can detect a sixth taste—fattiness.

Autonomic nervous system

Some of the activities of your body happen without you realising it, such as the beating of your heart, the movement of food in your intestines, sweating and pupil size. These activities are controlled by the **autonomic nervous system**.

Two parts of the autonomic nervous system are the sympathetic nervous system and the parasympathetic nervous system.

The sympathetic and parasympathetic nervous systems can be thought of as opposites that complement each other. The **sympathetic nervous system** speeds up the functions of the body and makes it work more efficiently. It is the system that prepares your body for emergencies by making you more alert and preparing your body to act. The **parasympathetic nervous system** slows everything down. It is the system in control when you are resting.

To prepare your body for intense activity, the sympathetic nervous system diverts blood away from areas that will not be used in the action, such as the digestive system. It diverts the blood to areas that will be used, such as the muscles. The sympathetic nervous system:

- diverts blood flow away from the digestive tract and the skin
- stops peristalsis—the muscular action that mixes food in the intestines
- maintains blood flow to the lungs and the muscles of the skeleton—blood flow to the muscles may be increased by up to 120%
- opens the bronchioles (airways to the lungs)—this increases the amount of air able to enter the lungs, increasing the supply of oxygen to the body
- increases heart rate, thereby increasing blood flow to the muscles of the skeleton
- relaxes the muscles in the eye and dilates the pupils, allowing more light to enter the eye and improving distance vision
- increases blood flow to the heart.

Figure 7.1.13 It is the actions of the sympathetic nervous system that cause the sensations associated with fear or stress.

The functioning of the parasympathetic nervous system:

- increases blood flow to the digestive tract
- stimulates the salivary glands and increases the rate of peristalsis, in support of digestion
- reduces the diameter of the bronchioles when there is a reduced need for oxygen
- controls the heartbeat
- contracts the muscles of the eye and reduces the diameter of the pupil to allow close vision.

Figure 7.1.14 shows how the parts of the human nervous system relate to one another.

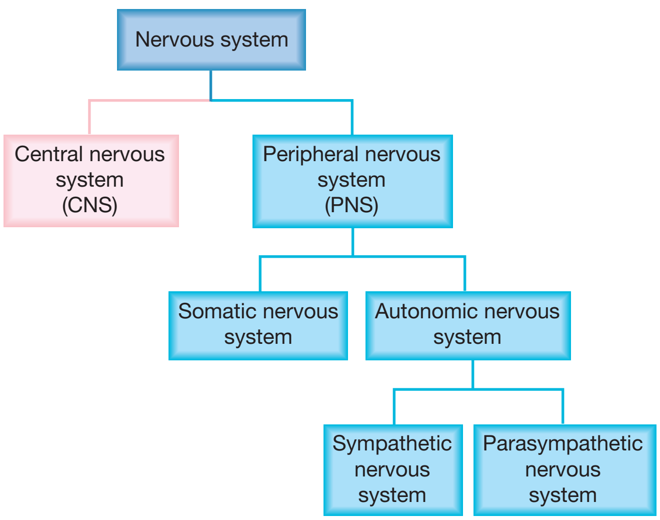


Figure 7.1.14 The relationship between different parts of the human nervous system

Responding to stimuli

A simple model of your nervous system is a stimulus–response model. Receptors stimulate the sensory nerves. The sensory nerves send a message to the brain. The brain works out the response that is required, then sends a message along motor nerves to the effectors—the muscles or glands that will put the response into effect. Figure 7.1.15 provides an example.

Reflex actions: a rapid response

If you touch something hot or sharp, you automatically pull your hand away. Arm muscles that are normally under your voluntary control react very fast, without waiting for instructions from the brain. This action, called a reflex action, protects your body from danger. Consider what happens when you touch a hot object. Receptors detect the temperature of your skin. This activates a sensory neurone, which sends nerve impulses to the spinal cord.

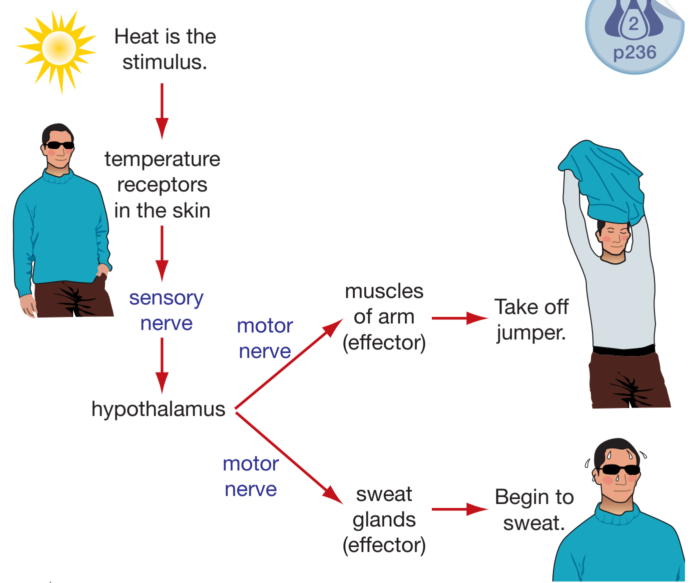


Figure 7.1.15 This stimulus–response diagram represents your body's reaction to being too hot.

Within the spinal cord, a relay neurone passes the message directly to a motor neurone, which sends impulses to the arm muscles, which are the effectors. The arm muscles contract, lifting your hand away from the hot object. A message is sent to the brain shortly afterwards. Only then can the brain register pain. The nerve pathway operating in a reflex action is called a reflex arc. Figure 7.1.16 shows an example of a reflex arc. Most reflex actions involve only a few neurones and are therefore very rapid.

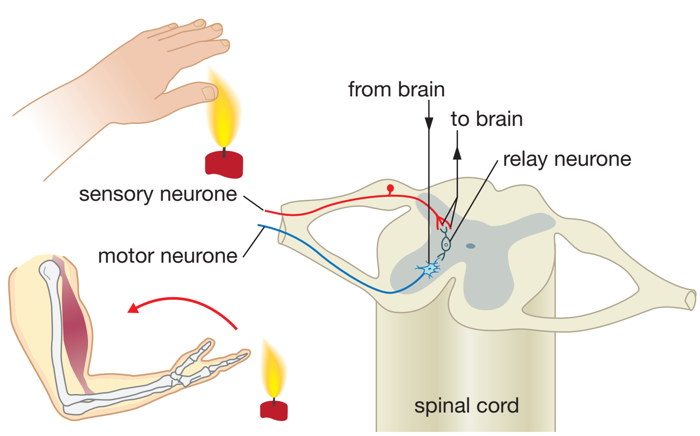


Figure 7.1.16 The reflex arc allows you to react very rapidly to protect your body from harm.

SCIENCE AS A

HUMAN ENDEAVOUR

Use and influence of science

The bionic ear and eye

Figure 7.1.17 A cochlear implant

The cochlear implant or 'bionic ear' was developed by an Australian scientist, Professor Graeme Clark.

The bionic ear

Professor Clark (Figure 7.1.18) was born in country New South Wales in 1935. His father was partially deaf, and this sparked Professor Clark's interest in the causes of deafness. He became a surgeon, specialising in otolaryngology, which is the study of diseases of the ear and throat. There was very little money available for his research, as most people believed it was impossible to restore hearing to the deaf.

Figure 7.1.18 Professor Graeme Clark (right) developed the cochlear implant, which allows some deaf people to hear again.

The cochlear implant (shown in Figure 7.1.17) mimics the way that the cochlea receives sounds. A microphone and a speech processor are placed behind the ear. They pick up sounds and turn them into electrical signals. These signals pass into the implant, which is placed in the skull and connected to the cochlea. The cochlea then stimulates the auditory nerve to send messages to the brain.

In 1978, Clark successfully implanted the first bionic ear into a man named Rod Saunders, who had lost his hearing in a car accident. Clark's success has been recognised worldwide.

The Australian bionic ear (shown in place in Figure 7.1.19) has now provided hearing to more than 150 000 people in more than 120 countries.

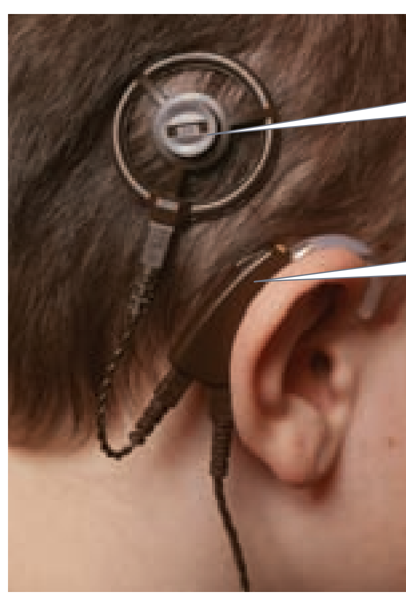


Figure 7.1.19 The bionic ear is worn behind the ear.

The bionic eye

The bionic eye is being developed by Bionic Vision Australia researchers at the University of New South Wales.

About 1.5 million people worldwide have a disease called retinitis pigmentosa, and about one in 10 people over the age of 55 have age-related macular degeneration. Both diseases cause cells in the retina of the eye to gradually die and the person becomes vision impaired or blind.

The bionic eye is still in the experimental stage, but it is hoped that it will be able to help people with these conditions. The bionic eye is a device that consists of a camera attached to a pair of glasses. How the device works is described in Figure 7.1.20.

One version of the bionic eye is designed to enable a person to distinguish light from dark. This will help the person move around large objects such as buildings, parked cars and benches or rubbish bins on footpaths.

A second version of the bionic eye will have many more electrodes. With it, the person may be able to recognise faces and read large print (Figure 7.1.21).

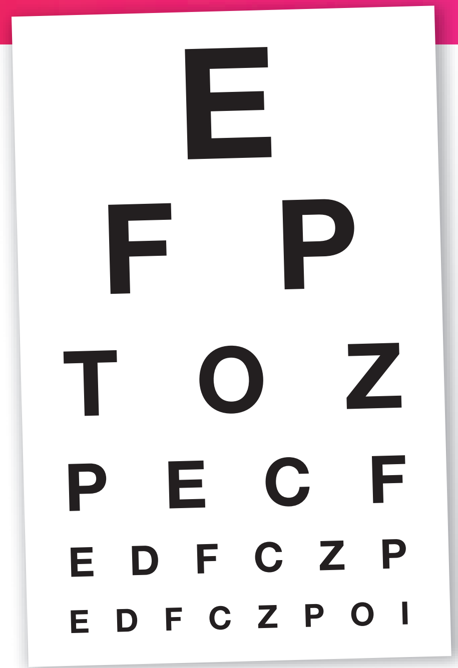


Figure 7.1.21 It is hoped that people fitted with the second version of the bionic eye will be able to read the letters on the third line of a Snellen Chart, such as the one shown here.

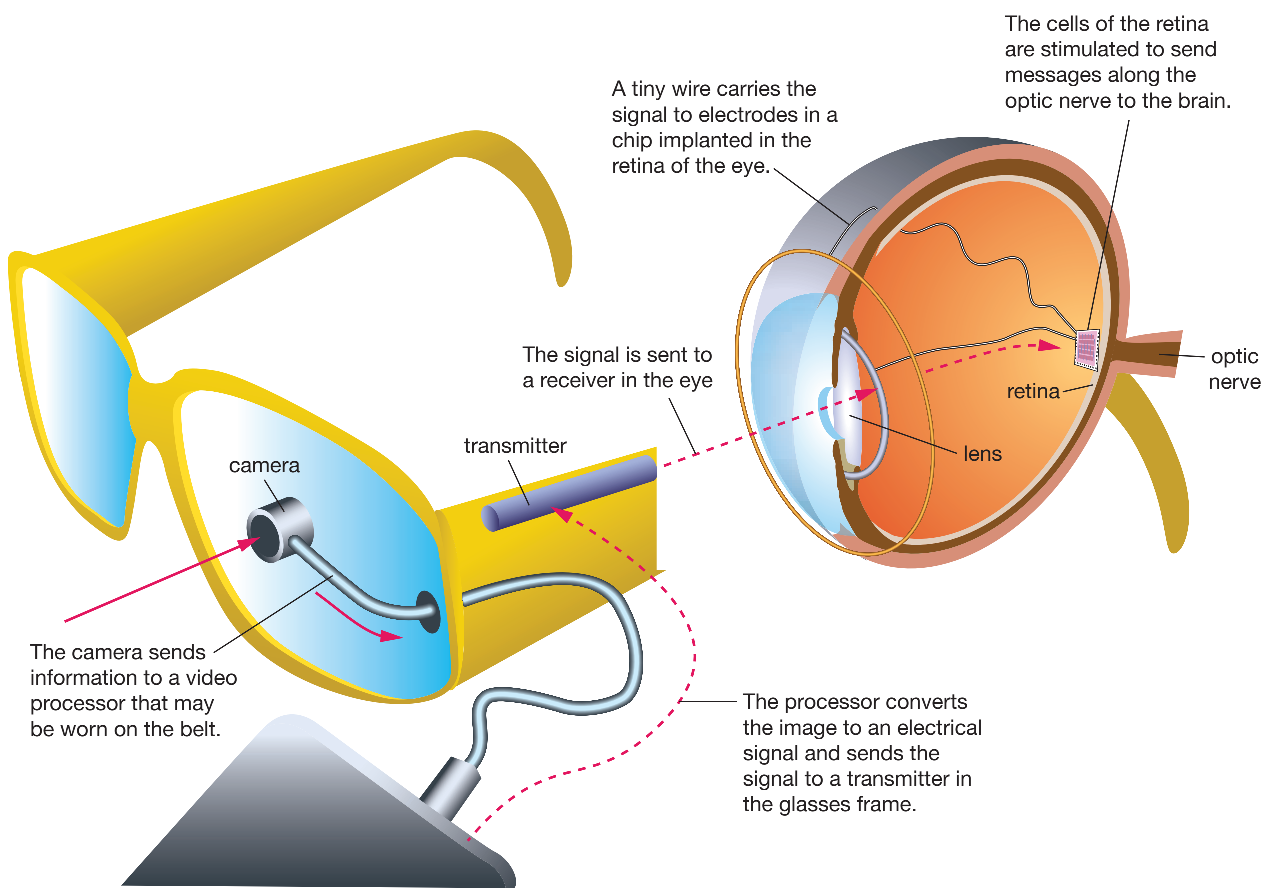


Figure 7.1.20 How a bionic eye works

7.4

7.1 Unit review

Remembering

1 **Name** the three main parts of a neurone.

2 **List** the parts of the central nervous system.

3 **Name** the layer of insulation found on nerves.

4 **List** three types of receptors found in skin.

5 **Name** two parts of the autonomic nervous system.

Understanding

6 a **Describe** the function of dendrites.

b **Explain** how their structure suits their function.

7 **Explain** why an injury to the left side of the brain often affects the right side of the body.

8 **Describe** an example of how your brain controls an activity inside your body without your knowing about it.

9 **Describe** the function of neurotransmitters.

Applying

10 **Use** a diagram of a reflex arc to **outline** how your foot is pulled away from a sharp object before you are aware of it.

Analysing

11 **Contrast** the sympathetic and parasympathetic nervous systems.

12 **Compare** the roles of a sensory neurone and a motor neurone.

13 **Contrast** a stimulus and a response.

14 **Compare** the roles of receptors and effectors.

Evaluating

15 **Propose** why severe damage to the neck region is often fatal.

16 **Propose** why many quadriplegic patients who are paralysed from the neck down can still maintain normal body functions such as breathing and digestion.

17 During a medical test called a PET scan, a sugar solution containing a radioisotope is injected into the patient. The most active brain cells use the most sugar, and so they absorb more of the radioisotope. A picture of the brain's activity is produced, based on where the radioisotope collects. **Deduce** how a PET scan could be used to determine whether a person's brain is functioning normally.

Creating

18 a **Construct** a model of a neurone. Materials you could use include string, balloons and drinking straws.

b **Label** the parts of your model.

c **Explain** why you selected the materials you did, for each part.

19 **Construct** a model of the semicircular canals in your ears to demonstrate how they provide the information you need to keep your balance.

Inquiring

1 Multiple sclerosis is a disease of the nervous system. Research the cause of the disease, the effect it has on the body, and current research being undertaken to find a treatment or cure.

2 Spina bifida is a birth defect that involves damage to the spine and spinal cord. Compare the spine and spinal cord of a person with spina bifida with those of a person without spina bifida. Describe the effects of these differences.

Figure 7.1.22

Child with spina bifida

7.1 Practical activities

1 Sensitivity

Purpose

To investigate whether touch receptors are evenly distributed in the skin.

Note: When the subject feels two pin pricks from two pins placed 2 mm apart, two nerves have been stimulated. This means that the receptors are no more than 2 mm apart. Feeling only one pin prick indicates fewer receptors, spaced more widely.

Materials

- cork
- three pins

SAFETY

The pins should just touch the surface of the skin. They should not be pressed hard enough to cause pain.

Procedure

1. Push the two pins through a cork so that the points are 2 mm apart.
2. Push the third pin through in a position that will enable the tester to use the same cork to test the skin with only one pin. See Figure 7.1.23.

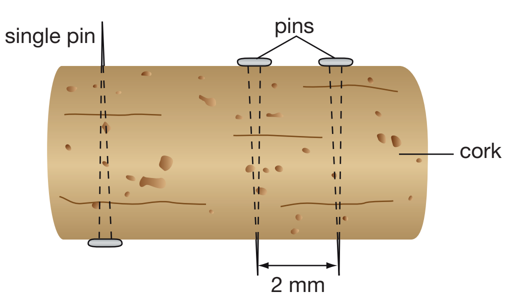


Figure 7.1.23

3. Work in pairs to test different surfaces of the body. One student is the tester. The other is the subject.
4. Holding the pins upright, the tester gently touches the skin of the subject. Test sometimes with one pin and sometimes with two.
5. Test various parts of the body, such as the:
   - back of the hand
   - palm of the hand
   - fingertips
   - upper arm
   - back of the neck.
6. When the pins touch the skin, the subject should indicate whether they can feel two points or one.
7. Test each part of the body five times, sometimes with one pin and sometimes with two pins.
8. The tester records the results, noting carefully whether one or two pins were used in the test.
9. The tester and the subject can change places and repeat the experiment.

Results

Construct a table to record your results.

Discussion

1. **Compare** the sensitivity of the various parts of your body. (Remember, it is only the pricks with two pins that will indicate levels of sensitivity.)
2. **Analyse** the relationship between the level of sensitivity and the function of the body part.
3. **Draw** conclusions about the distribution of touch receptors in your skin.

Extension

Temperature receptors in the skin can detect heat gain (warmth) and heat loss (cold). Design an experiment to investigate the distribution of temperature receptors in the skin. Before you begin, determine exactly what you want to test (warm, cold or both) and how you will do this. Record you results and compare these with the distribution of skin receptors.

2 Reaction times

Purpose
To calculate the reaction time for a simple task.

Materials
- metre ruler

Procedure
1. Work in pairs.
2. The person being tested (the subject) should sit with their elbow resting on the edge of a table.
3. The other person (the investigator) holds the ruler by the 100 cm mark so that it hangs vertically, with the 0 cm mark between the thumb and forefinger of the subject (Figure 7.1.24).

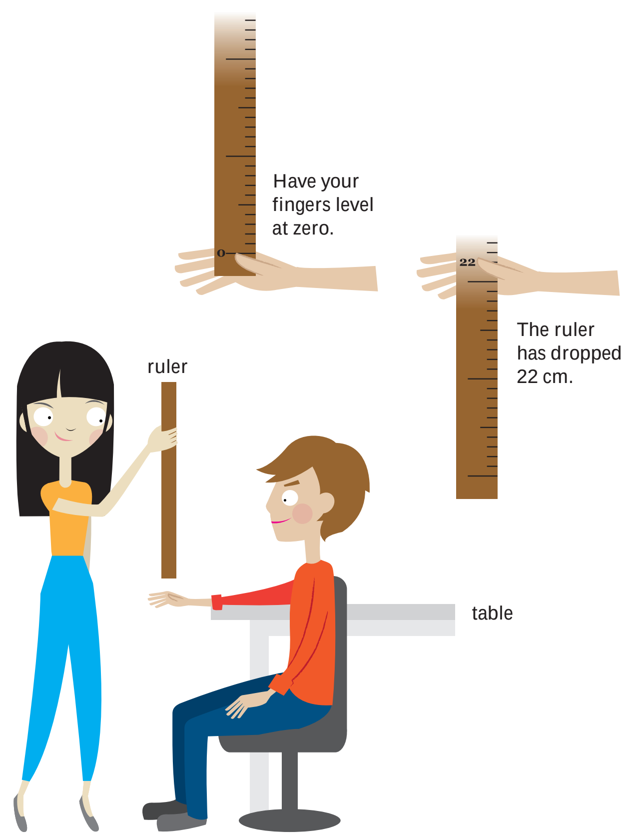


Figure 7.1.24

4. When the investigator releases the ruler, the subject tries to catch it as quickly as possible, using just their thumb and finger.
5. Record the distance the ruler has fallen, and convert it to 'time' using the graph shown in Figure 7.1.25.

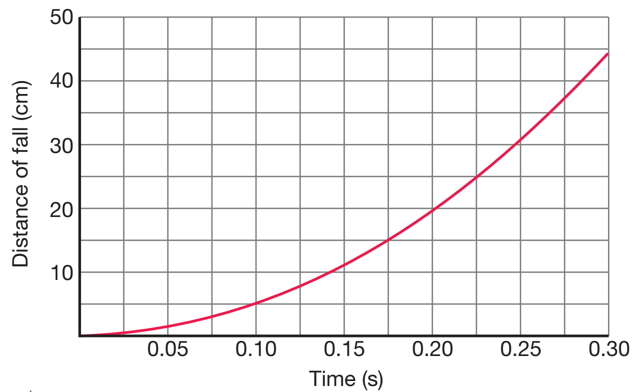


Figure 7.1.25 Graph of reflex time versus distance

6. Repeat the experiment five times to determine an average reaction time. You may wish to compare the times for left and right hands.

Results
Enter the data into a suitable table or spreadsheet, and calculate the average reaction time.

Discussion
1. a **Compare** your reaction time with those of other students.
   b **Propose** reasons for any differences.
2. **Interpret** your results to decide whether your reflexes improved with practice.
3. **Propose** how factors such as fatigue, alertness or distractions might affect your reaction time.
4. a **Describe** how your approach to catching the ruler changed as the experiment progressed.
   b **Propose** why these changes took place.

7.2 Chemical control

Your body has a second type of communications system—a system that reacts more slowly than the nervous system. In this system, chemicals are the messengers and the bloodstream is the pathway along which they travel. This system is the endocrine system and the chemicals are hormones. Hormones are responsible for the significant changes of puberty but they are also involved in less obvious ways on a daily basis throughout your life.

Endocrine system

Hormones are chemical substances that act as messengers in the body. They are produced in **endocrine glands** scattered throughout the body. Together all these glands form the **endocrine system**.

The endocrine system is coordinated by the **pituitary gland**, which responds to information from the hypothalamus. The **hypothalamus** is a portion of the brain and is made of nerve tissues. You can see its location in the brain in Figure 7.2.1. It constantly checks the internal environment—that is, the conditions within the tissues, organs and systems of your body. If these conditions change, the hypothalamus responds.

The most important function of the hypothalamus is to link the nervous system and the endocrine system. It secretes hormones that act on the pituitary gland. The pituitary gland responds by either secreting other hormones or producing less of the hormones. Through its action on the pituitary gland, the hypothalamus controls important aspects of the body such as body temperature, rate of metabolism and water content.

The pituitary gland is often called the 'master gland' because it controls the activities of other endocrine glands such as the ovaries, the testes and the thyroid gland. It is about 1 cm in diameter.

INQUIRY science 4 fun

I'm scared

What changes happen in your body when you are surprised or frightened?

Yes

Do this …

Ask a family member or friend to give you a surprise or fright.

Record this …

Describe the changes in your body.

Explain why these changes occurred.

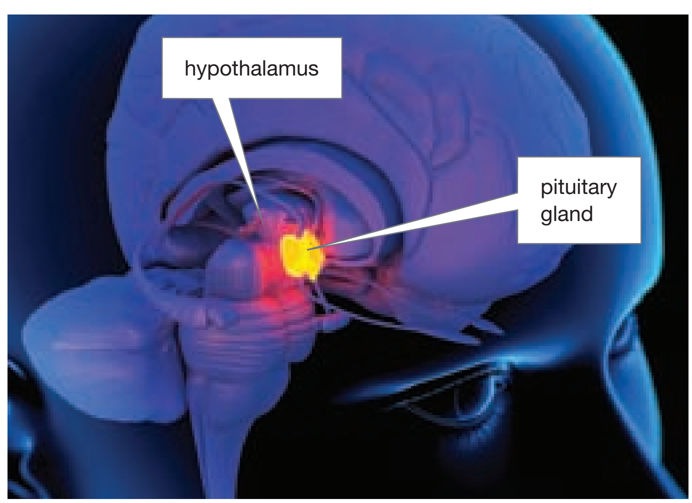


Figure 7.2.1 Two parts of the endocrine system: the hypothalamus, and the pituitary gland that attaches to it. These are located deep within the skull, where they are well protected.

Endocrine glands release their hormones directly into the bloodstream and are referred to as 'ductless' glands. The main endocrine glands of the body are shown in Figure 7.2.2.

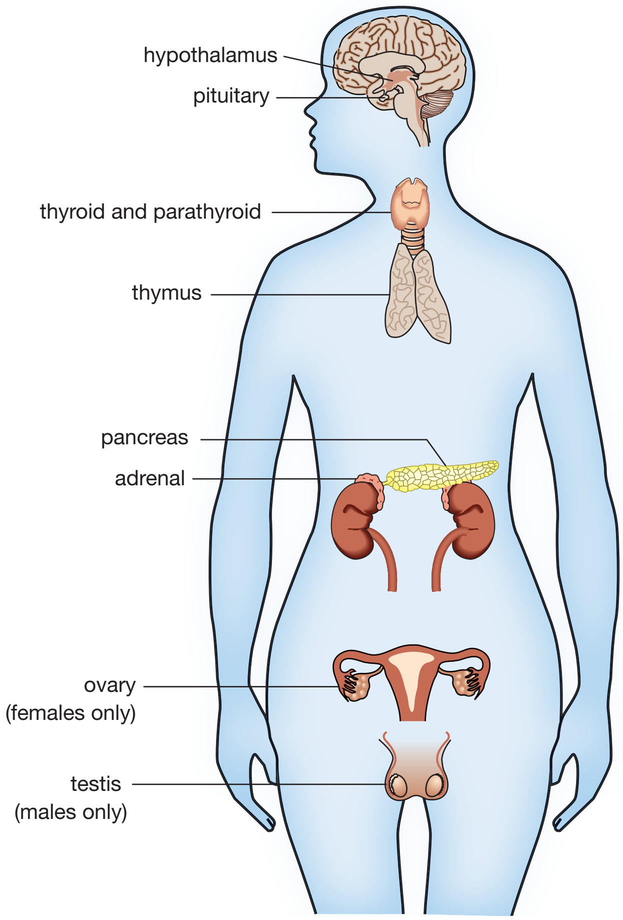


Figure 7.2.2 The main human endocrine glands

How hormones work

Hormones are produced in very small amounts and travel through the blood, reaching all your body cells. However, they do not affect all the cells. Hormones are specific. This means that they only act on particular cells in the body. These are the **target cells**.

Different hormones have different chemical structures. This means that their shape varies. It is the shape of the hormone that makes it specific. Within cells are receptors. A hormone is only active in cells that have receptors that fit the shape of the hormone (Figure 7.2.3).

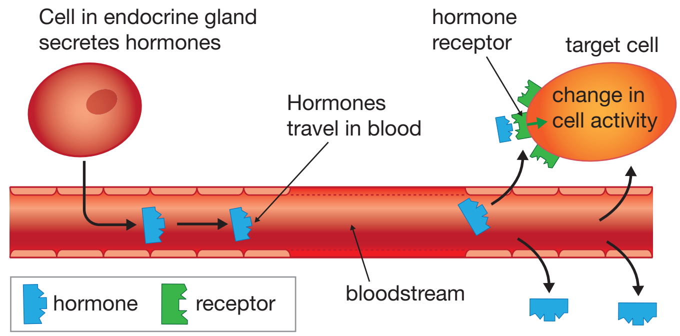


Figure 7.2.3 Hormones are only active in cells where the shape of the hormone and the shape of the receptors fit together like pieces of a jigsaw.

Controlling the internal environment

Your body works most efficiently when the internal environment is reasonably constant. This means that factors such as temperature, water content, available energy, available oxygen and concentration of wastes in the blood are all controlled. The process of maintaining a constant internal environment is known as **homeostasis**.

Homeostasis involves receptors that are sensitive to a particular stimulus, and effectors that have an effect on the same stimulus.

To understand this, consider a reverse-cycle air conditioner like the one shown in Figure 7.2.4 as an example of a machine that maintains a constant environment. A sensor called a thermostat is set at a particular temperature range, such as 21–23°C. If the temperature of the room goes above 23°C, the air conditioner switches on and cools the room until the required temperature is reached. The sensor detects this and then the air conditioner switches off until it once more detects a rise in temperature. If the sensor detects a lower temperature than 21°C, the heating system turns on. The temperature in the room rises and the heater turns off once the set temperature range of 21–23°C is reached.

1 p243

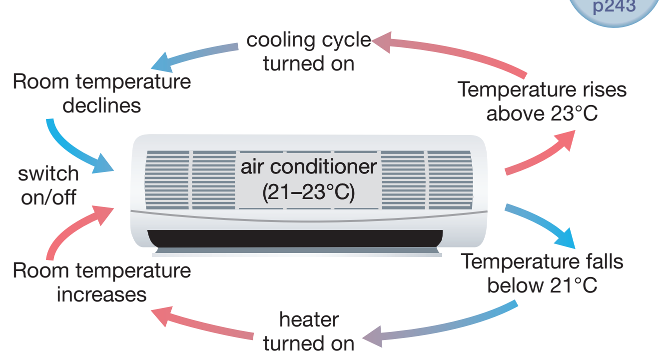


Figure 7.2.4 A reverse-cycle air conditioner maintains a preset temperature in a room by heating or cooling the air in response to temperature detectors.

Controlling body temperature

Digestion, growth and repair, respiration and manufacture of hormones are some of the chemical reactions taking place inside your body. All these reactions together are known as your **metabolism**. The heat they produce as a by-product maintains your body temperature regardless of the temperature of your surroundings. This is illustrated in Figure 7.2.5. Because you can maintain a constant body temperature, you are said to be **endothermic**. However, if the temperature inside your body was to increase by more than a few degrees above 37°C, your metabolism would stop, and you would die. If your body temperature fell below 37°C, your metabolism would slow down.

Figure 7.2.5

Your body temperature stays the same regardless of the temperature of the environment. There are things you can do to help your body, such as adding clothing when it is cold, and removing clothing and using shade when it is very hot.

Hormonal control of temperature

The hypothalamus acts on the pituitary gland to control body temperature through the action on another endocrine gland—the thyroid gland.

The hypothalamus receives information from temperature receptors in the skin and from internal structures including the hypothalamus itself.

If the hypothalamus detects a fall in body temperature, it produces a hormone that causes the pituitary gland to secrete more thyroid-stimulating hormone (TSH). TSH stimulates the thyroid to release more of the hormone thyroxine. Thyroxine travels in the blood to all cells and causes the rate of metabolism in the cells to increase. Increased metabolism generates more heat and warms the body.

Producing the hormones that cause these changes takes time, and therefore the endocrine system does not have immediate control of body temperature.

Nervous control of temperature

Body temperature is also controlled by the nervous system and this is a more immediate response. When the hypothalamus detects a drop in temperature, it sends nerve impulses to muscle groups around vital organs such as the heart and lungs. Small shaking movements begin in these muscles. Eventually the shaking movements extend to the large muscles of the arms and legs, and you begin to shiver. Shivering increases the activity of muscle cells, producing heat and raising body temperature. This is the body's way of creating warmth by using energy.

Another aspect of nervous control is the process that reduces blood flow to your skin when you are cold. The sympathetic nervous system causes a narrowing of the blood vessels near the surface of the skin. This reduces blood flow and therefore heat flow to the skin. If the external temperature is very cold, the blood flow to the extremities (fingers, toes, nose and ears) is reduced further and you can lose feeling in them—your toes and fingers go numb.

When the hypothalamus detects a rise in body temperature, nerve messages are sent to the sweat glands and blood vessels. Blood vessels close to the skin dilate (increase in diameter) so that more blood (carrying heat) can reach the skin surface. The extra blood near the surface makes your skin more red.

The message from the hypothalamus causes the sweat glands to produce more sweat (Figure 7.2.6). Heat from your body causes the sweat (which is mostly water) to evaporate. The rate at which heat is lost by evaporation depends on the difference in temperature between the body and the surrounding air, and the relative humidity of the air.

2 p243

7.5

One litre of sweat, when it evaporates, removes about 209 kJ of heat from the body.

Figure 7.2.6

It takes a lot of heat to evaporate a small amount of water. This makes sweating a very effective cooling mechanism.

Water balance

The kidneys are important organs in homeostasis. They control both salt and water balance within the body. You take in water and salts through food and drink. The body also manufactures about 350 mL of water per day as a product of cellular respiration.

You lose some water in the air you breathe out. You lose water and salts through sweat and in the faeces you produce; however, most salts and water are lost through urine. The body needs to balance its losses and gains. The kidneys are the organs that control the amount of water and salt lost. The balance between gains and losses is shown in Figure 7.2.7.

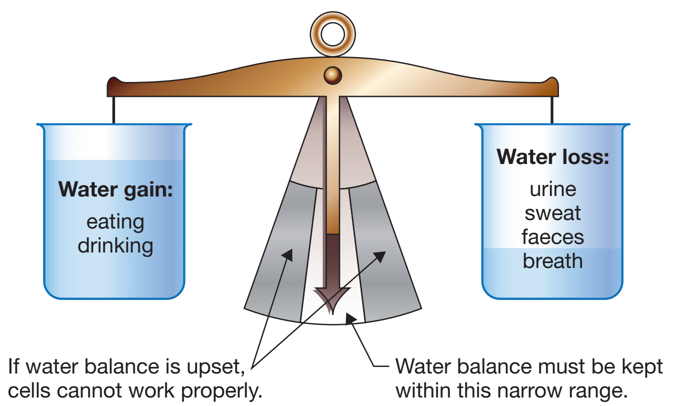


Figure 7.2.7 Gains and losses of water by the body must be balanced. If there is too much or too little water in the body, it will not function correctly.

About a quarter of the blood from every heartbeat passes through the kidneys—about 50 litres/hour. Of this about 7 litres is processed by millions of microscopic filters within the kidney. These filters remove harmful wastes (such as urea), salts and water from the blood. The kidney returns to the blood the salts, glucose and water needed by the body. Wastes, excess salts and excess water pass from the kidneys into the bladder, where they are stored before being released from the body as urine.

If you drink a lot more water than your body requires, you produce large amounts of light-coloured, dilute urine. If your water intake is inadequate, you produce dark-coloured, concentrated urine. The amount of water in urine is controlled by **antidiuretic hormone (ADH)**. ADH causes the kidneys to reabsorb water directly from the renal tubules of the kidney. Salts and waste products are concentrated in the liquid, which will eventually become urine. ADH is secreted by the pituitary gland under the control of the hypothalamus.

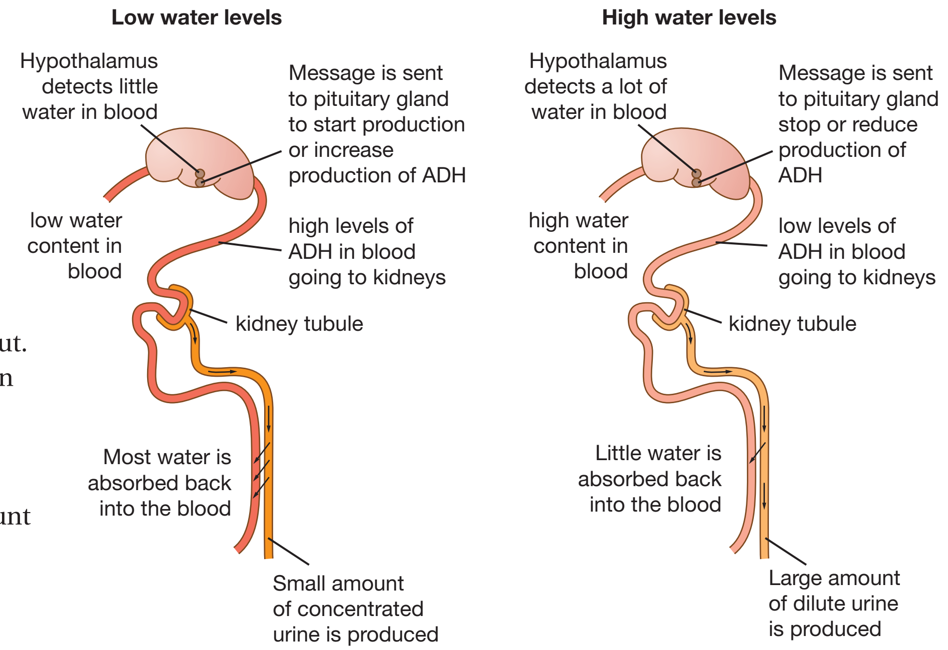


Figure 7.2.8 The volume of urine excreted by the kidneys is controlled by antidiuretic hormone (ADH) in a negative feedback system.

The hypothalamus monitors the volume of blood passing through it and the concentration of water in the blood. Dehydration increases the production of ADH and water is retained in the body.

Figure 7.2.8 illustrates the relationship between the parts of the body involved in water balance. Figure 7.2.9 demonstrates the feedback system involved in this process.

7.7

7.8

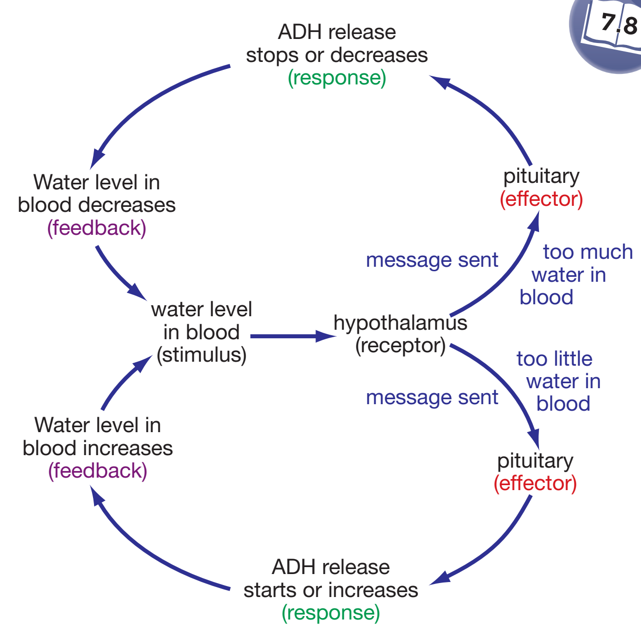


Figure 7.2.9 Homeostasis is achieved using negative feedback systems. In this type of system the response of the system (in this example the amount of ADH produced) works to change the inputs to the system (in this case the amount of water in the blood).

Blood sugar control

To provide energy for your body throughout the day, your cells need a continuous supply of glucose for cellular respiration. Too much glucose makes your blood thick, meaning that it can move only slowly through your blood vessels. Too little glucose makes you feel dizzy because you have insufficient energy. Glucose is carried around the body dissolved in the blood plasma. It enters the blood from the digestive tract and is absorbed by most body cells. Despite this intake and usage, glucose levels in the blood remain fairly constant at about 0.8–1 mg/mL. The steady concentration is due to the action of two hormones: insulin and glucagon (Figure 7.2.10). These hormones are made by groups of specialised cells in the pancreas, called 'islets'.

An increase in blood glucose levels after eating is detected by receptors in the pancreas. The pancreas then releases the hormone **insulin**. Insulin causes the liver and muscles to extract glucose from the bloodstream and convert it into a larger molecule called **glycogen**. The glycogen is stored in the liver and glucose levels in the blood are reduced.

When glucose is taken from the bloodstream during activity, the pancreas detects this and responds by releasing another hormone, called **glucagon**. Glucagon has the opposite effect to insulin. So, by the controlled release of the two hormones, glucose levels are kept fairly constant.

People with the disease diabetes are either not able to produce insulin or their tissues are not able to respond to it.

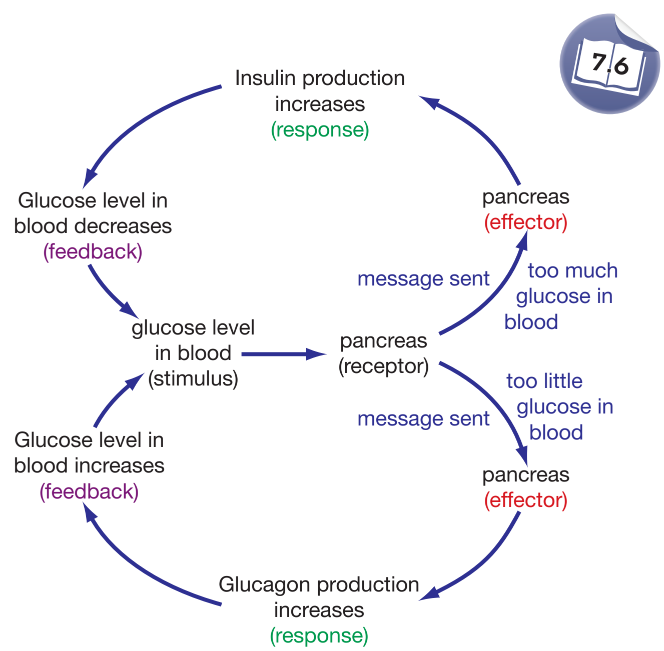


Figure 7.2.10 Control of glucose in the blood is by a negative feedback system. The body responds to increased glucose levels in the blood by producing insulin. Insulin causes glucose to be removed from the blood. When glucose levels in the blood fall, glucagon allows the glycogen in the liver to be released and glucose is returned to the blood.

Responding to stress

If you are in a frightening or stressful situation, your nervous system registers this and sends messages to the **adrenal glands** situated on your kidneys. They produce a hormone known as **epinephrine** (commonly called **adrenalin**).

Epinephrine causes your heart rate to increase, blood vessels to contract and air passages to dilate (open up). This reaction of the body to adrenalin makes you more alert and prepares your body to act in an emergency. The response is triggered by the sympathetic nervous system.

Nearly all the body tissues are target cells for epinephrine. However, the effect of the hormone varies from tissue to tissue. The smooth muscles of the airway relax, allowing more oxygen to be taken into the body. But the smooth muscles of the blood vessels contract, increasing blood pressure.

Epinephrine inhibits insulin secretion by the pancreas. Glucose therefore remains in the blood where it can be taken up by the cells, especially muscle cells, and used to release energy.

Figure 7.2.11 Both your nervous system and your endocrine system react to stress and fear. People with large amounts of epinephrine in their bloodstream can do things they would not normally be able to do, such as leap over a fence.

Once the hormones have done their job and the frightening situation is past, the hormones break down quickly. Constant high levels of this hormone in the body can do harm.

7.2 Unit review

Remembering

1 **Recall** the term used to describe the cells that respond to hormones.

2 **Name** the hormones that control glucose levels in the blood.

3 **List** three endocrine glands and the hormones they produce.

Understanding

4 **Define** the term *homeostasis*.

5 **Describe** the relationship between:
  a hormones and the endocrine system
  b the pituitary gland and the hypothalamus
  c antidiuretic hormone and the colour of urine.

6 **Explain** why sweating is an efficient way for the body to lose heat.

7 a **Explain** why it is important that your body temperature remains constant.
  b **Describe** two involuntary reactions that keep your temperature from rising.
  c **Describe** one involuntary reaction that prevents your body temperature from falling.

Applying

8 a **Identify** the endocrine glands labelled A, B and C in Figure 7.2.12.
  b **Identify** by its letter the gland that produces the hormone that controls the concentration of glucose in the blood.

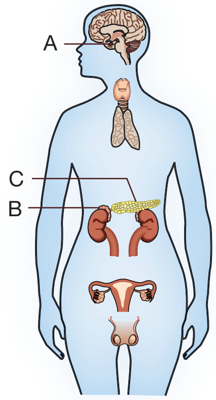


Figure 7.2.12

9 About 7 litres of blood is filtered by the kidneys in every hour. **Calculate** the number of times your blood would be filtered each day. Assume you have 5 litres of blood.

Analysing

10 **Compare** the way that glucose levels and temperature are controlled in the body.

11 **Discuss** the need for two hormones to control glucose levels in the blood rather than just one.

Evaluating

12 **Use** the information in the table below to **propose** differences there would be if the data came from a person who:
  a ate a lot of salty food
  b had been out in the sun for a long time
  c ate a large amount of sugar.

Substance	Amount in blood (%)	Amount in urine (%)
Water	90–93	95
Glucose	0.1	0
Salts	0.37	0.6
Urea	0.03	2

13 **Propose** why it is important that glucose is not excreted in urine.

14 The changes in hormones in response to an increase in body temperature are described on page 239. The changes in response to a fall in body temperature are not described. **Propose** what these changes might be. There are no different hormones involved.

Creating

15 a **Construct** a sketch-line graph showing the expected changes in your blood glucose levels after eating some lollies.
  b **Describe** what is causing the glucose levels to change.

16 **Construct** a flow diagram showing the reaction of your body to fear.

Inquiring

1 Find out how epinephrine is used to treat heart attack and allergic reaction.

2 Research the functions of the thyroid gland and the effects of having an overactive or underactive thyroid.

7.2 Practical activities

1 Model feedback system

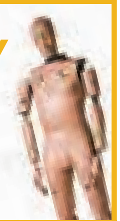
Purpose

To demonstrate a feedback system, using people.

Materials

- blindfold
- chairs and desks to create an obstacle course, or an area of the school that includes some obstacles

SAFETY



Do not put the subject into any dangerous situations.

Procedure

1 Work in pairs. One person is the controller and the other is the subject.

2 The subject is blindfolded and follows the course in response to commands provided by the controller.

3 The controller directs the subject as quickly and accurately as possible around the course using only the commands 'left' or 'right'.

4 On completing the course, the controller and the subject change position. In this second trial the controller may also use the words 'forward', 'back' and 'stop'. This represents a more sophisticated form of feedback.

Discussion

1 **Propose** what is being controlled in this system.

2 a **Compare** a natural feedback system with this model.

b **Identify** the part represented by the controller.

c **Identify** the part represented by the subject.

3 **Compare** the success of the feedback system in the first trial with the second trial, when more information was provided to the subject.

4 **Assess** the model as a representation of a natural feedback system such as temperature control or level of glucose in the blood.

2 Changing temperature

Purpose

To investigate the effect of exercise on body temperature.

Materials

- electronic clinical thermometer (if available, data-logging equipment could be used for this experiment)
- area of the school where students can run

SAFETY

Students with health problems may not be able to take part in this experiment.

Procedure

1 Work in pairs. One person is the subject and the other is the recorder.

2 Record the skin temperature of the subject at the start of the experiment. *Note*: Measure the skin temperature by holding the thermometer inside a bent elbow. Measure the internal temperature at the ear using an electronic clinical thermometer.

3 The subject undertakes 10 minutes of vigorous exercise, enough for them to feel hot and possibly turn red in the face.

4 Record the skin temperature and the internal temperature of the subject.

5 Observe and record any other changes resulting from the exercise.

Results

Record all measurements and observations.

Discussion

1 **Describe** the changes to the skin temperature during the experiment.

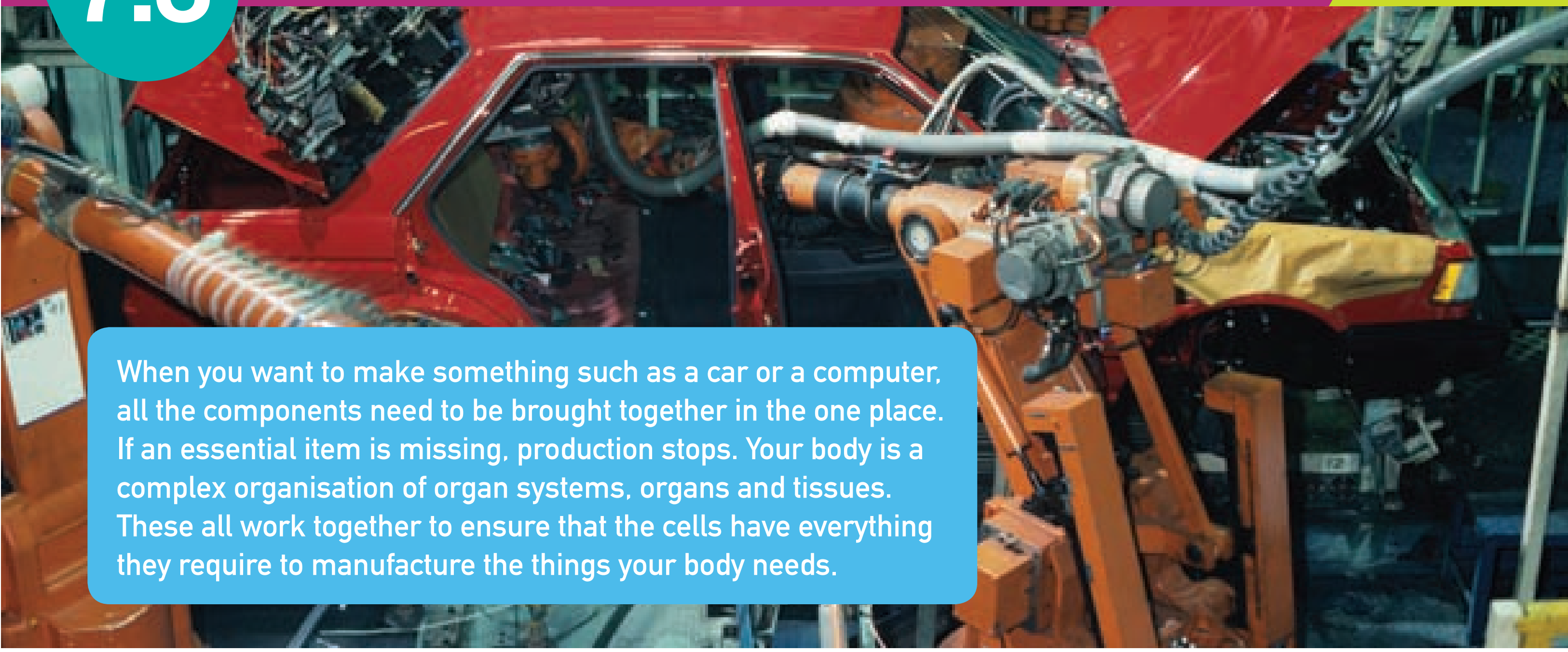
2 **Describe** the changes to the internal body temperature during the experiment.

3 **Compare** the changes in skin temperature with the changes in internal body temperature.

4 **Describe** any other changes that were observed.

5 **Propose** ways in which these other changes could contribute to the observed changes in temperature.

7.3 Coordinated body systems



When you want to make something such as a car or a computer, all the components need to be brought together in the one place. If an essential item is missing, production stops. Your body is a complex organisation of organ systems, organs and tissues. These all work together to ensure that the cells have everything they require to manufacture the things your body needs.

INQUIRY science 4 fun

It smells!

How long does it take for a scent to travel across a room?

Yes

Collect this …

- spray can of perfumed deodorant or air freshener
- partner
- stopwatch or watch with a second hand

Do this …

1. Close all the windows and doors in the room to reduce air movement.
2. You stand on one side of the room facing the wall with your eyes closed.
3. Your partner gives a short spray of deodorant into the air and records the time.
4. You call out as soon as you can smell the scent. Record the time.
5. Repeat the experiment using twice the amount of deodorant. However, you will have to wait until all the scent has cleared from the room before you do this.

Record this …

Describe what happened.

Explain why you think it happened.

Metabolism

Within your cells, a large number of chemical reactions take place. Collectively these reactions are known as metabolism—the chemical processes that maintain life and allow organisms to grow and reproduce, maintain their structures and respond to their environments.

The chemical reactions of metabolism are divided into two groups:

- reactions that break down organic matter—examples include respiration, which breaks down the glucose molecule to releases energy, and the breakdown of wastes into harmless substances for excretion
- reactions that build complex molecules from simpler substances—an example is the construction of new cells and cell components such as proteins and genetic material (Figure 7.3.1).

Figure 7.3.1

These plants are able to grow because their metabolism builds simple chemicals into the complex components of new cells.

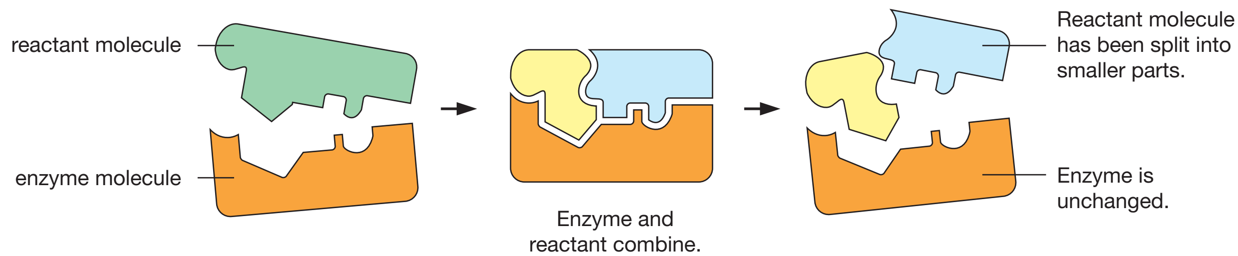


Figure 7.3.2 The 'lock-and-key' model explains the action of enzymes. In this diagram a larger molecule has been split into smaller ones. The opposite reaction can also occur with other enzymes, where smaller molecules are joined to form a larger one.

Enzymes

All the reactions in your body are helped along by **enzymes**. These are organic **catalysts**—substances that speed up the rate of a reaction without being used up in the process. Without the help of enzymes, many reactions would occur too slowly to maintain life.

There are over 700 enzymes in the human body and each one is specific to one particular chemical reaction. Scientists have constructed a model of how enzymes work. This model is known as the 'lock-and-key' model, shown in Figure 7.3.2.

Each enzyme has a particular shape that allows it to attach to a specific molecule that is going to be changed by the chemical reaction—the **reactant molecule**. In a reaction, the enzyme and the reactant molecule (or molecules) join together and the reactant molecules are then changed in some way.

1 p252

That's fast!

Enzymes can increase reaction speeds by up to ten billion times. That's like taking a minute to do something that otherwise would take 18 000 years!

SciFile

Getting nutrients

The source of many of the raw materials your body needs for metabolism is the food you eat. When you chew on an apple or a slice of bread, the nutrients it contains are needed by your body but they are not always in a form that your body can use. It is the job of the digestive system to chemically change the complex molecules in the apple and the bread into simple chemical substances your body can use.

The food you eat contains complex carbohydrates, proteins and lipids. Through the reactions of chemical digestion they are progressively broken down, so that when the food reaches the small intestine it is in the form of simple chemical substances.

Figure 7.3.3 The nutrients in the food you eat are not in a form that can be used by the body. They have to be changed chemically by the digestive system.

- Carbohydrates are broken down into glucose.
- Proteins are broken down into amino acids.
- Lipids (fats and oils) are broken down into fatty acids and glycerol.

These simple chemical substances are small enough to pass through the thin walls of the villi lining the small intestine, through the thin walls of capillaries and into the bloodstream, as shown in Figure 7.3.4.

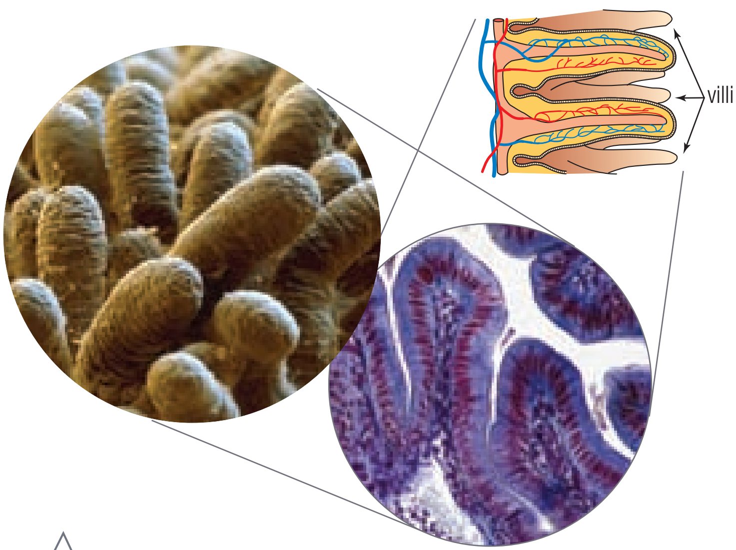


Figure 7.3.4 Villi are small projections on the wall of the small intestine. They greatly increase the surface area through which nutrients can be absorbed.

Diffusion

The simple chemical substances produced by digestion are very small particles. They move by diffusion through the cells of the villi and capillaries. **Diffusion** is the movement of particles of a substance from an area of high concentration of that substance to an area of low concentration of that substance. In simpler terms it means that the particles move from an area where there is a lot of that type of particle to an area where there is not much at all. Diffusion takes place in liquids and gases where the particles have enough energy to move around.

Figure 7.3.5 models how diffusion works. The particles are moving around, bumping into each other on both sides (A and B). However, they are separated from one another by the barrier. Side A has a higher concentration of red particles than side B. Side B has a higher concentration of yellow particles than side A. If the barrier between the two sides is removed, then the particles can move freely. More red particles move to the right than to the left. Eventually the red particles are evenly distributed across the whole area. In the same way, more yellow particles move to the left and eventually are evenly distributed across the whole area, as shown in the lower part of Figure 7.3.5.

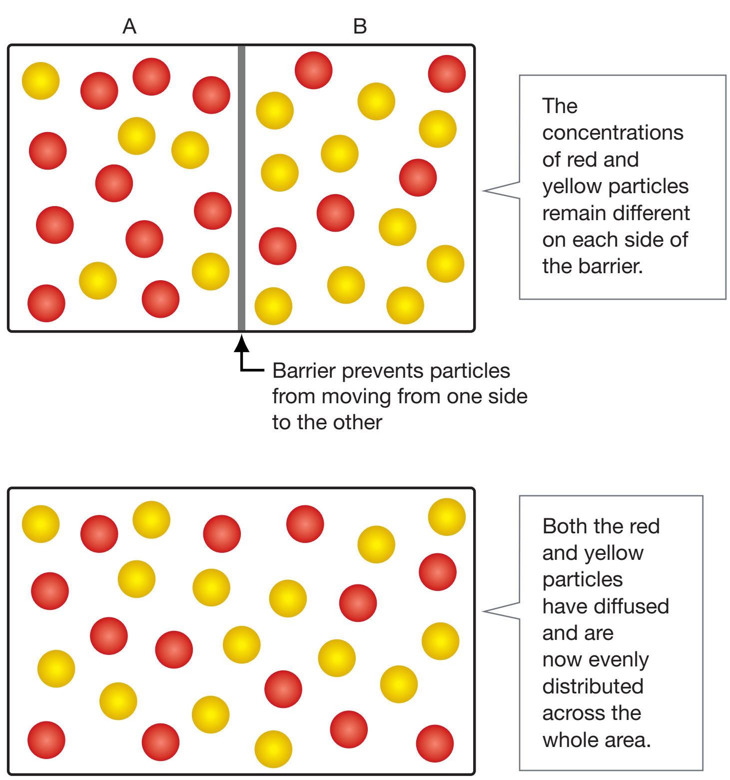


Figure 7.3.5 The process of diffusion

After eating, there are high concentrations of glucose, amino acids, fatty acids and glycerol in the small intestine. In the bloodstream there are low concentrations of these molecules. Most of the molecules move by diffusion from the small intestine into the blood capillaries in the villi.

The flow of blood in the capillaries quickly carries the digested materials away, so there is always a higher concentration in the small intestine and lower concentration in the blood, and diffusion continues.

2 p253

Getting oxygen

The air you breathe enters your respiratory system through your nose and mouth. It passes down the trachea, bronchi and bronchioles, ending up in the alveoli. The walls of the alveoli are only one cell thick and are surrounded by blood capillaries (Figure 7.3.6). Oxygen dissolves in the moist surface of the alveoli and moves by diffusion across the short distance from the space inside an alveolus to the blood.

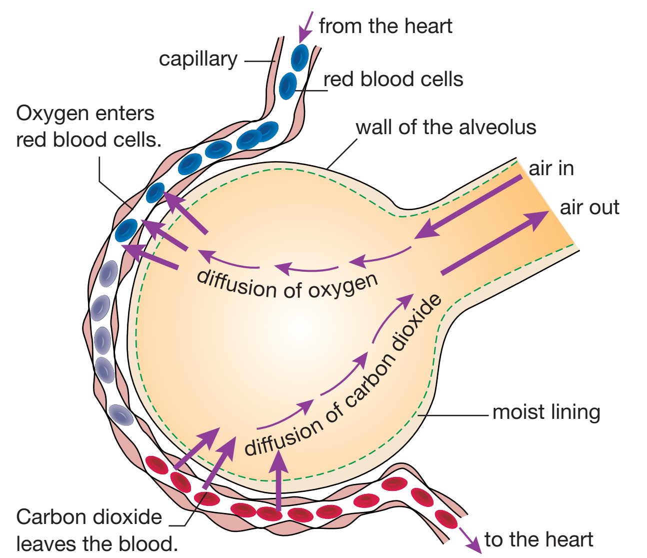


Figure 7.3.6 The walls of the alveoli are only one cell thick, and so are the walls of the blood capillaries. The ideal situation for gas exchange is where the surface of the alveolus and the blood capillary are in contact.

Once in the blood, the oxygen combines with haemoglobin in the red blood cells. The flow of blood carries the oxygen away, so the concentrations in the alveolus and the blood never become equal. In this way, oxygen continues to move into the blood.

Circulation

The circulatory system of arteries, capillaries and veins is an efficient system that carries materials to and from every cell of your body. The heart is the pump that keeps the blood moving and without it the cells would soon be starved of the materials they need to function.

Heartbeat

The heart is made up of cardiac muscle. Cardiac muscle naturally contracts and relaxes without any input from the nervous system. The cycle of the heartbeat is initiated by a small patch of muscle, called a pacemaker (or SA node), shown in Figure 7.3.7.

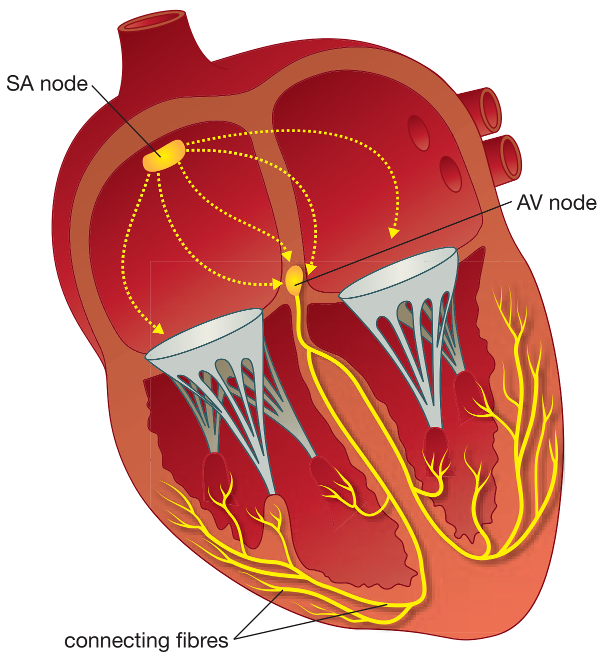


Figure 7.3.7 The heart has two specialised areas of muscle (the SA node and the AV node) that control and synchronise the heartbeat.

The rhythm of relaxation and contraction of the muscles in the pacemaker sets the rhythm for all the other cardiac muscle. The pacemaker stimulates both atria to contract simultaneously. When the stimulus reaches the tissue between the atria and the ventricles, another small patch of specialised tissue (the AV node) stimulates both ventricles to contract. An electrocardiograph of a normal heartbeat is shown in Figure 7.3.8.

If the impulses in the ventricles become disorganised because the stimulus is not picked up correctly, the muscles of the ventricle begin to twitch spasmodically. This is a condition known as ventricular fibrillation. Blood flow stops and unless the heart rhythm is restarted, death will follow swiftly.

A defibrillator is used to give the heart a jolt using electric current, in an attempt to restore the heart's natural rhythm and save the person's life. That is what is happening in Figure 7.3.9. Defibrillators are found in hospital emergency rooms, ambulances and commercial aircraft.

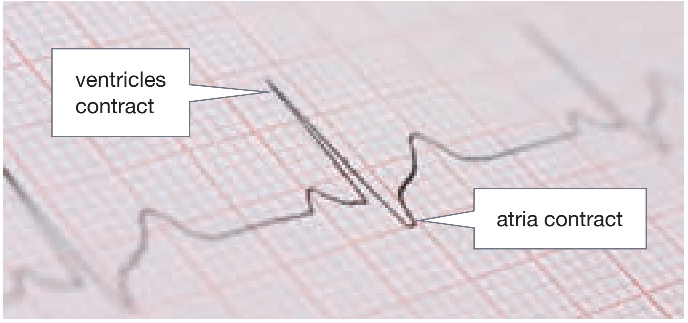


Figure 7.3.8 An electrocardiograph creates a picture of the heartbeat. The high peak is the contraction of the ventricles. The lower peak is the contraction of the atria. Then the heart rests.

Figure 7.3.9 Defibrillators are used in hospitals to restart the heart of a person who has suffered heart failure.

Changes to heart rate

The rate at which your heart beats is changed according to the needs of your body.

Stress or fear causes nerves of the autonomic nervous system to produce noradrenalin, a hormone that affects the heart in two ways:

- It increases the rate and strength of the heartbeat, which leads to an increase in blood flow.
- It increases the strength of the contractions.

Under the effect of noradrenalin, the heart may pump up to five times as much blood per minute as normal.

Vigorous exercise, such as the cross-country race shown in Figure 7.3.10, accelerates the heartbeat in two ways.

- As cellular respiration increases, so does the carbon dioxide (CO_2) level in the blood. Receptors in the carotid artery (in your neck) and aorta detect the increased CO_2 concentration and send messages to the medulla (in the brain). Nerves of the sympathetic nervous system then stimulate the heart to beat faster.
- As muscular activity increases, more blood is pumped back to the right atrium. The atrium wall stretches to hold the extra blood. Stretch receptors in the wall of the atrium send nerve impulses to the medulla. Nerves of the sympathetic nervous system stimulate the heart to beat faster.

Figure 7.3.10 When you exercise, receptors in your body detect changes. The sympathetic nervous system is stimulated. It sends impulses to effectors that respond in ways that meet the changed needs of your body.

When the stress or fear subsides, or you stop the vigorous exercise, the changes are detected by the receptors in the aorta and the carotid artery. The message is relayed to the medulla. This time the medulla stimulates the parasympathetic nervous system and its actions slow the heartbeat.

In the cells

Your body is made up of billions of microscopic cells. Within the cell are smaller structures known as organelles that can only be seen using an electron microscope (Figure 7.3.11).

Figure 7.3.11 Organelles are so small that they can only be seen clearly when magnifications of over 100 000 are used.

Mitochondria are the organelles in which cellular respiration takes place. Oxygen and glucose enter the cell from the blood capillaries and move through the cytoplasm to the mitochondria. Once in the mitochondria, the oxygen and glucose are used in cellular respiration. Cellular respiration is a series of chemical reactions assisted by enzymes that releases energy from glucose.

While the reactions of respiration are taking place in the mitochondria, chemical reactions to produce proteins are occurring in the **ribosomes**—another of the cell's organelles. At the ribosomes, amino acids from the digestion of proteins are reassembled into proteins your body can use. Enzymes and hormones are proteins, as are parts of cell membranes and muscle fibres.

Lysosomes are organelles that treat wastes within cells. Cells and organelles within your body are replaced continuously. Lysosomes digest dying cells, damaged organelles, and viruses or bacteria that have invaded the cell. The products of lysosome digestion move from the cell to the bloodstream.

Removing wastes

The liver is our largest internal organ. Its position in the body is shown in Figure 7.3.12. It carries out many different functions, some of which are related to waste treatment. The liver:

- breaks down insulin and other hormones
- breaks down haemoglobin (from dead red blood cells), creating products that are added to bile and then disposed of through the digestive system
- breaks down or modifies toxic substances and most medicines—an excess of toxins, one of which is alcohol, may cause permanent damage to the liver
- converts ammonia to urea.

Apart from the end-products of the breakdown of haemoglobin, other wastes are carried from the liver to the kidneys and are excreted in the urine.

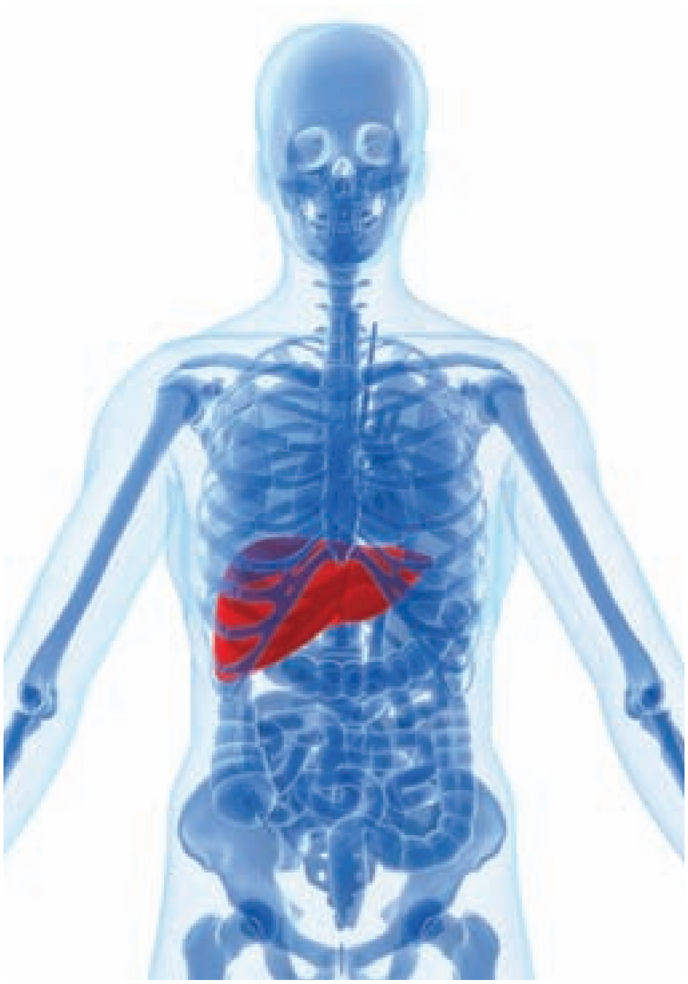


Figure 7.3.12 The liver is a very important internal organ. It has many functions, only a few of which are related to waste disposal.

Interdependence of body systems

The systems described in this chapter are interdependent. Each system depends on the others in a variety of ways and cannot function without them. Figure 7.3.13 shows the interrelationships between the excretory, digestive, circulatory and respiratory systems. The nervous and endocrine systems control the activities of these systems.

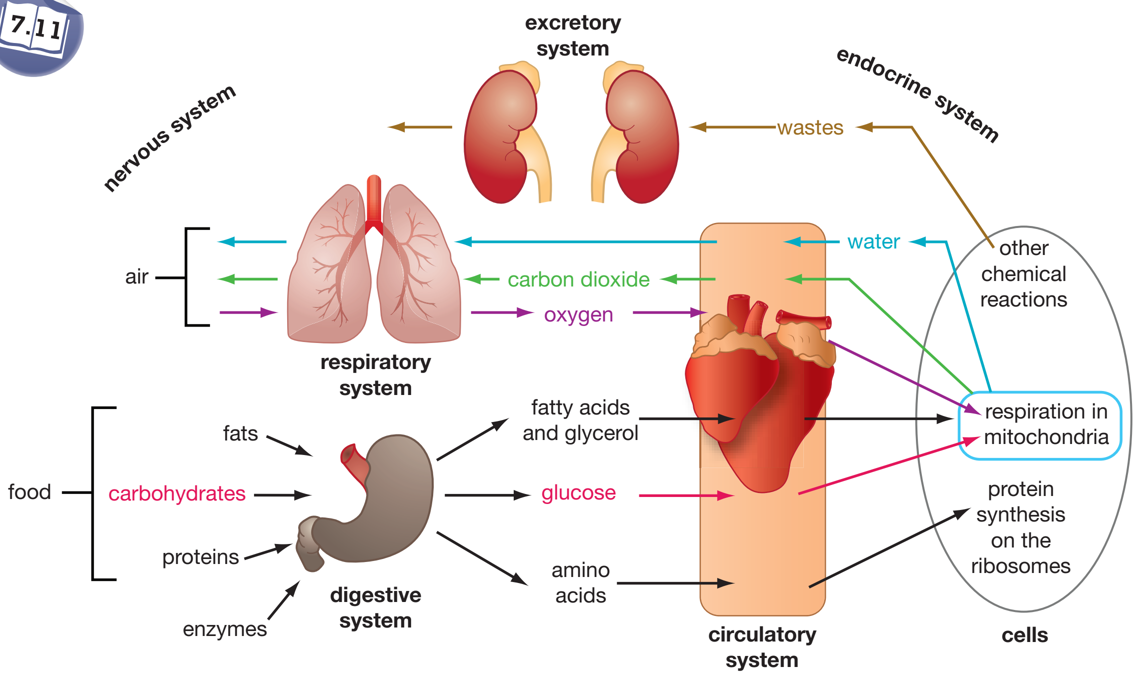


Figure 7.3.13 The interrelationships between the systems of your body

SCIENCE AS A HUMAN ENDEAVOUR

Use and influence of science

Artificial pacemakers

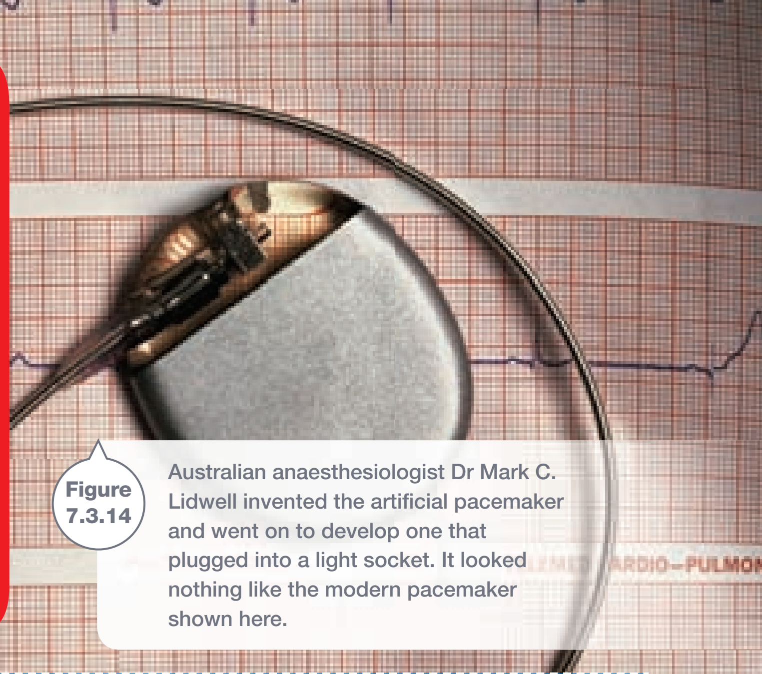


Figure 7.3.14 Australian anaesthesiologist Dr Mark C. Lidwell invented the artificial pacemaker and went on to develop one that plugged into a light socket. It looked nothing like the modern pacemaker shown here.

In 1899 the *British Medical Journal* reported experiments that John A McWilliam had carried out on the human heart.

McWilliam used electrical impulses to make the heart muscle contract. By stimulating the heart at the rate of 60–70 electrical impulses per minute, he was able to keep the heart muscle contracting at 60–70 beats per minute.

This research preceded the development of artificial pacemakers—instruments used when the heart's natural pacemaker is defective. A defective natural pacemaker may cause the heart to beat too slowly, too quickly or in an irregular fashion. Any of these can cause health problems. Artificial pacemakers (Figure 7.3.14) have been developed to help control abnormal heart rhythms.

The first artificial pacemaker was invented by Australian anaesthesiologist Dr Mark C. Lidwell. He used his device to resuscitate a newborn baby at the Crown Street Women's Hospital, Sydney, in 1926. Lidwell did not patent his device and chose to remain anonymous because research of this nature was very controversial at the time. However, two years later, Lidwell worked with a physicist, Edgar H. Booth of The University of Sydney, to develop a portable artificial pacemaker that plugged into a light socket. The circuit was created by applying a pad soaked in strong salt solution to the skin and inserting a needle insulated except at its point into one of the ventricles of the heart.

Refinement of artificial pacemakers continued, but the biggest breakthrough came with the development of the silicon transistor. From that time in 1956, there was rapid development towards pacemakers that were wearable and then to ones that could be implanted in the body.

Swedish scientists pioneered the use of pacemakers in 1958, when Arne Larsson (Figure 7.3.15) was the recipient. The first device failed after only three hours. A second device lasted two days. In total Arne received 26 different pacemakers over a period of 43 years. He died in 2001 at the age of 86.

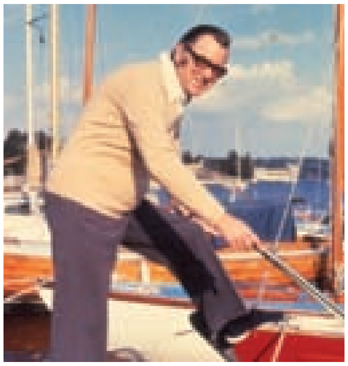


Figure 7.3.15 Arne Larsson

Modern artificial pacemakers are small devices placed in the chest or abdomen that use batteries to send electrical pulses to prompt the heart to beat at a normal rate (Figure 7.3.16). An electrode is placed next to the heart wall and small electrical charges travel through a wire to the heart.

Most pacemakers have a sensing device and send out signals to the heart only when necessary. The sensing device turns the signal on when the heartbeat is too slow. When the heart is beating normally, the sensing device turns the signal off.

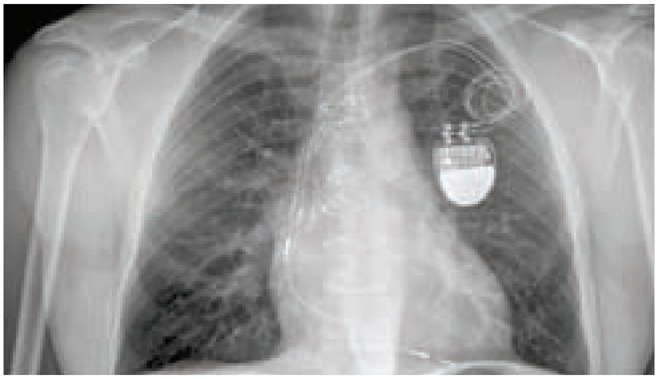


Figure 7.3.16 Modern artificial pacemakers are inserted into the body and work only when the heartbeat becomes irregular.

7.3 Unit review

Remembering

1 **Name** the process by which:
   a oxygen moves from the lungs into the bloodstream
   b food is converted to molecules the body can use
   c energy is released from glucose
   d the body gets rid of wastes.

2 **Recall** the word used to describe each of the following.
   a the chemical processes that maintain life
   b organic catalysts
   c the movement of particles of a substance from an area of high concentration of that substance to an area of low concentration of that substance
   d a molecule that is going to be changed by a chemical reaction
   e the force of the blood against the walls of the arteries

3 **Recall** the information required to copy the table below into your notebook and complete it.

Complex molecule	Simple molecule following digestion
lipid	
	amino acid
	glucose

Understanding

4 **Explain** why complex molecules such as proteins in your food have to be broken down into simpler chemical substances such as amino acids.

5 a **Describe** the function of the SA node and the AV node in the heart.
   b **Explain** what is happening when the heart is fibrillating.
   c **Explain** why a defibrillator is used in that circumstance.

6 **Describe** how the 'lock-and-key' model of enzyme action explains the specific nature of enzyme action.

Applying

7 **Use** diagrams similar to those in Figure 7.3.2 on page 245 to **demonstrate** a reaction where a large molecule is split into two smaller molecules.

8 **Use** annotated diagrams to **demonstrate**:
   a how diffusion occurs
   b the roles of the circulatory system and diffusion in the movement of nutrients from the small intestine
   c the interdependence of the roles of the circulatory system, the respiratory system and diffusion in removing carbon dioxide from the body.

Analysing

9 The chemical reactions of metabolism are divided into two groups. **Contrast** these two groups.

10 a **Analyse** the information provided in this unit to **identify** the systems involved in getting nutrients to the cells of your body.
   b **Demonstrate** how the systems work in an interdependent way to achieve this task

Evaluating

11 In your body there are many enzymes and each is specific to a reaction.
   a **Deduce** the benefit to your body's functioning of having specific enzymes.
   b **Propose** the effect on your body if enzymes were not specific to a reaction.

12 Imagine you did not have a circulatory system and that substances such as oxygen, nutrients, hormones and wastes moved through your body by diffusion. **Propose** why it would be impossible for your body to function.

Creating

13 **Construct** a flow diagram of the heartbeat, starting and ending with contraction of the atria.

14 **Construct** an outline of the human body, making it fill an A4 page.
   a Sketch in the parts of the body involved in making the energy in your food available to your cells.
   b Join the parts with arrows showing the direction in which substances or information is moving.
   c Label the arrow with the name of what is moving and the effect it is going to have.

Inquiring

1 Research the work done in the body by the liver.

2 Research the life and work of Australian heart surgeon Victor Chang.

3 Find out who Mark Dorrity is and why he suffers from a condition known as rhabdomyolisis.

7.3 Practical activities

1 Enzyme activity

Purpose

To demonstrate the action of enzymes.

Materials

- 50 mL starch solution
- iodine
- 2 × 50 mL beakers
- stirring rod
- amylase
- Tes-Tape
- labels
- 50 mL measuring cylinder
- water bath at about 30°C

SAFETY

Iodine stains. Avoid contact with skin and clothes.

Procedure

1 Label the 50 mL beakers ‘enzyme’ and ‘no enzyme’.

2 Using Tes-Tape, test the starch solution for the presence of glucose.

3 Add a few drops of iodine to the solution until the starch is showing a distinct blue-black colour.

4 Add 20 mL of the coloured starch solution to the two 50 mL beakers. Your set-up should look like Figure 7.3.17.

5 Add amylase to the beaker labelled ‘enzyme’. (Use an amount equivalent to a match head.)

6 Stir the amylase and starch solution mixture.

7 Place both beakers in the water bath.

8 Predict what you think will happen and record your prediction.

9 After about 10 minutes, note any colour change in the beakers.

10 Using the Tes-Tape, test both beakers for glucose.

Results

1 Record any change in appearance of the beakers.

2 Record whether glucose was present in either of the beakers.

Discussion

1 **Compare** the results you obtained with your prediction.

2 If glucose was present in either of the beakers, **explain** where the glucose came from.

3 **Account** for any colour change that occurred.

4 **Explain** why the beakers were heated to 30°C.

5 **Summarise** the results of this experiment, relating any changes to the action of amylase.

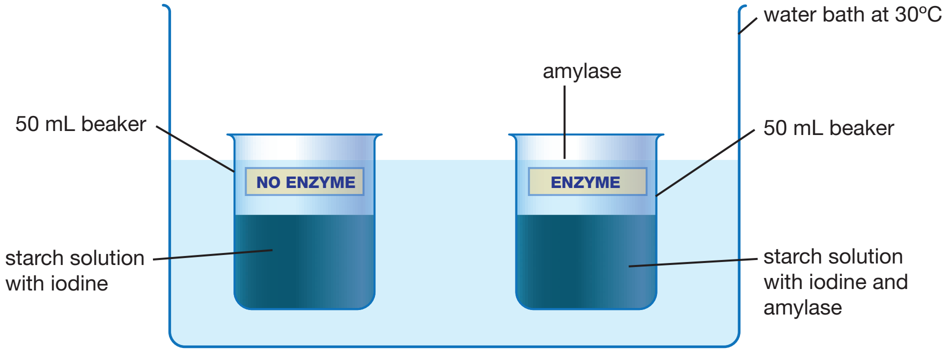


Figure 7.3.17

2 Diffusion

Purpose

To demonstrate the process of diffusion in cells.

Materials

- food colouring
- 3 pieces of dialysis tubing 15 cm long
- 3 × 500 mL beakers
- 3 × 50 mL beakers
- stirring rod
- water
- string
- 3 retort stands with clamps

Procedure

1 Add 300 mL of water to each of the 500 mL beakers. Set them up on the bench with a retort stand behind each one (see Figure 7.3.18).

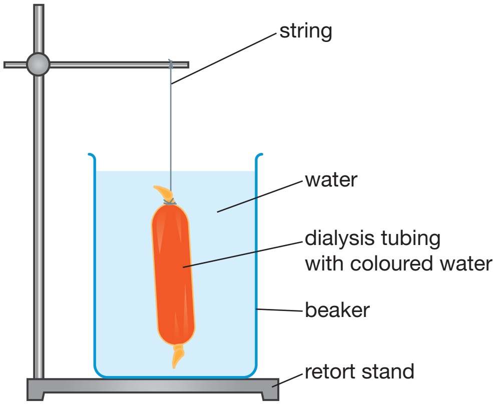


Figure 7.3.18

2 Let the water settle.

3 Add 25 mL of water to each of the 50 mL beakers. Label the beakers 1, 2 and 3.

4 Create solutions of different concentrations using the food colouring. Add 10 drops of food colouring to beaker 1, 20 drops to beaker 2 and 40 drops to beaker 3.

5 Run water from the tap over the three lengths of dialysis tubing.

6 Tie one end of each piece of tubing in a tight knot.

7 Rub the other end of the tubing to open it up.

8 Fill one piece of tubing with the coloured water from beaker 1.

9 Close the end of the tubing by tying it with string.

10 Rinse off the dialysis tube 'sausage' you have created so that there is no coloured water on the outside.

11 Using the other end of the string, tie the 'sausage' to the retort stand and suspend it over one of the large beakers.

12 Repeat steps 8 to 11, adding the other solutions to the dialysis tubing.

13 Carefully lower the dialysis tubing into the large beakers, taking care to disturb the water as little as possible.

14 Observe any changes.

Results

Note how long it takes:

a before colour starts to 'leak' out of the dialysis tubing

b for the colour to move half way across the water in the beaker

c until all the beaker is uniformly coloured.

Discussion

1 **Compare** the rate of movement of the coloured solutions in the three beakers.

2 **Interpret** any differences in terms of the concentration of the original solutions.

3 **Identify** the part of the model that represents the cell.

4 **Propose** an aspect of diffusion of oxygen in the lungs, or nutrients in the digestive system, that is not included in this model.

5 **Propose** a way of demonstrating diffusion of materials into cells using similar equipment.

7 Chapter review

Remembering

1 a **Name** the 'master gland' of the endocrine system.
  b **Recall** where it is situated.
  c **Recall** the organ that controls the 'master gland'.

2 **Name** the two main parts of the human nervous system.

3 **Name** the system that delivers materials to cells.

4 **Recall** the word that means 'maintaining a constant internal environment'.

Understanding

5 **Explain** the relationship between proteins and amino acids.

6 **Define** the term *metabolism*.

7 **Explain** why the human body needs the following systems.
  a digestive system
  b respiratory system
  c excretory system
  d nervous system
  e endocrine system
  f circulatory system

Applying

8 a **Use** the example of a reverse-cycle air conditioner to **explain** the term *negative feedback*.
  b **Describe** two examples of negative feedback in the human body.
  c **Demonstrate** using diagrams how this feedback works.

9 a **Describe** the changes that would occur in your body if you went from a warm environment to a very cold environment.
  b **Explain** why these changes take place.
  c **Identify** the systems involved in the changes and describe how the changes are brought about.

10 a **Describe** the changes that occur in your body as you start to do some vigorous exercise.
  b **Identify** the systems that are causing the changes.
  c **Explain** how the changes are brought about.
  d **Explain** how the changes help your body maintain that level of activity.

11 **Demonstrate** how the level of glucose in your blood is controlled.

12 **Use** Figure 7.3.13 on page 249 to **demonstrate** that multicellular organisms rely on coordinated and interdependent internal systems

Analysing

13 **Compare** the nervous system and the endocrine system.

14 a **Contrast** the roles of the sympathetic and parasympathetic nervous systems in the body.
  b **Explain** why both systems are required.

Evaluating

15 a **Assess** each of the statements below and decide whether they are true or false.
    i The endocrine system uses enzymes to send chemical messages around the body.
    ii Hormones are distributed to all parts of the body by the circulatory system.
    iii The digestive system can work independently of the other systems of the body.
    iv The kidneys are the only organs involved in treating wastes in your body.
  b For each statement you decided was false, **justify** your decision.

Creating

16 **Use** the following ten key terms to **construct** a visual summary of the information presented in this chapter.

endocrine system	nervous system
metabolism	hormones
pituitary gland	hypothalamus
receptors	target cells
central nervous system	peripheral nervous system

Thinking scientifically

Q1 Two groups of people were involved in a trial to see which activity had the greatest effect on total urine production. One group sat in the full sun on a hot day for 30 minutes. The other group exercised vigorously for 30 minutes. Neither group had anything to drink after the experiment started.

The average urine production for the group was measured at half-hourly intervals and the following results were obtained.

Time (min)	Volume of urine produced (mL)	
	Group 1	Group 2
0	50	50
30	53	50
	Vigorous exercise for 30 minutes	Sat in the sun for 30 minutes
60	60	30
90	10	20
120	8	20
150	35	25
180	40	23

Select the statement that is most likely to be true.

A In the time following the activity (exercise or sunbaking), the group who were sunbaking produced less urine.

B In the time following the activity (exercise or sunbaking), the group who were exercising produced less urine.

C Both groups produced the same amount of urine in total.

D There was a steady decline in the amount of urine produced by both groups.

Q2 Identify the change that is *unlikely* to be occurring in the body of the young man shown here.

A increased levels of cellular respiration

B reduced heart rate

C constriction of blood vessels to the skin, fingers and toes

D shivering

Q3 The composition of the blood and urine of four groups of students was compared, and the results are shown in the table below.

Identify the group most likely to have been involved in vigorous exercise prior to the samples being taken.

A Group 1

B Group 2

C Group 3

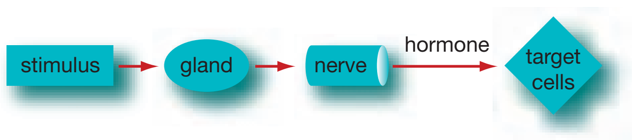
D Group 4

Component	Group 1		Group 2		Group 3		Group 4	
	Blood	Urine	Blood	Urine	Blood	Urine	Blood	Urine
Water (%)	90	90	85	80	80	70	80	70
Protein (%)	9	0	9	0	9	0	9	0
Glucose (%)	0.1	0	0.09	0	0.05	0	0.09	0
Urea (%)	0.003	0.05	0.004	0.055	0.006	0.07	0.004	0.05
Sodium (%)	0.35	0.45	0.35	0.55	0.25	0.15	0.35	0.35

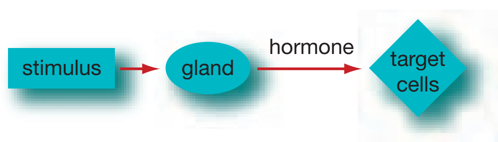
Q4 After eating, levels of glucose in the blood increase. Specialised cells in the pancreas detect the high glucose levels and react by producing insulin. Insulin causes the liver and muscles to increase their uptake of glucose, removing it from the bloodstream.

Select the model that best fits control of glucose levels in the blood.

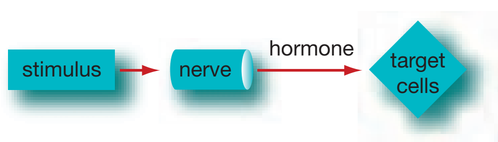
A



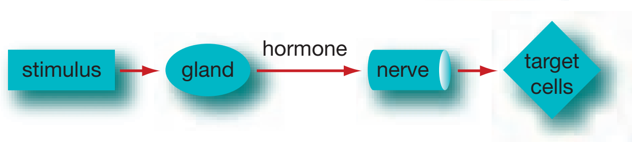
B



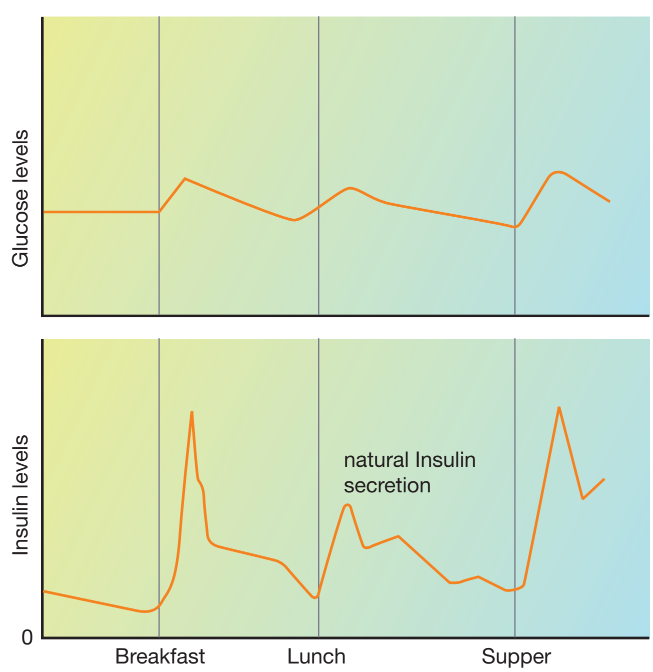
C



D



Q5 Select the answer that best fits the data in the graphs below, which show the relationship between glucose and insulin levels in the blood.



Levels of insulin are highest:

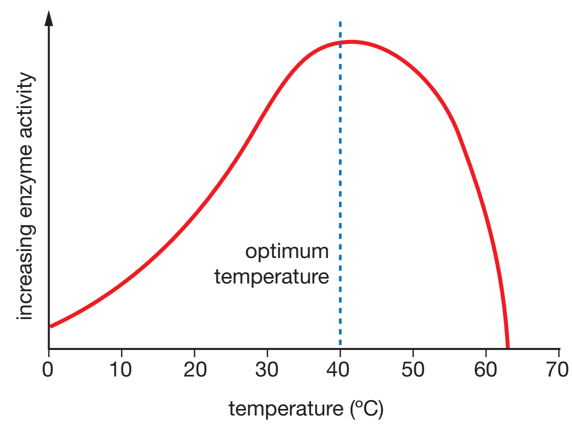
A when glucose levels are increasing

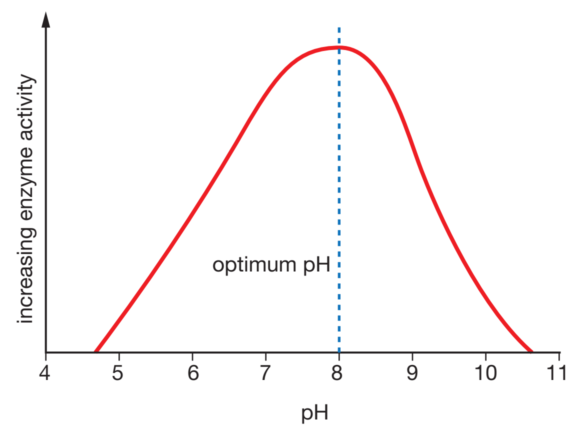
B when you are eating a meal

C when glucose levels are highest

D a short time after the peak in glucose levels.

Q6 The following graph shows the level of activity of a human enzyme at different temperatures and pH.





The normal internal temperature of the human body is 37°C. The pH of the mouth is about 7.5, in the stomach it is about 3, and in the small intestine it is about 8.

Select the statement that best fits all the data presented.

A The enzyme works best at low pH and high temperature.

B Temperature and pH have no effect on activity of the enzyme.

C The enzyme would be able to function best in the small intestine.

D The enzyme is most likely a digestive enzyme from the stomach.

Glossary

Unit 7.1

Autonomic nervous system: the system controlling involuntary actions such as the heartbeat

Axon: a nerve fibre that sends nerve impulses away from the cell body

Brain stem: part of the brain where the spinal cord enters the skull; it controls the body's vital functions, such as breathing, blood pressure and heart rate

Cell body: the part of the neurone that contains the nucleus

Central nervous system (CNS): the brain and the spinal cord

Cerebellum: part of the brain that is responsible for coordination and balance

Cerebrum: part of the brain that controls conscious thoughts, controls the movement of every body part, and receives sensory messages from each body part

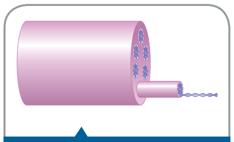
Dendrites: branches from the cell body that receive messages from other neurones

Effectors: muscles or glands that put the messages into effect

Medulla: the lower half of the brain stem

Motor neurones: nerve cells that carry messages from the CNS to effectors

Myelin sheath: the insulating layer that covers a neurone



Myelin sheath

Nerve impulse: the electrical message carried by a nerve cell

Neurone: a nerve cell

Neurotransmitter: a chemical message released at the end of an axon to be received by the next neurone's dendrites

Optic nerve: the nerve that carries messages to the brain from the retina at the back of the eye

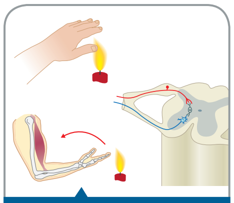
Parasympathetic nervous system: part of the nervous system that slows the body down and controls it when it is resting

Peripheral nervous system (PNS): the nerves that carry messages to and from the central nervous system and other parts of the body

Receptors: special cells that detect stimuli

Reflex actions: quick, automatic actions that protect the body from danger; they are also known as reflexes

Reflex arc: the nerve pathway operating in a reflex action



Reflex arc

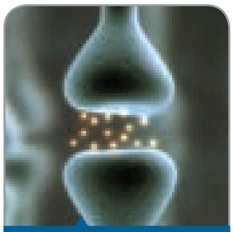
Sensory neurones: nerve cells that carry messages from cells in the sense organs to the CNS

Somatic nervous system: part of the nervous system that coordinates the movement of the body and receives information from the sensory organs

Stimulus: any factor that stimulates a receptor and brings about a response

Sympathetic nervous system: part of the nervous system that speeds up the functions of the body and makes the body work more efficiently

Synapse: the space between two neurones



Synapse

Unit 7.2

Adrenal glands: endocrine glands situated on the kidneys

Adrenalin: the common name for the hormone epinephrine

Antidiuretic hormone (ADH): a hormone that controls the amount of urine produced by the body

Endocrine glands: glands that produce hormones

Endocrine system: all the endocrine glands of the body

Endothermic: able to maintain a constant body temperature

Epinephrine: a hormone produced in the adrenal glands; it is commonly known as adrenalin

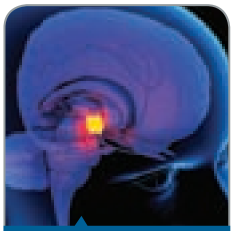
Glycogen: the chemical store of glucose in the liver and muscles

Glucagon: a hormone that has the opposite effect to insulin; it releases glucose from stores in the liver and muscles

Homeostasis: the process of maintaining a constant internal environment

Hormones: chemical substances that act as messengers in the body

Hypothalamus: a portion of the brain that constantly checks the internal environment of the body



Hypothalamus

Insulin: hormone produced in the pancreas that causes the liver and muscles to extract glucose from the bloodstream and store it in the liver and muscles

Metabolism: all the chemical reactions occurring in the cells

Pituitary gland: the endocrine gland that controls the activities of other endocrine glands; it is often called the 'master gland'

target cells: the cells on which a hormone acts

Unit 7.3

Catalyst: a substance that speeds up the rate of a reaction without being used up in the process

Diffusion: the movement of particles of a substance from an area of high concentration to an area of low concentration

Enzyme: an organic catalyst

Mitochondria: organelles where cellular respiration occurs

Reactant molecule: the molecule that is going to be changed by a chemical reaction

Ribosome: the organelle where proteins are manufactured