

2 Control and coordination

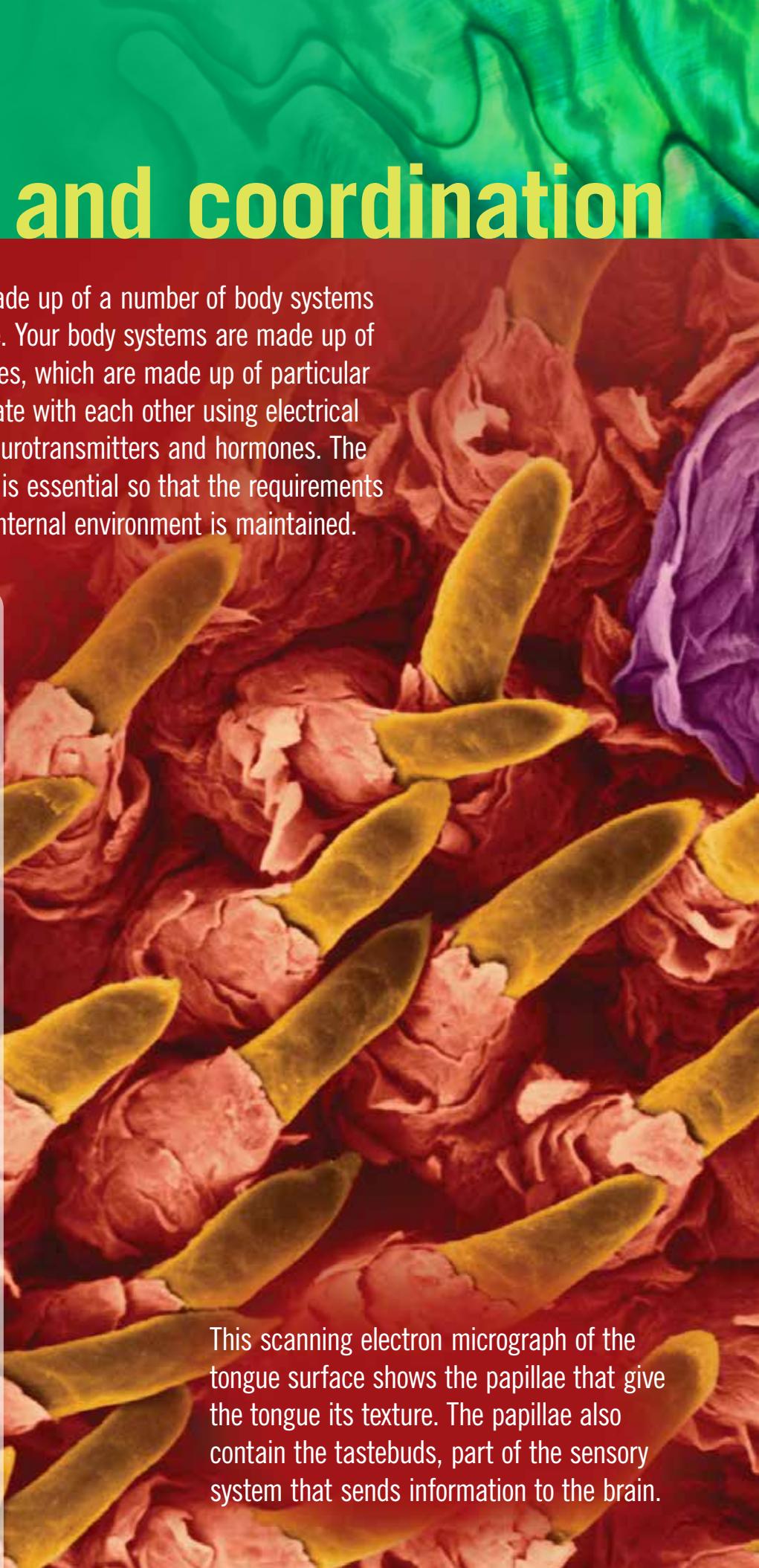
You are a multicellular organism made up of a number of body systems that work together to keep you alive. Your body systems are made up of organs, which are made up of tissues, which are made up of particular types of cells. Your cells communicate with each other using electrical impulses and chemicals such as neurotransmitters and hormones. The coordination of this communication is essential so that the requirements of your cells are met and a stable internal environment is maintained.

Think about body systems

- What's so good about negative feedback?
- Ouch! How do you react without thinking about it?
- What's the link between glucose, glycogen and glucagon?
- Which hormone causes male sex organs to grow?
- What's the link between hormones and the menstrual cycle?
- Which neurotransmitter acts like the brakes on your emotions?

In this chapter:

- 2.1** Coordination and control 32
2.2 Nervous system — fast control 38
2.3 Getting the message 44
2.4 Getting in touch with your brain 52
2.5 Endocrine system — slow control 58
2.6 Plant hormones at work 64
2.7 SCIENCE AS A HUMAN ENDEAVOUR
Keeping emotions under control? 70
2.8 SCIENCE AS A HUMAN ENDEAVOUR
Total recall? 75
2.9 SCIENCE AS A HUMAN ENDEAVOUR
Sleep on it 80
2.10 SCIENCE AS A HUMAN ENDEAVOUR
The teen brain 84
2.11 SCIENCE AS A HUMAN ENDEAVOUR
Getting back in control 87
2.12 SCIENCE AS A HUMAN ENDEAVOUR
Opening up your brain 90
Study checklist/Digital resources 94
Looking back 95



This scanning electron micrograph of the tongue surface shows the papillae that give the tongue its texture. The papillae also contain the tastebuds, part of the sensory system that sends information to the brain.

YOUR QUEST

Speedy reactions?

How fast can you react to a potentially threatening situation? Imagine you are in the situation below. How would you feel? How would you react? Would everything start to happen in slow motion and then quickly speed up? Can an incident be avoided?



When you first see the danger, you detect it using receptors in your eyes. This message is then sent to your nervous system, which will tell your body what to do. As there is potential danger in this situation, your endocrine system may also react by producing hormones such as adrenaline to trigger your body to 'get up and go'. Hopefully this all happens fast enough to avoid anyone getting hurt!



INVESTIGATION 2.1

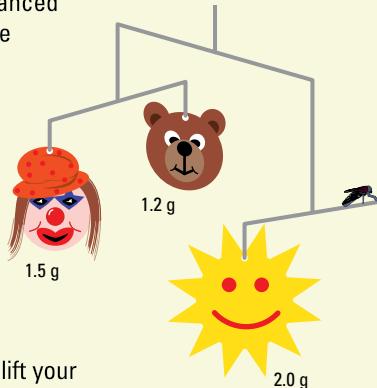
Fast or slow

AIM To increase awareness of different types of responses to stimuli

METHOD AND RESULTS

- Carefully observe each situation below and then answer questions 1 to 4.

- (a) A mobile has lost a piece and is hanging crooked. When a fly lands on the mobile, it becomes balanced again. Given the masses in the diagram, what is the mass of the fly?



- Response:*
Solving
the puzzle
(b) Ouch! You step on a sharp object.

Response: You lift your foot quickly.

- (c) You have been in three classes before lunch. You had very little breakfast and you feel that you have no energy. Your friend Janine, who knows everything, tells you that you have low blood sugar and must eat your lunch so that your blood sugar level can get back to normal. The bell rings, and you rush to the canteen to get lunch.
Response: Getting your blood sugar back to normal

- Order the responses from fastest to shortest response time.

DISCUSS AND EXPLAIN

- Using your current understanding of how you respond to your environment, suggest reasons for the different types of responses and how your body processes the information to bring about the response.

- Suggest a question or hypothesis for each scenario that you could investigate.

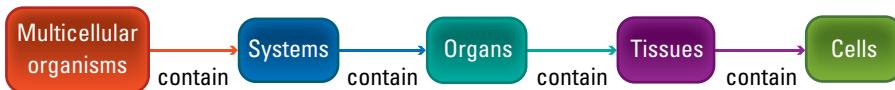
- Propose another scenario and predict what your body's response would be. Suggest why and how it would respond in this way.

- Find out how seeing danger quickly approaching can result in a change of behaviour (such as running faster, stopping or screaming). Outline the involvement of both nerves and hormones.
 - Construct a cartoon or comic strip to summarise your findings.

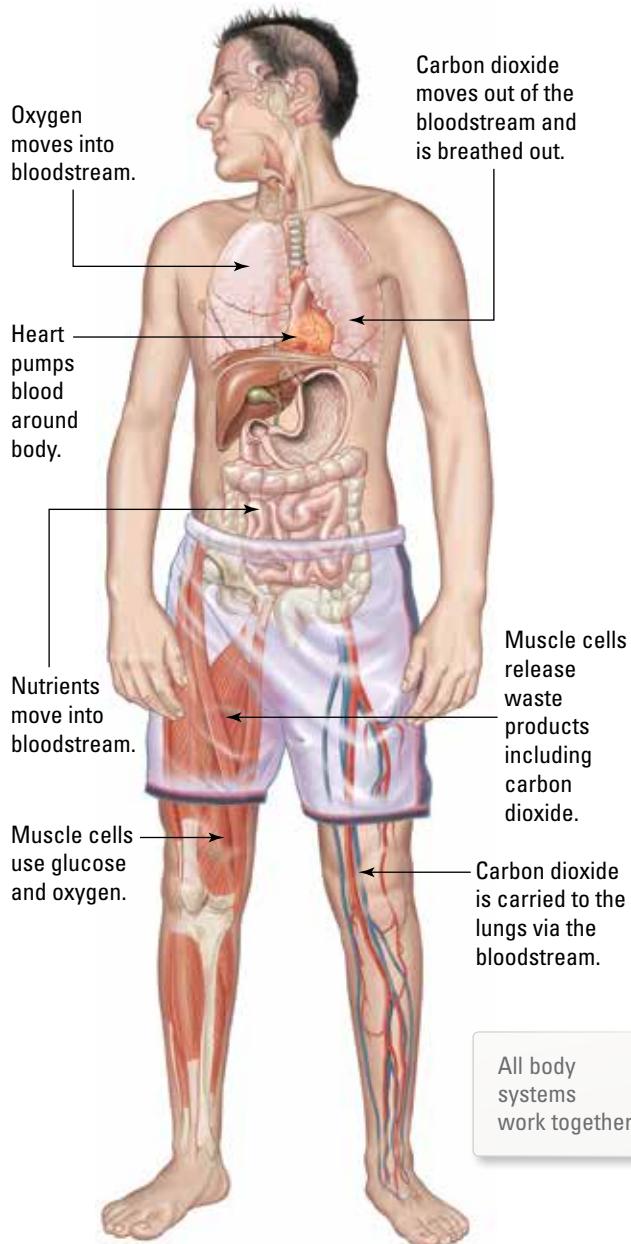
- Find some activities that can be used to determine your reaction time. Test your classmates and record times to see who is the fastest.

Coordination and control

You are a **multicellular organism** made up of many cells that need to be able to communicate with each other. They need to be able to let other cells know when they need help and support, when they need more of something or when they need to get rid of something.



Multicellular organisms show a pattern of organisation in which there is an order of complexity.



Working together

Your cells can be organised to form tissues. These tissues make up organs, and the organs make up systems, which perform particular jobs to keep you alive.

The cells of multicellular organisms cannot survive independently of each other. They depend on each other and work together. Working together requires organisation, coordination and control.

While one of your cells may be a part of one of the systems in your body, it may also need to communicate and interact with other systems to stay alive. It may depend on your digestive system to break down nutrients so that its chemical requirements are in a form that can be used, and your circulatory system to deliver these. Your respiratory system will also be involved in ensuring a supply of oxygen and removal of carbon dioxide. Other organs in the excretory system will also be involved in removing wastes that may otherwise be toxic. Your systems need to work together so that a comfortable stable environment for the cells is maintained.

Homeostasis

The internal environment in which your cell lives needs to be kept constant. Temperature, pH and concentrations of ions, glucose, water and carbon dioxide need to be within a particular range. Maintenance of this constant internal environment is called **homeostasis**.

Stimulus–response model

To be able to achieve homeostasis, any changes or variations (stimuli) in the internal environment need to be detected (by receptors). If a response is required, this needs to be communicated to effectors to bring about some type of change or correction so



the conditions can be brought back to normal. This is described as a **stimulus–response model**.

Receptors

Receptors identify changes inside and outside your body. These special types of nerve cells may be located in sense organs such as your eyes, ears, nose, tongue and skin. Different types of receptors respond to particular stimuli.

Type of receptor	Which stimuli does it respond to?	Where in your body?
Photoreceptor	Light	Eye
Mechanoreceptor	Sound	Ear
Chemoreceptor	Chemicals	Tongue, nose
Thermoreceptor	Temperature	Skin

Control centre

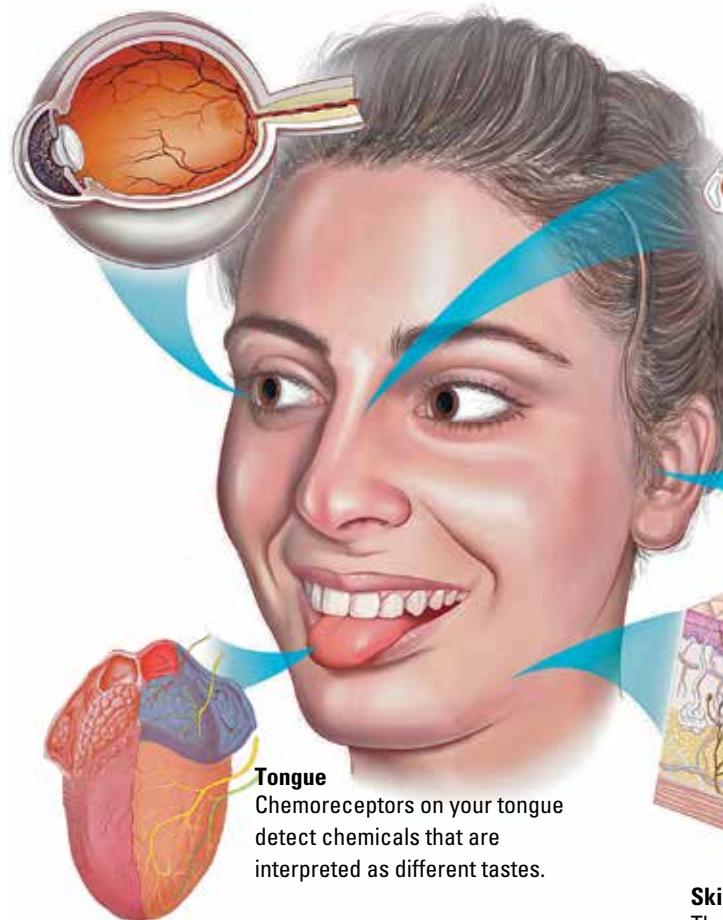
Once a stimulus has been detected by a receptor, a message in the form of a nerve impulse travels to the central nervous system (brain and spinal cord). It is here that the message is processed to determine which response will be appropriate. A message is then sent to the appropriate effector.

Effectors

Effectors such as muscles or glands receive the message from the central nervous system to respond in a particular way. Their response depends on the original stimulus. For example, if your hand is too close to a candle flame, then muscles in your arm may respond to move your hand away from it. Some other examples are shown in the thermoregulation figure on page 36.

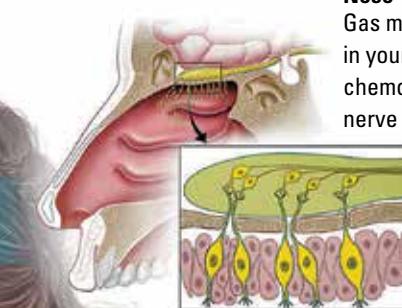
Eye

Photoreceptors in the retina of the eye detect light and send nerve impulses along the optic nerve to your brain.



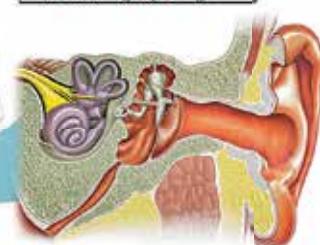
Tongue

Chemoreceptors on your tongue detect chemicals that are interpreted as different tastes.



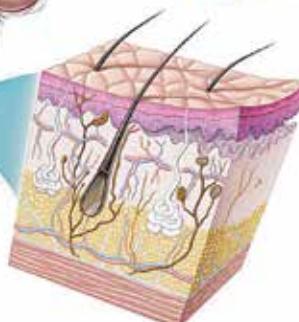
Nose

Gas molecules dissolve in mucus in your nose, causing cilia of chemoreceptors to generate nerve impulses along the olfactory nerve to your brain.



Ear

Mechanoreceptors in the cochlea of your ear detect vibrations and send impulses along the auditory nerve to the brain.



Skin

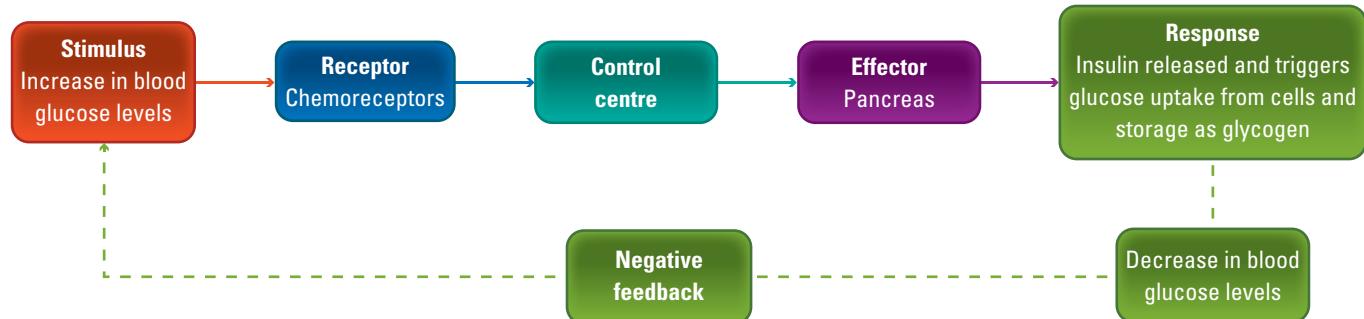
Thermoreceptors in skin detect heat and mechanoreceptors detect vibration, pressure, touch and pain.

Giving feedback?

Stimulus-response models can also involve negative or positive feedback. Most biological feedback systems involve negative feedback.

Negative feedback

Negative feedback occurs when the response is in an opposite direction to the stimulus. For example, if levels of a particular chemical in the blood were too high, then the response would be to lower them. Likewise, if the levels were too low, then they would be increased.

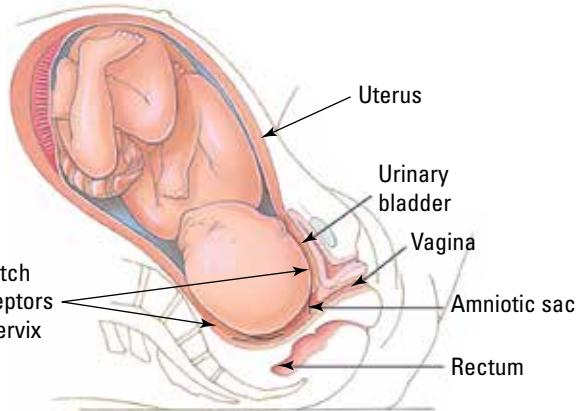


The regulation of **glucose** levels in your blood involves negative feedback. If an increase in blood glucose levels has been detected by receptors, the **pancreas** responds by secreting **insulin**, which may trigger an increased uptake of glucose by liver and muscle cells and the conversion of glucose into **glycogen** for storage. This lowers the blood glucose levels.

Positive feedback

Whereas negative feedback involves a response in an opposite direction to the stimulus, **positive feedback** results in the response going in the same direction. An example of positive feedback is when a mother is breastfeeding her baby. Mechanoreceptors in her nipple detect the baby sucking. The message is transferred to her central nervous system (in this case, her spinal cord) which then sends a message to muscles lining the milk glands to respond by releasing milk. The response continues until the baby stops sucking and the stimulus is removed.

Positive feedback is also responsible for the increase in contractions during childbirth. As the baby moves into the cervix (the area that connects the uterus to the vagina), it causes stretching of receptors that result in the release of a hormone called **oxytocin**. Oxytocin causes the uterus to contract. As the baby is pushed further into the cervix, the stretch receptors are further stretched, resulting in more oxytocin release



and stronger contractions. Once the baby is born, the stimulus disappears, so oxytocin levels drop, as do the contractions.

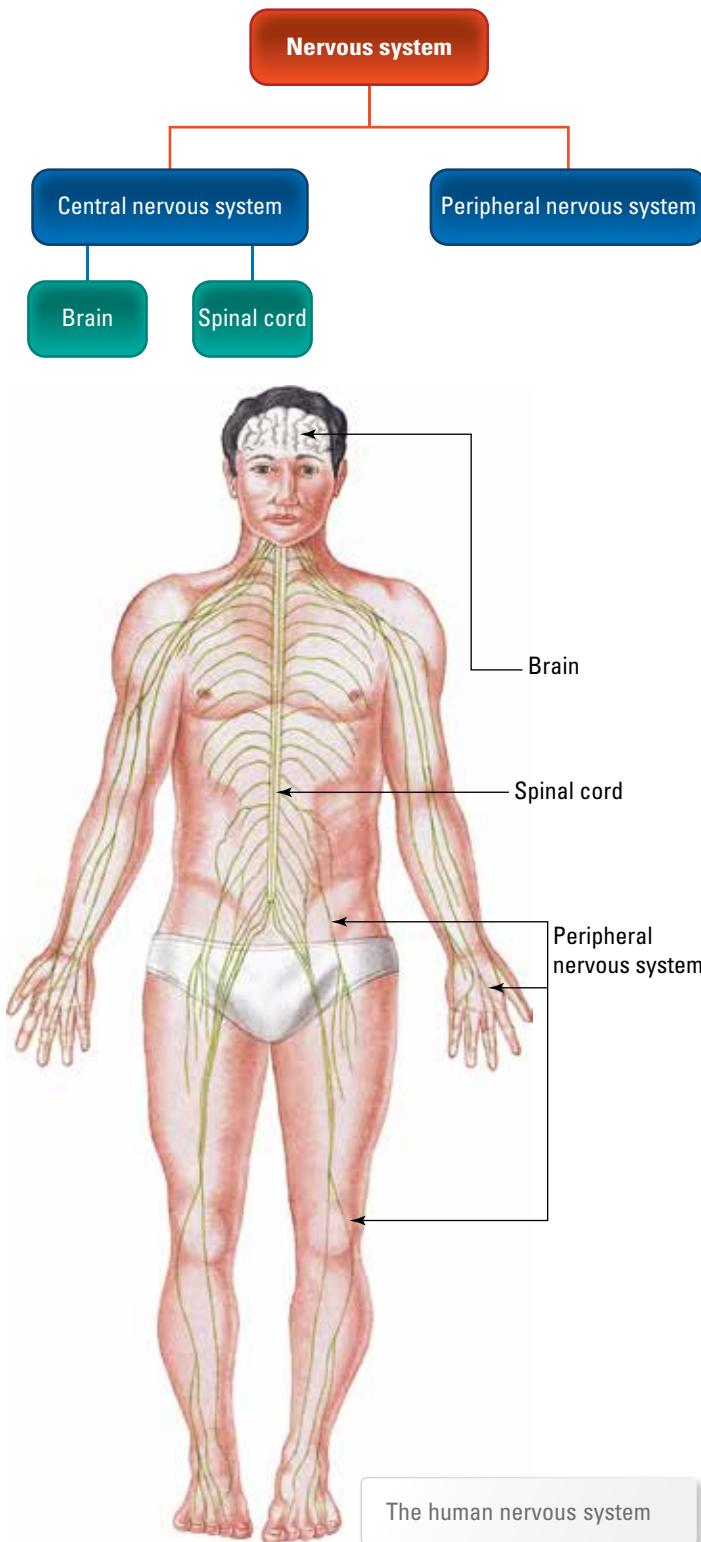
All under control

To work together effectively, these systems require coordination. The two systems with this responsibility are the **nervous system** and the **endocrine system**. While both of these systems require **signalling molecules** to communicate messages throughout the body, they have different ways of going about it.

Feature	Endocrine system	Nervous system
Speed of message	Slow	Fast
Speed of response	Usually slow	Immediate
Duration of response	Long lasting	Short
Spread of response	Usually slow	Very localised
How message travels through body	In circulatory system — in bloodstream	In nervous system — along nerves and across synapses
Types of message	Hormones (chemicals)	Electrical impulse and neurotransmitters (chemicals)

Nervous system

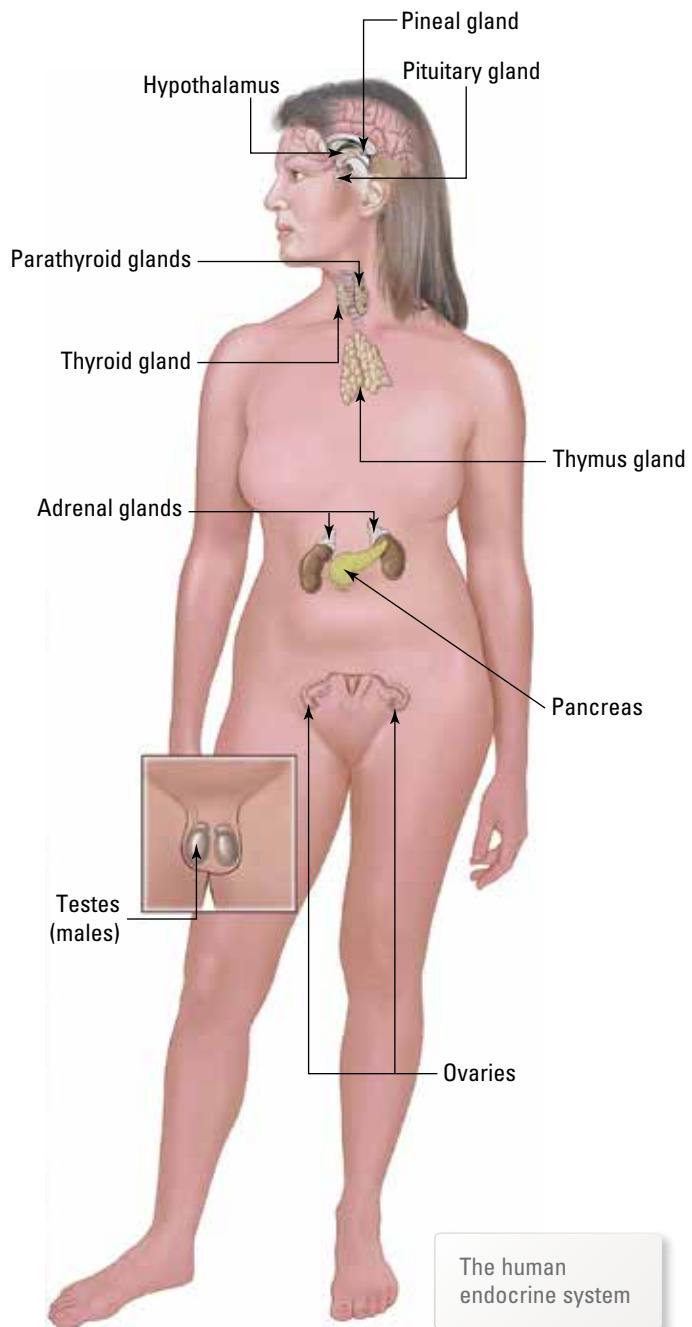
Your nervous system is composed of the **central nervous system** (brain and spinal cord) and the **peripheral nervous system** (the nerves that connect the central nervous system to the rest of the body). Messages are taken to the central nervous system by **sensory neurons** and taken away from it by



motor neurons. The nervous system sends the message as an electrical impulse along a neuron and then as a chemical message (**neurotransmitters**) across the gaps (synapses) between them.

Endocrine system

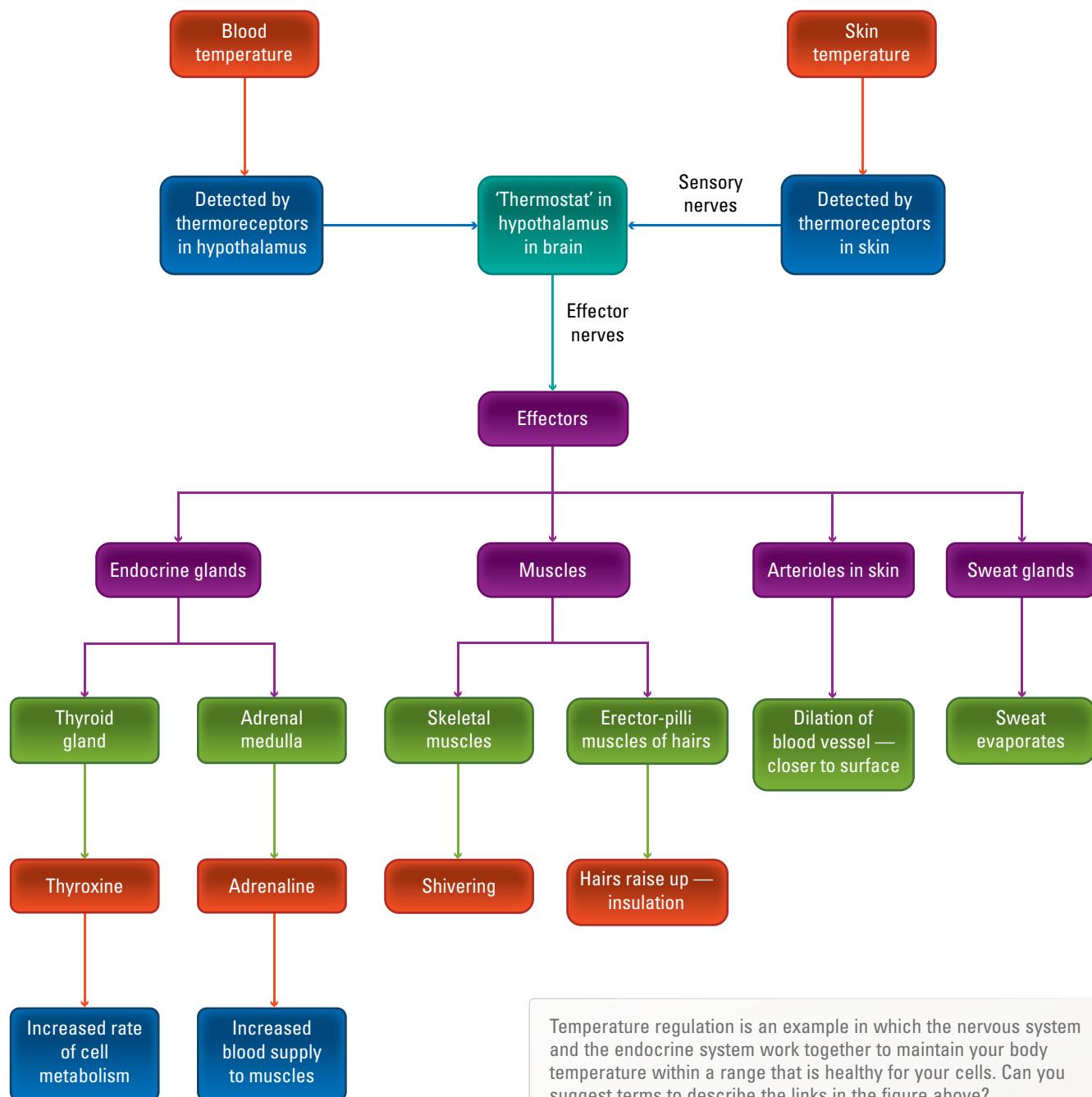
Your endocrine system is composed of **endocrine glands** that secrete chemical substances called **hormones** into the bloodstream. These chemical messages are transported throughout the circulatory system to specific target cells in which they bring about a particular response.



Working together

The control of body temperature, referred to as **thermoregulation**, provides an example of the nervous and endocrine systems working together. Evidence suggests that a part of your brain called the hypothalamus contains a region that acts as your body's **thermostat**. It contains thermoreceptors that detect the temperature of blood that flows through it.

If your body temperature increases or decreases from within a particular range, messages from thermoreceptors in your skin or hypothalamus trigger your hypothalamus to send messages to appropriate effectors. The effectors (such as those shown in the figure below) then bring about a response that may either increase or decrease body temperature.



Temperature regulation is an example in which the nervous system and the endocrine system work together to maintain your body temperature within a range that is healthy for your cells. Can you suggest terms to describe the links in the figure above?

UNDERSTANDING AND INQUIRING

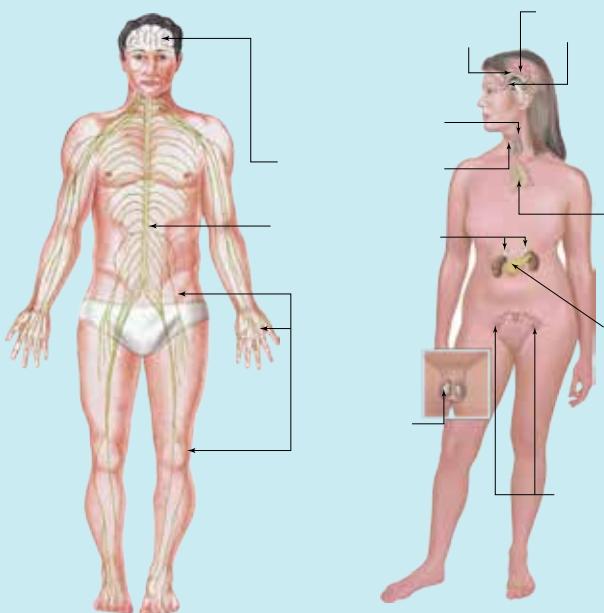
REMEMBER AND THINK

- 1 Construct a flowchart to show the relationship between the following:
 - (a) cells, organs, multicellular organisms, tissues
 - (b) effector, response, control centre, stimulus, receptor.
- 2 Identify the type of receptor that would respond to the following stimuli:

(a) light	(c) chemicals
(b) sound	(d) temperature.
- 3 Organise the terms below into a Venn diagram so that they are grouped into their families.

Central nervous system	Electrical impulse
Endocrine gland	Glucagon
Insulin	Homeostasis
Hormone	Motor neuron
Neurotransmitter	Pancreas
Peripheral nervous system	Sensory neuron
Stimulus-response model	

- 4 What is a stimulus–response model?
- 5 Give an example of a negative feedback mechanism in the human body.
- 6 Distinguish between:
 - (a) receptors and effectors
 - (b) negative and positive feedback
 - (c) sensory neurons and motor neurons
 - (d) central nervous system and the peripheral nervous system
 - (e) the endocrine system and the nervous system
- 7 Label the endocrine system and nervous system in the figures below.



- 8 Match the terms listed in the box with the correct description below.

Central nervous system	Chemoreceptors
Control centre	Effector
Electrical impulse	Endocrine gland
Endocrine system	Glucagon
Glucose	Glycogen
Homeostasis	Hormone
Insulin	Motor neuron
Negative feedback	Nervous system
Neurotransmitter	Pancreas
Peripheral nervous system	Receptor
Response	Sensory neuron
Stimulus	Stimulus–response model

- (a) I describe a model that helps you to achieve homeostasis.
- (b) I am a response that is in the opposite direction to the stimulus.
- (c) I consist of the brain and the spinal cord.
- (d) I take messages to the central nervous system.
- (e) Insulin is an example of what I am.
- (f) I detect chemicals and can detect a decrease in blood glucose levels.
- (g) I carry chemical messages within the nervous system.
- (h) I take messages away from the central nervous system.
- (i) I secrete hormones into your bloodstream.
- (j) I help you to respond to stimuli.
- (k) I use hormones to transport messages throughout your circulatory system to a target cell.
- (l) I am a ‘central’ part of the stimulus–response model.
- (m) I am the result of the action of an effector.
- (n) I carry the message through your neurons.
- (o) I am known as a storage polysaccharide and am made up of many glucose subunits.
- (p) Your pancreas releases hormones to keep my blood levels within a narrow range.
- (q) I am released by your pancreas when blood glucose levels are below normal.
- (r) I am involved in maintaining a constant internal environment within your body.
- (s) My release from the pancreas results in a lowering of blood glucose levels.
- (t) My cells release both insulin and glucagon.
- (u) I use neurons, electrical impulses and neurotransmitters to pass on messages.
- (v) I am detected by a receptor.
- (w) I detect a stimulus.
- (x) I contain neurons that connect the central nervous system to the rest of the body.

Nervous system — fast control

Whether you are catching a ball, slicing carrots, breathing or stopping a fall, you need to be in control. You need to be able to detect and respond in ways that ensure your survival. This requires control and coordination. Your nervous system assists you in keeping in control, and coordinating other body systems, so that they work together and function effectively.

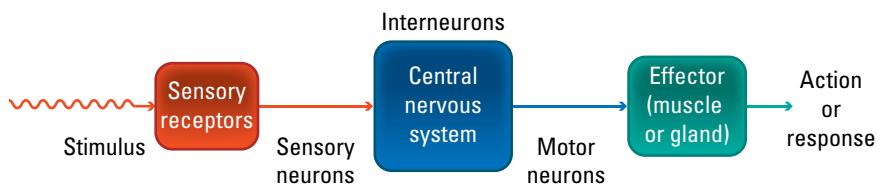
What a nerve!

Your nervous system is composed of the **central nervous system** (brain and spinal cord) and the **peripheral nervous system** (the nerves that connect the central nervous system to the rest of the body). These systems are made up of nerve cells called **neurons**. The axons of neurons are grouped together to form **nerves**.

Neurons

There are three different types of neurons: **sensory neurons**, which carry the impulse generated by the stimulus to the central nervous system; **interneurons**,

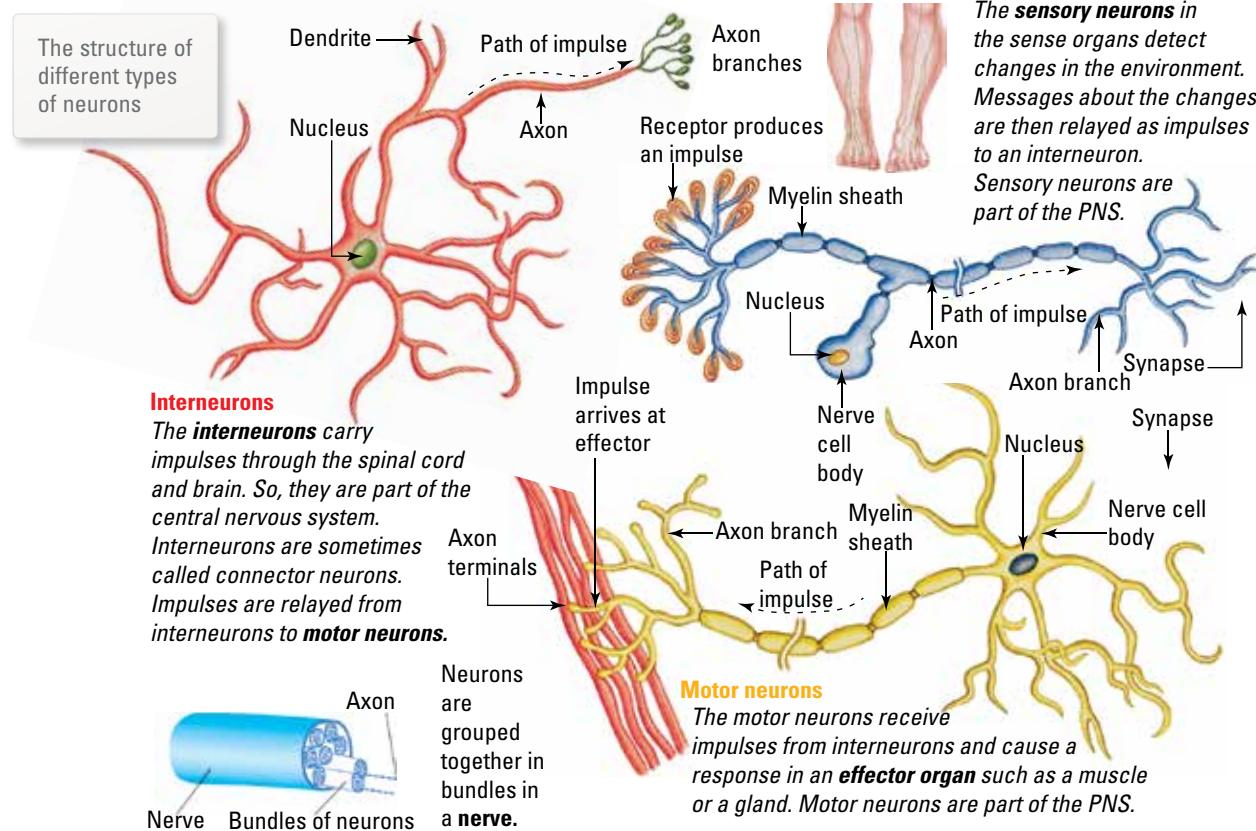
which carry the impulse through the central nervous system; and **motor neurons**, which take the impulse to effectors such as muscles or glands.

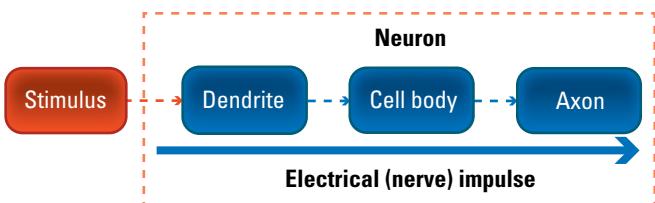


Structure of a neuron

Neurons, like most other eukaryotic cells, contain a **nucleus** and other cell **organelles**, **cytosol** and a **cell membrane**. However, the various types of neurons are all quite different. These differences mean that each particular neuron type is suited to its specific communication role in the nervous system.

Neurons are made up of three main parts: a cell body, dendrites and an axon. On the cell membrane of the **cell body** of a neuron are highly sensitive branching extensions called **dendrites**. These dendrites possess



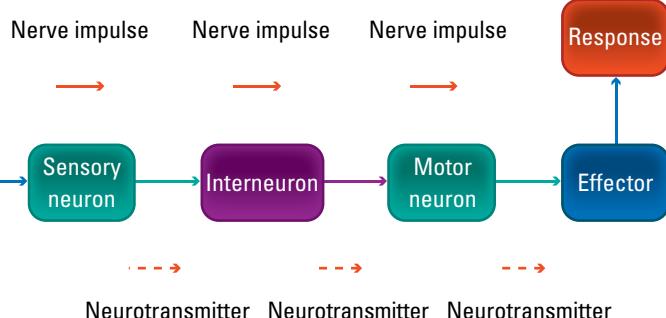


An electrical impulse moves in only one direction through a neuron.

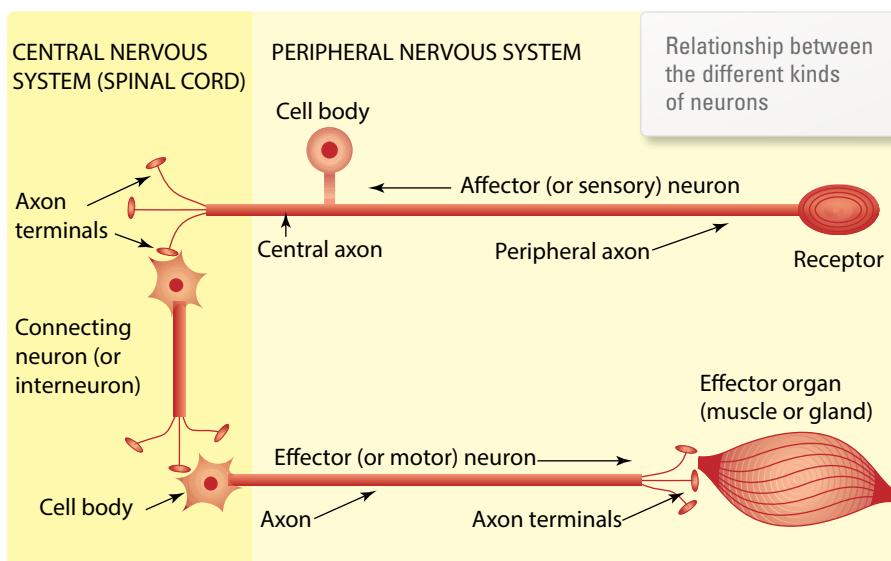
numerous receptors that can receive messages from the other cells. Once this message has been received it moves as an electrical impulse in one direction from the dendrite, through the cell body and then through a long structure called an **axon**. This structure is often covered with a white insulating substance called **myelin**, which helps speed up the conduction of the message through the neuron.

Synapses

The gap between neurons is called a **synapse**. When the nervous impulse has reached the axon terminal of a neuron, tiny **vesicles** containing chemicals called **neurotransmitters** are transported to the cell membrane of the neuron. These chemicals are then released into the synapse.



Your nervous system involves the use of both electrical signals (nerve impulses) and chemical signals (neurotransmitters).



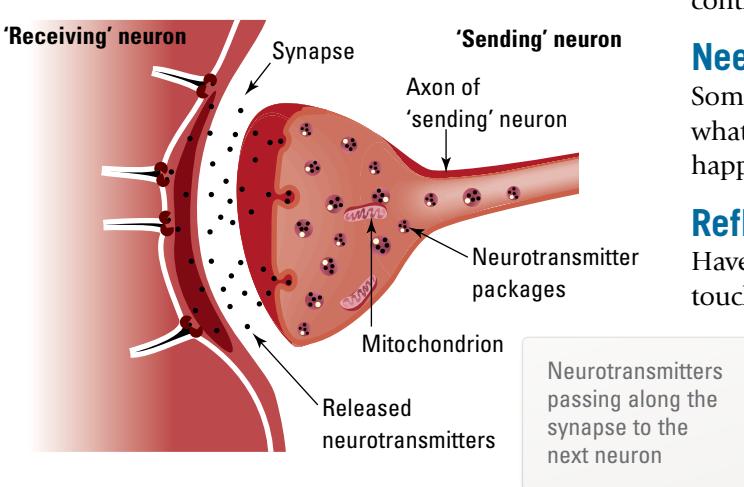
The neurotransmitters move across the synapse and bind to receptors on the membrane of the dendrites of the next neuron. This may result in triggering the receiving neuron to convert the message into a nervous impulse and conduct it along its length. When it reaches the axon terminal, neurotransmitters are released into the synapse to be received by the dendrites of the next neuron. This continues until the message reaches a motor neuron which then communicates the message to an **effector**, such as a muscle or gland. The effector may then respond to the message; for example, a muscle cell may contract or a gland may secrete a chemical.

Need to think about it?

Sometimes, you need to consciously think about what your body does. At other times, however, actions happen without you having to think about them.

Reflex actions — Act! No need to think!

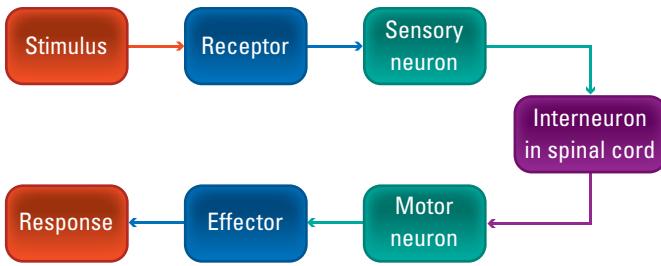
Have you ever had sand thrown in your eyes or touched something too hot? Sometimes you don't have time to think about how you will react to a situation. Some actions need to be carried out very quickly — it may be a matter of survival! These actions are examples of reflex actions.



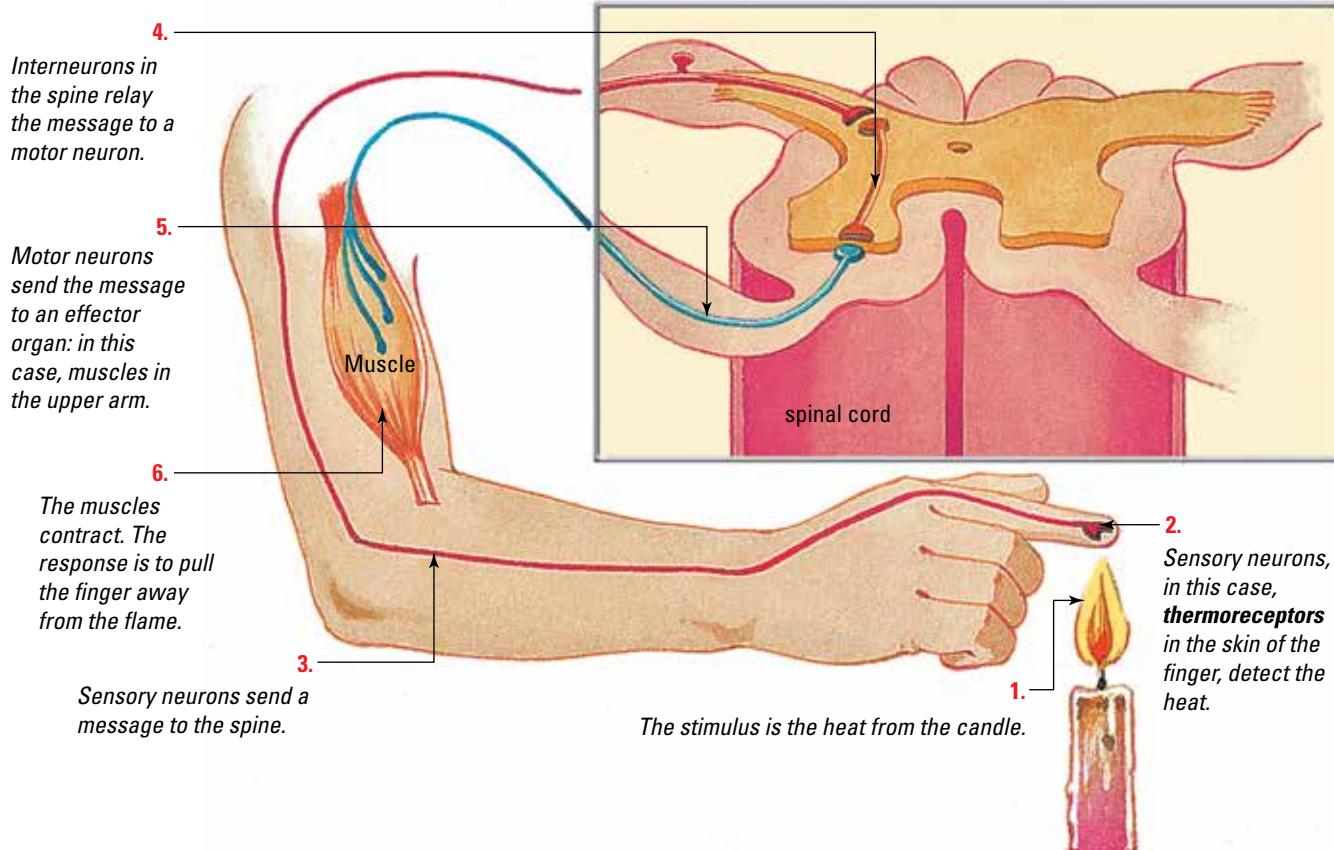
Neurotransmitters passing along the synapse to the next neuron

Reflex actions may involve only a few neurons and require no conscious thought. Once the stimulus is detected by a receptor, the message is sent via the sensory neuron to the interneuron in the spinal cord and then from the motor neuron to the effector to bring about a response. The message does not have to go the brain. This type of pathway, which involves only a few neurons and travels only to and from the spinal cord, is called a **reflex arc**.

You also react to many internal stimuli using reflex actions. Breathing, for example, is a response regulated by chemoreceptors detecting changes in carbon dioxide



Watch out! Sometimes you need to react very quickly and there is no time to think.



levels in your blood. It's very helpful that you don't have to remember to breathe — imagine what would happen if you forgot to!

Think about it

More complex actions involve many interconnecting neurons and specialised parts of the brain. The messages pass into and along the spinal cord to be interpreted. When **thinking** takes place, we can make decisions about which responses are needed. Impulses are then sent along appropriate motor neurons to the effectors. This is called a **conscious response**. Many learned actions can become automatic if the same pathways are used often enough. Skill development

and control in playing musical instruments and sport, for example, depend on practice during which the same pathways are often used.

Chemical warfare

Beware of toxic ticks, stinging trees, nasty nettles or jellyfish! Many plants and animals have ways of repelling boarders or paralysing their prey.

Pests and poisons

How do they do it? Blue-ringed octopuses, paralysis ticks, tiger snakes and other animals and plants produce cocktails of poisons that block the production

INVESTIGATION 2.2

How good are your reflexes?

AIM To investigate some automatic responses

Materials:

well-lit room chair
stopwatch or clock with a second hand

METHOD AND RESULTS

Work in pairs for both parts of this activity. Decide who will be the experimenter and who will be the subject. Then swap roles and repeat both parts.

PART A: KEPT IN THE DARK

- 1 If you are the experimenter, look closely at the eyes of your partner, noting the size of the pupils.
- 2 Ask your partner to close his or her eyes for 60 seconds.
- 3 At the end of this time, monitor your partner's eyes for any changes.



PART B: KNEE JERK

- 1 Have your partner sit on a chair with one leg crossing over the other knee.
- 2 Use the edge of your hand to gently strike the crossed leg of your partner just below the knee in the joint.
- 3 You may need to repeat this a few times to get a response from your partner.

► Record your observations.

DISCUSS AND EXPLAIN

PART A: KEPT IN THE DARK

- 4 What changes did you notice?
- 5 Identify the (a) stimulus and (b) response.
- 6 Why do you think this reflex action is important to our survival?
- 7 Can you control the size of your pupil?
- 8 Describe your observations.
- 9 Identify the (a) stimulus, (b) response and (c) effector.
- 10 Did you get the response the first time? Why or why not?
- 11 Can you control a knee-jerk response?

CONCLUSION AND EVALUATION

- 12 Summarise your overall findings.
- 13 Suggest possible improvements to this experiment and suggest further relevant investigations that could be carried out.



and action of neurotransmitters at synapses.

The poison from a red-back spider, for example, empties the impulses out of the neurotransmitters.

Interfering with the neurotransmitters' job of carrying the message to the next neuron interferes with the transference of the message and can cause spasms and paralysis.

Many plants produce chemicals that sting by strongly stimulating the pain receptors in the skin. Messages are sent rapidly to the brain, which interprets them as pain. Other plants, including chrysanthemums, produce insecticides such as pyrethrums. These target the nervous system

of insects, resulting in their death. The commercial production of such natural pesticides is a large industry and is regarded as environmentally friendly because natural pesticides replace the use of more harmful chemicals.

Nerve nasties

Similar chemicals have been used as agents of human warfare. These chemicals specifically target the nervous system. Nerve gas, for example, contains a substance which prevents neurotransmitters functioning properly at the synapses. The neurotransmitters accumulate, causing the nervous system to go haywire. Such chaos can result in death.

The first nerve gas, tabun, was initially developed when German scientists were developing a better insecticide. This has led to more deadly agents such as sarin and VX. All nerve gases block the body's production of an enzyme called acetylcholinesterase. This enzyme regulates the nerves controlling the action of particular muscles. A deficiency of acetylcholinesterase leads to tightening of your diaphragm, convulsions and death.





Some chemicals can specifically target your nervous system and disrupt its functioning. Scientists and experts working with dangerous materials use suits such as those shown here for protection.

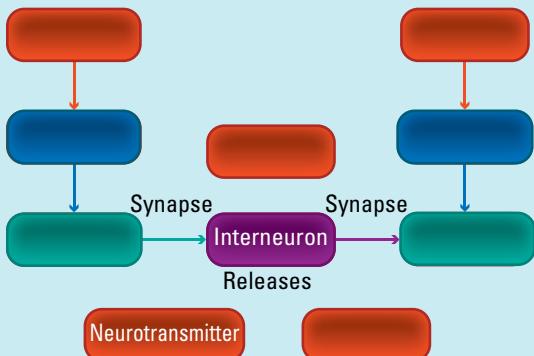
UNDERSTANDING AND INQUIRING

REMEMBER

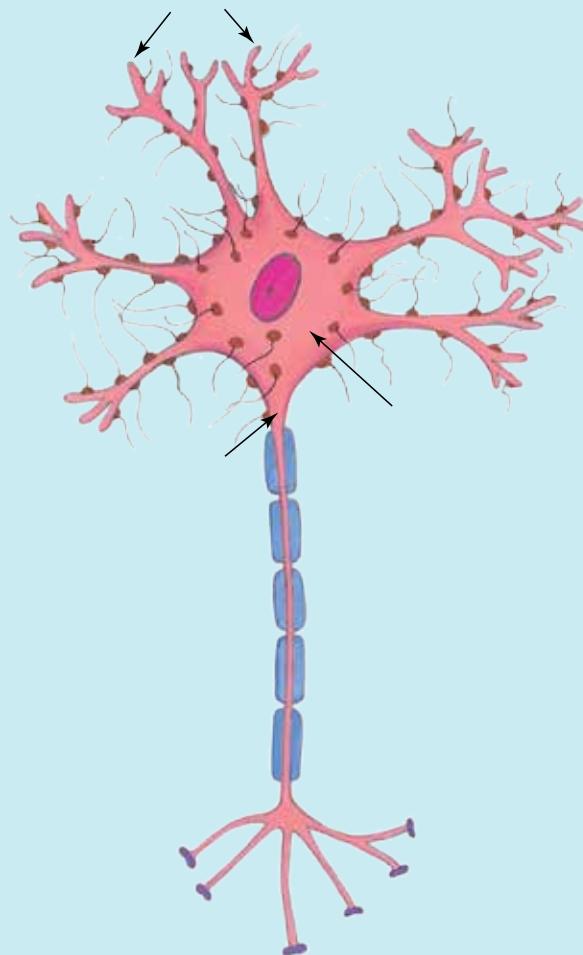
- 1 Match the term with its description in the table below.

Term	Description
Central nervous system	Gap between neurons
Motor neuron	Made up of neurons
Nerves	Nerves that connect the central nervous system to the rest of the body
Neuron	Takes messages to the central nervous system
Neurotransmitter	Made up of a cell body, dendrites and axon
Peripheral nervous system	Brain and spinal cord
Sensory neuron	Chemical messenger that carries messages from one neuron to another across a synapse
Synapse	Takes messages away from central nervous system

- 2 Suggest how you could link the nervous system terms in the flowchart below.



- 3 Label the cell body, dendrites and axon on the motor neuron below and show the direction in which the impulse travels.



- 4 Distinguish between:
- (a) a receptor and an effector
 - (b) a sensory neuron, an interneuron and a motor neuron
 - (c) a neuron and a nerve.
- 5 Construct a diagram to describe how impulses are transmitted between sensory and motor neurons.
- 6 Distinguish between a reflex action and a conscious response. Provide an example of each.
- 7 Describe one way in which animals can cause paralysis.

- 8** Describe how some plants defend themselves against:
(a) humans
(b) insects.

THINK AND DISCUSS

- 9** Suggest how the structure of the different types of neurons suits them to their function.
- 10** Describe the advantage of the presence of myelin on the axon of a neuron.
- 11** Identify which of the following responses are reflex actions and which are conscious responses: sneezing, blinking, scratching your head, clapping, breathing.
- 12** Suggest a reason why the pupil of your eye increases in size in dim light.
- 13** How does blocking the production and action of neurotransmitters cause paralysis?
- 14** What could be the effect of toxins on aquatic food chains?
- 15** Suggest ways in which chemicals that affect the nervous system may be mopped up.
- 16** What do insecticides do?
- 17** Suggest why nerve gas is used in warfare.

INVESTIGATE AND DISCUSS

- 18** Conduct a survey of insecticides at your local nursery, garden supplies shop or supermarket. Construct a table in which to record:
(a) the names of commercial brands of insecticides
(b) the target organisms
(c) the active chemical ingredients
(d) information given about safety precautions.
Find out how the main ingredients act in each of the insecticides and include them in a report in your survey.
- 19** Researchers studying Gulf War syndrome carried out experiments on chickens to discover the cause of the illness.
(a) Find out about their experiments and conclusions.
(b) Do you think the researchers were justified in carrying out these experiments? List arguments for and against.
- 20** Test your knowledge of the nervous system by completing the **A nervous response** interactivity in your eBookPLUS. **int-0670**
- 21** Learn more about your nervous system by completing the **A bundle of nerves** interactivity in your eBookPLUS. **int-0015**
- 22** There is a danger that chemical and biological weapons may one day be used in acts of terrorism.
(a) Search the media for relevant examples of chemicals and their effects.

eBookplus

- (b) Report on your findings and discuss them with your team.
- 23** Is the use of chemical warfare ever justifiable?
Discuss this with your team, recording all the various opinions and views.
- 24** What sorts of strategies do we have in Australia to cope with threats of chemical warfare? How effective do you consider these to be? In your teams, brainstorm other strategies that could be used.
- 25** On your own or in a team, write a story, newspaper article or diary entry that describes the effects of a chemical warfare attack in Australia.
- 26** Working in groups of four, make a list of about 10 different poisonous or venomous Australian plants and animals. Each person is to research and report on at least one. As a group, decide what aspects to include in the report. Present your findings as a PowerPoint presentation or poster with a taped commentary.

CREATE

- 27** Make models of the different neuron types using balloons, string or cotton, straws and tape.
- 28** In a group, act out a simple reflex arc and a conscious response.

INVESTIGATE, THINK AND DISCUSS

- 29** Imagine that you are a scientist involved in researching the nervous system. Propose a relevant question or suggest a hypothesis for a scientific investigation and outline how you would design your investigation. Search the internet for relevant research or information.
- 30** Find examples of how developments in imaging technologies have improved our understanding of the functions, interactions and diseases of the nervous system. Share your findings with your class.
- 31** Investigate how technologies using electromagnetic radiation are used in medicine, for instance in the detection and treatment of cancer of the brain or other parts of the nervous system.
- 32** There are often claims made about particular products in the media relating to the nervous system. Examples include drugs that regulate moods or enhance memory. Select one of these examples (or one of your own), find out more about it and then evaluate the claims being made in advertisements or in the media.

work
sheet

→ **2.1** The nervous system

Getting the message

Watch out! Your survival can depend on detecting changes in your environment.

Five senses

Imagine not being about to see, hear, feel or sense the world outside your body. No sound, no colour, no taste or smell — just darkness and silence. Without senses, you might not even be able to sense that!

Sense organs are used to detect **stimuli** (such as light, sound, touch, taste and smell) in your environment. Examples of human sense organs are your eyes, ears, skin, tongue and nose. These sense organs contain special cells called receptors. These receptors are named according to the type of stimuli that they respond to (as shown in the table below). You have photoreceptors for vision, chemoreceptors for taste and smell and mechanoreceptors for pressure, touch, balance and hearing.

Five receptors

Thermoreceptors enable you to detect variations in temperature and are located in your skin, body core and part of your brain, called the hypothalamus.

Mechanoreceptors are sensitive to touch, pressure, sound, motion and muscle movement and are located in your skin, skeletal muscles and inner ear.

Chemoreceptors are sensitive to particular chemicals and are located in your nose and tastebuds and **photoreceptors** are sensitive to light and are located only in your eyes.

Pain receptors enable you respond to chemicals released by damaged cells. Detection of pain is important because it generally indicates danger, injury or disease. Although these receptors are

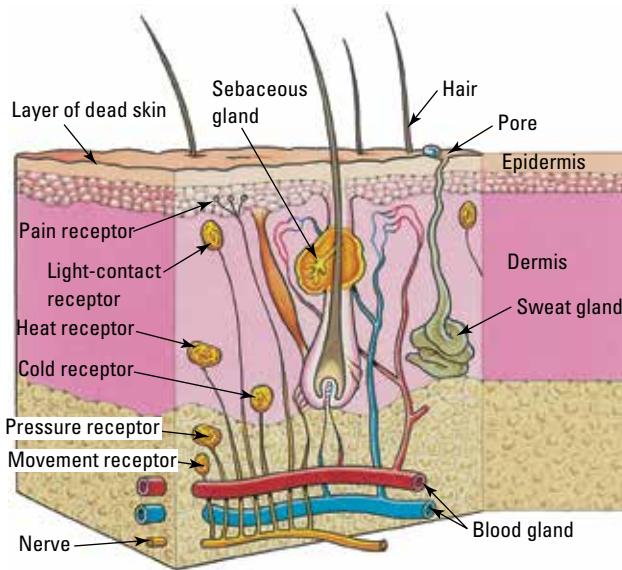
Examples of different types of receptors

Sense	Sense organ	Stimulus	Receptor	Type of receptor
Sight	Eye	Light	Rods and cones in the retina	Photoreceptor
Hearing	Ear	Sound	Hairs in the cochlea	Mechanoreceptor
Touch	Skin	Heat, cold Pressure, movement	Separate receptors for each type of stimulus	Thermoreceptor Mechanoreceptor
Taste	Tongue	Chemical substances: sweet, salty, bitter and sour	Tastebuds	Chemoreceptors
Smell	Nose	Chemicals: odours	Olfactory nerves inside nose	Chemoreceptors

located throughout your body, they are not found in your brain.

Touch — sharp or hot?

Your skin contains a variety of types of receptors. Pain receptors and mechanoreceptors enable you to detect whether objects are sharp and potentially dangerous. There are also **hot thermoreceptors** that detect an increase in skin temperature above the normal body temperature (37.5°C) and **cold thermoreceptors** that detect a decrease below 35.8°C . These thermoreceptors can also protect you from burning or damaging your skin. The sensitivity of these receptors can depend on how close together they are and their location in your skin.



Your skin contains a variety of receptors that provide you with a sense of touch.

INVESTIGATION 2.3

Touch receptors in your skin

AIM To detect where the skin is most sensitive to light contact

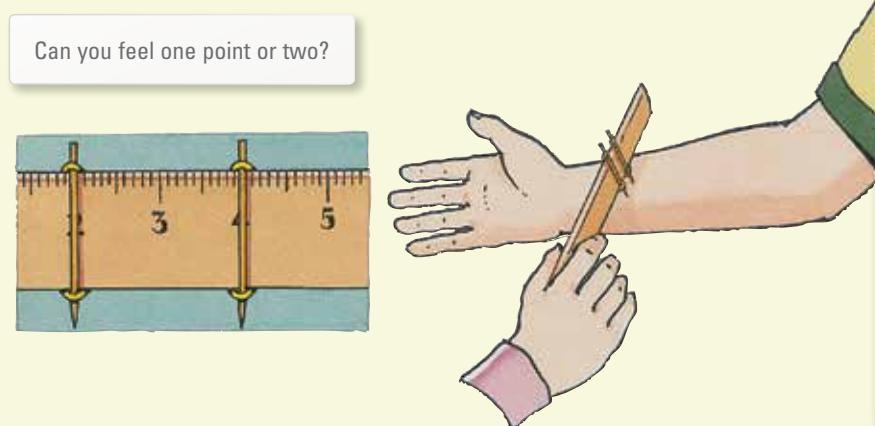
Materials:

2 toothpicks ruler 2 rubber bands blindfold

METHOD AND RESULTS

	Distance (cm) between two points when only one point is felt	
Part of the skin	Your partner	You
Inside forearm		
Palm of hand		
Calf		
Finger		
Back of neck		

- 1 Construct a table with the headings shown above.
- 2 Use rubber bands to attach two toothpicks to a ruler so that they are 2 cm apart.
- 3 Predict in which areas of the body the skin will be most sensitive and least sensitive.
- 4 Blindfold your partner. Gently touch your partner's inside forearm with the points of the two toothpicks.
- 5 Ask your partner whether two points were felt. Move one toothpick towards the other in small steps until your partner is unable to feel both points. To make sure that there is no guesswork, use just one point from time to time.



Smell — sweet or stinky?

The sweet scent of a rose or the stink of garbage? Gaseous molecules from the air are breathed in through your nose. When dissolved in the mucus of your nasal cavity, the hair-like cilia of your nasal chemoreceptors are stimulated to send a message via your **olfactory nerve** to your brain to interpret it, giving you the sensation of smell.

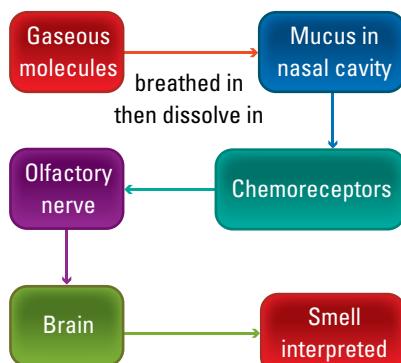
3 Record the distance between the toothpicks when your partner can feel only one point when there are really two points in contact.

4 Repeat this procedure on the palm of one hand, a calf (back of lower leg), a finger and the back of the neck.

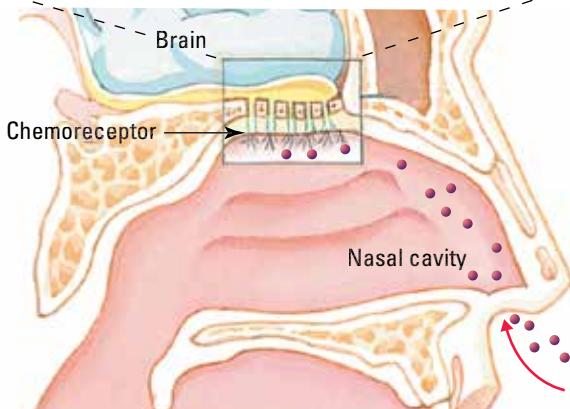
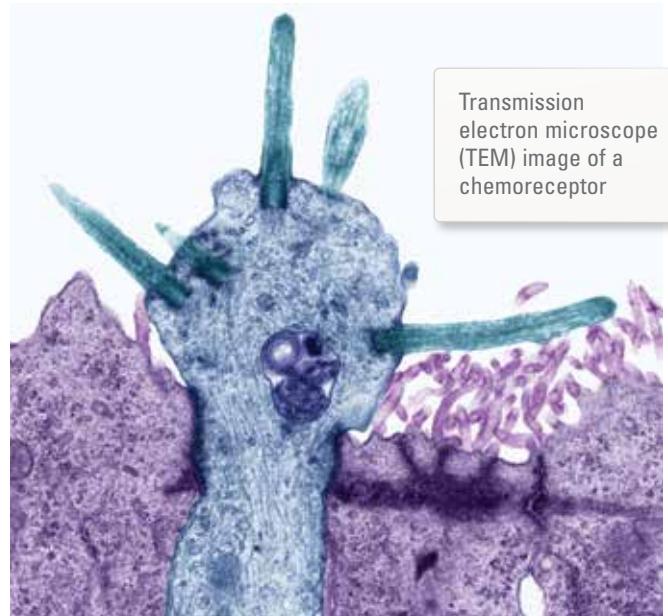
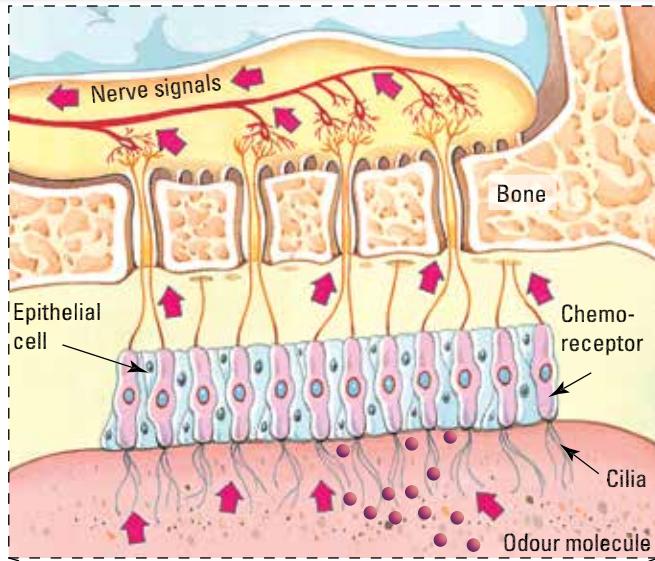
5 Swap roles with your partner and repeat the experiment.

DISCUSS AND EXPLAIN

- 6 Which touch receptors were being used in this experiment?
- 7 Construct a graph to represent your data and comment on observed patterns.
- 8 Which area of the skin was (a) most sensitive and (b) least sensitive?
- 9 Suggest why the skin is not equally sensitive all over the body.
- 10 Which parts of the skin are likely to have the most contact receptors?
- 11 Discuss how your predictions compared to your experimental results.
- 12 Suggest improvements to this investigation and further experiments to investigate contact receptors.

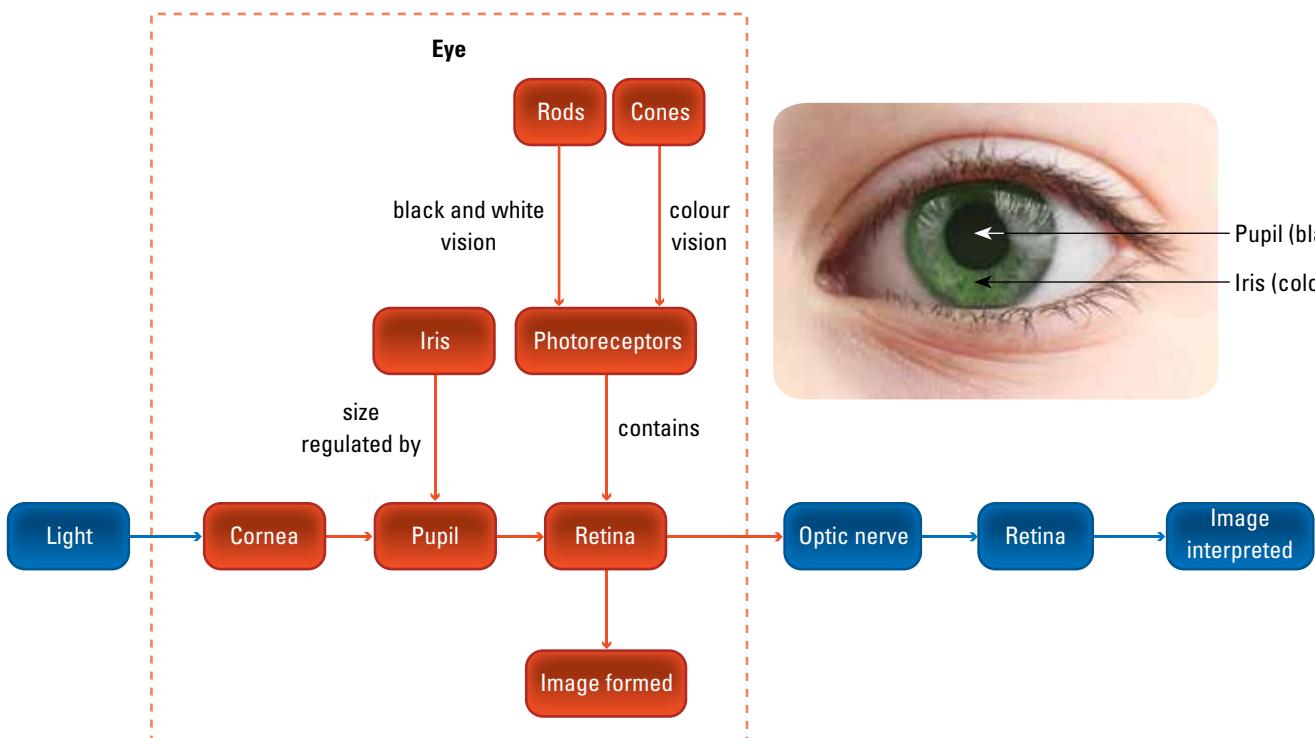


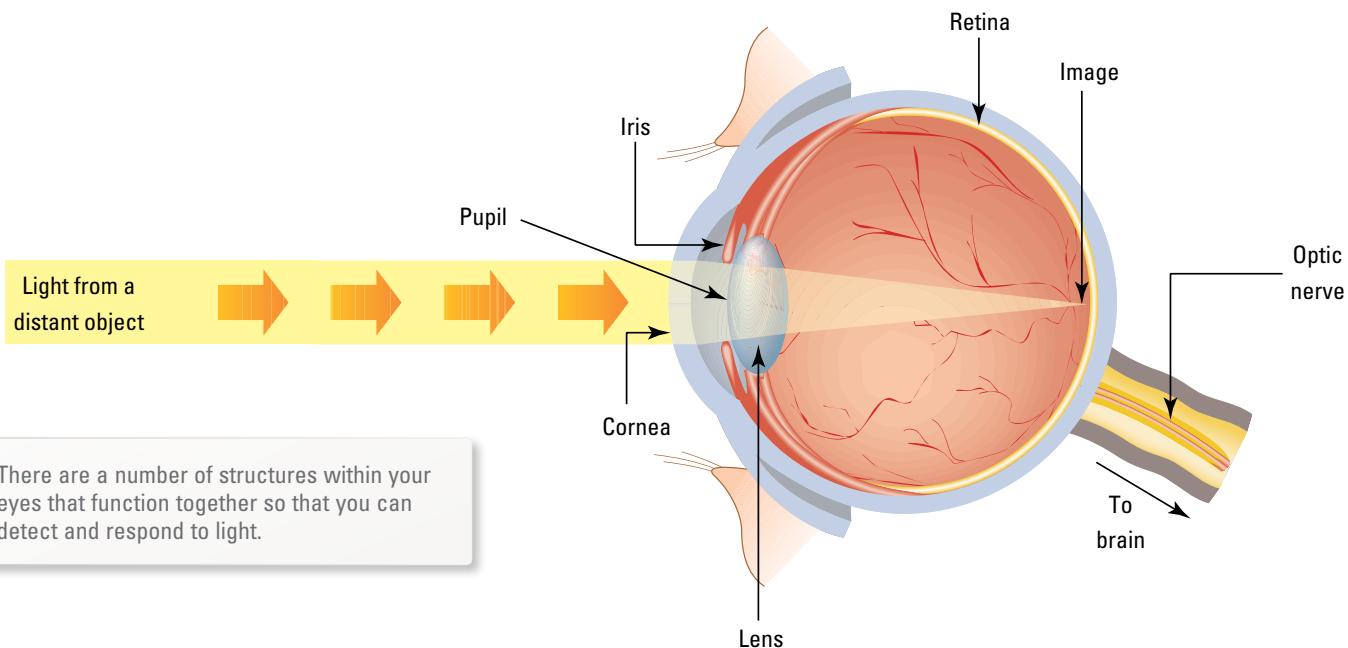
Chemoreceptors in your nose enable you to have a sense of smell.



Sight — in the wink of an eye

Your eyes, like your other sense organs, are made up of many different parts, each with its own special job to do. Look into a mirror (or into the eyes of the person next to you). The dark spot in the centre of your eye is called the **pupil**. Your pupil is simply a hole in the **iris**. Your iris is the coloured part of your eye. The amount of light entering into your eye is determined by the size of your pupil, which is controlled by your iris.

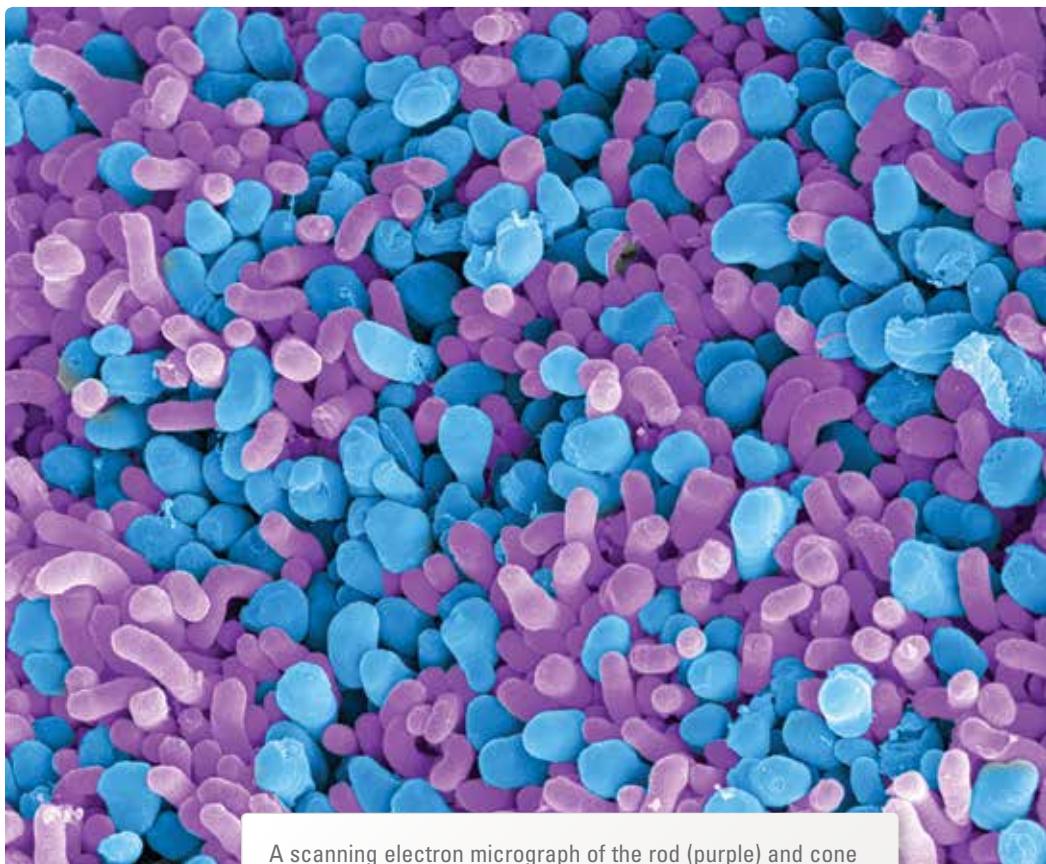




Your iris is a ring of muscle, so when it relaxes the pupil appears bigger, letting more light into the eye; and when it contracts, the pupil looks smaller, letting less light into the eye. In a dark room, your pupil is large so that as much light as possible can enter your eye. If you were to move outside into bright light, your pupil would become smaller. This **reflex action** helps to protect your eyes from being damaged from too much light.

Getting the picture

The **cornea** is the clear outer 'skin' of your eye. It is curved so that the light approaching your eye is bent towards the pupil. The clear, jelly-like **lens** bends or focuses light onto a thin sheet of tissue that lines the inside of the back of your eye called the **retina**. The lens is connected to muscles which can make it thick or thin. This allows your retina to receive a sharp image of distant or nearby objects. **Short-sightedness** and **long-sightedness** are conditions in which a sharp image is not received on the retina. In these cases, the image can be sharpened by using artificial lenses such as those in glasses.



A scanning electron micrograph of the rod (purple) and cone (blue) cells in the eye. The rod cells detect light intensity and the cone cells respond specifically to colour.

INVESTIGATION 2.4

Getting an eyeball full!

AIM To investigate the structure of an eye

CAUTION

In this activity you will be using sharp instruments. Discuss with your teacher and other members of the class a list of safety rules that should be followed carefully before beginning this activity.

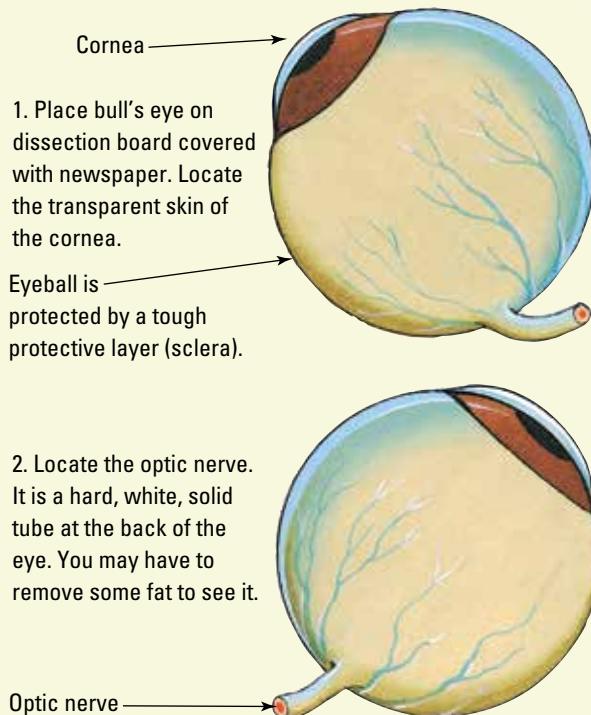
Materials:

bull's eye or similar
dissection board
newspaper
paper towelling
scalpel or razor blade

safety glasses
forceps
stereo microscope
water

METHOD AND RESULTS

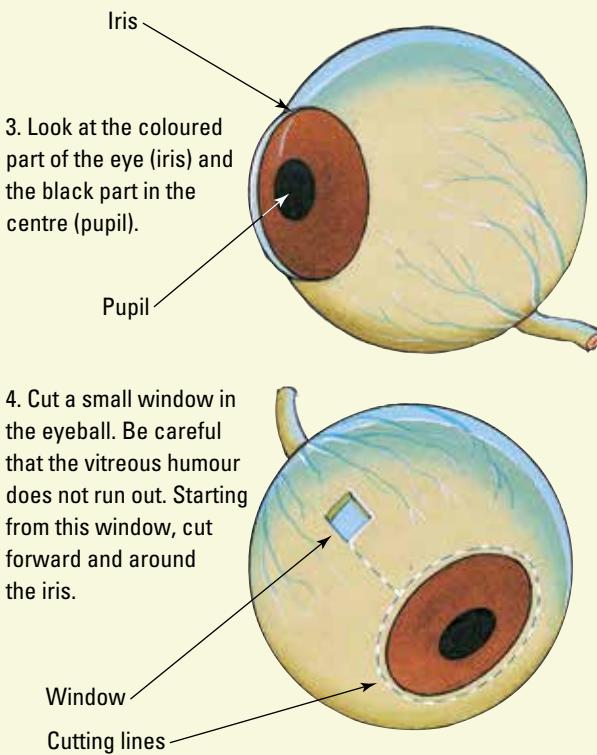
- ▶ Carefully place the bull's eye on a dissection board which has been covered with newspaper and paper towelling.
- 1 Draw and label the structures of the bull's eye before and after your dissection. (Use the diagrams below to help you to label your drawing.)
- 2 Add descriptive comments to your labels as you make your observations throughout this activity.
- ▶ Put on safety glasses just in case any of the aqueous or vitreous humour squirts out at you. Aqueous and vitreous humour are jelly-like liquids which give eyes their shape.



- 3 Carefully cut a small window just behind the iris using a razor blade or scalpel. Record your observations regarding the toughness of the sclerotic coating.
 - ▶ From this window, cut towards and then all the way around the iris so that you have cut the eye into two parts.
 - ▶ Lift off the top part of the eye and examine the iris.
 - ▶ Remove the lens with forceps and see if you can read the print on the newspaper through it.
 - ▶ Use water to rinse out the jelly-like material (humour) from inside the eye and examine the retina.
- 4 Record your observations.
 - ▶ Follow your teacher's instructions regarding the cleaning of your equipment and disposal of the dissected eye.

DISCUSS AND EXPLAIN

- 5 What is the black part in the middle of the iris?
- 6 What did you observe when you looked at the newspaper through the lens?
- 7 What did the retina look like? Could you find the optic nerve?
- 8 Summarise your findings in a table underneath your labelled bull's eye drawings.
- 9 What does the diaphragm in a microscope do? Which part of the eye does the diaphragm in a monocular microscope most resemble?
- 10 Find out more about one of the parts of the eye that you have observed, such as its function, related diseases or surgery.



INVESTIGATION 2.5

In the dark

AIM To investigate the effect of light intensity on the iris of a human eye

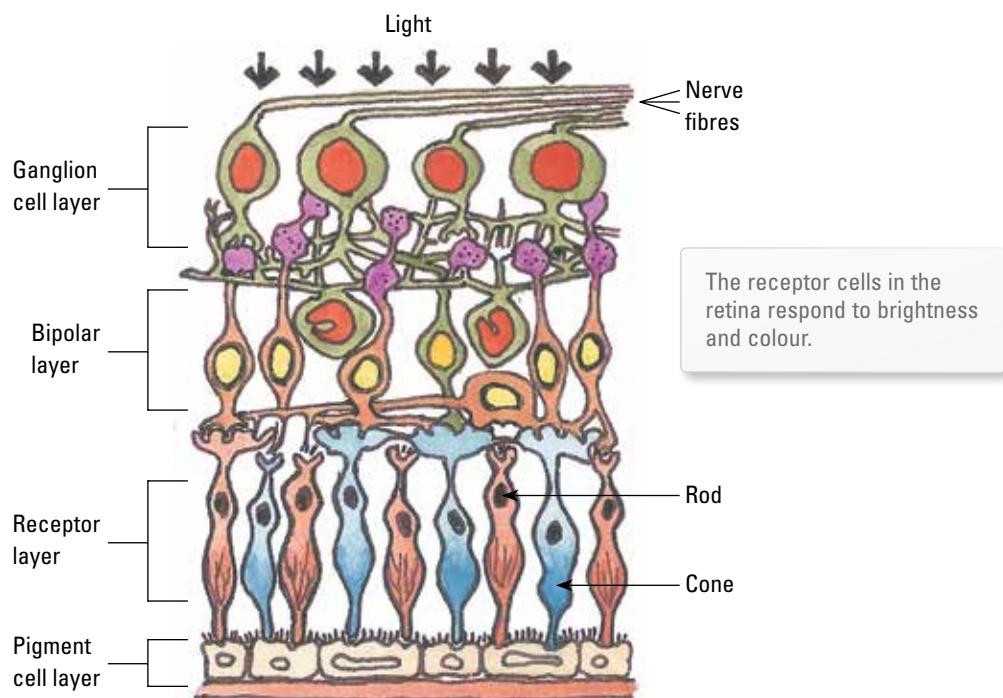
METHOD AND RESULTS

- Cup your hands loosely over both eyes so that you cannot see anything but your hands. Keep your eyes open. Look at the insides of your hands.

- After about one minute, have your partner look carefully at your pupils.

DISCUSS AND EXPLAIN

- What happens to the iris as your hands are removed?
- Explain your observations.



Although your eye receives light and produces an image of what you see, it is your brain that interprets and makes sense of the image. The photoreceptors in the retina respond to the light stimuli by sending signals to your **optic nerve** which then forwards them to your brain for interpretation.

Black and white or colour?

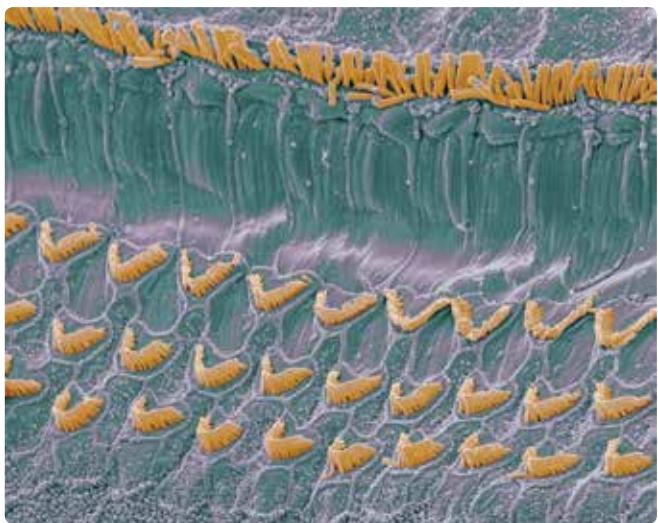
Why do you see in black and white at night and in colour during the day? It is because of **rods** and **cones**. These are two different types of photoreceptors located in your retina. Rods are more sensitive to light and allow you to see in black and white in dim light. Cones are responsible for colour vision, are less sensitive to light and operate best in daylight. At night, there is not enough light for your cones to sense colour.

Are you colour blind? **Colour blindness** is an inherited condition that is generally more common in males; however, females can also be colour blind, due to the way in which the condition is inherited. There are also different types of cones. If you have a deficiency of one or more of these it may mean that you find it difficult to see a particular colour or combinations of colours.

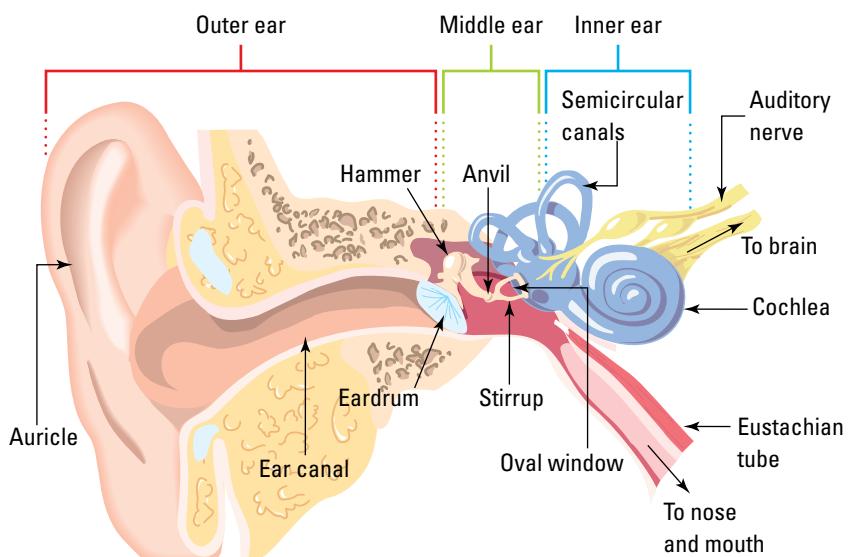
Hearing — catching vibrations

The ear is your sense organ that detects sound. When the air inside your **ear canal** vibrates, it causes your **eardrum** to vibrate at the same rate. Three tiny bones known as **ossicles** in your **middle ear** receive this vibration from your eardrum and then pass it to your inner ear. Inside your inner ear, thousands of tiny hairs

attached to nerve cells of the snail-shaped **cochlea** detect the vibration and send a message to your brain via your **auditory nerve**. Your brain interprets the message as hearing sounds.



An electron micrograph of hair cells in the cochlea



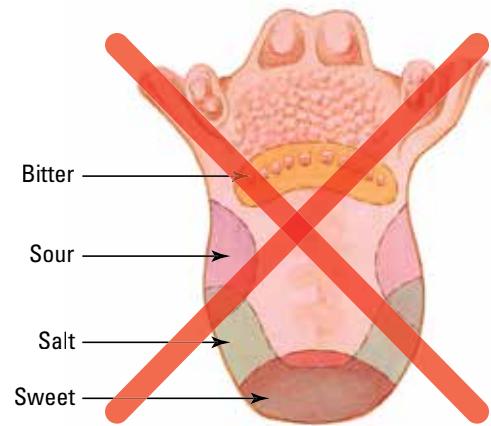
Your ear contains specialised structures that help you to detect sound.

Tasting — sweet or sour?

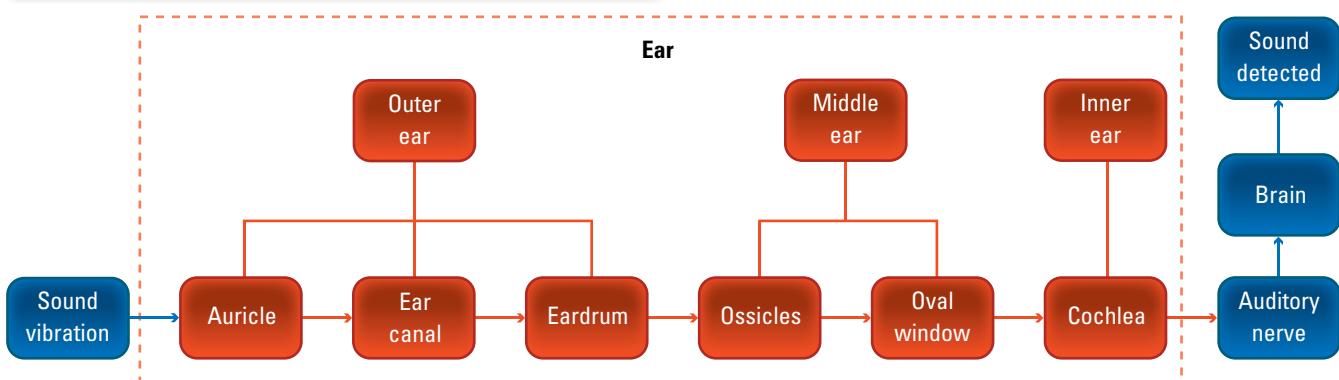
Change of taste

The **tongue** is your sense organ for taste. It was once thought tastebuds in different regions of your tongue could detect particular flavours such as salty, sweet, sour, bitter and savoury. New scientific discoveries have, however, disproved this model and it has now been replaced with a new model to explain how we gain our sense of taste.

In the new model, **tastebuds** located within bumps called **papilla** across your tongue have the ability to sense all flavours. This is because each of these tastebuds contains taste cells with receptors for each of type of flavour.



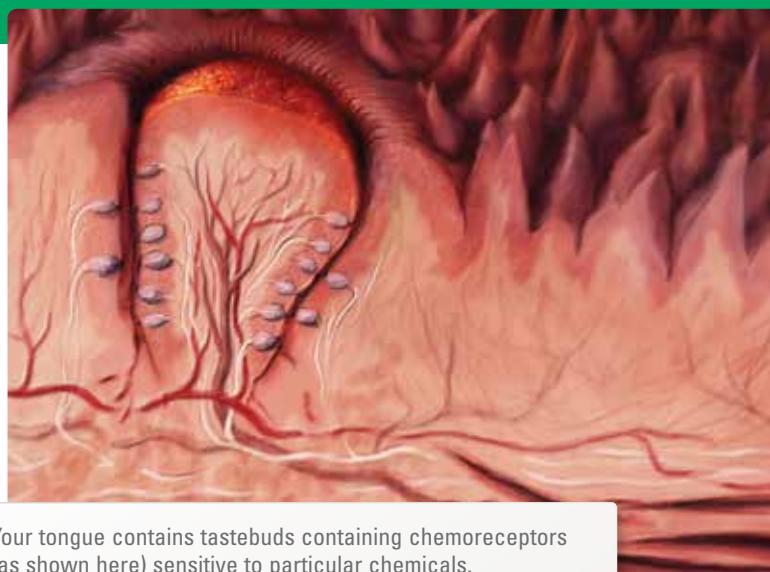
This model of taste is now obsolete. Current research suggests that we do not have different areas on our tongue for different taste sensations.



Hardwired for flavour

Our brains are wired so that we enjoy sweet, savoury and salty foods so that we can obtain the energy, protein and nutrients that we need to survive. Mass-produced foods, however, are often packed with high amounts of sugar and salt. This has resulted in our sense of taste increasing our chance of suffering from conditions such as diabetes, heart disease and obesity.

Researchers have discovered tiny compounds that can magnify the taste of foods, so that they can taste saltier and sweeter than they really are. The use of these taste enhancers could lead to reduced sugar, salt and monosodium glutamate (MSG) being added to foods and fewer taste-related diseases.



Your tongue contains tastebuds containing chemoreceptors (as shown here) sensitive to particular chemicals.

UNDERSTANDING AND INQUIRING

REMEMBER

- 1 State the purpose of the sense organs.
- 2 List examples of:
 - (a) five stimuli detected by human sense organs
 - (b) five human sense organs
 - (c) five types of receptors.
- 3 Provide an example of a type of receptor. State where you would find it and the stimulus that it detects.
- 4 Identify the location of the:
 - (a) optic nerve
 - (b) olfactory nerve.
- 5 Describe the difference and relationship between the pupil and iris in the eye.
- 6 Construct a mind map to show the structures that are important to vision.
- 7 In which part of the human body is an observed image:
 - (a) formed
 - (b) interpreted?
- 8 Outline the differences between the functions of rods and cones in the eye.
- 9 Construct a flowchart that shows structures involved in:
 - (a) smell
 - (b) vision
 - (c) sound.
- 10 Describe the new model that is used to explain the involvement of our tongues in the sensation of taste. How is this different to the previous model?
- 11 Suggest a reason why we are 'hardwired for flavour'.
- 12 Suggest how the discovery of taste enhancers may reduce the chances of getting 'lifestyle' diseases such as some types of diabetes, heart disease and obesity.

THINK AND DISCUSS

- 13 If cats have rods, but no cones, what does that mean in terms of how they see the world?
- 14 Why is the thickest part of your skin on the soles of your feet?
- 15 Why are some parts of your skin, such as the back of your hand, more sensitive to heat than others?
- 16 How do movement receptors receive a sensation of movement when they are well below the surface of the skin?
- 17 When you walk into a dark room at night, you cannot see anything. A minute later, without any additional light, you can see. What behaviour of the eye allows this to happen?
- 18 Olfactory receptor cells are important to enable us to smell things. A human has about 40 million, whereas a rabbit has 100 million and a dog has 1 billion! What effect might this difference have on the chances of survival for these animals?
- 19 Make some spectacles out of cardboard and use red-coloured cellophane for the lenses. If you wear the spectacles when a light or torch is turned on, your eyes will be using only their cones. When you return to the dark and remove the spectacles, your rods will be unaffected by the red light. Therefore you won't need to adapt to the dark, and can use your eyes immediately.

INVESTIGATE

- 20 Investigate and report on the work of Australian scientists such as Fiona Wood and Marie Stoner on artificial skin.
- 21 Click on the **Virtual medical centre** weblink in your eBookPLUS to find a flowchart on how hearing occurs.

Getting in touch with your brain

Take a guess. What looks like a grey wrinkled walnut and is about the size of a large grapefruit? Hint: you are using it to figure out what the mystery object is!



What is in your brain?

The average brain weighs around 1.5 kilograms and is made up of about 80 per cent water, 10 per cent fat and 8 per cent protein. Although our brains contain about a billion brain cells, only about 10 per cent are active neurons (nerve cells); the remaining brain cells are there to nourish and insulate the neurons. These neurons can grow extensions called **dendrites**, which reach out like branches on a tree, allowing communication between other neurons.

This communication is very important in relaying information about your environment and deciding what to do with it.

More than just a bag of chemicals!

Your brain is more than just a mix of chemicals and cells. It is the control centre of all of your body's functions and is responsible for intelligence, creativity, perceptions, reaction, emotions and memories. It can be said that your brain is at the wheel, steering your body's systems so that it continues to function correctly, whether it's remembering the taste of chocolate, working out a crossword puzzle, controlling your heartbeat or monitoring the glucose level in your blood.

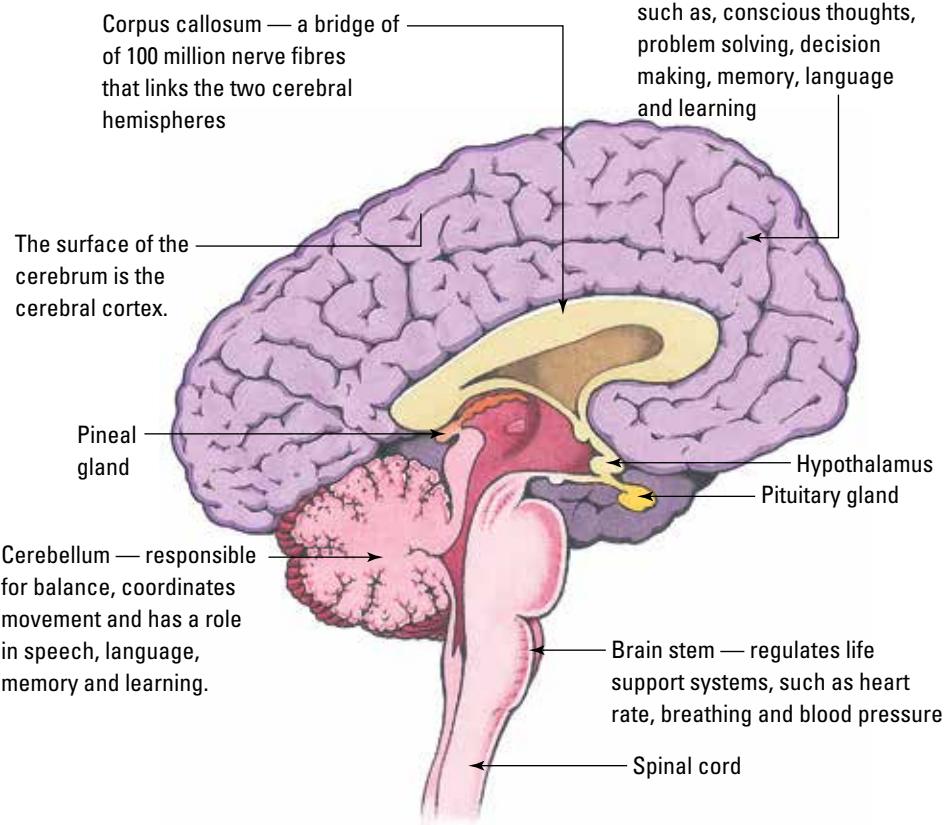
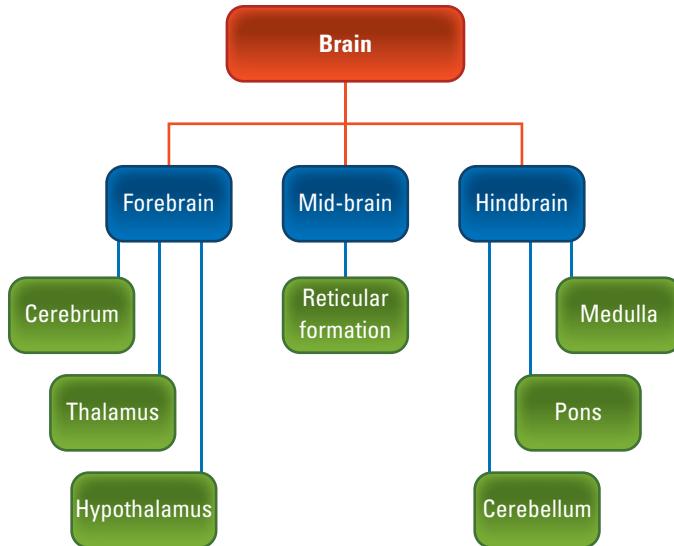
When you think, you are using your brain. Another name for thinking is **cognition**. You also 'feel' with your brain. Happiness, sadness and anger are examples of feelings or **emotions** that are interpreted by your brain. Your brain also interprets messages about your internal and external environments, and plays a key role in **regulating** processes that keep you alive.

Patterns of organisation

Your brain cells are organised into different areas within your brain. Although they may have different functions, they communicate and work together to keep you alive. There are a number of different models that are used to describe the structure of the human brain.

From back to front

Your **hindbrain** is really a continuation of your spinal cord. It develops into the **pons** and cerebellum, and the **medulla oblongata** (medulla). Extending through your hindbrain and midbrain is a network of fibres called the **reticular formation** — a network of neurons that opens and closes to increase or decrease the amount of information that flows into and out of the brain. The reticular formation helps regulate alertness (from being fully awake or deeply asleep), motivation, movement and some of the body's reflexes (such as sneezing and coughing). The **forebrain** develops into the cerebrum, **cerebral cortex** (outer, deeply folded surface of the cerebrum) and other structures such as the **thalamus**, **hypothalamus** and **hippocampus**.



Brain stem or medulla

Not all actions in your body require conscious thought. These are called involuntary actions and you don't need to think about them for them to occur. Breathing, heartbeat, blood pressure, coughing, vomiting, sneezing and salivating are all examples of involuntary actions controlled by your **brain stem**.

Your brain stem (or medulla) is located between your spinal cord and your cerebrum. If this vital structure is damaged, death may result. One of the reasons drugs such as heroin and cocaine are so dangerous is that they can impair the functioning of this structure, causing interruptions to heartbeats or breathing.

Cerebellum

What's grey on the outside, looks like two clams side by side, is about the size of your fist and without it you'd fall over? The answer is your **cerebellum**.

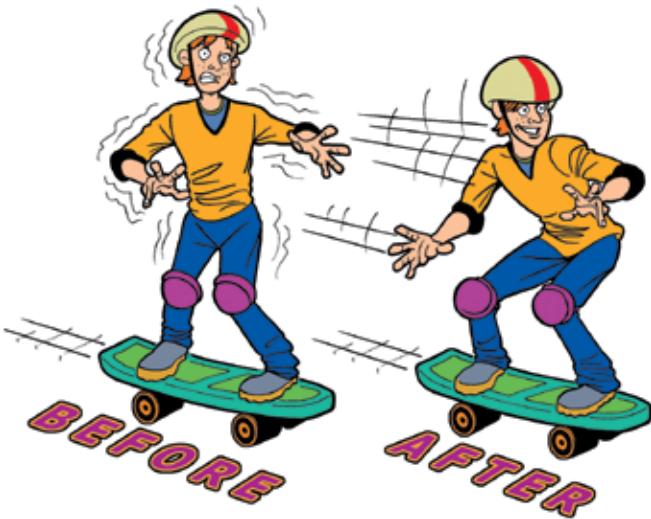
Your 'little' brain

Your cerebellum is located near the brain stem, underneath the cerebrum. Although it takes up only about 10 per cent of your brain's volume, the cerebellum contains over half of all of your brain's neurons. Your cerebellum has key roles in posture, coordination, balance and movement. Current research also suggests that it may also be involved in memory, attention, spatial perception and language.

The word *cerebellum* means 'little brain' in Latin and that's just what it looks like. There are two halves (or hemispheres), one for each side of the brain. Each of these hemispheres consists of three lobes. There is a lobe that receives sensory input from your ears to help you to maintain your balance. Another lobe gets messages from your spinal cord to let your brain know what some other moving parts of your body are up to. There is even a lobe that communicates with your cerebrum, the thinking part of your brain.

Taking charge

When you start learning a new skill, you have to think carefully about what you are doing. Once you have got the hang of it, your cerebellum takes over from your thinking context to tell your body what to do. Research has shown that when the cerebellum is in charge, you can move faster and are less clumsy. Other research suggests that long-term memory traces for



motor learning are located in your cerebellum and that movement may help your thinking because of increased signals travelling between your cerebrum and cerebellum.

Cerebrum

The **cerebrum** is the largest part of the brain and makes up about 90 per cent of your brain's total volume. The cerebrum is responsible for **higher-order thinking** (such as problem solving and making decisions) and controls speech, conscious thought and voluntary actions (actions that you control by thinking about them). The cerebrum is also involved in learning, remembering and personality.

The cerebrum is made up of four primary areas called lobes. Each of these lobes is associated with particular functions.

You can use a piece of paper to model how the cerebrum can fit into such a small area. If you screw up the piece of paper so that it is roughly the size of your fist you can see how the cerebrum, with its large surface area, can fit into a small area within your skull. Its many wrinkles and folds are the reason that only about one-third of this structure is visible when you look at the outside of a brain.

Left and right — two brains in one?

Your cerebrum is divided into two grey wrinkly **cerebral hemispheres** — the right cerebral hemisphere (mainly responsible for the left side of your body) and the left cerebral hemisphere (mainly responsible for the right side of your body). While each hemisphere is specialised to handle different tasks they work together as an integrated whole, communicating with each other through a linking bridge of nerve fibres called the **corpus callosum**.

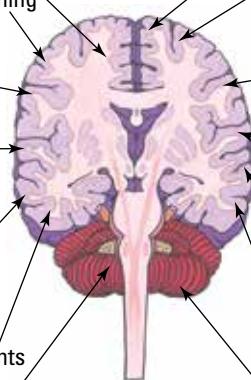
Although each cerebral hemisphere processes information differently they are both involved in putting together the total picture of what you sense around you. During your learning, it is important to employ learning activities that utilise the strengths of both hemispheres (even if it can feel a little uncomfortable sometimes). This will allow you to focus on 'whole-brained' learning.

Right cerebral hemisphere

1. I don't mind randomness.
2. I learn best when I make up the whole picture after learning its parts.
3. I want to use diagrams, graphics and pictures.
4. I prefer to see or experience a topic before I learn about it.
5. I like collecting information about how things relate to each other.
6. I prefer learning environments that are spontaneous rather than structured.
7. I like novelty and surprises without a definite outcome.

Left cerebral hemisphere

8. I prefer things in order.
9. I learn best when I learn the parts after seeing the whole picture.
10. I want to use symbols, words and letters.
11. I like to read about a topic first before it is discussed in class.
12. I like to collect relevant facts about a topic.
13. I prefer precise, organised instructions.
14. I want organisation and predictability.



Although the left and right cerebral hemispheres have specialised functions, they communicate with each other. Depending on the task, you can switch from one side of your brain dominance to the other a number of times each day.

HOW ABOUT THAT!

Like your thumbprint, your brain is unique. Not only may it be a different size and weight from your friends, but the learning connections between cells in your brain are different. These connections are made as a result of your experiences and this forms your own personal 'cognitive map', which can change over time as you build up more experiences. This difference in our brain's 'internal wiring' can explain why people at the scene of the same accident can have such different eyewitness reports.

Tasty words and colourful letters?

A small percentage of the population have their senses crossed and associate letters with a flavour, numbers with a gender and sounds with colour. This condition is known as **synaesthesia**. It has been likened to receiving information in one sense and it triggering an experience in another. So while you might hear music, the sounds trigger seeing particular colours! There are thought to be at least 54 documented types of this condition.

SYNAESTHESIA

0123456789

Someone with synaesthesia might perceive certain letters and numbers as they are shown here.

INVESTIGATION 2.6

Brain dissection

AIM To investigate the structure of the brain

CAUTION Handle dissecting instruments with care and ensure they are placed in a sterilising solution after use.

Wear gloves throughout the dissection and wash your hands thoroughly at the end.

Materials:

a semi-frozen sheep's brain
dissecting board
dissecting instruments (scalpel, forceps, scissors)
plastic ruler
paper towel
gloves

METHOD AND RESULTS

- 1 Construct a table with the headings shown below.

Brain structure	Appearance			
	Colour	Texture	Other features	Size
Cerebrum				
Cerebellum				
Brain stem				

- ▶ Place the brain so that the cerebral hemispheres are at the top of the board and the brain stem is at the bottom.
▶ Identify the external features of the brain: the cerebral hemispheres, cerebellum and brain stem.
▶ Use your forceps and try to lift the meninges (membranes protecting the brain). You may be able to observe the cerebral fluid between these membranes and the hemispheres.

- 2 Carefully observe the overall appearance of each structure and, using a plastic ruler, measure its size (length, width and

height). Include this information in a table like the one below left.

- 3 Draw a diagram of the sheep's brain, labelling the external features.
▶ On your diagram, identify and label the part of the brain that controls the sheep's:
(a) heart rate
(b) balance required for walking
(c) ability to locate its lamb.
4 Using your scalpel, cut the brain in half between the right and left hemispheres, and separate the two cerebral hemispheres.



- 5 Draw a cross-section of the brain. Be sure to label it!
▶ Now make a second cut down through the back of one of the hemispheres to see inside the cerebellum and brain stem.

- 6 Record your observations.

DISCUSS AND EXPLAIN

- 7 (a) Which structures contained the grey and white matter?
(b) Find out why these structures are different colours.
8 Which part of the sheep's brain is the biggest? Is this the same pattern in human brains?
9 The brain is usually protected by a bony skull. It is also covered with three layers of connective tissue called meninges and surrounded by cerebral fluid. Suggest how the meninges and cerebral fluid help protect the brain.
10 Summarise your findings.
11 Identify strengths and limitations of your investigation of the brain and suggest improvements.



Currently there is exciting research being conducted in this area, investigating how people with this condition form and remember memories. Some of these investigations involve the use of **functional magnetic resonance imaging (fMRI)** to get a 3-dimensional image of the brain so that the areas of the brain that are activated during different mental tasks can be recorded.

It's a bit like a ...

Using **analogies** and **metaphors** can be very useful in helping you to connect information that you already know to new information. An example that has been used in the past is 'the brain is like a computer'. This

provides a framework of known ideas to relate to new ideas.

While analogies and metaphors and models can be very useful in your learning, they also have limitations. The more we find out about the brain, the less suitable a previously used metaphor may be. Examples of other analogies that have been used for the brain include comparing it to a hydraulic system, a telephone switchboard and, more recently, an ecosystem in a jungle! These analogies often reflect the most current technological innovation of the time.

Did you notice examples of analogies and metaphors mentioned throughout these pages? How effective have they been in helping you 'get a handle' on new information about the brain?

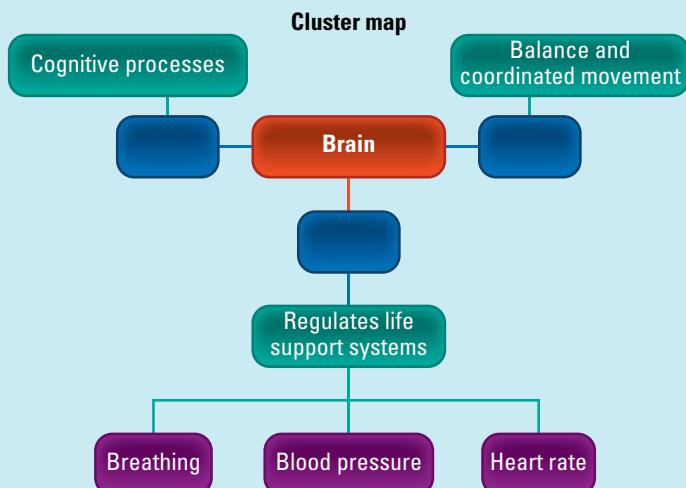
UNDERSTANDING AND INQUIRING

REMEMBER

- 1 Name the organ that has been described as the control centre of your body.
- 2 Identify the part of your brain that:
 - (a) takes up the greatest volume
 - (b) regulates heartbeat, breathing and blood pressure
 - (c) generates the most complex thoughts
 - (d) coordinates movement
 - (e) manages communication between left and right hemispheres.
- 3 Use analogies to describe the appearance of the:
 - (a) brain
 - (b) cerebrum
 - (c) cerebellum.
- 4 Distinguish between:
 - (a) cerebrum and cerebellum
 - (b) left and right cerebral hemispheres
 - (c) cerebrum and cerebral cortex
- 5 Copy the cluster map shown and insert 'cerebrum', 'cerebellum' and 'brain stem' into their appropriate location.

INVESTIGATE, THINK AND DISCUSS

- 6 Christopher Reeve, the actor who played Superman in the early Superman movies, damaged his brain stem when he fell off a horse. Find out and report on:
 - (a) the effect this had on his brain function
 - (b) medical research that may help others with such damage.
- 7 Find out more about the cerebellum and how it may be involved in learning.
- 8 In teams, research the structure and functions of different parts of the brain.



9 *Brains react to music like a drug.* This was a claim made in the media in 2011. It was based on a scientific study that used PET (positron emission tomography) and fMRI brain scans to record brain activity of volunteers while they listened to their favourite piece of music. The PET scan detected a release of dopamine (a neurotransmitter responsible for feeling a sense of reward and pleasure) in their brains and the fMRI scan showed increased blood flow to the emotional response areas.

- (a) For this investigation suggest:
 - (i) a hypothesis
 - (ii) the dependent variable(s) and independent variable
 - (iii) an appropriate control group
 - (iv) controlled variables.



eLesson

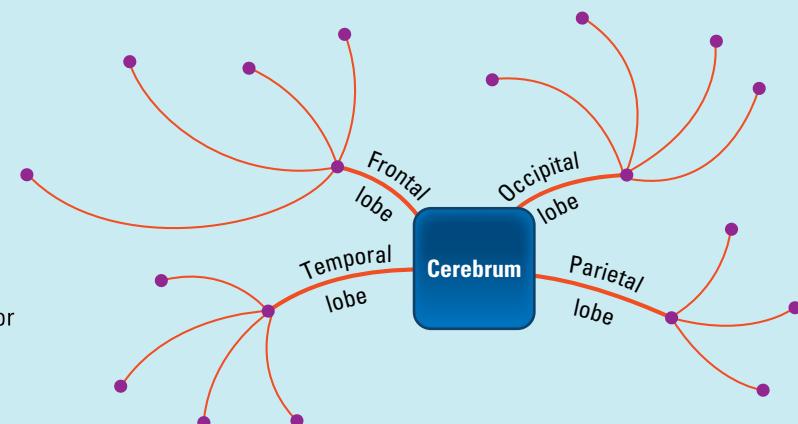


Willis and the brain

Watch a video from *The story of science* about early research on the brain.

eles-1783

- (b) Find out more about similar investigations. Is the media claim supported by your findings? Explain.
- 10** Find out more about the Nobel Prize winning physicist Richard Feynman, who described seeing equations in colour, and the expressionist artist Wassily Kandinsky, who associated musical tones with specific colours.
- 11** Recently a technique called diffusion tensor imaging (DTI) has been used to compare the connectivity between the brains of grapheme–colour synaesthetes and non-synaesthetes. Find out more about this research and the findings.
- 12** Work out whether you are left- or right-brain dominant:
- Give a mark out of 5 for each of the statements shown in the diagrams on page 54 for each hemisphere of the brain.
 - Add up the total score for each side. In which hemisphere of the brain did you score higher?
 - What does this mean in terms of your learning?
- 13** Use the **Synaesthesia** weblink in your eBookPLUS to find out about different hypotheses regarding synaesthesia and the types of research that scientists are currently involved in. On the basis of your findings, what hypothesis would you suggest?
- 14** Investigate why damage to the right side of the brain often affects the left side of the body.
- 15** What is meningitis and how does it affect the brain?
- INVESTIGATE, THINK, CREATE AND DESIGN**
- 16** Design an instruction manual to help someone learn a new physical skill. Be creative and make it fun and exciting. Evaluate the effectiveness of your manual by trying it out on other students in the class.
- 17** Design an activity that uses the cerebellum to learn a more about the brain.
- 18** Nobel Prize winner Roger Sperry described the hemispheres of the brain as 'each with its own memory and 'competing for control'.
- Find out why Roger Sperry was awarded the Nobel Prize in medicine in 1981.
 - Do you agree with his comments about the brain's hemispheres? Explain.
 - Construct a model of the right and left hemispheres that creatively shows the types of tasks that they are involved in.
- 19** Construct a labelled model of the brain using food, coloured plasticine or other materials.
- 20** The cerebrum is made up of four primary areas called lobes. Each of these lobes is associated with particular functions. Find out which of the following



terms is associated with each lobe and then construct a completed mind map. Terms to use include words, pictures, explicit memory, hearing, sensory, motor, spatial, decision, planning, working memory, vision, colours, movement and higher-order thinking.

- 21** Use the **Brain interactive** weblink in your eBookPLUS to find out about the parts of brain that control your body.
- 22** Use the **Brain map**, **Brain tour** and **Brain animation** weblinks in your eBookPLUS to investigate the structure and function of the brain.

ANALYSE AND DISCUSS

Animal	Brain size as % of body mass
Mouse	10
Chimp	0.8
Elephant	0.1
Dolphin	1
Cat	1
Human	2

- 23** The table above shows the brain size as a percentage of body mass for a number of animals. Use this data, your own knowledge (and other resources if required) to answer the following questions.
- Construct a graph using the information in the table.
 - Comment on any trends or patterns in the graph.
 - Suggest and discuss two possible explanations for the observed patterns.
 - Suggest a relevant hypothesis that could be investigated.
 - Formulate three questions about how the data was collected (method used).
 - Suggest three relevant questions that could be further investigated.

Endocrine system — slow control

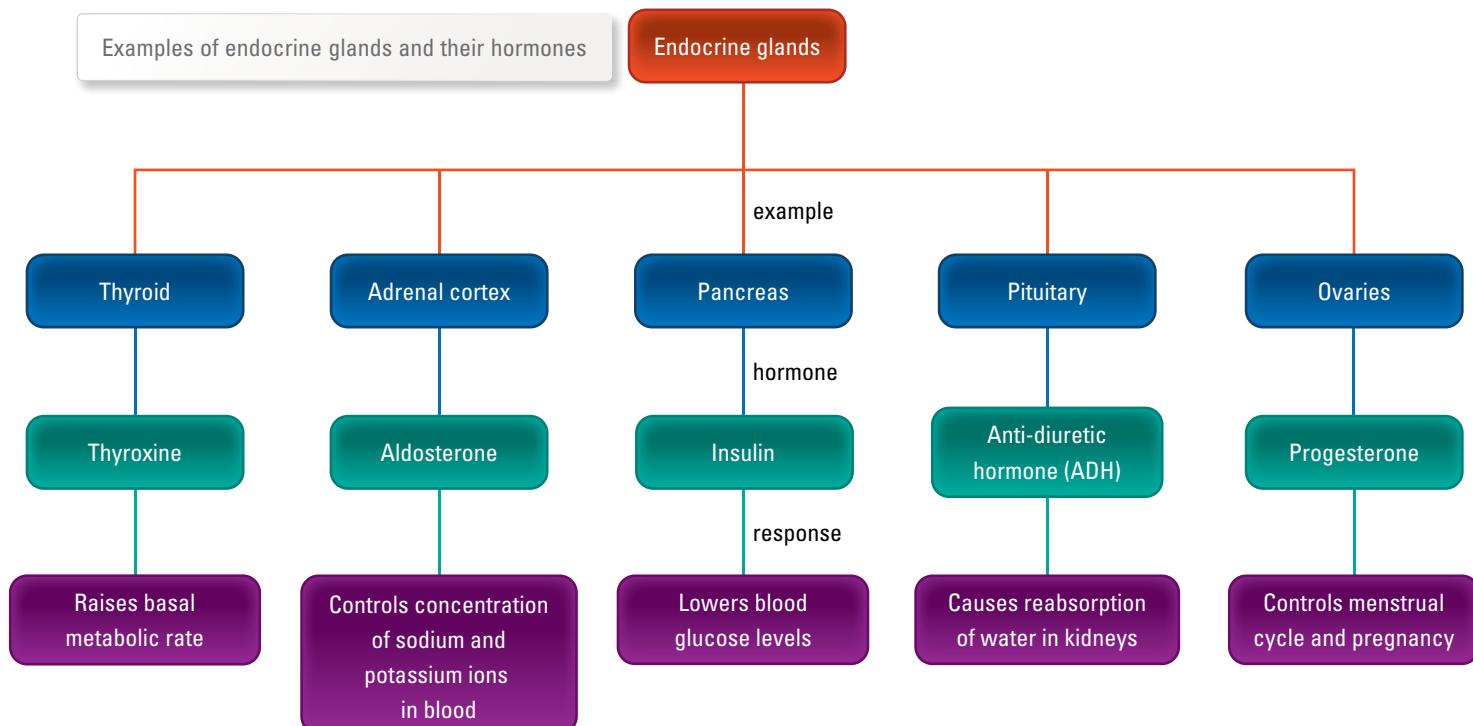
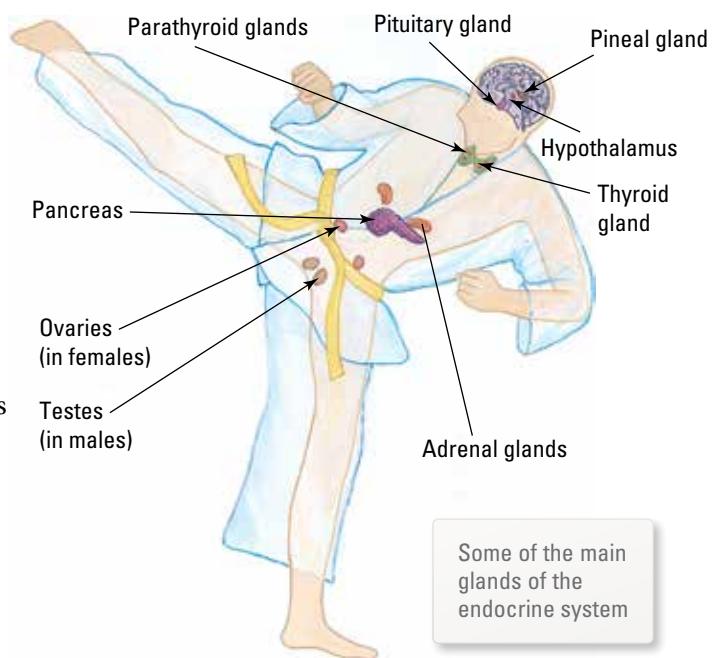
Thirsty? Too hot or too cold? Feeling different or noticing changes in how you look, feel or act? Chemicals in your blood not only help to keep you balanced, but are also very important in controlling and coordinating your growth and development.

Helpful hormones

Your nervous system is not the only means of controlling and coordinating activities in your body. Your endocrine system uses chemical messengers called **hormones**. They are produced in your **endocrine glands** and are released directly into your bloodstream. Although hormones are carried to all parts of your body, only particular cells have receptors for particular hormones. It is a little like radio signals, which are sent out in all directions but picked up only by radios attuned to a particular signal. These **target cells** are attuned to the hormones carried through your body and respond in a particular way.

Hormones control and regulate functions such as metabolism, growth, development and sexual reproduction. Like the nervous system, the endocrine system detects a change in a variable, and often acts using a negative feedback mechanism to counteract

the initial change. The endocrine system also works with the nervous system to regulate your body's responses to stress. The effects of the endocrine system are usually slower and generally longer lasting than those of the nervous system.



Endocrine glands in your brain

Endocrine glands are located in various parts of your body. Your pituitary gland, the hypothalamus and the pineal gland are examples of endocrine glands that are located in your brain.

I'm the boss! The **pituitary gland** is often referred to as your 'master gland' because it controls many other endocrine glands, stimulating them to release their own hormones. For example, your thyroid gland, ovaries and testes are all controlled by hormones released by this endocrine gland. Hormones released by the pituitary gland can control water balance, growth, development and reproduction-related processes.

Feeling hungry or too hot? Your **hypothalamus** sends hormones to the pituitary gland to control its release of hormones to other endocrine glands. It also releases hormones that control body temperature, growth, sex drive, thirst, hunger and sensations of pleasure and pain. The hypothalamus links your nervous system to your endocrine system and is involved in reflex actions such as those involved in the beating of your heart and breathing.

Feeling sleepy? Your **pineal gland** produces the hormone melatonin which controls body rhythms such as waking and sleeping.

Keeping balance

Keeping warm

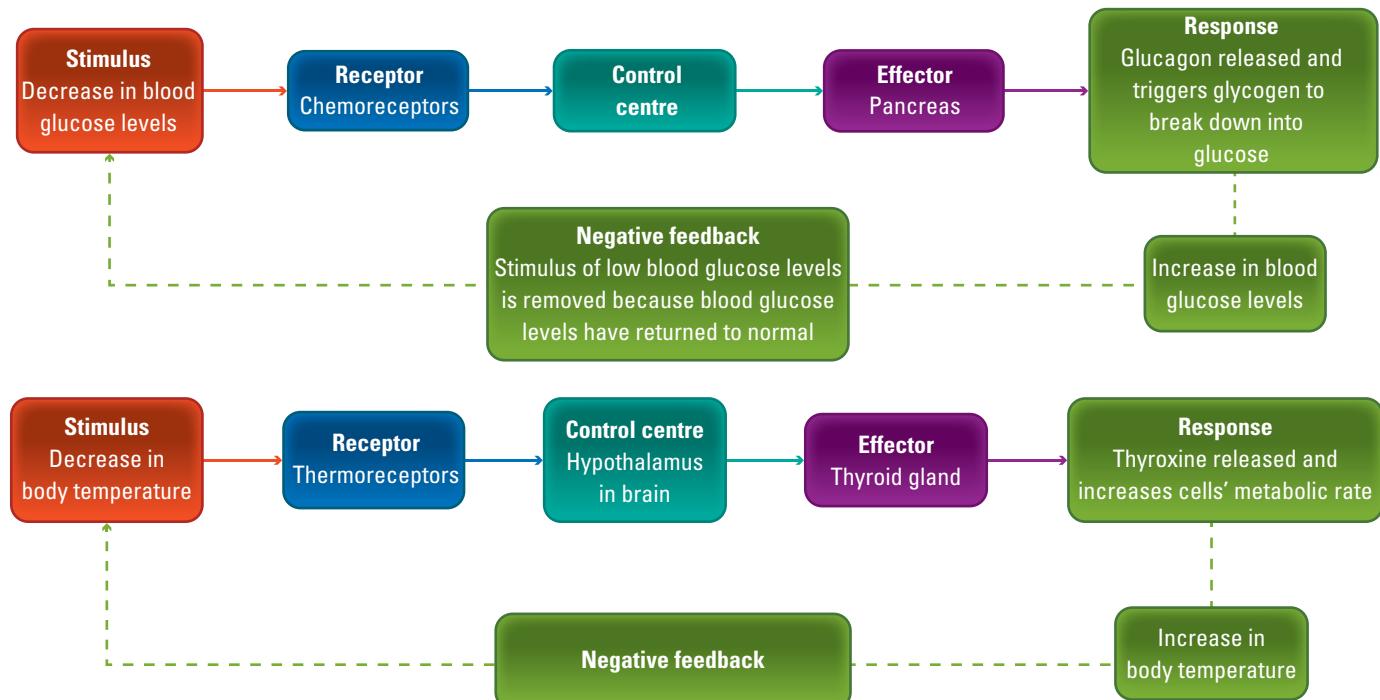
Negative feedback helps our body to keep its internal conditions stable so that you can function effectively. An example of this is if your body temperature is too low. The decrease in body temperature acts as the

stimulus, which is detected by thermoreceptors in your body. This message is taken to the hypothalamus, which activates warming mechanisms. One of these mechanisms involves the thyroid gland. It responds by secreting the hormone thyroxine, which increases the metabolic rate of cells, releasing heat to warm you. Raising body temperature reduces the need for the hypothalamus to direct the thyroid gland to secrete thyroxine. Regulation of body temperature is referred to as **thermoregulation**. This process shown below (and in more detail on page 36) provides an example of how the endocrine and nervous systems both work together to keep your body functioning effectively.

Sweet control

The regulation of blood glucose levels involves your endocrine system and negative feedback. After you have eaten a lot of sugary food, your blood glucose levels increase. This rise is detected by cells in your **pancreas**, which then secretes the hormone **insulin**. Insulin travels in the bloodstream and specific target cells in your liver and muscles respond by increasing the uptake of glucose into the cells and the conversion of **glucose** into **glycogen**, which is then stored. The result is that blood glucose levels return to their 'normal' levels (see page 34).

If a decrease in blood glucose levels is detected, the pancreas secretes the hormone **glucagon**. This hormone also travels in the blood to the liver and muscle cells, but in this case the response is that glycogen is broken down into glucose. Glucose is released into the blood, increasing blood glucose levels back to their 'normal' level (see figure below).



Reproductive control?

The endocrine system also plays a key role in controlling and coordinating human reproduction and development.

His hormones ...

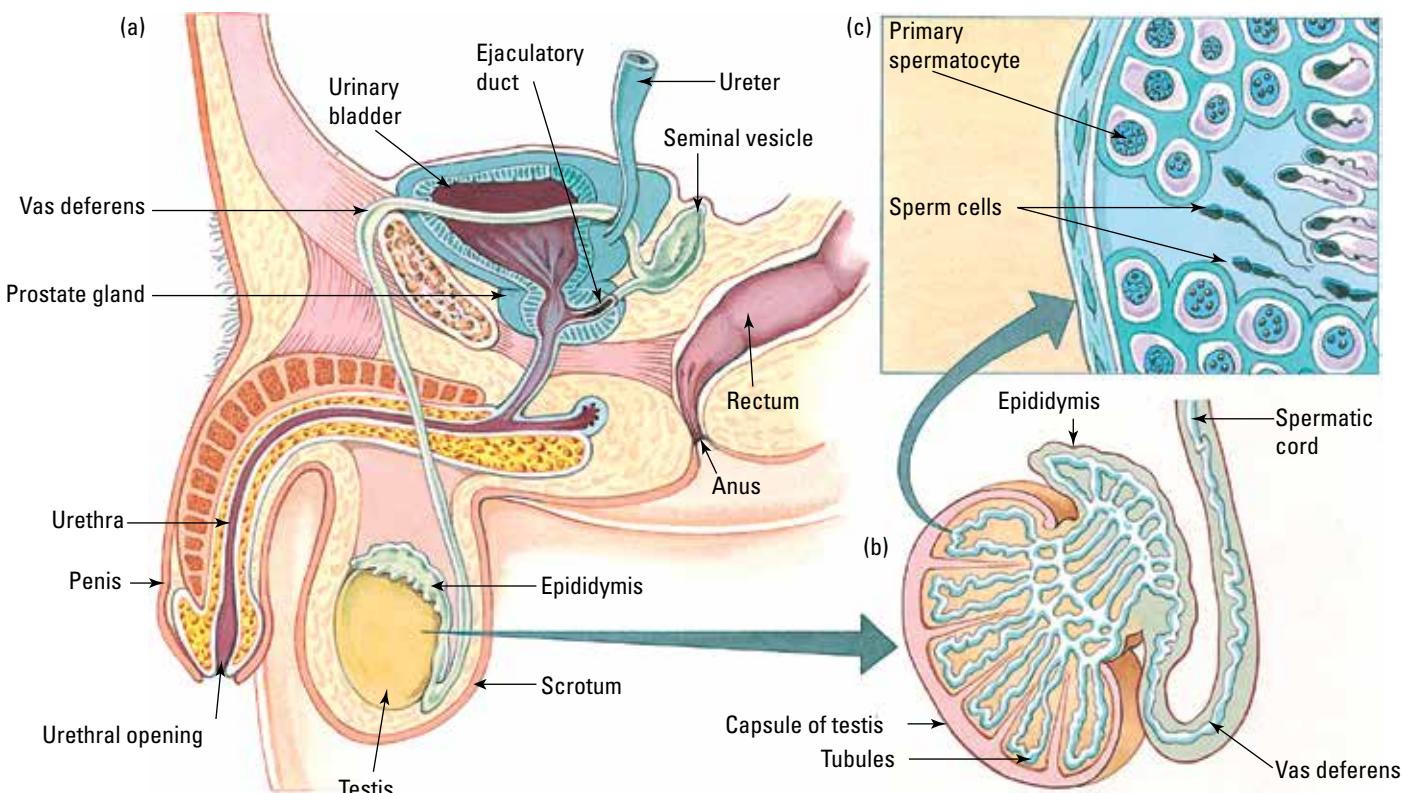
When a male has reached puberty, his **pituitary gland** secretes **luteinising hormone** (or **LH**). LH acts on his **testes** to produce another hormone called **testosterone**. An increase in testosterone levels causes his sex organs to grow and testes to begin to produce **sperm**. Other secondary sex characteristics are increased muscle development, changes in his voice, muscle and hair growth and hormones.

Her hormones ...

When a female has reached puberty, her **pituitary gland** secretes **follicle-stimulating hormone** (or **FSH**). FSH then acts on her **ovaries**, and **follicles** (structure in which the egg develops) begin to grow. A hormone called **oestrogen** is secreted by the growing follicles, which causes the thickening of the lining of the **uterus**.

to prepare it for a potential fertilised egg. Increased levels of oestrogen also stimulate the **hypothalamus** to produce more FSH and LH. Increasing levels of LH cause the follicle to swell. The mature follicle bulges on the surface of the ovary, ruptures, and the **ovum** (unfertilised egg cell) is released from the **ovary** into the **fallopian tube**. This process is called **ovulation**.

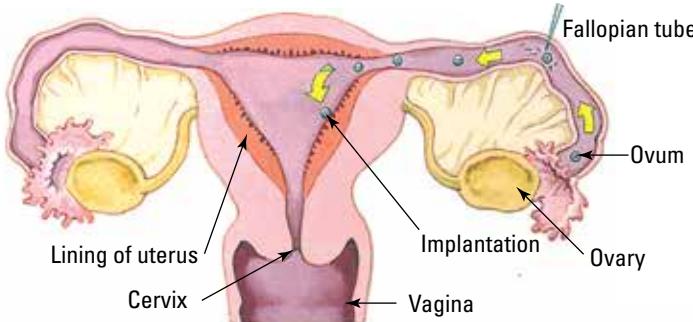
Once ovulation has occurred, the empty follicle from which the egg was released becomes a **corpus luteum**. This structure secretes another hormone called **progesterone**. This hormone continues to prepare the uterine lining for pregnancy. If **fertilisation** does not occur, both the ovum and corpus luteum break down. This causes the progesterone levels to drop and hence the lining of the uterus (endometrium) to break down. Blood and uterine lining are discharged through the vagina in a process called **menstruation**. When progesterone levels drop, the pituitary gland produces FSH and the cycle begins again. These cyclic changes in the ovaries and lining of the uterus as a result of changing hormone levels in the blood are called the **menstrual cycle**.



(a) The male reproductive system

(b) The internal structure of the testes

(c) An increase in the level of testosterone during puberty triggers the testes to produce sperm cells.



The female reproductive system

Harnessing hormones

Hormones can be harnessed to either increase or decrease fertility. In some situations, hormones can even be involved in aborting embryos. There are a number of issues that have been expressed about the production, availability, uses and consequences of these hormones.

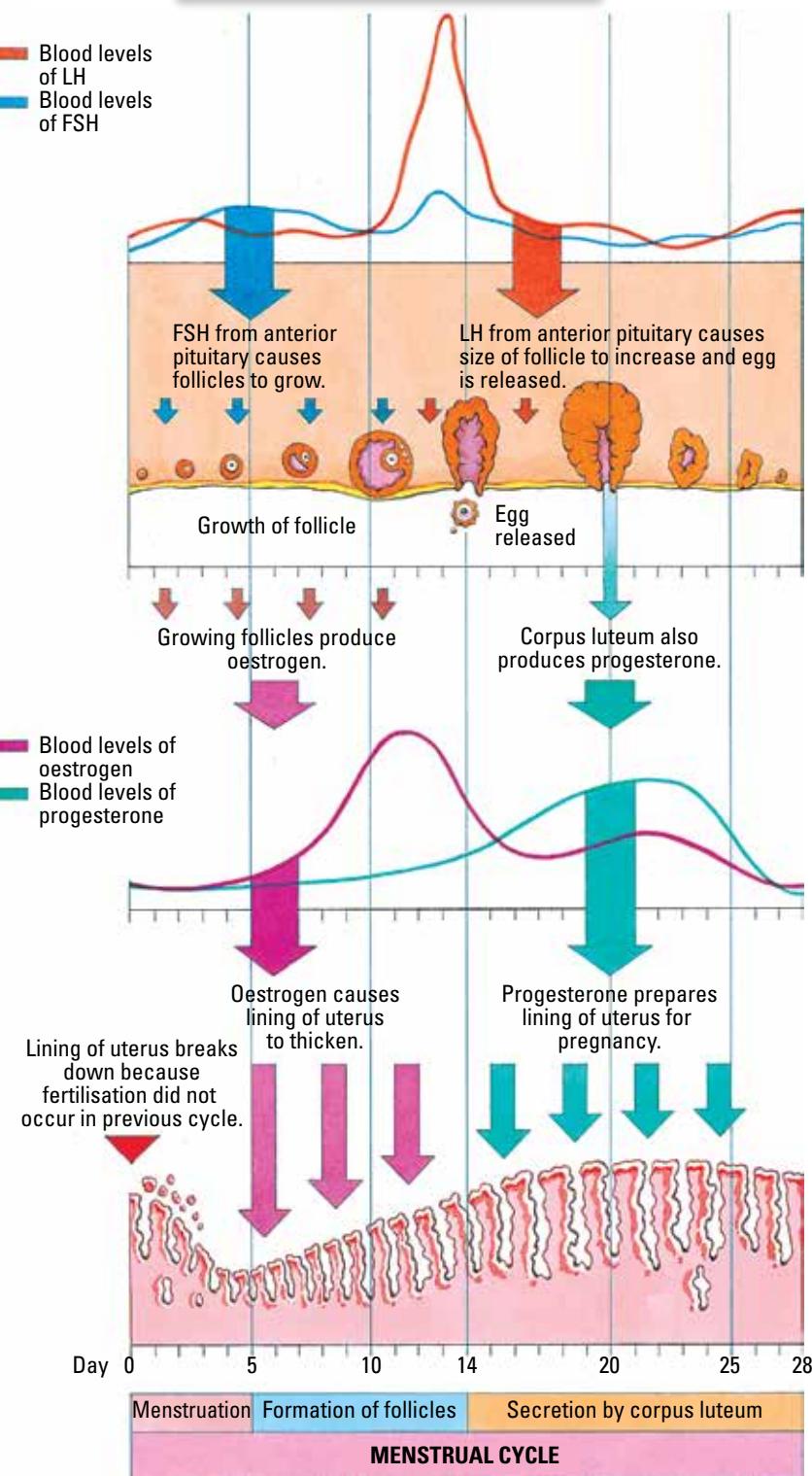
Harnessing hormones for her

A commercially produced hormone RU486 (Mifeprex), also known as the abortion pill, is one such example. RU486 not only offers possibilities of contraception, but it also can terminate a pregnancy by blocking the action of progesterone. This causes the lining of the uterus to break down so that the embryo is unable to implant into it. This pill is less invasive and has fewer side effects than a surgical abortion and it enables termination at a much earlier stage. The possibility of using this pill as an abortion option, however, has resulted in a division of opinions as to whether it should be made widely available in Australia. There have been some reports suggesting that it is being over-used in other countries.

While other hormone-based contraceptives are increasingly available, they are no longer seen only in a pill form. They are now appearing in patches, gels, implants and insertable vaginal rings. There is also research on the development of a 'morning-before' pill. This pill

- Blood levels of LH
- Blood levels of FSH

The effect of LH and FSH on the follicles



works by altering the ion content of the woman's reproductive tract for about 36 hours. The changes that it produces make it more difficult for the sperm to swim and hence less likely for them to reach the ovum to fertilise it.

There are also plans to develop contraceptive drugs that target hormone receptors rather than altering hormone levels. These new contraceptives may work by tricking the egg into thinking that it is already fertilised so that it blocks sperm from penetrating it. Other new contraceptives may involve the development

of hormones that prevent the fertilised egg from implanting in the uterus.

Harnessing hormones for him

Scientists are working on developing male contraceptive pills. These are based on combinations of androgen and progesterone. Androgen blocks sperm development and progesterone blocks testosterone production. While combinations of these hormones may be used to prevent fertility, there are possible side effects that need to be considered.

UNDERSTANDING AND INQUIRING

REMEMBER

- 1 Match the term with its description in the table below.

Term	Function
Anti-diuretic hormone (ADH)	Increases blood glucose levels
Glucagon	Lowers blood glucose levels
Insulin	Increases metabolic rate of cells
Oestrogen	Causes testes to produce sperm
Progesterone	Controls menstrual cycle and pregnancy
Testosterone	Causes thickening of the uterine lining
Thyroxine	Causes reabsorption of water in kidneys

- 2 Identify three endocrine glands located in your brain.
 3 What are hormones and where are they produced?
 4 Are all parts of the body affected by a particular hormone? Explain.
 5 Describe how hormones are transported throughout the body.
 6 Outline why the pituitary gland is often referred to as your 'master gland'.
 7 Provide an example of negative feedback that includes the involvement of a hormone.
 8 Distinguish between:
 (a) hormones and endocrine glands
 (b) menstruation and ovulation
 (c) endometrium and uterus
 (d) testes and sperm.

- 9 Describe the relationship between the:

- (a) pancreas, liver, glucose, glucagon, glycogen and insulin
- (b) pituitary gland, LH, testes, testosterone and sperm
- (c) pituitary gland, FSH, ovary, oestrogen, follicles, uterine lining, hypothalamus, LH, ovum, fallopian tube and ovulation
- (d) corpus luteum, uterine lining, progesterone and menstruation.

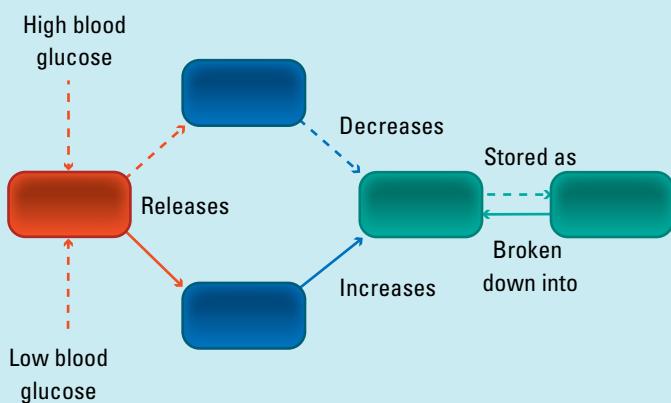
- 10 Explain why adrenaline is referred to as the 'fight or flight' hormone.

- 11 (a) What are other names for RU486?
 (b) Why do people use RU486 and how does it work?
 12 Other than pills, in which forms can hormone-based contraceptives be used?
 13 (a) Name the two hormones that may be used in a male contraceptive pill.
 (b) Outline how these hormones can be used to prevent fertility.

THINK AND DISCUSS

- 14 Suggest how you could link the endocrine system terms in the flowchart below.

Glucagon	Insulin	Pancreas
Glycogen	Glucose	



- 15** Use the information provided in this section to make up your own summary mind map on the endocrine system.
- 16** Suggest some advantages and disadvantages of the effects of adrenaline in modern-day living.
- 17** How might hormone replacement therapy help reduce the effects of menopause in women?
- 18** What three things do the endocrine system and the nervous system have in common?

CREATE

- 19** Use the question 14 diagram and the diagrams on pages 34 and 59 to help you write and act out a play about how blood glucose is controlled in your body.

INVESTIGATE, DISCUSS AND PRESENT

- 20** Discover more about the hormones used to increase milk or food production (for example, lactation in cows and goats or growth in cows, sheep or chickens). Gather information on the advantages and disadvantages of these hormones. Use the information in a class debate entitled: *Hormones should be used to increase food production for humans*.
- 21** Find out and report on hormones that could be used to the advantage of humans. Present your information in an advertising brochure.
- 22** A synthetic chemical called pyrethrin is increasingly being used in sheep dip. It breaks down within a few days, but during that time it can kill many types of invertebrates in the waterways.
- Why are sheep dipped?
 - How could sheep dip reach waterways?
 - Suggest implications for the deaths of invertebrates on other organisms.
- 23** (a) Find out about the history, development and side effects of RU486.
(b) Search media resources and the internet for arguments for and against the availability and use of RU486.
(c) Share and discuss your information with others in your team.
(d) Reflect on your findings and discussions and then state your opinion on the availability and use of RU486. Give reasons for your opinion.
(e) As a class, be involved in a debate on RU486.
- 24** Find out more about research on male contraceptives. Prepare a newspaper article or brochure outlining your findings.

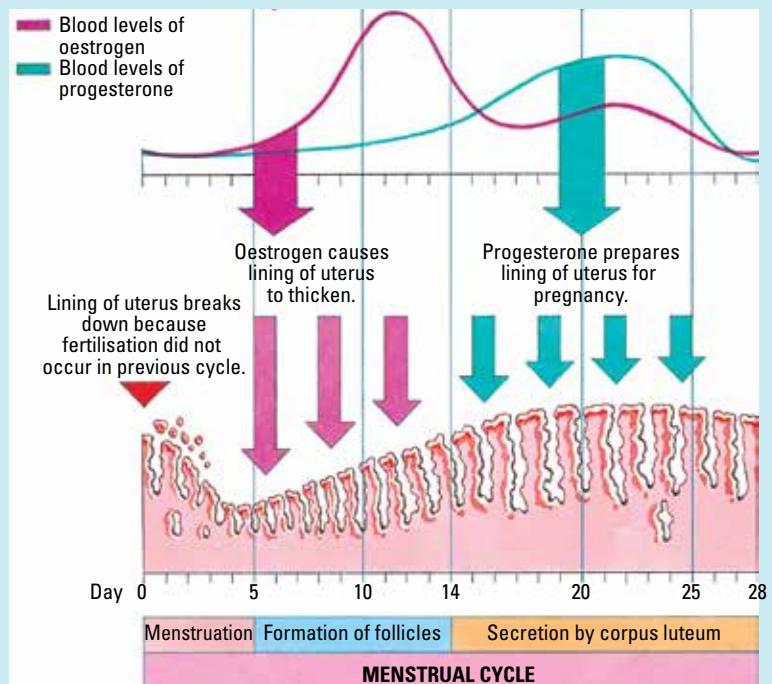
- 25** Male and female fertility patterns are different. Find out the key differences and comment on how they may

affect the development and use of effective hormone-based contraceptives.

- 26** Find out about other ways in which your body temperature is regulated.
- 27** How are hormones involved in the balance of water in your body?
- 28** Find out about the effects of having deficiencies in any of the hormones listed in the table at the beginning of this section.
- 29** Investigate the statement: *Too much adrenaline can cause stress-related diseases*.

ANALYSING DATA

- 30** Refer to the diagram on page 61 and the figure below to answer the following questions.
- Which hormone in the graph is at the highest level just prior to ovulation?
 - When is ovulation likely to occur?
 - When is progesterone at its highest levels?
 - At what stage in the cycle is the endometrium the thickest?
 - Describe the changes in the concentrations of each of the hormones throughout the menstrual cycle.
 - Research the changes in the levels of FSH (follicle stimulating hormone) and LH (luteinising hormone) throughout the menstrual cycle.



eBook plus

work
sheet

→ 2.3 The endocrine system

Plant hormones at work

Plant moves

Have you ever watched a plant move? They do, and most gracefully too. If you watch plants over a length of time, or using time-lapse photography, you can see how they move with the sun and the moon. These movements may be choreographed by hormones or by their internal biological clocks.

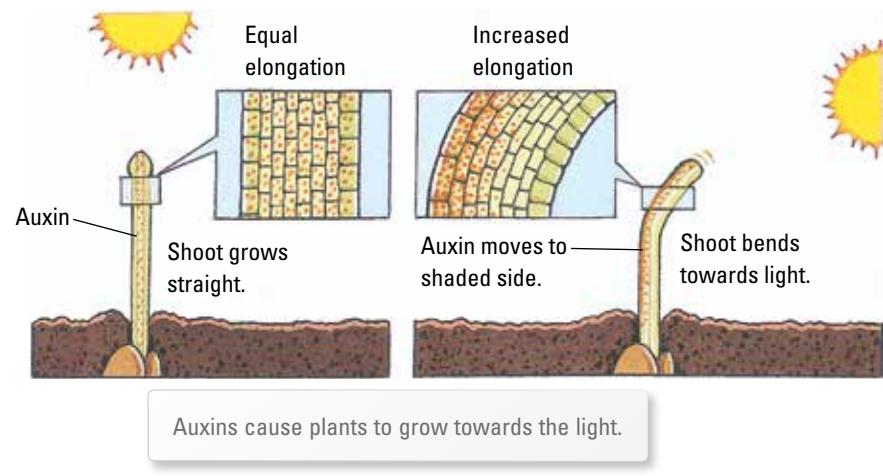
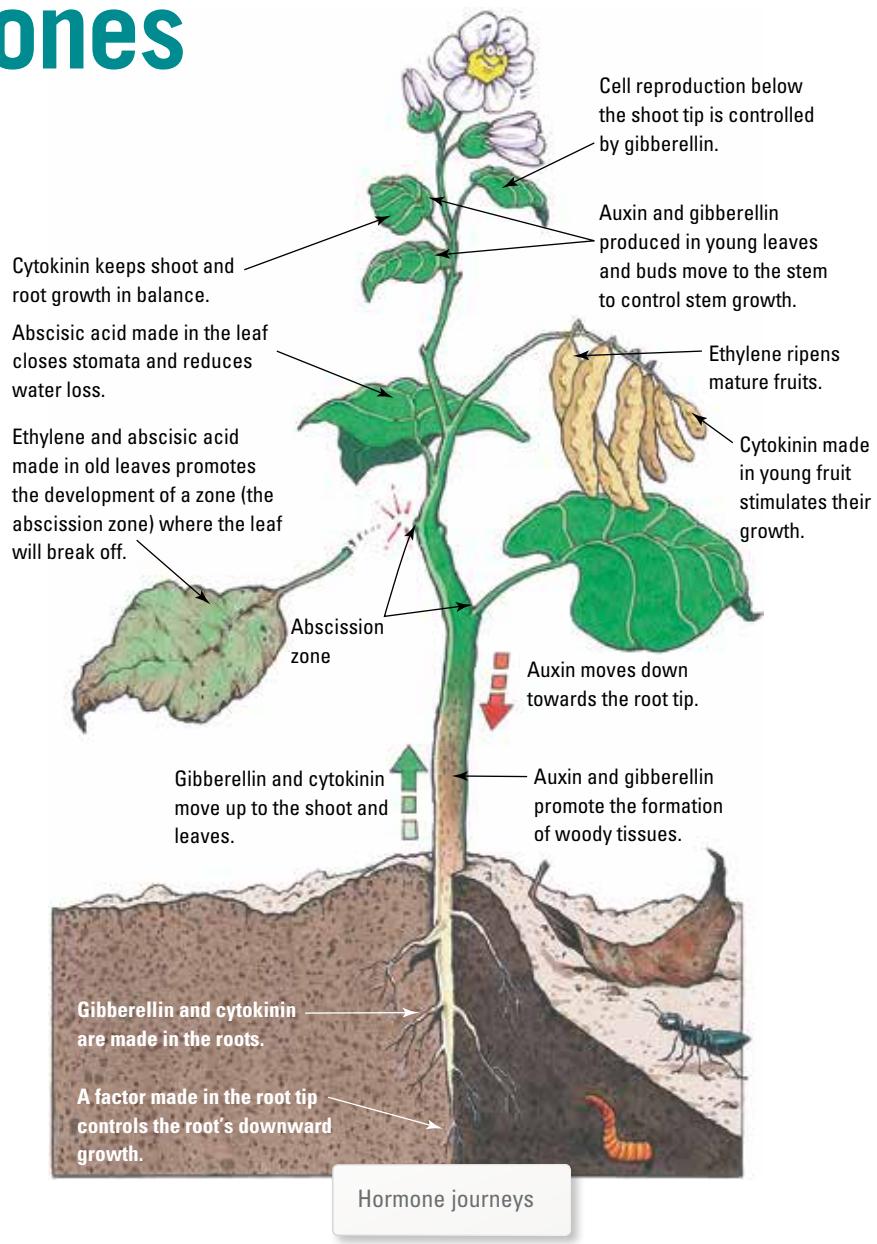
Not nervous

Plants do not have a nervous system. Instead, the way plants grow, develop and respond to their internal and external environments is usually coordinated by plant hormones. Plant hormones are mainly produced in the growing tips of roots and shoots, in buds and in developing fruits. Only very small quantities are needed for an effect. The same hormone may produce different responses in different parts of the plant.

Plant hormones are generally divided into five main types: **auxins**, **cytokinins**, **gibberellins**, **abscisic acid** and **ethylene**. In some cases, a number of these hormones work together to produce a response. The illustration above right shows where these plant hormones are produced and what their effects are.

Bent on light

When light shines on the tips of a plant's shoots, **auxins** are produced and released. These auxins travel down the plant and cause the cells on the side opposite the light to grow longer than those on the other side. This causes the stem to bend towards the light.



Is it time yet?

Like us, plants have internal biological clocks and may have different patterns of movement in a 24-hour cycle. The leaves of some plants, for example, may be horizontal during the day and then drop into a 'sleeping' position at night. If you were to place these plants in 24 hours of daylight or darkness, they would continue their 'sleeping' movements because the sleep pattern of these plants is internally controlled. Such a 24-hour cycle is referred to as a **circadian rhythm** or cycle. The opening and closing of flowers is another example of a plant's activities that involves a circadian rhythm. Unlike a plant's movement towards light, these kinds of movements are independent of the direction of the stimulus.

The timing of flowering of many plants is controlled by the length of uninterrupted darkness. Long-day plants flower only when the number of daylight hours is over a certain critical minimum (or when darkness is less than a critical value). Short-day plants flower only when exposed to daylight that is under a certain maximum number of hours.

Gladioli, cabbage and hibiscus are long-day plants, while daffodils, rice and chrysanthemums are short-day plants. Day-neutral plants, such as potatoes and tomatoes, do not depend on day length to flower. Hormones also are currently thought to play a role in determining when plants flower.

Examples of short-day, long-day and day-neutral plants are shown in the table at the top of the next page. How would you tend to classify plants that flower in spring?

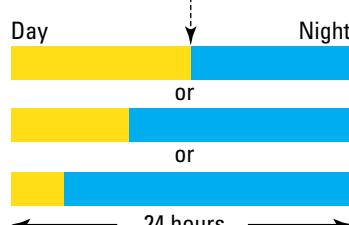


Getting into circadian rhythm: a flower performs its daily dance. Source: © Biozone International Ltd/Richard Allan.

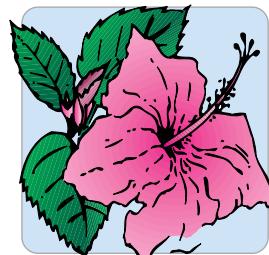
(a) Short-day plant: Poinsettia



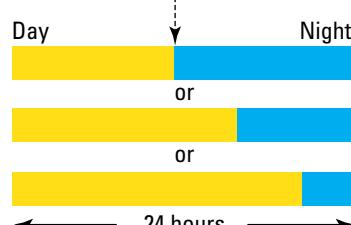
Critical day length
12.5 hours or less



(b) Long-day plant: Hibiscus



Critical day length
12 hours or longer



Different plants flower in response to different day and night lengths.

- (a) The poinsettia (*Euphorbia pulcherrima*) is a short-day flower and flowers only when the day length becomes less than 12.5 hours.
(b) The hibiscus (*Hibiscus spp.*) is a long-day plant and flowers only when the day length becomes greater than 12 hours.

Some examples of short-day, long-day and day-neutral plants

Short-day	Long-day	Day-neutral
Monocotyledons Rice (<i>Oryza sativa</i>)	Wheat (<i>Triticum aestivum</i>)	Corn (<i>Zea mays</i>)
Dicotyledons <i>Chrysanthemum</i> (<i>Chrysanthemum spp.</i>)	Cabbage (<i>Brassica oleracea</i>)	Potato (<i>Solanum tuberosum</i>)
Poinsettia (<i>Euphorbia pulcherrima</i>)	Hibiscus (<i>Hibiscus syriacus</i>)	Rhododendron (<i>Rhododendron spp.</i>)
Violet (<i>Viola papilionacea</i>)	Spinach (<i>Spinacea oleracea</i>)	Tomato (<i>Lycopersicon esculentum</i>)

LINKING ABA TO SAVING OUR PRECIOUS WATER RESOURCES

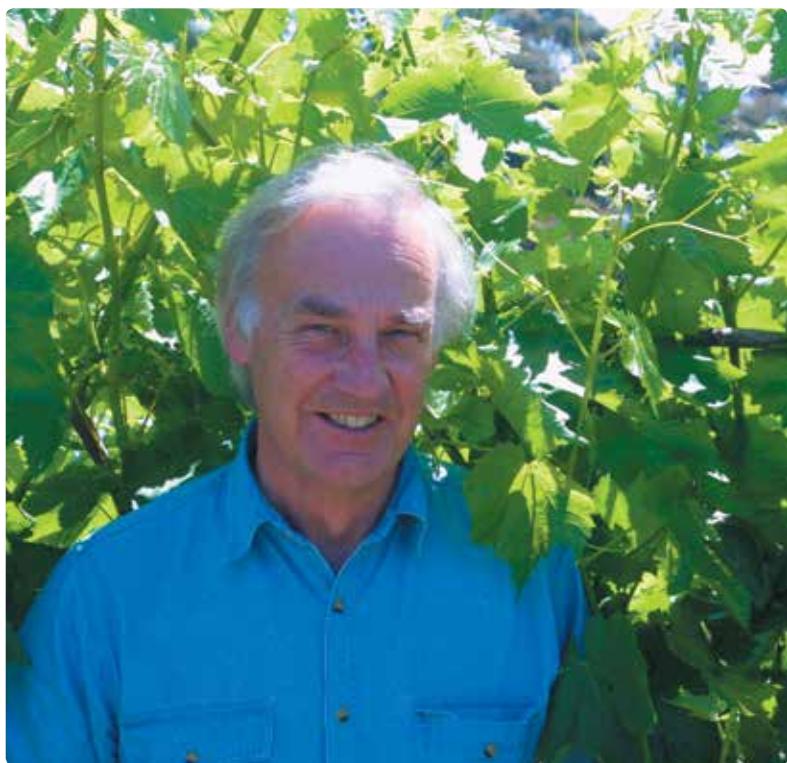
While virtually all of Australia's horticultural crops are grown using some form of irrigation to supplement rainfall, crops grown under cover are *entirely* dependent on irrigation. Water for irrigation is becoming an increasingly scarce and expensive commodity. It is therefore vital that we understand the ways that plants use this water so that we can optimise its use and improve economic returns to farmers.

Nearly all of the water used by plants passes through pores on the leaf surface called stomata. This causes plants a dilemma. How can they keep their stomata open to obtain carbon dioxide for photosynthesis, while at the same time restrict excessive water loss through them? The answer lies in a surprisingly complex set of control mechanisms.

Right at the heart of the control mechanisms is the plant hormone abscisic acid (ABA). ABA induces stomatal closure and if it is not present plants very quickly die from excessive water loss. Understanding how plants control the amounts of ABA in roots and leaves has therefore been a research priority for scientists over the last few decades.

It has been necessary to develop sensitive methods for measuring ABA because, like most hormones, it is present only at very low concentrations. Using these methods we have been able to show that the ABA concentration in roots responds very quickly to reductions in the amount of water in the soil and that this additional ABA is transported to the leaf to signal stomatal closure.

Dr Loveys said, 'Our scientific team has also used the latest molecular techniques to identify the genes responsible for ABA synthesis and breakdown. Knowledge about the complex ways that the environment interacts with the genetic makeup of the plant to control ABA synthesis and breakdown is allowing us to devise novel irrigation techniques to optimise these mechanisms and improve the efficiency of water use.'



Dr Brian Loveys is a CSIRO Chief Research Scientist investigating the role of the plant hormone abscisic acid in the regulation of water use in grapevines.

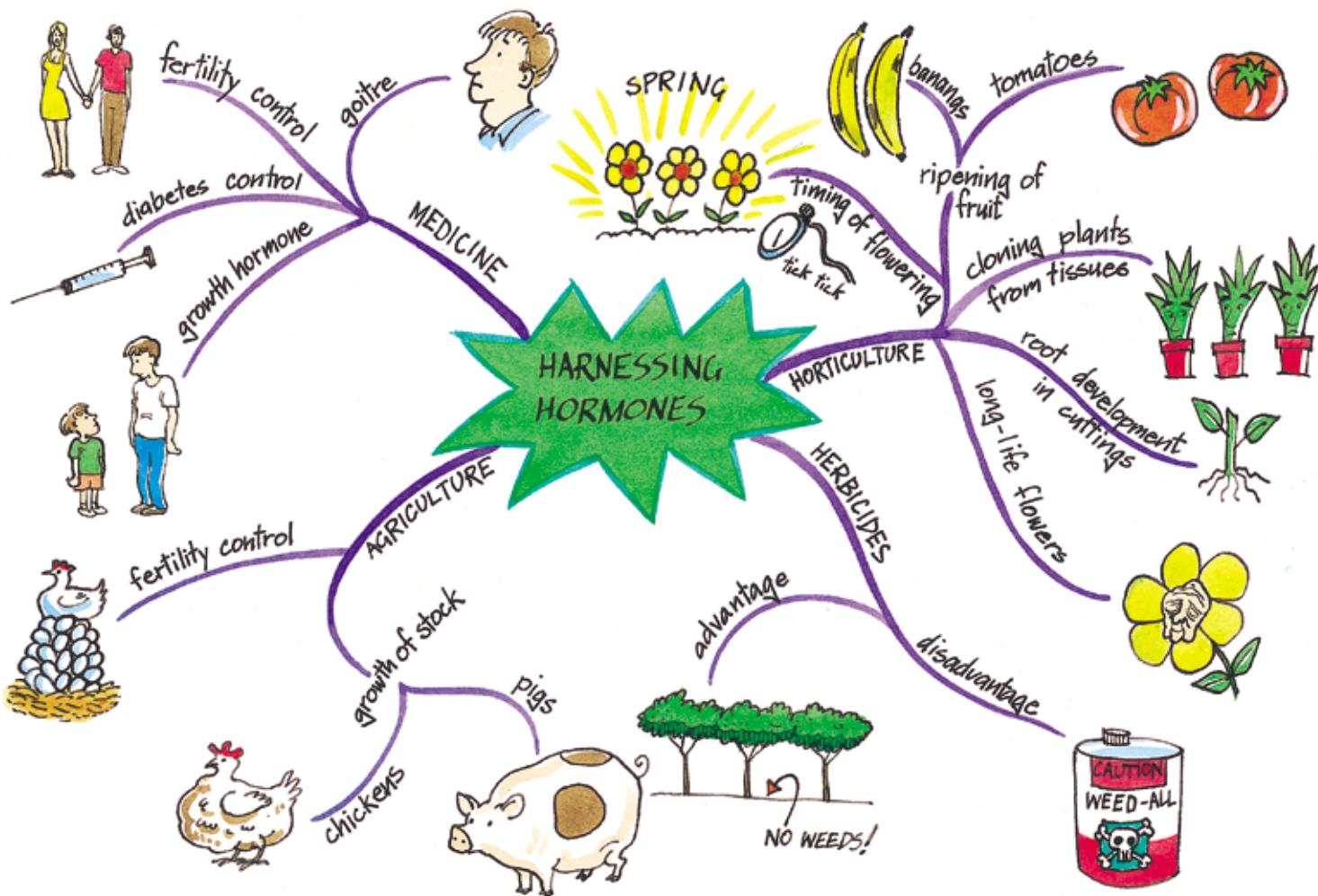
'In addition to providing information that is useful to farmers, the research has significantly increased our body of knowledge about how all plants function, and furthermore, has been a lot of fun.'

Harvesting hormones

Observations made in the days of gas street lamps caused scientists to think about the trees downwind of the lamps that shed their leaves. Experiments led to the discovery that the ethylene gas used in the lamps was responsible. Further research showed that

ethylene was a plant hormone that promotes a plant's ability to shed leaves.

Such investigations have increased our level of understanding and allowed us to put some hormones to work. The mind map below shows some of the many uses of hormones.



DID YOU KNOW?

Weed killers

Some selective weed killers which use plant hormones work on particular plants but not others. A type of weed called a dandelion is a common problem in lawns. It produces a familiar yellow flower which turns into a large puffball containing small seeds attached to a feathery umbrella-shaped structure, which helps the plant to

disperse its seeds on the wind. Lawns containing the dandelions can be sprayed with selective weed killer without killing the grass. The selective weed killer contains a growth hormone that causes the weeds to grow too quickly. The weed killer is absorbed by the weeds in larger quantities than grass.

INVESTIGATION 2.7

The effect of a commercial rooting powder on cutting development

AIM To investigate the effect of a commercial rooting powder on the development of plant cuttings

Materials:

10 cuttings (daisies and geraniums work well, but so will lavender and rosemary — they'll just take a little longer)
2 × 12-centimetre flowerpots or tubs
a micro test tube of rooting powder
potting mix
2 labels

METHOD AND RESULTS

- 1 Construct a table to summarise your data.
- ▶ Trim the lower leaves off all ten cuttings.
- ▶ Fill the flowerpots with soil and label one *Control* and the other *Test*.
- ▶ Plant five cuttings in the control pot and water them.
- ▶ Dip the other five cuttings in the rooting powder, plant them in the test pot and water them.
- ▶ Place them in a warm position and keep the pots watered equally.
- 2 After one week, dig one cutting up from each pot and compare their root growth.
- 3 Continue doing this for the next four weeks, adding observations to your table as you go.

DISCUSS AND EXPLAIN

- 4 Sketch the features of plants from each pot.
- 5 Identify the pot in which the plants grew the best.
- 6 Identify which pot contained the plants with the most developed roots.
- 7 Suggest the plant hormone that you think may be present in the rooting powder.
- 8 Discuss reasons horticulturalists use rooting powders.
- 9 Suggest improvements to the design of this experiment.
- 10 Suggest a hypothesis that could be investigated using similar equipment. (You may use internet research to identify relevant problems to investigate.)
- 11 Design an investigation to test your hypothesis. Include an explanation for your choice and treatment of variables.



INVESTIGATION 2.8

Plant responses to hormones

AIM To investigate the effects of plant hormones

Materials:

2 pieces of holly	2 small bottles of water
a small apple	2 × 1 L beakers or large jars
plasticine	tray or board
labels	

METHOD AND RESULTS

- ▶ Select two pieces of holly that are similar (size, age, number of leaves).
- ▶ Set up the experiment as shown in the diagram below and leave for 24 hours. The plasticine is used to cover the pouring lip of the beaker. Label each beaker with your name and date.



- 1 Observe and record the holly in the two beakers every 24 hours until there are some obvious differences between them.

DISCUSS AND EXPLAIN

- 2 What differences did you observe in the two beakers over the period of the experiment?
- 3 What do you think might have caused these differences?
- 4 Why was it important to select twigs of holly that were similar?
- 5 What do you think is responsible for the different responses?
- 6 Construct a hypothesis that relates to this investigation.
- 7 Identify strengths and limitations of the investigation and suggest ways in which it could be improved.
- 8 Suggest a research question about plant hormones that could be investigated.
- 9 Design an investigation to further explore your research question.

UNDERSTANDING AND INQUIRING

REMEMBER

- 1 If plants do not have a nervous system, what coordinates their life cycle?
- 2 List the five types of plant hormones.
- 3 List the main locations in plants where hormones are produced.
- 4 Describe how hormones allow a plant to grow towards light.
- 5 What is a circadian rhythm? Give an example.
- 6 Which two factors are thought to control the timing of flowering?
- 7 Give examples of:
 - (a) long-day plants
 - (b) short-day plants
 - (c) day-neutral plants.
- 8 Identify the relationship between street gas lamps and the discovery of ethylene.
- 9 State examples of ways in which hormones could be used for:
 - (a) horticulture
 - (b) agriculture
 - (c) medicine.

INVESTIGATE, THINK AND DISCUSS

- 10 Which types of plants do you think would flower in winter and summer?
- 11 By knowing the effects of plant hormones, horticulturists are able to control the timing of the flowering of plants and the ripening of fruits. Why do you think they do this?

- 12 Why would gardeners put bulbs of some kinds of plants, such as tulips, in a refrigerator for some weeks before planting?

INVESTIGATE, DISCUSS AND PRESENT

- 13 Find out more about the Dutch biologist Friedrich Went (1863–1935) and his research that led to the isolation of the auxin that causes plants to bend towards light.
- 14 Find out more about one of the following types of hormone: auxins, ethylene, abscisic acid or gibberellins. Summarise your information in a poem, poster or newspaper article.
- 15 Find out which group of plant hormones is responsible for the carpets of colour created by trees losing their leaves during autumn.
- 16 Find out more about the effects of ethylene on plants. Present your findings in a creative format.
- 17 The presence of chemical wastes in water supplies and our environment has caused some concern. Some of these chemical wastes contain hormones or chemicals that interfere with hormones. Find out and report on two examples of these.
- 18 It takes just one bad apple to spoil the whole bagful. Investigate the validity of this statement.
- 19 The herbicide Agent Orange was used in the Vietnam War. Find out and report on (a) why it was used, (b) how it worked, and (c) issues surrounding its use.
- 20 Find out more about Australian research that involves plant hormones. In your report identify the hormone and its function and the reason for the research.

Keeping emotions under control?

Feeling happy, sad, scared, disgusted or angry? Did you know that these six are caused by the effects of chemicals binding to receptor sites on your cells?

Just survive!

Imagine a situation in which you have felt threatened. How did you feel? How did you react? Did you want to run, or did you want to stay and fight?

Your emotions enable you to react to situations. They influence your behaviour. Our ancestors relied on their emotions to survive. Sometimes there is no time to think about how to react to a situation. This is when your emotional brain can get into the driver's seat and take control.

Your 'emotional brain' or **limbic system** is made up of a collection of structures within your brain. The limbic system is involved in memory, controlling emotions, decision making, motivation and learning. These include

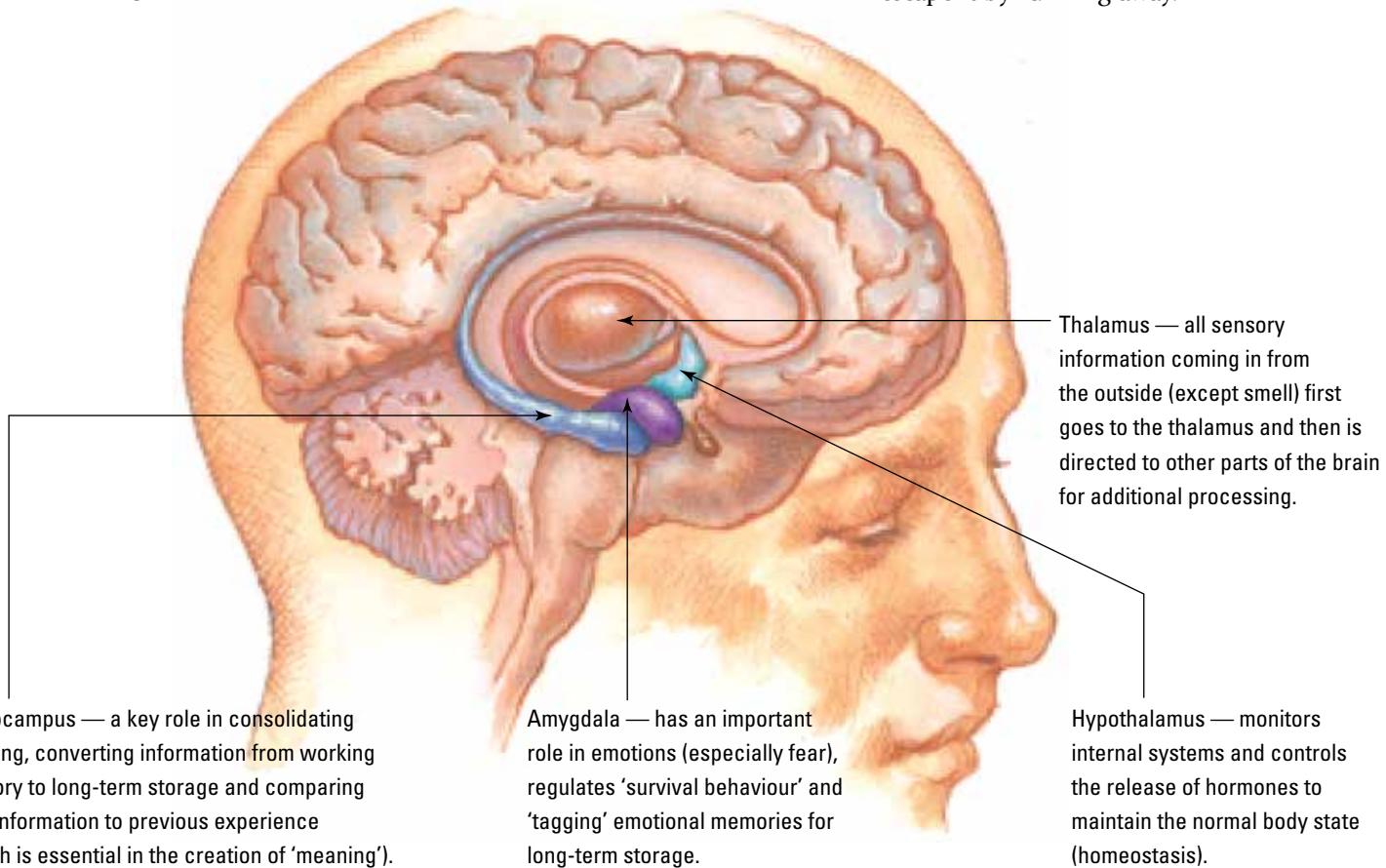
parts of your thalamus, hypothalamus, hippocampus and **amygdala**.

Feeling angry?

Feeling angry? Is your heart racing; are your hands cold; do you have a sick feeling in your stomach?

Anger can be one of our most primitive emotions. It is certainly a powerful one. Uncontrolled anger can lead to physical fights, arguments and self-harm. Controlled anger, however, can be a very useful emotion that can help motivate you to make positive changes.

When you feel angry, your hypothalamus responds by sending messages to your **pituitary** to instruct your **adrenal glands** to release **adrenaline**. This hormone acts to increase your heart rate, dilate your pupils, constrict skin blood vessels and shut down digestion. This helps you to see any threats better and provides your muscles with more glucose and oxygen just in case you need to face the danger and *fight*, or take *flight* and escape it by running away.



Tagged as a threat

Your 'flight or fight' response actually originates in your amygdala. It is this tiny part of your limbic system (about the size of your thumbnail) that decides the emotional value of what is happening. It asks: 'Does this mean something significant to me?' It may sense a particular facial expression or tone as being threatening, or it may detect an event that was previously 'tagged' as being a negative experience.

Keeping the anger

Staying angry, or long periods of stress, can damage another part of your limbic system called your hippocampus. If the stress or anger lasts more than a few minutes, your adrenal glands also release cortisol. Sustained high levels of this hormone can lead to the death of hippocampus neurons, which may result in diminished learning, spatial recall and memory.

False alarms

Your prefrontal cortex or thinking brain is also involved in assessing a threat and placing it in context. If your thinking brain considers it to be a false alarm, it sends a message to your hypothalamus to trigger actions to calm things down; it does this by sending out messages to decrease your stress hormone levels and their effects.

Mirrored feelings

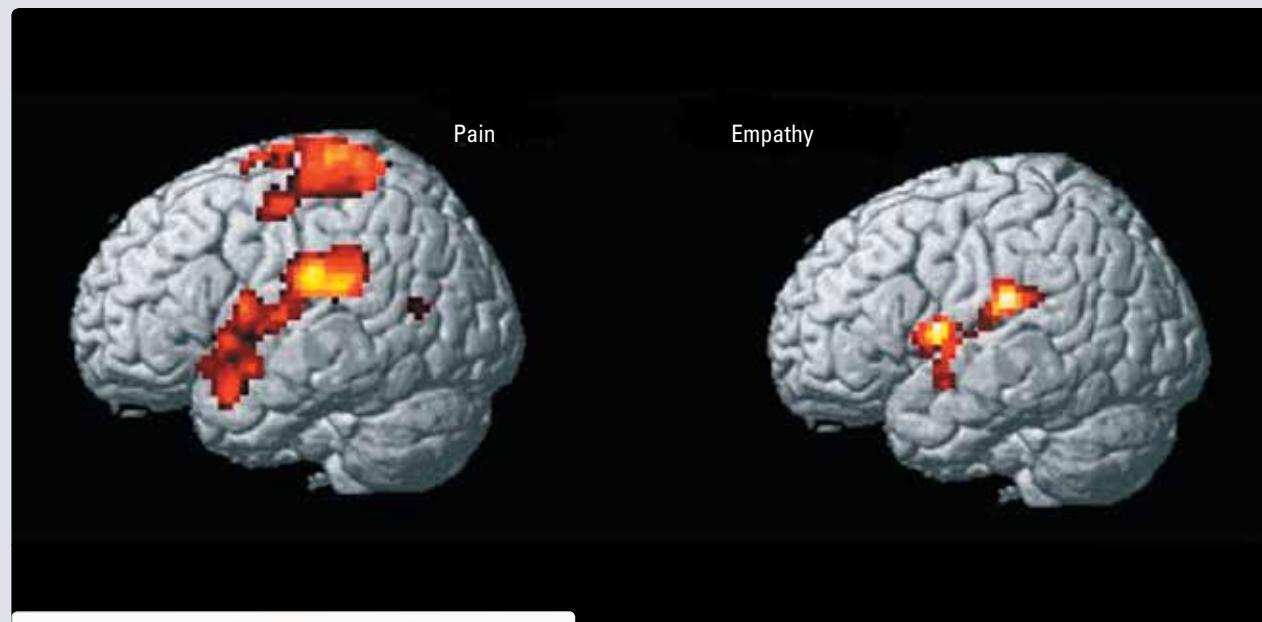
Feel upset, or feel upset for someone else? **Mirror neurons** are a group of neurons that activate when you perform an action and when you see or hear others performing the same action. Research is suggesting that these neurons are important in being able to feel **empathy** towards other people. If this theory is further supported, how could this connection increase the chances of the survival of our species?

HOW ABOUT THAT!

MRI

Early brain research used dead or diseased brains. Advancements in scientific applications of technology have enabled researchers to examine living brains. One such technology is magnetic resonance imaging (MRI) which allows scientists to actually

see which parts of the brain are active when various tasks are performed; these parts 'light up' with different colours to show brain activity.



Brain studies using MRI have produced some very interesting findings! These images show the responses of a person in pain (left) and a person watching someone in pain (right).

Mood chemistry

Neurotransmitters are chemicals involved in passing messages between your nerve cells (neurons). Within your brain there are many neurotransmitters that influence how you feel and react; **serotonin**, **norepinephrine** and **dopamine** are three examples. Imbalances of these neurotransmitters can contribute to a variety of mental illnesses.

Serotonin acts like the brakes on your emotions. It can produce a calming effect and is important for maintaining a good mood and feelings of contentment. It also plays a role in regulating memory, appetite and body temperature. Low levels of serotonin can produce insomnia, depression and aggressive behaviour and are also associated with obsessive-compulsive and eating disorders.

Norepinephrine can act like the accelerator. It can promote alertness, better focus and concentration. Your brain also needs this chemical to form new memories and to transfer them to your long-term storage.

Dopamine is important for healthy assertiveness and autonomic nervous system function. Dopamine levels can be depleted by stress or poor sleep. Too much alcohol, caffeine and sugar may also lead to reduced dopamine activity in your brain. People

with Parkinson's disease have a diminished ability to synthesise dopamine.

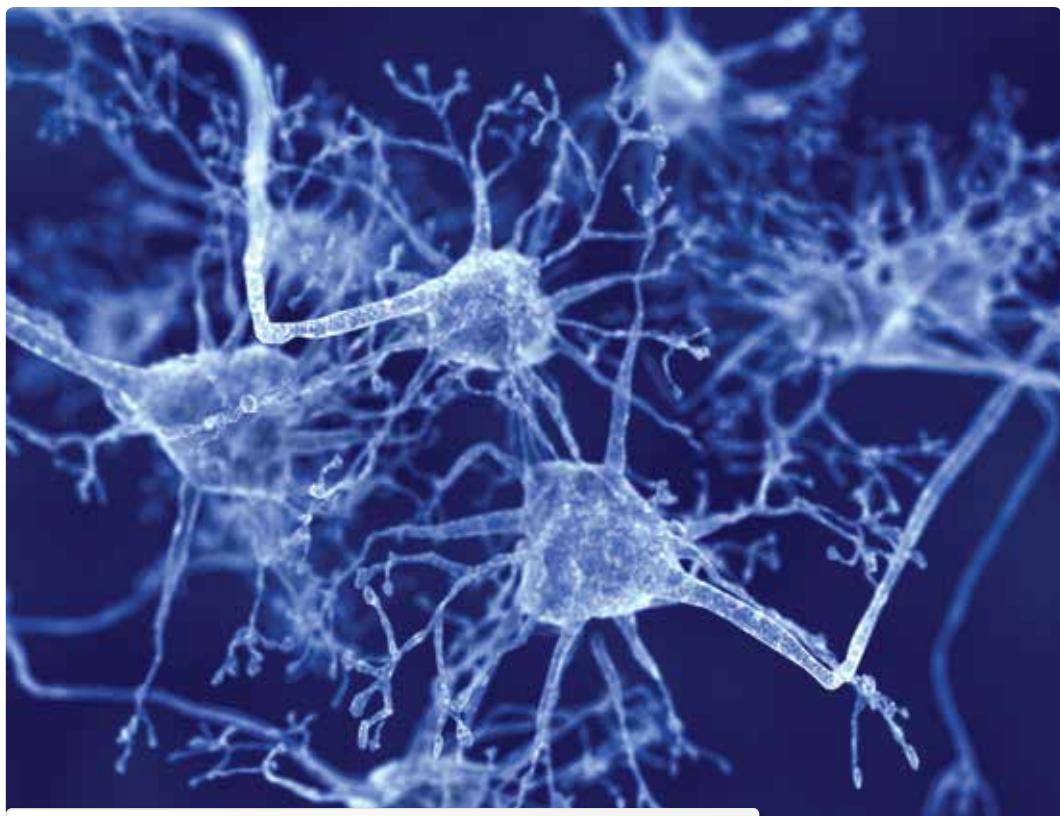
Emotions and learning

Are emotions gatekeepers to your intellect? Are emotions important to your learning too? If emotions are important to your learning, are some emotions better than others? Can some emotions actually interfere with your learning?

If this is the case your learning can be enriched if you are in a safe, caring and inviting climate for learning. If you were to describe your ideal learning environment, what would it look like, feel like and sound like?

Feeling safe and taking risks

In a safe and caring environment, learners can learn by trial and error, ask questions and feel safe enough to risk making mistakes or getting something wrong. When the learner experiences stress or feels threatened, survival instincts can take over. Chemicals are released that place their body in a heightened alert phase, to help prepare them for a possible dangerous situation. If a learner is in this stressed state it is difficult to use higher-order thinking, and it can be difficult to learn effectively.



Neurotransmitters are chemicals that carry messages between neurons.

While your hippocampus has an important role in forming long-lasting memories, your amygdala can act as a memory filter, labelling information to be remembered by tying it to events or emotions that are experienced at the time.

When you are experiencing a time of stress, your survival instincts can take over. You produce chemicals that place your body in a heightened alert phase, to

help prepare you for a possible dangerous situation. When you are in a stressed state it is difficult to use your higher-order thinking and you may find it difficult to learn effectively.

Not all challenges and stresses are bad for learning. When the brain is faced with a challenging, intricate and complex problem, all of its parts can be involved and attention, meaning and relevance for learning can result.

UNDERSTANDING AND INQUIRING

REMEMBER

- 1 Name six basic human emotions.
- 2 Match the term with the most appropriate description in the table below.

Term	Description
Amygdala	Collection of structures within your brain involved in memory, controlling emotions, decision-making, motivation and learning
Hippocampus	Organ involved in sensory memory and 'attention'
Limbic system	Involved in converting information from working memory to long-term storage and helping to make 'meaning' of new information by comparing it to previous experience
Thalamus	Plays a key role in emotions and regulates 'survival behaviour' and 'tagging' emotional memories for long-term storage

- 3 Describe the function of your amygdala.
- 4 Describe the relationship between your pituitary, your adrenal glands and adrenaline.
- 5 Outline the relationship between prolonged stress or anger, cortisol and learning.
- 6 Describe how your hypothalamus can be involved in controlling stress.
- 7 Explain how the release of adrenaline can increase your chances of survival.
- 8 (a) Identify three neurotransmitters in your brain that can influence how you feel and react.
(b) Describe the effects that each of these neurotransmitters can have on your behaviour.

THINK AND DISCUSS

- 9 Suggest how mirror neurons may increase the survival of our species.
- 10 Respond to each of the questions asked in 'Emotions and learning' section:
 - (a) Are emotions gatekeepers to your intellect?
 - (b) Are emotions important to your learning?
 - (c) If emotions are important to your learning, are some emotions better than others?
 - (d) Can some emotions actually interfere with your learning?
- 11 What if no-one ever got angry? Would this be a good thing? Imagine what the world would be like. Construct a PMI chart about your imagined world.
- 12 (a) List some examples of angry behaviour that you have seen.
(b) Suggest ways in which this angry behaviour could have been managed.
- 13 Discuss appropriate ways of managing behaviour. Which of these appeal to you? Why?
- 14 (a) If you were angry with one of your team members or classmates, suggest appropriate ways of managing your anger.
(b) With your team, agree on a set of rules or strategies that could be used to manage anger or conflicts if they occur.
- 15 (a) Suggest questions to find out viewpoints, perspectives and opinions of others.
(b) With your team or class, discuss strategies that could be used to deal with situations when viewpoints differ.
- 16 If anger is one of our most primitive emotions, it must have some survival advantages. Discuss with your team what these advantages might be. Present your findings in a visual tool.

INVESTIGATE, THINK AND DISCUSS

- 17 (a) Research the effects of at least three different human hormones, such as testosterone, adrenaline, cortisol and oestrogen, and then report your findings back to your team.
- (b) Use this information and your own opinions to discuss the following question: *Do our hormones determine who we are and what we do, or can we have some conscious control over this?*
- (c) In your team, decide on a brief statement that summarises the opinion.
- (d) How strongly do you agree with your group's opinion? Rate your response on a scale of 0 to 5, with 0 meaning 'Strongly disagree' and 5 'Strongly agree.' Give reasons for your response.
- (e) Survey your class or do a class spectrogram to determine how many of, or the degree to which, your class members agree with this statement.
- (f) Find out and record differing opinions of as many of your class as you can.
- (g) Have you changed your initial opinion or has it stayed the same? Explain.
- 18 Have you seen a young child throw a tantrum? This is a case of not being able to control emotions. Although the child's amygdala is fully mature, the necessary links with the cortex are not yet fully developed. Find out more about these links between different parts of the brain and their effects on behaviour. How could you explain this to the parent of a toddler?
- 19 Find examples of music that helps relax you and calm you down when you are feeling stressed. Share your music with others to see if it has the same effect on them.
- 20 Some convicted murderers may have killed in a 'fit of rage'. Find out if there are any documented links between committing murder and frontal lobe activity in the brain.
- 21 Find out about the connections between brain neurotransmitters, behaviour and the following medications: Prozac, Zoloft, Topamax, Provigil and Abilify. Report your findings to the class.
- 22 In 1947, the Swedish biologist Ulf von Euler discovered norepinephrine and later won a Nobel prize for his research. Find out more about research into this neurotransmitter and how it may be involved in helping you to learn.
- 23 *Our emotions are our personalities.* Do you agree with this statement? Discuss your opinion with others in your team. Present a summary of your discussion to the class.
- 24 Select one of the following statements, then find out what information you need to know in order to make a decision as to whether the statement is correct or incorrect.
- Males need competition so that they feel stimulated and know their place in the hierarchy, whereas females first do things to be liked and, if that doesn't work, then use a 'victim strategy'.
 - Boys are more interested in objects, and girls in human relations.
 - In order for boys to achieve at school, they need to compete and struggle through the class hierarchy.
 - Male thinking is more competition-driven whereas female thinking is more security-driven.
 - Males collect facts whereas females are more interested in the relationship between the facts.
- 25 Can fears or phobias be unlearned? Find out more about research involving chemicals such as glutamate to achieve this.
- 26 Investigate and report on problems associated with extreme emotions.
- 27 Select one of the statements below and use both your own experience and that of others expressed in the media to discuss it from different perspectives.
- To an extent, emotions can justify our actions.
 - Emotion has its own language.
 - Emotion is more powerful than reason.

CREATE AND CONSTRUCT

- 28 (a) On your own, in a pair or in a team, write a story about anger management.
- (b) Present your story to the class as a puppet play, picture storybook or song.

eBookplus

work
sheets

→ 2.4 Body continuum
2.5 The brain

Total recall?

While learning is about gaining new knowledge, memory is about retaining and then retrieving that knowledge. To achieve this you need to coordinate your thinking.

What is memory?

If a friend gave you her phone number, how long could you remember it without writing it down? While learning is about gaining new knowledge, memory is about retaining and then retrieving that learned information. That is, for us to remember something, we have to be able to **record** the experience and **store** it in an appropriate part of the brain. If we are unable to **retrieve** or pull out that information, we have forgotten it.

Building memories

Modelling memory?

Scientists construct models to communicate ideas. Models can be concrete (for example, a plastic model of the brain) or symbolic (for example, a map or diagram). Models provide the opportunity for learners to bring previous knowledge into their working memory. This helps learners to attach meaning to, and make sense of, their new learning.

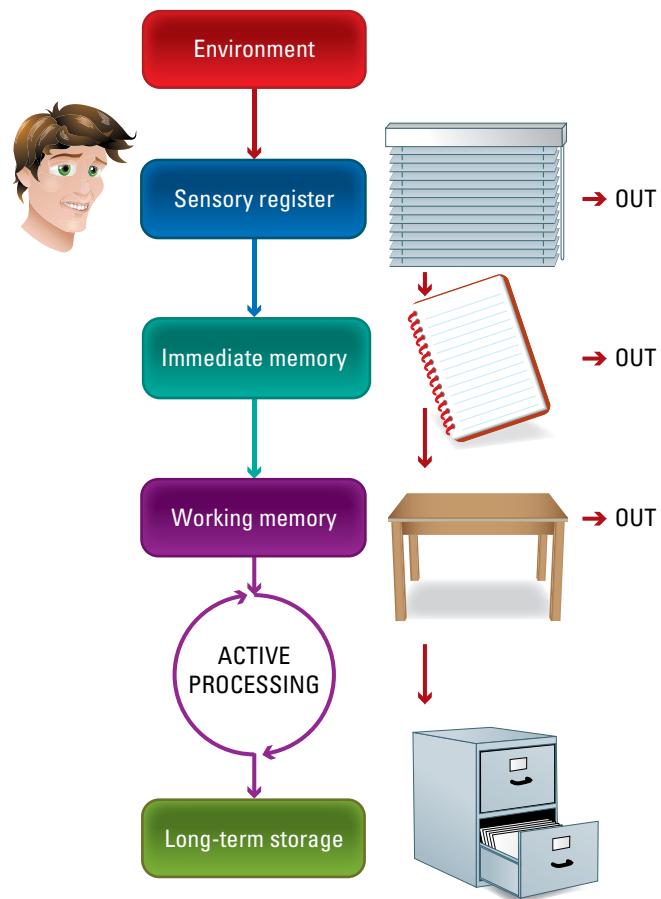
A model can be used to represent various stages in how information is processed by your brain. Shown at right is a simplified version of an information-processing model. While this model has many limitations, it provides a framework that can be used to help you attach previous knowledge to new learning about the stages of memory.

Filtering

What was that? You use your senses (for example, sight and hearing) to detect various stimuli in your environment. Incoming information is filtered through a system called the **sensory register** (shown in the model as venetian blinds). This system filters incoming information on the basis of its importance to you. Your sensory register involves your **thalamus** (a part of the limbic system of your brain) and a portion of your brain stem called the **reticular activating system (RAS)**. The more important the information is to your survival, the higher the chance that it will get through for further processing in your brain.

Even if information has made it through your sensory register, it doesn't mean that you will remember it. You

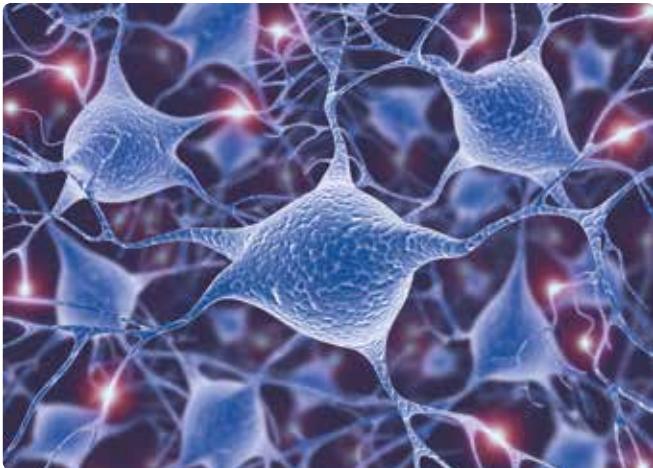
will remember information only if you have stored it in **long-term storage** (shown in the model as a filing cabinet). It is the job of your **hippocampus** to encode it and send it to one or more of the long-term storage areas in your brain. This encoding takes time and is usually done during deep sleep.



Memories are not stored as a whole or in one place. When you retrieve and reconstruct memories, storage areas distributed throughout your brain are activated. While long-term storage can be thought of as where your memories are stored in your brain, your long-term memory relates to the dynamic process of sorting and retrieving the information.

Synaptic patterns

Memory is not stored in just one place in your brain. It is currently thought that memories exist as patterns of connections at the synapses between the brain's neurons. To store a particular memory, nerve signals travel along a



specific pathway through certain synapses. Each time this memory is remembered, nerve signals are reactivated to again travel along this pathway.

Just visiting

Before any information is stored in long-term storage, it needs to pass through your temporary short-term memory. Examples of short-term memory include immediate memory (shown as a notepad in the model) and working memory (shown as a table in the model).

'Notepad' memory

Information that has made it past your thalamus moves to your immediate memory where a decision is made about what to do with it. Your past experience helps to determine its importance. An example of the length of time information will stay in this type of memory is when you temporarily remember a phone number and ring it. After this time the information may be lost or, if considered important enough, moved to your working memory.

'Working table' memory

It is within your working memory that information generally captures your focus and demands attention. There is a limited capacity (amount of information dealt with) and time limit for this type of memory. Research suggests that this capacity changes with age. Between the ages of 5 and 14 years there is a range of about 3–5 'chunks' that can be dealt with at one time; after this age it increases to about 5–7 chunks. This limited capacity is one of the reasons why you need to memorise songs, poems or other information in stages. By memorising a few lines at a time and repeating them (or rehearsing them) you are able to increase the number of items in your working memory. This is an example of chunking.

Studies have suggested that the time limit in working memory is about 10–20 minutes. This is often the

amount of time you can spend on one activity. This time, however, can be influenced by interest and motivation. Both of these can have emotional elements and also involve a special part of your brain called the **amygdala**.

Remember to learn

Your past experiences influence new learning. What you already know acts as a filter to help you focus on things that have meaning and ignore those that don't. Your self-concept (how you see yourself in the world) is also shaped by your past experiences. It is your self-concept that often determines how much attention you will give to new information.

You can transfer things from your short-term memory into your long-term memory by rehearsing information (practising) and applying meaning to it. The two key questions asked in the decision of whether to move information into long-term memory are:

- does it make sense?
- does it have meaning?

I don't understand! This is the type of comment made when a learner is having trouble making sense of new learning. Determining whether new information 'makes sense' is related to whether the new information fits in with what you already know.

Why do I have to know this? Whether the new information 'has meaning' relates to whether it is relevant to you and whether you consider that the purpose of remembering it is worthwhile. You can improve the chance that you remember something by making connections between the new learning and your previous knowledge.

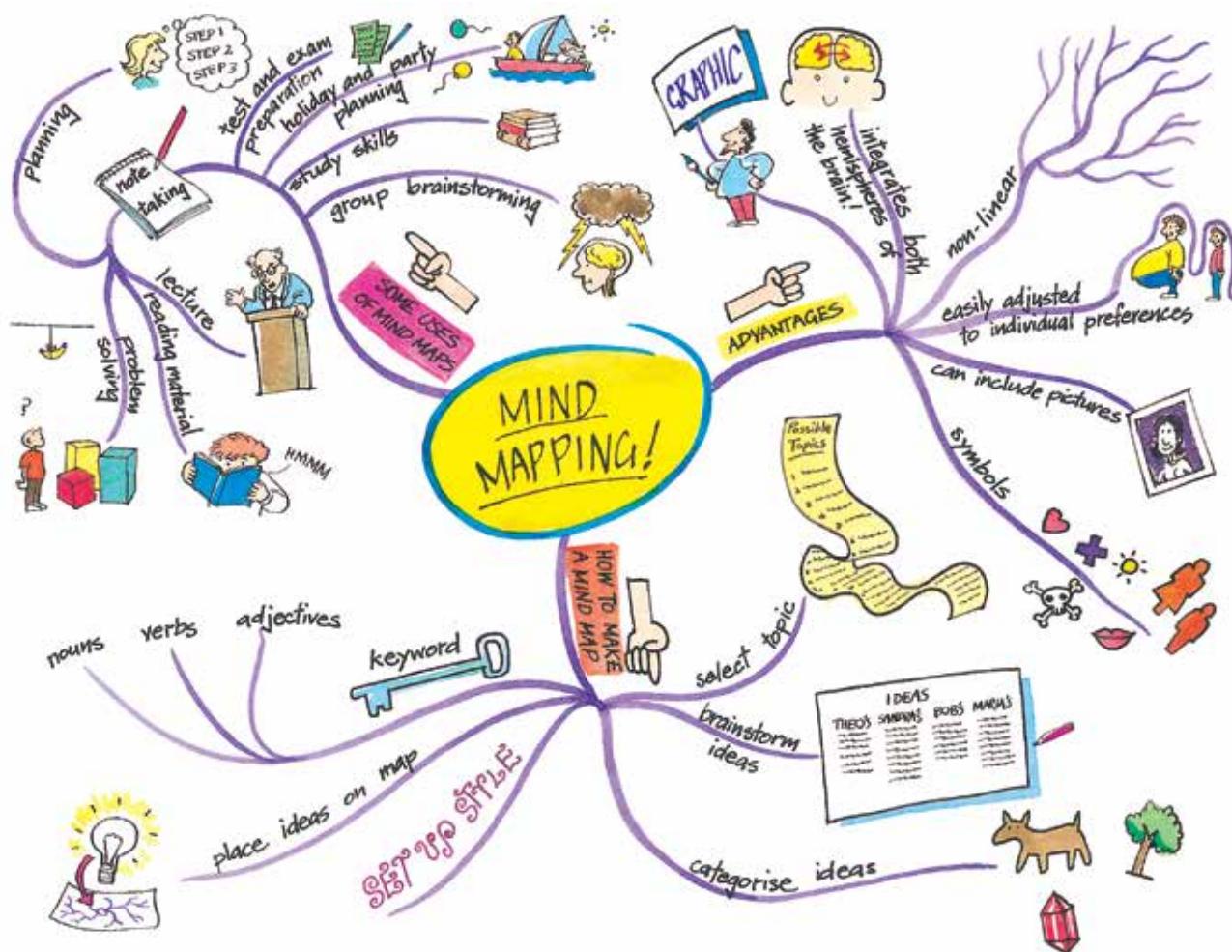
If both sense and meaning are present, there is a very high chance that the information will be sent to long-term storage.

Is meaning present?	Yes	Moderate to high	Very high
	No	Very low	Moderate to high
		No	Yes

Is sense present?

Unlocking memory doors

There are keys that you can use to unlock your memory doors. Seven of these are primacy, recency, repetition, standing out, association, chunking and visuals.



Primacy and recency

When you read a book or see a movie you will usually remember the beginning and the ending. **Primacy** is about recalling and remembering the first time that you do something. **Recency** is the opposite. It is remembering the last time or the ending.

Repetition

Repetition, or regularly reviewing information, is needed to reactivate your stored memory and prevent it from being buried under layers of other information. Research suggests that you can achieve about 90 per cent recall if you review content within 24 hours. This drops to 30 per cent if you review after 72 hours (3 days). Repetition can be achieved visually, by reading, playing games with the new information, highlighting or using visual thinking tools.

Standing out

Think about a lesson that you remember well. What made it more memorable than other lessons? Was it fun? Was there something different or new about the experience? Did you use mnemonics or analogies? A **mnemonic** is a technique that helps you remember

something. This may involve telling a tale (using key terms within a story), linking (linking terms and images) or using acronyms (using the first letters of words; for example, SPEWS). Some of these ideas are very effective because they overlap with other memory keys. All of these things can help content stand out and make it easier for you to remember it.

Association

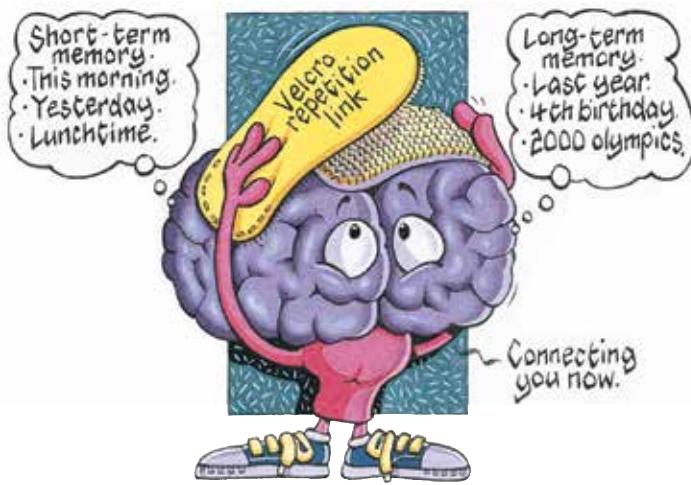
If new knowledge is linked to previous knowledge your recall is greatly enhanced. This is called learning by **association**. It helps you to anchor the information in time and space. Using real-life examples or metaphors can assist in this, as can the use of smell, music and colour.

Chunking

How do you eat a whole elephant? The answer of course is 'a bit at a time'. Learning is similar. You don't have to learn it all at once. The short-term memory of teenagers can usually contain only five (plus or minus two) bits of information at once. By organising information into small **chunks**, it is easier to remember it.

Visuals

Reading text in colour can help you to use both sides of your brain. The same can be said for a dramatic acting out; for example, performing the story of how blood flows through your body.



Memory neurotransmitter

A key neurotransmitter involved in learning and memory formation is **acetylcholine**. This neurotransmitter is released in the brain during learning. Acetylcholine is involved in the strengthening of connections between neurons in the brain and hence in the formation of new memories. Consequently, drugs that boost the amount of acetylcholine release are used as an effective treatment for diseases such as Alzheimer's, that impair cognition.

Memory blockers

Scientists are working on drugs to improve or even erase memory. Drugs that can enhance learning are being sought as an easy way to do well in tests and exams. However, there are disadvantages and advantages to drugs designed to block memories.

Current research includes studies on drugs that specifically block or erase problem memories at the molecular level. While this can be a great advantage to those who suffer post-traumatic stress disorder (PTSD), there are concerns that other memories could also be erased.

Researchers are exploring the possibility of using chemicals called beta-blockers, cortisol and hydrocortisone to alter our memory processes. Beta-blockers can bind to the receptors on the cell surface that would usually bind to adrenaline and noradrenaline. By blocking these hormones, beta-blockers may stop the hormones' stressful effects and prevent deep memory formation.

While all this research is exciting and innovative, what are the ethical considerations? Who controls which memories are to be erased and when? What do bad memories have to do with our consciences and our perceptions of right and wrong? Will there be global rules and regulations? If so, who will write them and make sure that they are maintained?

Stressful memories down deep

Your hippocampus and amygdala are also involved in emotional responses to an experience or memory. When your sense organs pick up a stimulus it goes to your thalamus and is then dispatched to your amygdala to assess its emotional quality. If it is recognised as potentially threatening, it triggers your body to release adrenaline and noradrenaline to set you up for fight or flight. The hippocampus then processes the memory and imprints it deeper than it would other memories. This will allow you to be primed quickly for action if it occurs again.

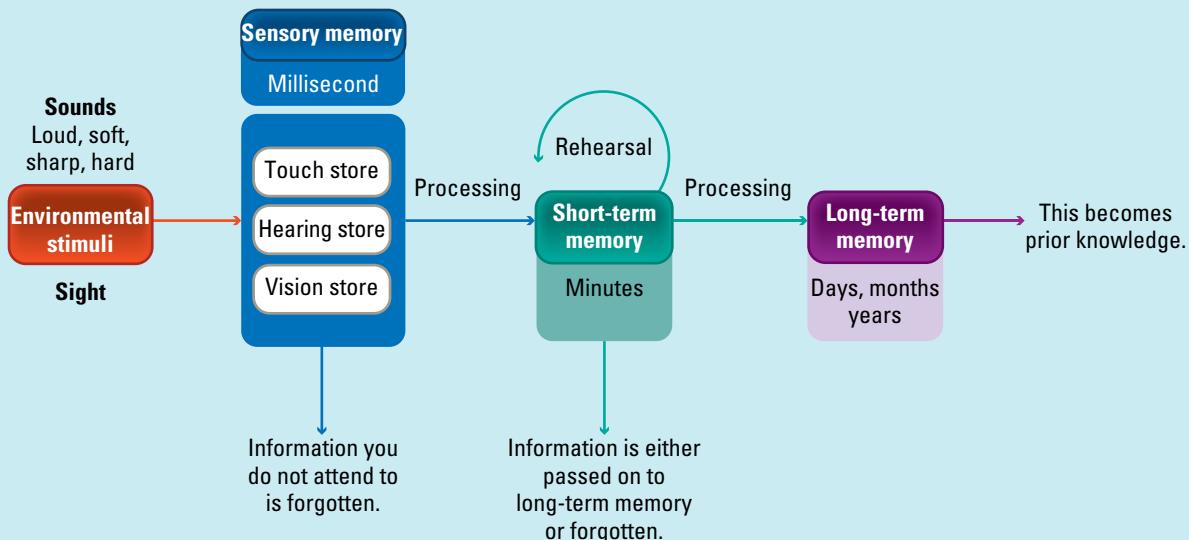
In this way, memories of traumatic or highly emotional events are burned into your brain more deeply and are remembered for longer. While in evolutionary terms this may have increased our chances of survival, traumatic events can result in PTSD.

UNDERSTANDING AND INQUIRING

REMEMBER

- 1 How can you transfer short-term memory into long-term memory?
- 2 Construct a mind map to summarise the five memory systems.
- 3 Sketch seven keys. On each key, describe a memory key strategy.
- 4 Name the part of the brain that transfers information from short-term memory to long-term memory.

- 5 List the five different memory systems described in this section and write a brief description of each in your own words.
- 6 The colour red is directly stored in your long-term memory. List examples of vehicles, signs and symbols that have applied this knowledge. Suggest why your brain processes the colour red in this way.
- 7 Create and present a rhyme, song or poem about:
 - (a) your memory systems
 - (b) memory keys.
- 8 Suggest the advantage of traumatic or emotionally charged events being remembered more deeply.



INVESTIGATE, THINK AND DISCUSS

- 9 Carefully observe the information processing memory model above.
- Identify strengths and limitations of this model in its communication of how memories are formed.
 - Suggest improvements to this model.
 - Identify the similarities and differences between this model and the one on page 75.
 - Which model best helps you understand the concepts related to memory? Why?
 - Explain why scientists used models to communicate their understanding of our brain's function.

10 On the basis of what you know about how the brain functions, suggest why one of the 'memory door' strategies helps you to remember.

11 Get a pencil and paper and then concentrate on the number below for 7 seconds. After 7 seconds, look away and write the number down. Did you get it right? Compare with others in your team.

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Now repeat the procedure again with the number below. Did you get it right? Compare with others in your team. Did you get the same results for each number? Discuss your results with your team. Suggest a reason for any differences between results.

3847918362

- 12 Although we all use the same senses to collect information from our environment, they do not contribute equally to our learning. Learners develop preferences for certain senses over others. This is where terms such as 'visual', 'auditory' and 'kinaesthetic' learners originate.
- Research each of these and develop a set of questions that can be used to determine which preferences you and others in your class have.
 - Discuss the impact that these differences can have on your learning.
 - Suggest how you can use this knowledge to be a more effective learner.

- Find out the possible effects of the following chemicals on learning: adrenaline, phenylalanine, norepinephrine, calpain and choline.
- Find out more about memory-enhancing drugs. Construct a PMI chart to summarise and share your findings.
- Write a newspaper article, cartoon or web page on ways to improve your memory.
- Find out more about research on memory and chemicals that may be used to enhance or erase it. Organise a class debate on one of the following statements.
 - Drugs that have an effect on memory should be illegal.
 - Everyone should have access to drugs that erase memories.
 - Research on drugs that alter memories should be stopped.
- The colour red is directly stored in your long-term memory. List examples of vehicles, signs and symbols that have applied this knowledge. Suggest why your brain processes the colour red in this way.

INVESTIGATE, CREATE AND PRESENT

- Find out more about the information-processing model; then, in teams of 8, discuss how you could act it out. Include the following roles: sensory register, immediate memory, working memory, long-term storage (two people), incoming information (three people).
- Research the structure and function of the thalamus, amygdala or hippocampus and construct a model to communicate your findings to others.
- Use the **Memory games** and **Brain games** weblinks in your eBookPLUS to test your memory and learn more about the brain and nervous system.
- Learn how your brain controls all your thoughts, actions and feelings by completing the **Brain control** interactivity in your eBookPLUS. **int-0010**

eBookplus

Sleep on it

Are you a night owl or an early bird? Do you get sleepy during the day or find it hard to wake up in the mornings? Did you know that sleeping is as essential to your health as food and water?



A very old network ...

One of the oldest portions of your brain is your **reticular formation**. This network of fibres and cell bodies is located in the central core of your brain stem (medulla oblongata) and extends through other areas of your brain. It can be considered a network of neurons that opens and closes to increase or decrease the amount of information that flows into and out of your brain. It helps regulate your alertness (from being fully awake or deeply asleep), motivation, movement and some of your reflexes.

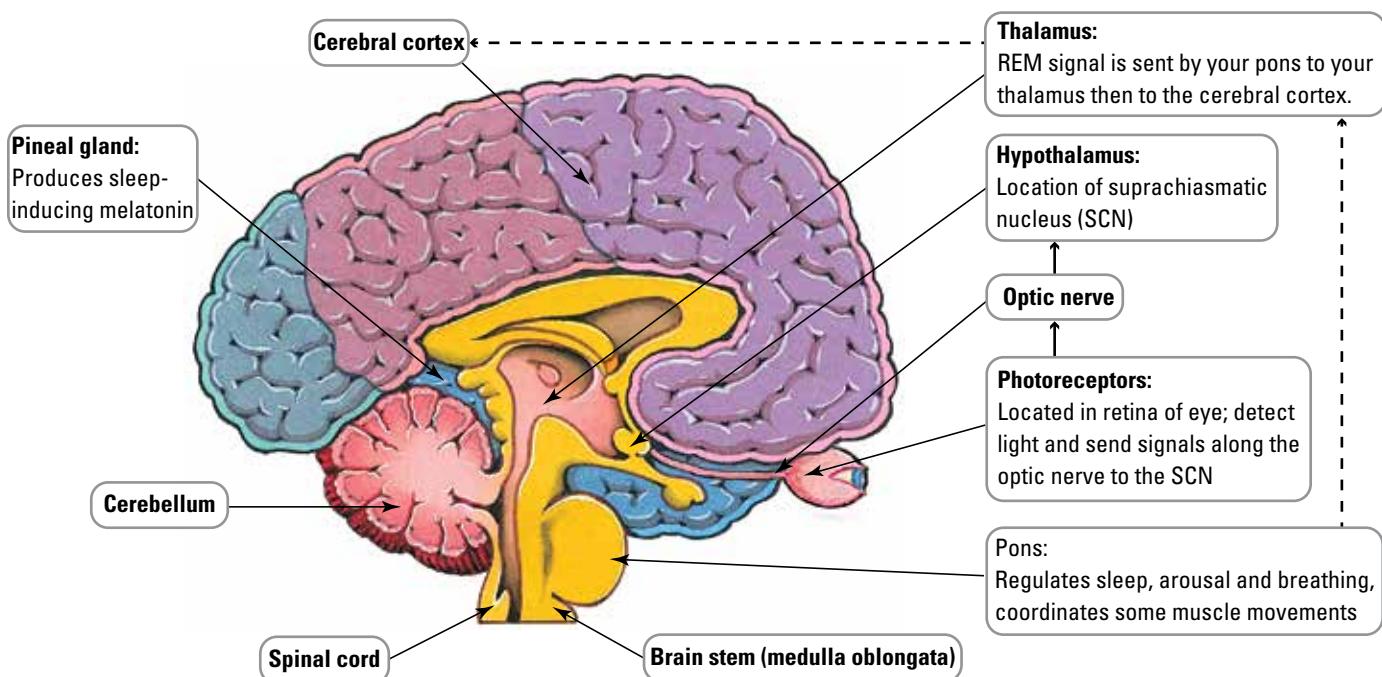
What's your rhythm?

Your **circadian rhythm** is the regular pattern of mental and physical changes that happen to you throughout a 24-hour time period. This rhythm may be controlled by your body's biological clock. This clock is really a pair of pin-sized structures made up of about

20 000 neurons called your **suprachiasmatic nucleus (SCN)**, which is located in your hypothalamus, near where your optic nerves cross.

Catch that yawn

Why do you often get drowsy when it is dark and wake up when it is light? The answer lies in your nervous system and levels of chemicals in your brain. **Photoreceptors** in the retina of your eye detect light and create signals that travel along your optic nerve to your SCN. Your SCN then sends signals to a number of different parts of your brain.



In the evening, the signal that light is decreasing travels from your SCN to your **pineal gland**, which then produces a hormone called **melatonin**. Increased levels of melatonin in the evening tell your body that it's time to sleep and you begin to feel drowsy. During adolescence, these levels peak later in the day, which may explain why you get tired later at night and want to sleep in the next morning.

There is also evidence that the accumulation of a chemical called **adenosine** in your blood while you are awake may cause drowsiness. While you sleep, this chemical gradually breaks down.

Sleeping switches

Neurotransmitters can also control whether you are asleep or awake by acting on particular groups of neurons in your brain. The neurotransmitters serotonin and norepinephrine keep some parts of your brain active while you are awake. During sleep, the production of these neurotransmitters is switched off. As these chemicals are involved in logical and consequential thinking, your judgement of time and location can become distorted.

Some foods and medicines can change the balance of your neurotransmitters and affect how alert or

drowsy you are and also how well you sleep. Drinks or foods that contain caffeine stimulate some parts of your brain and can cause insomnia (inability to sleep).

Neurons involved in controlling sleep also interact closely with your immune system. Infectious diseases like the flu can make you feel sleepy. This may be because of the powerful sleep-inducing chemicals of our immune system called **cytokines**. Sleep may also help you to conserve energy and other resources that the immune system may need.

Catching sleep waves

During the night, your body experiences sleep cycles lasting 90–110 minutes, with periods of REM (rapid eye movement) and non-REM sleep. You might have three to five sleep cycles each night.

Dropping off

There are four stages of non-REM sleep, and about 75 per cent of your night's sleep is spent in non-REM sleep. Stage one lasts for about 5 per cent of your sleep and is a transition period from wakefulness to sleep. During this stage, your muscles may contract and you may feel 'jumps' or 'twinges' in your legs. In the second stage (45 per cent of an average night's sleep) your brainwaves become larger and eye movements cease. In your third (12 per cent) and fourth (13 per cent) stages of non-REM sleep, your brain will show delta wave activity. You will be in a deep sleep and be difficult to arouse.

Dream time

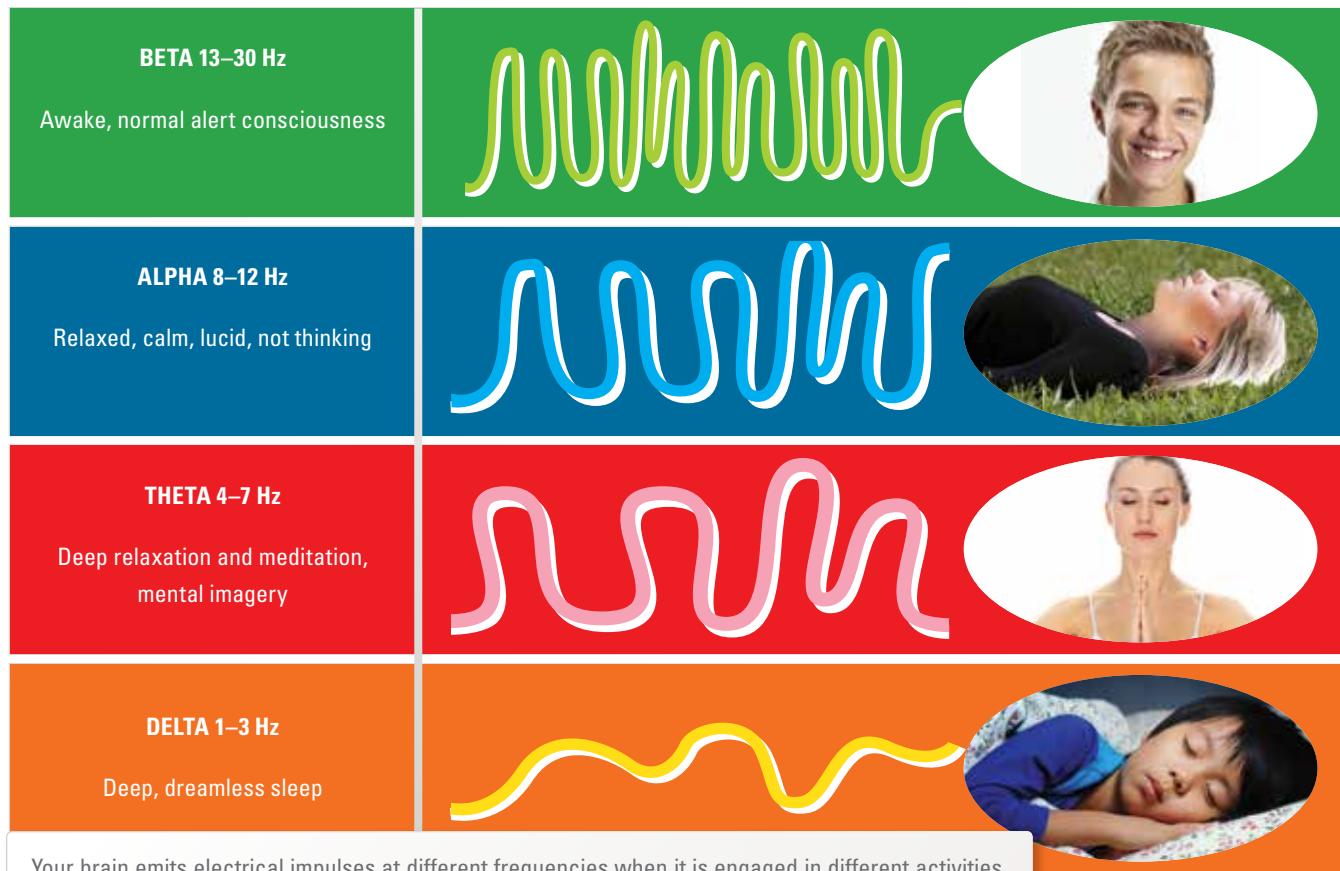
Your REM sleep is your dream time, and usually makes up about 20–25 per cent of the night's sleep. In REM sleep your breathing becomes more rapid, irregular and shallow and your eyes flick in different directions. Your first REM sleep each night lasts about 70–90 minutes. If you are woken during REM sleep, you can often describe your dreams.

REM sleep is triggered by the pons in your brain. Your pons also shuts off neurons in your spinal cord to temporarily paralyse your limbs so that you don't act out your dreams. The REM sleep signal is sent by your pons to your thalamus, then to the cerebral cortex. As REM sleep stimulates the regions of your brain used in learning, some believe that dreams are the cortex's attempt to interpret and put meaning to new information and experiences.

Heavy smokers may have reduced amounts of REM sleep and sleep lightly. Although alcohol can help you to fall into a light sleep, it also reduces REM and deep restorative stages of sleep.



Some examples of ways in which you can improve the quality of your sleep



Sleep learning

Recent research has shown that, while you are asleep, your brain consolidates and practises what has been learned during the day. This suggests that learning continues to take place while you sleep. If this is true, it is another reason for getting a good night's sleep before a test or exam, rather than staying up all night studying!



REM sleep is triggered by a structure in the brain called the pons.

Catching brain waves

Your brain emits waves of electrical impulses at different frequencies when it is engaged in different activities. These frequencies are measured in cycles per second (cps) or Hertz (Hz). Technologies such as an **electroencephalogram (EEG)** can be used to measure the patterns of this electrical activity.

Beta (β) waves (13–30 Hz) are the fastest waves with the shortest wavelength. When your brain is emitting beta waves you are using many of your senses and are strongly engaged. An example of this may be if you were involved in an active conversation at a party or playing sport. This type of brainwave is associated with short-term memory, alertness and concentration and is in very high levels if you are anxious about something.

When your brain is emitting **alpha (α) waves** (8–12 Hz) it is likely that you are calm and relaxed, but still aware of your environment. If you are involved in solving a problem, reflecting on an experience or creatively visualising something, you may be emitting this type of wave. When your brain is in this state you may be processing information and activating your long-term memory.

When you are in a deep dreamless sleep, your brain will be emitting **delta (δ) waves**.

HOW ABOUT THAT!

An electroencephalograph (EEG) can be used to measure the overall patterns of electrical activity of your brain. When you are asleep, theta and delta wave activity is present. When you are awake, your brain tends to show alpha waves if you are relaxed and beta waves if you are alert.

An EEG records electrical activity in the brain via electrodes on the scalp.



UNDERSTANDING AND INQUIRING

REMEMBER

- 1 What is a circadian rhythm?
- 2 Where is your suprachiasmatic nucleus (SCN) located and what does it do?
- 3 How is light involved in whether or not you are sleepy?
- 4 What effect do increased levels of melatonin have on your body?
- 5 What effect can the switching off of serotonin and norepinephrine have on you?
- 6 Suggest why infectious diseases like the flu might make you feel sleepy.
- 7 Do you spend more time in REM or non-REM sleep? In which one are you likely to dream?
- 8 What stops you from acting out your dreams?
- 9 Which types of brainwaves are seen in deep, dreamless sleep?

THINK AND DISCUSS

- 10 Discuss the effect of light pollution in your bedroom.
- 11 Why might you be more vulnerable to asthma at night-time?

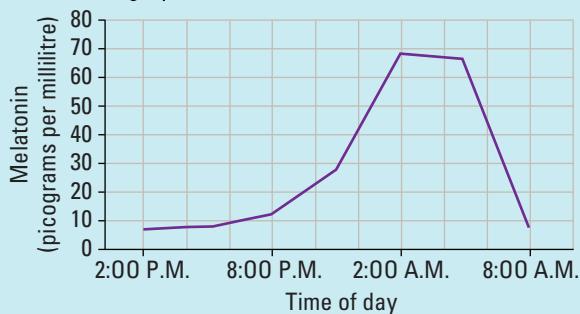
INVESTIGATE

- 12 Travelling from one time zone to another can disrupt your circadian rhythm and you can experience a condition known as jet lag. Find out more about how light therapy has been used to help reduce the effects of jet lag by helping to reset biological clocks.
- 13 While most adults need about 7 or 8 hours sleep, teenagers usually require about 9 hours. Find out more about research into adolescence and sleep.
- 14 Investigate and report on one of the following sleep conditions: sleep apnoea, narcolepsy, restless leg syndrome, talking in your sleep, sleepwalking, night terrors.
- 15 If you don't get enough sleep, you may be drowsy and unable to concentrate. Severe sleep deprivation may result in hallucinations and mood swings. What are some other consequences of sleep deprivation?
- 16 If someone is in a coma or under anaesthesia, are they really asleep?

17 There is an early morning dip in blood pressure at about 2 or 3 am. Investigate and discuss why there are more records of heart attacks within the first six hours of waking than at any other time.

- 18 Select one of the following, research it and:
- (a) summarise your findings into a poster or multimedia presentation to share with others
 - (b) describe how scientific evidence or knowledge can be used to validate your findings
 - (c) use internet research to identify two problems related to this topic that could be investigated.
- The effects of decongestants and antidepressants on sleep
 - Theories for why we yawn. Do you agree with any of these? Why?
 - Ways to sleep more effectively
 - Theories of how sleep may affect learning
 - Patterns of age and sleep
 - The effects of 'sleep debt'
 - Microsleeps
 - Driver fatigue
 - The effects of shift work on sleep
 - The effects of total blindness on sleep

- 19 (a) Describe the pattern observed in the melatonin levels in the graph below.



- (b) Suggest an interpretation of the observed pattern.
- (c) Use other resources to find out more about melatonin and its effects on your body.
- (d) Suggest a link between light, melatonin and the body's resulting responses.
- (e) Suggest how melatonin levels may affect your learning.
- (f) Research seasonal affective disorder (SAD) and determine a possible link to melatonin levels.
- (g) Find out about and report on at least one example of research related to melatonin.

The teen brain

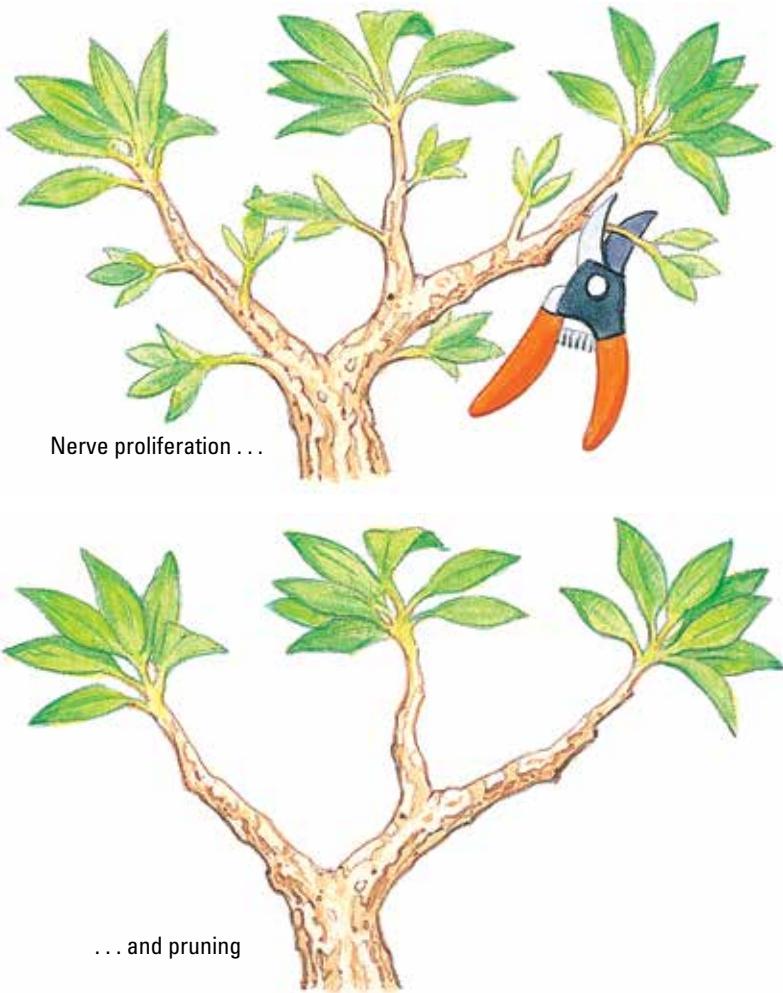
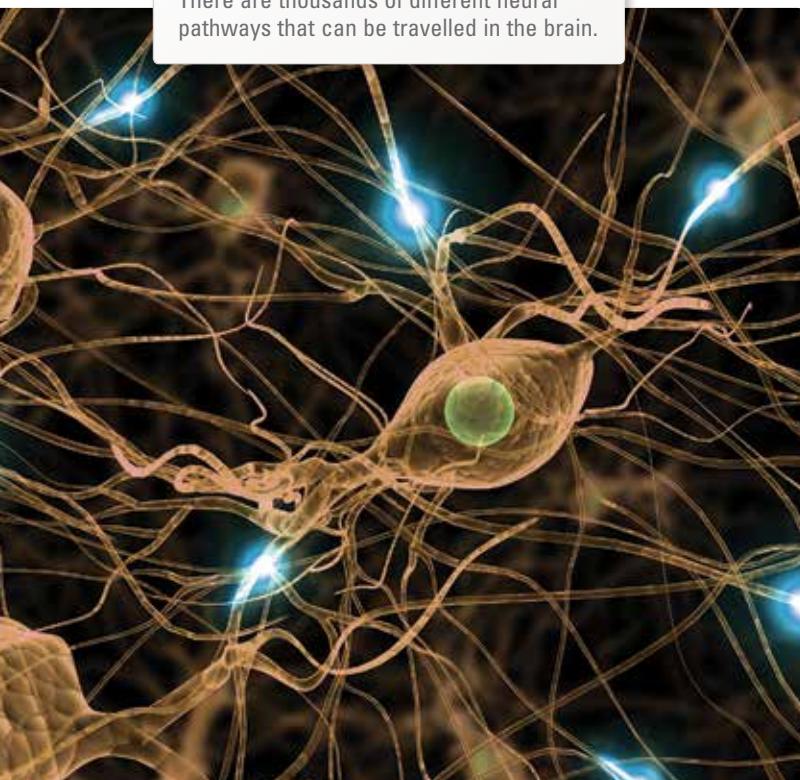
Did you know that you had more neurons in your brain before you were born? Most of your brain development occurs in two stages: growth spurts and pruning. Throughout the first months of your life, your brain grew rapidly, producing millions of brain cells. A few months before you were born, there was dramatic pruning of your brain cells to remove unnecessary cells.

Like pruning a tree

Between the ages of about 6 and 11, neurons grow bushier and make dozens of connections (synapses) to other neurons, creating new pathways for nerve signals. This process peaks at around ages 11–12.

Use it or lose it! **Synapses** are the connections between the neurons where the message is passed from one neuron to the next. The synapses that carry the most messages get stronger and those that are not used much grow weaker. **Synaptic pruning** is the elimination of the weakest connections between neurons in the brain's cortex (grey matter). During this adolescent pruning up to 30 000 synapses may

There are thousands of different neural pathways that can be travelled in the brain.

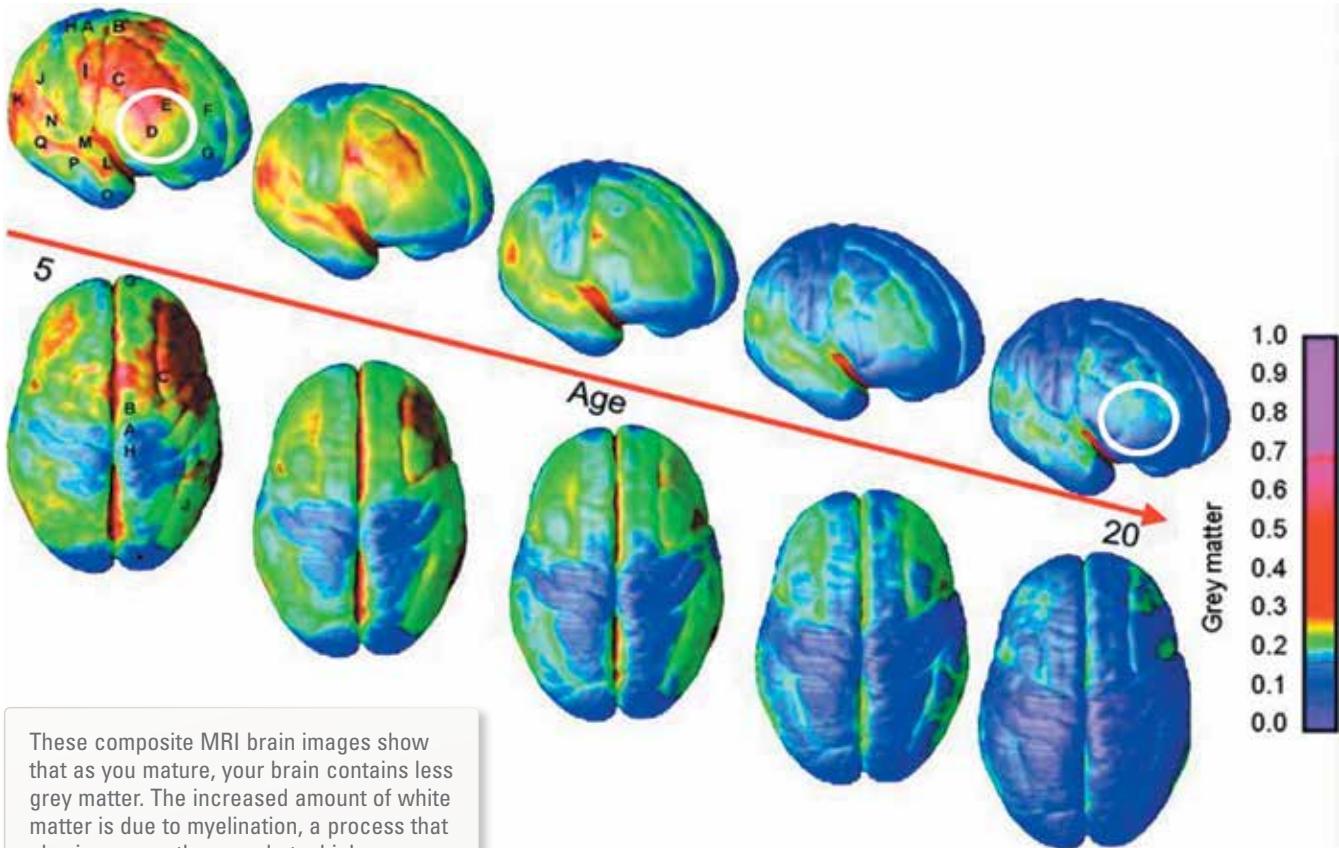


be eliminated each second. Only the connections that experience has shown to be useful are preserved. It is a bit like pruning a tree. The weaker branches are cut back to allow the other branches to flourish.

Wrapped in a white coat?

Your brain uses synaptic pruning to consolidate your learning by pruning away less travelled connections and myelinating neurons involved in the busy connections so that they become fixed as synaptic pathways.

In the process of **myelination**, neurons are coated with a white material called **myelin**. The myelin coat acts like the plastic material wrapped around electrical wires for insulation. While myelination of neurons insulates, it also increases the speed at which the nerve impulse



These composite MRI brain images show that as you mature, your brain contains less grey matter. The increased amount of white matter is due to myelination, a process that also increases the speed at which your neurons can communicate messages.

can move through it and hence the speed at which the message is communicated.

Images of the brain using MRI technology show that the amount of grey matter in the brain is reduced throughout childhood and adolescence and the amount of white matter increases. Does this suggest a link between increased cognitive (thinking) abilities and myelination?

'Teeny' neuroscience discoveries

Knowledge about the teen brain is definitely a work in progress. Neuroscience research is providing us with many new discoveries due to the development of technologies that can provide images of living, growing brains. Using technologies such as PET (positron emission tomography) scans and fMRI (functional magnetic resonance imaging), scientists can observe growth spurts and losses, and map our brain's activity while we are involved in a variety of experiences.

Prefrontal cortex

It was once thought that brains had finished their development by the end of childhood, but we now

know that adolescence is a very busy time for brain growth and change. The prefrontal cortex in the brain undergoes a growth spurt at about 11–12 years of age, followed by a period of pruning and organisation of new neural connections. It is often referred to as the 'area of sober thought', and is now thought not to reach full maturity until the age of around 25. The prefrontal cortex is responsible for impulse control, planning, decision making, strategising and judgement. Is this why some teenagers act before they think about the possible consequences of their actions?

Basal ganglia

The basal ganglia act like a personal assistant to the prefrontal cortex, helping it to prioritise information. They grow neural connections at about the same time as the prefrontal cortex, and then prune them.

Corpus callosum

This bundle of nerves that connects the left and right hemispheres of the brain is thought to also be involved in problem solving and creativity. During your teens, the nerve fibres thicken and increase the effectiveness of information processing.

Amygdala

The amygdala is the emotional centre of your brain. This is the brain's area for primal feelings such as fear and rage. Since a teenager's prefrontal cortex may not yet have matured, they may use their amygdala and associated gut instincts when making decisions. Teenagers also tend to rely more on this part of the brain when processing emotional information, which may lead to impulsive behaviour. Adults are more likely to rely on their more developed and rational prefrontal cortex, which can balance out inappropriate emotions and impulses from their amygdala.

Dopamine spikes

Are adolescents neurally wired to take risks? In 2010, scientists observed fMRI images of participants involved in particular learning activities. Their research results led them to hypothesise that risk-taking in adolescents may be due to overactivity in the mesolimbic dopamine system of their brains.

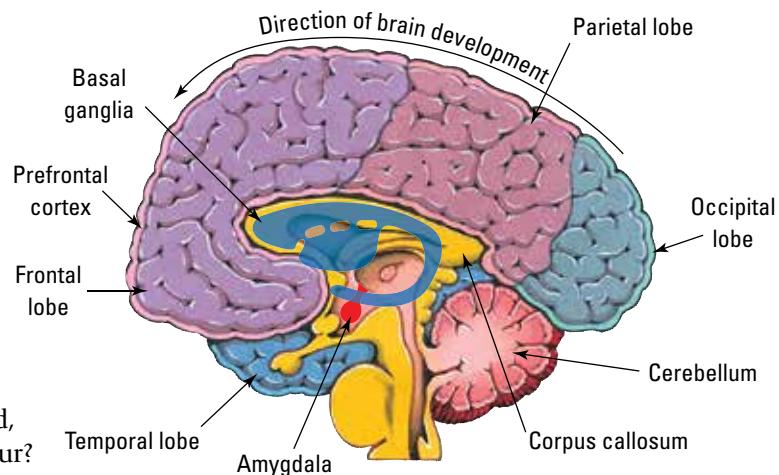
What are the implications of this possible new knowledge? Is the risk-taking observed in many teenagers due to a spike in their levels of the neurotransmitter dopamine? While further research may support or disprove this hypothesis, the possibility that this may be the case opens many new possibilities for research and consequent issues. If it is supported, how accountable are teenagers for their behaviour? It can be seen that from research exciting new knowledge can be developed, but the implication of this knowledge also needs be considered or explored.

Who determines the future uses of new knowledge in scientific discoveries?

The neurotransmitter dopamine is known to be important for motivation to seek rewards.

Back-to-front brain development

Did you know that your brain develops from bottom to top, from back to front, and from right to left? The development of your brain has been 'programmed' for the two tasks that confront survival of the human race (staying alive and getting into the gene pool). In the first 10 years of life, you learn the skills to stay alive. In the next 10 years, you learn how to be a productive and reproductive human. This wiring of your brain is essential to the survival of our species.



Your brain develops from back to front!

UNDERSTANDING AND INQUIRING

INVESTIGATE

Select one of the following statements and claims and list five questions that it raises. Investigate these questions and present your findings in a creative and interesting way.

- (a) You were born with a very immature brain (about 1/3 adult size) because of your mother's upright stance (walking on two legs) and her relatively narrow birth canal.
- (b) That we are a cooperative, social species with a rich language-driven culture is due to our limited and 'helpless' early brain development and long dependence as children.
- (c) Some research suggests that the corpus callosum is bigger and more developed in women than in men. Other studies contradict this.

- (d) Female brains may be smaller, but they mature a lot faster and have more synapses.
- (e) Girls are better at ... than boys because their brains are better.
- (f) Boys are better at ... than girls because of the way their brains develop.
- (g) Teenagers get into so much trouble because they think and act through their amygdala.
- (h) A drug should be developed so that the brains of teenagers are more like those of adults.
- (i) It is important to survival of the species for adolescents to be wired to take risks so that they can learn new ways of doing things.
- (j) Schools should start later in the day because teenagers need more sleep than those of other ages.

Getting back in control

Imagine not being able to move. Your brain tells your legs or arms to do something but they ignore you. How would it feel? What can you and science do to help?

Damage to the spinal cord of the nervous system may be the result of a disease or an accident or be congenital (already present at birth). Whatever the cause, this type of damage can be devastating and debilitating.

Although there is currently no cure for spinal injury, teams of scientists around the world are involved in research that is aimed at improving the quality of life for those with this injury. Perhaps a technology not yet developed may one day lead to a cure.

Paralysis and spinal injury

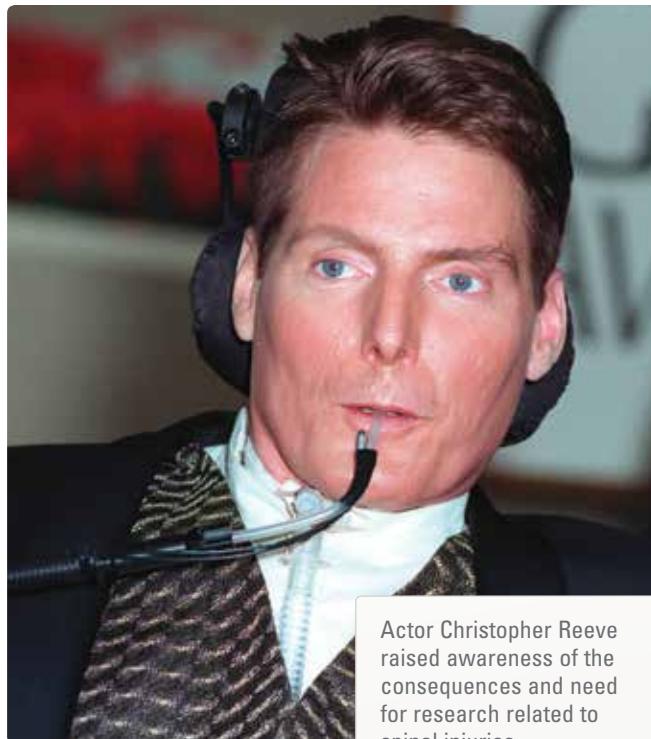
All of the nerves in your peripheral nervous system throughout your body connect to your spinal cord. Damage to this cord can prevent communication of messages between your brain and your body. This loss of communication can lead to **paralysis** (loss of movement).

Damage to different parts of the spinal cord results in different types of paralysis. For example, if you were in an accident in which the lower back section of your spine was completely crushed, messages would not be able to travel between your legs and feet and your brain. This loss of communication would mean that you would not be able to sense pain, heat, cold or touch in these parts of your body. You would also be unable to stand or walk as you would not be able to control the muscles in your legs and feet.

Christopher Reeve, an actor who played Superman in a series of early movies, damaged his spinal cord in the neck region in a sporting accident. The consequence was that he was paralysed below the neck and required the use of a machine to breathe air into and out of his lungs as he was unable to breathe for himself. In the years following his accident he raised awareness of spinal injuries and increased public and political interest in related research.

Paralysis and disease

A number of diseases can also result in paralysis. One such condition is motor neuron disease. Although the cause of this disease is still unknown, its effects are devastating. While the brain and the senses are usually



Actor Christopher Reeve raised awareness of the consequences and need for research related to spinal injuries.

unaffected, the person with the disease becomes increasingly paralysed.

Motor neuron disease, as the name suggests, targets motor neurons and progressively destroys them. Sensory neurons, however, remain unaffected. This means that a person paralysed with motor neuron disease could hear and see a mosquito, feel it biting their arm, feel the itchiness, but be unable to move to scratch it or talk to tell someone to scratch it for them.

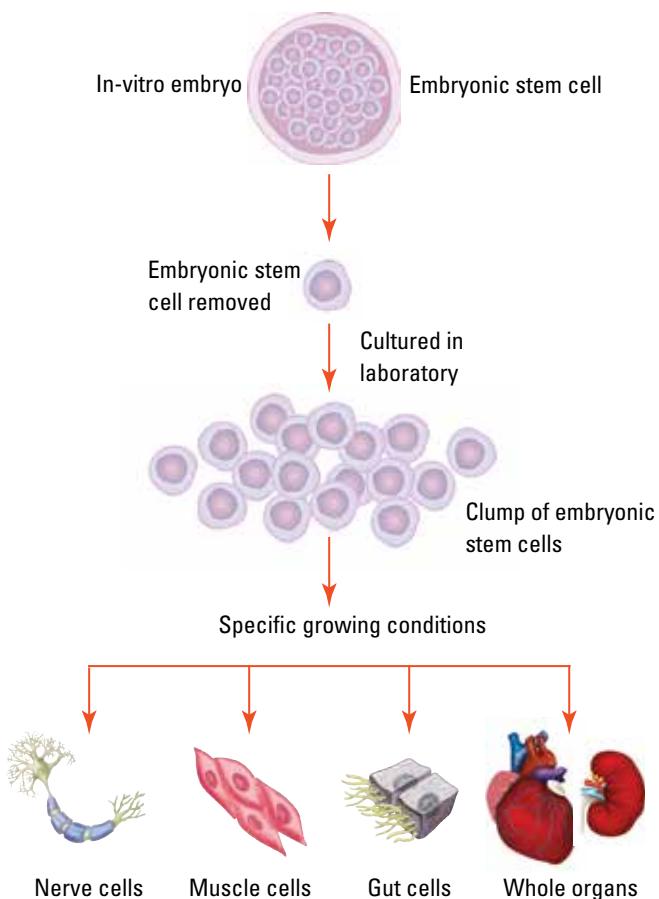
People with motor neuron disease sense their environment, but increasingly cannot respond to it. This paralysis eventually involves all muscles within the body. Sadly, motor neuron disease is fatal.

Stem cells — a possible treatment?

Embryonic stem cells (a topic introduced in *Science Quest 8*) have many properties that scientists find exciting. They can produce new cells for longer than other cells and under the right conditions they can be made to differentiate into particular cell types. Some current research is investigating the injection of nerve cells produced from embryonic stem cells into the

site of spinal injury. Although it is early days for this research, it is hoped that it may lead to the recovery of muscle function in some cases.

Although the possible applications of this research are exciting, technologies involving the use of human embryonic stem cells are fraught with issues and controversy. Most of this debate centres on the source of the stem cells — human embryos that have been obtained from the surplus embryos of couples undergoing IVF treatment.



The use of stem cells to treat (and possibly even cure) a variety of diseases is being investigated. The research is, however, accompanied by much debate.



Broader applications of this technology, for example **implanted electrodes** and **neural prostheses**, are being researched and developed in order to provide assistance to people with a variety of disabilities. There have already been cases in which paralysed people have been able to move their wheelchairs by just thinking about the movement, or those who are unable to talk have been able to use their brain to result in their thoughts being spoken aloud.

Could such technology be used in other ways — could it be used to help blind people to see, and deaf people to hear? What other senses could be assisted using this technology? Could it be used to enable us to experience senses that humans do not currently possess?

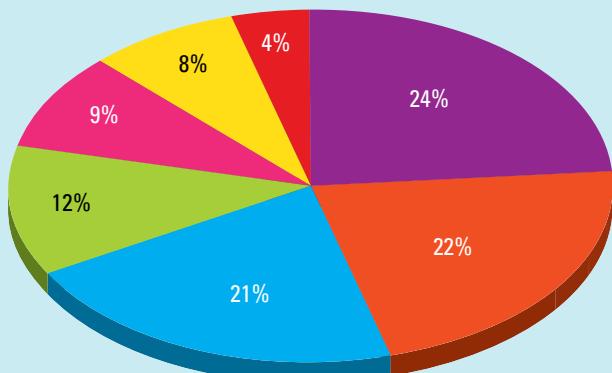
UNDERSTANDING AND INQUIRING

REMEMBER

- 1 Define the terms *spinal cord*, *paraplegia*, *quadriplegia* and *paralysis*.
- 2 Outline the properties that make stem cells interesting to researchers.
- 3 Describe evidence that suggests that stem cells may one day be used to restore some mobility after a spinal injury.
- 4 Outline how brain-control interface technology can bring about body responses.
- 5 Describe an application of implanted electrodes or neural prostheses.

THINK

- 6 Use the graph below showing the causes of spinal injury to answer the following questions.



- Motor vehicle occupants
- Unprotected road users (motorcyclists, pedal cyclists, pedestrians)
- Low falls (on the same level, or from a height of less than 1 metre)
- High falls (from a height of 1 metre or more)
- Struck by or collision with a person or object
- Water-related
- Other

- (a) What are the two leading causes of spinal injury?
- (b) What percentage of spinal injuries are sports related? Suggest which sports might have the highest risk of spinal injury.
- 7 Explain why an injury in the neck region of the spinal cord may result in quadriplegia, whereas an injury in the lower back region of the spinal cord may result in paraplegia.
- 8 Imagine that you are on an ethics committee for a university. An ethics committee is a group of people that decides whether experiments should be carried out on ethical grounds. Discuss whether you would allow scientists to do experiments that involve deliberately crushing the spinal cord of rats.

INVESTIGATE

- 9 Draw a map to show the location and type of wheelchair access available at your school. Do the same for your local shopping centre. Are there any places it would be impossible for a disabled person to get to? Find out from your local council what regulations there are relating to wheelchair access to parks and public and commercial buildings.



Standard disability parking and access signs

- 10 Investigate some improvements to wheelchair design that have been made in the last 20 years.
- 11 Find out about wheelchair designs for particular sports such as wheelchair basketball and racing.

THINK, INVESTIGATE, DISCUSS AND CREATE

- 12 Formulate questions about brain-control interface technology that could be investigated scientifically and then design an experiment that could be used to investigate one of your questions.
- 13 Intercranial electrodes may be very useful in brain-control interface applications and benefit those who are paralysed or have conditions such as motor neuron disease.
 - (a) As a group, formulate questions about intercranial electrodes, brain-control interface applications, paralysis and motor neuron disease.
 - (b) Research questions proposed by your group and then discuss your findings.
 - (c) Suggest further questions that could be explored and research these.
 - (d) Use your imagination and creativity to share your findings as a model, a science fiction story, an animation or a multimedia documentary.
- 14 (a) Find out more about modern brain implant technologies.
 - (b) Suggest ethical issues that may be raised about the research and application of these technologies.
 - (c) Organise a class debate that considers various perspectives on these technologies.

Opening up your brain

Your brain is amazing, mysterious and powerful. While you use it to formulate, ask and investigate questions, sometimes these questions are about the brain itself! What do you know about your brain? Why not open your brain up to new ideas, new discoveries and new questions about brains?

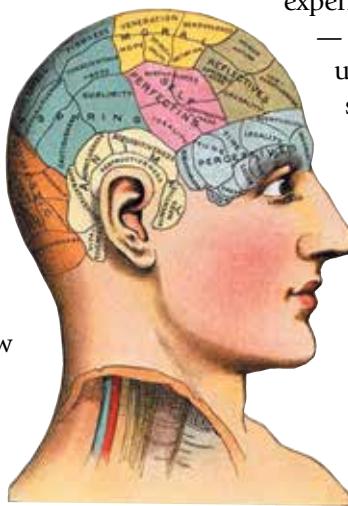
Brain in mind

Throughout history, humans have asked many questions about the human brain and there have been varied theories about its structure and how it works. Some questions have been about how brain cells interact with each other and what happens when the brain grows, ages or is damaged. Other questions relate to how it is involved in our learning, experiences and emotions, or how it contributes to make us who we are. There have even been investigations to design and construct artificial brains!

Phrenology

Frantz Joseph Gall, a German physician, developed the theory of phrenology in 1796. He believed that the brain was made up of a number of individual 'organs' which could be detected by visible inspection of the skull. This led to the belief that the size, shape and bumps of a person's skull determined their character and mental capacity. This theory was particularly popular between 1810 and 1840. While phrenology is now dismissed as a **pseudoscience**, some of its assumptions are still valid. The idea that mental processes can be localised in the brain is one such claim and is supported by our modern neuroimaging techniques.

Duchenne and an assistant give a demonstration of the mechanics of facial expression using electropuncture.



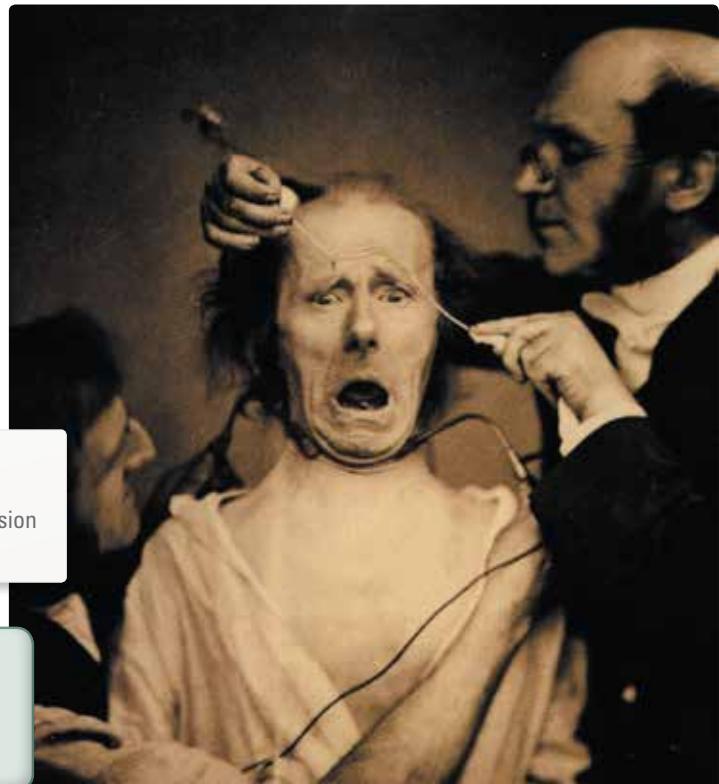
Neurology

Guillaume-Benjamin-Amand Duchenne de Boulogne (1806–1875) was a French neurologist who greatly advanced the science of muscular electrophysiology and electromyography. In 1835, he began

experimenting on therapeutic electropuncture — which involved applying an electric shock under the skin with sharp electrodes to stimulate the muscles. This increased his understanding of the conductivity of neural pathways. Some refer to Guillaume as the father of modern neurology and in recognition of his research (and discovery), Duchenne muscular dystrophy is named after him.

An integrated approach

Our interest in brains has given rise to a variety of new branches of science. Examples of these include neurobiology, neuroscience, neurophysiology, neuropsychology and neuroanatomy. The frontiers of brain science also require an



WHAT DOES IT MEAN?

The word *phrenology* comes from the Greek terms *phren*, meaning 'mind', and *logos*, meaning 'knowledge'.

integrated approach that combines approaches and technologies from various scientific fields. Scientists in medical, biological, molecular biological, theoretical science, psychology, biophysics and various computer technologies can all be involved in trying to find out more about particular aspects of our brains.

Brain on display

It is no wonder that some scientific terms are often referred to in an abbreviated form! This is especially the case with some of the names of imaging technologies used to look at the structure and function of the brain. **Computerised axial tomography (CAT)** and **magnetic resonance imaging (MRI)** produce computer images of the brain's internal structure. Scanning technologies that provide information about brain function include: **electroencephalography (EEG)**; **magnetoencephalography (MEG)**; **positron emission tomography (PET)**; **functional magnetic resonance imaging (fMRI)**; and **functional magnetic resonance spectroscopy (fMRS)**. A key advantage of these scanning technologies is that they can analyse the brain while its owner is alive — and using it!

PET

PET was the first technology used to observe brain functions. It involves injection of a radioactive solution into the brain. The amount of radiation measured in particular regions indicates levels of activity in those parts at that time.

EEGs and MEGs

EEGs and MEGs involve the attachment of multiple electrodes to the scalp and the measurement of either electrical or magnetic activity occurring in the



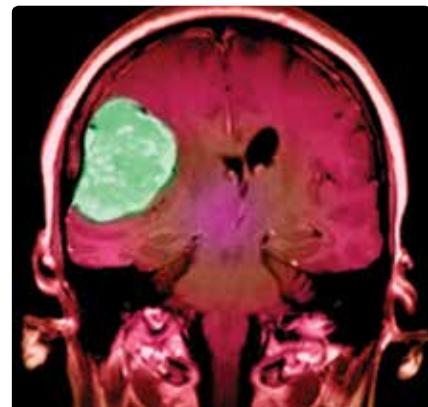
Scientists use various technologies to study the structure and function of brains. These technologies provide us with information that enables us to develop models so that the knowledge can be communicated to others.

brain during mental processing. These technologies record activation of groups of neurons responding to a specific event and help to determine how quickly this occurs in the brain.

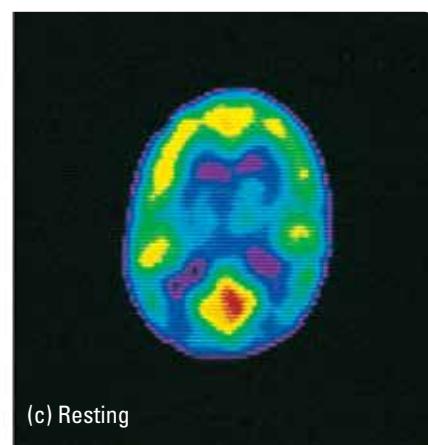
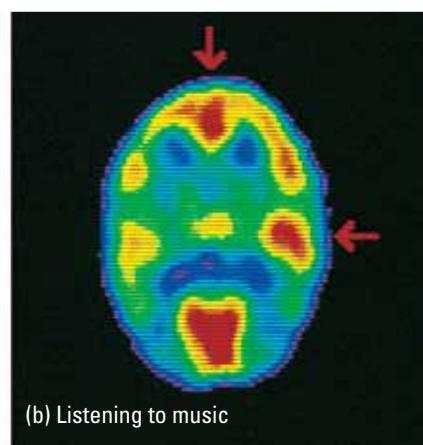
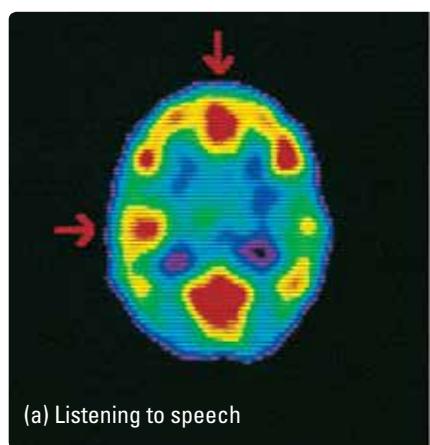
fMRI and fMRS

Areas in your brain involved in thinking require more oxygen than the parts not involved.

This oxygen is transported by haemoglobin, a molecule that contains iron, which is magnetic.



MRI scan of a benign brain tumour



PET scans of people with normal brain activity participating in different tasks. Red indicates the greatest level of brain activity, whereas blue indicates the brain areas that are least active.

fMRI uses a large magnet to compare the amount of oxygenated haemoglobin entering brain cells with the amount of deoxygenated haemoglobin that is leaving them. The computer generated images colour the regions with greater oxygenated blood. This allows the pinpointing of the activated brain regions to be located within a centimetre.

While fMRS uses the same equipment as fMRI it uses different computer software. This technology can record and identify levels of specific chemicals during brain activity and has been used to study language function in the brain.

Neurotechnology

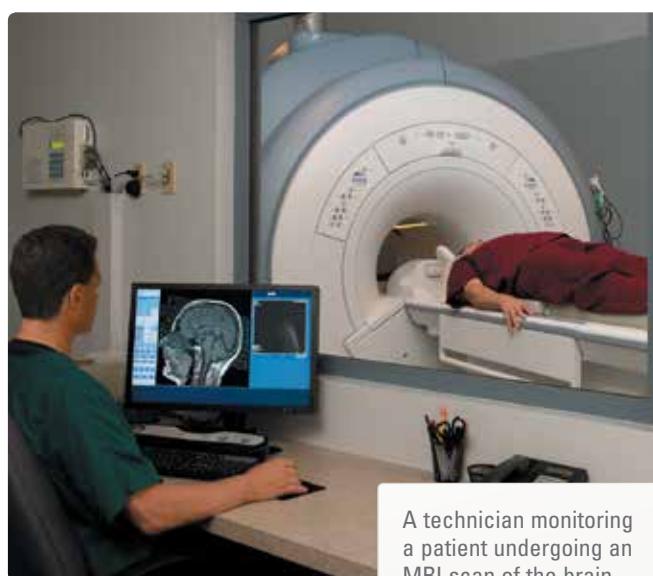
We have learned more about the human brain in the past 10–15 years than we have in the rest of recorded history. This new information is leading revolutionary changes in how we use our brains and think about them. New technologies are providing us with new knowledge about the brain and how it works. With new knowledge, previously held ideas often need to be modified. In some cases, the previous understanding or theories have needed to be discarded completely so that new theories can be developed to replace them.

Neuroplasticity and neurogenesis

Contrary to what was believed in the past, our brains and brain connections, or neural pathways, are not static and unchanging. They are constantly wiring

and rewiring. Stimulation and challenging your brain encourages the growth of dendrites and the production of new neurons. Lack of stimuli can result in weakening of existing connections and possible pruning of them. You may also lose new neurons in the process.

Currently there are some exciting research projects on **neurogenesis** (meaning ‘the birth of new neurons’). This research is investigating whether factors such as exercise and different moods can influence how many neurons are being ‘born’ each day and how many survive.



A technician monitoring a patient undergoing an MRI scan of the brain

PMI chart on neurotechnology

Plus	Minus	Interesting
<ul style="list-style-type: none">New medicines For example, these may be individually styled and used to cure or treat mental illnesses with high efficacy and negligible side effects. This may lead to a major decrease in mental illnesses such as depression, schizophrenia, bipolar disorders, substance abuse and obsessive-compulsive disorders.	<ul style="list-style-type: none">New weapons For example, neuroweapons that influence how the brain (and person) responds to particular stimuli or situations	<ul style="list-style-type: none">Neuroeducation For example, a tablet to ingest or a connection to an implant in your brain to pass on the knowledge of a new language, topic or skill
<ul style="list-style-type: none">New chemicals For example, chemicals that may be ingested to:<ul style="list-style-type: none">— influence learning, memory processes, decision making and attention— influence moods, motivation, feelings and awareness— restore and extend the capacity of our senses (enhancing the sense of sight, hearing, smell or taste)	<ul style="list-style-type: none">New marketing strategies For example, neuromarketing that uses knowledge of the brain to prioritise their products over others	<ul style="list-style-type: none">Neuromodulators For example, a tablet to ingest to help people feel happy all of the time

**Brain sell**

Find out more about how advertisers are getting inside our heads using neuromarketing.

eles-1080

Shaped by neurotechnology

Our society shapes the development of new technologies. It is also shaped by these technologies. Discoveries in neurotechnology have been enhanced by developments in information technologies.

Development of nanobiochips and brain-imaging technologies increase the accuracy of biological and neurological analysis. Nano-imaging techniques will enable analysis of events at the neuromolecular level in the brain. Knowledge of these events will enhance our understanding about how our brains work and give us power to modify their function.

In the future, neurotechnology may provide us with knowledge that may lead to the development of new treatments for diseases, new industries — and new problems to consider and solve. How will new neurotechnologies change human societies? How will they change us?

UNDERSTANDING AND INQUIRING

REMEMBER

- 1 Phrenology has a colourful history and varied interpretations. Give an example of how it has been used.
- 2 Phrenology is considered by many to be a pseudoscience. What is meant by this term? Do you agree? Explain your response.

INVESTIGATE, THINK AND DISCUSS

- 3 (a) Use the internet to identify claims regarding the effects of exposure to types of electromagnetic radiation (such as X-rays, microwaves and gamma rays) on humans.
 (b) Find evidence that supports or negates the claims.
 (c) Identify issues that are relevant to human exposure to these types of radiation and construct PMI charts to summarise the key points and concerns.
 (d) Analyse the language used by media reports in terms of bias and perspective.
 (e) Select one of the issues and organise a class debate.
- 4 Research ways in which the development of imaging technologies has improved our understanding of the structure and function of the human brain.
- 5 Investigate how electromagnetic radiation technologies are used in the detection and treatment of cancer. Report your findings as a television documentary, podcast or newspaper article.
- 6 There are claims that brain scans can reveal personality types and the type of career that you are best suited to. Find out more about these claims.
 - (a) On the basis of your findings, do you agree that brain scans are capable of this? Justify your response.
 - (b) Find out and discuss issues related to the use of brain scans in this way. Do you agree with using brain scans in this way? Explain why.

7 Frantz Gall believed that the brain was made up of a number of individual 'organs' that created one's personality. Find out examples of these 'brain organs' and how this information was used. Not everyone agreed with the ideas of phrenology. Find examples of arguments for and against phrenology, summarising your findings in a PMI chart.

- 8 If you were to hear about a new model or theory about the brain in the media, describe how you would use scientific knowledge to determine its possible validity.
- 9 Use your knowledge of science to test claims made in advertising or expressed in the media (or in this text) with regard to any of the following.
 - The Mozart effect increases the depth of learning.
 - Mobile phones can cause brain cancer.
 - Neuro-linguistic programming (NLP) helps people lead better, fuller and richer lives.
 - Some people are real left-brainers!
 - Faulty mirror neurons can lead to autism.
 - Sleep enhances memory.
 - Zapping the brain using transcranial direct current stimulation can spark new ideas.

INVESTIGATE, THINK AND CREATE

- 10 Phrenology gave rise to the invention of the psychograph. Use the **Psychograph** weblink in your eBookPLUS to find out what it is and about its history.
- 11 Carefully observe the neurotechnology PMI chart in this section. Select one of the boxes and research a particular aspect of it that is of interest to you. Develop an advertising or political campaign (complete with multimedia aspects) to either promote or criticise your neurotechnology application.

STUDY CHECKLIST

NERVOUS SYSTEM

- state another name for a nerve cell
- draw a neuron, labelling the dendrites, cell body and axon
- state the function of receptors and provide examples of at least three types
- use a flowchart to show how receptors are involved in your ability to sense your environment
- use a flowchart to describe the stimulus–response model
- describe how negative feedback can assist you in maintaining homeostasis
- outline the overall function of the nervous system
- outline the key components of the nervous system
- draw a labelled diagram of the structure of a neuron
- use a flowchart to show how a message is conducted and transmitted in the nervous system
- compare and contrast nervous impulses and neurotransmitters
- use a flowchart to describe the process involved in a reflex action
- explain the need for some reactions to be reflex actions
- compare reflex actions with those under conscious control
- describe how damage to the nervous system can result in paralysis
- outline the effects of motor neuron disease on the ability to sense and respond to the environment
- recall the types of brain waves and the chemicals the body produces that are associated with sleep drugs

- identify the cerebrum, cerebellum and brain stem and outline their key functions
- list three neurotransmitters in the brain that can influence feelings and actions

ENDOCRINE SYSTEM

- outline the overall function and key components of the endocrine system
- recall the main glands of the endocrine system and some of the hormones they produce
- use a diagram to show how the stimulus–response model can be used to describe the involvement of the endocrine system in homeostasis

SCIENCE AS A HUMAN ENDEAVOUR

- consider how the development of imaging technologies has improved our understanding of the functions and interactions of body systems
- use knowledge of science to test claims made in advertising or expressed in the media
- recognise aspects of science, engineering and technology within careers such as medicine, medical technology, biomechanical engineering, pharmacy and physiology
- comment on how scientific understanding, including models and theories, are contestable and are refined over time through a process of review by the scientific community

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DIGITAL RESOURCES



ANSWERS for this chapter can be found online in your eBookPLUS.

Individual pathways

Activity 2.1 Investigating control systems doc-14549	Activity 2.2 Analysing control systems doc-14550	Activity 2.3 Investigating control systems further doc-14551
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FOCUS activity

Access more details about focus activities for this chapter in your eBookPLUS.
doc-10630

eLessons

Brain sell

Watch an ABC *Catalyst* report to find out more about how advertisers are getting inside our heads using neuromarketing.

Searchlight ID: eles-1080

Willis and the brain

Watch a video from *The story of science* about early research on the brain.

Searchlight ID: eles-1783

Interactivities

Brain control

Learn about how your brain controls all your thoughts, actions and feelings.

Searchlight ID: int-0010

Brain

Use this interactivity to test your knowledge of the roles of the four lobes of the cerebral cortex.

Searchlight ID: int-1865

A nervous response

In this interactivity, your knowledge of the nervous system is tested by challenging you to identify the sequence of events required to kick a ball.

Searchlight ID: int-0670

A bundle of nerves

Learn more about your nervous system by completing this interactivity in your eBookPLUS.

Searchlight ID: int-0015

LOOKING BACK

Link to assessON for questions to test your readiness **FOR** learning, your progress **AS** you learn and your levels **OF** achievement. www.assesson.com.au



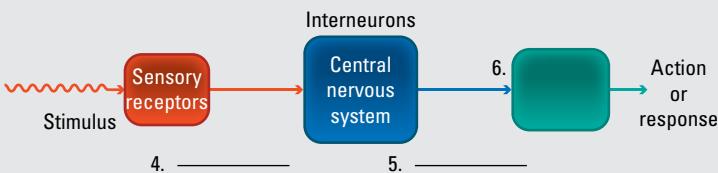
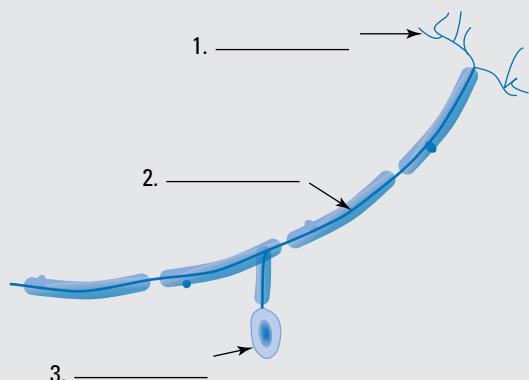
- Construct a flowchart to show:
 - the following terms in order from smallest to largest:
organs tissues
organelles systems
cells atoms
molecules
 - the stimulus-response model.

- Complete the following table.

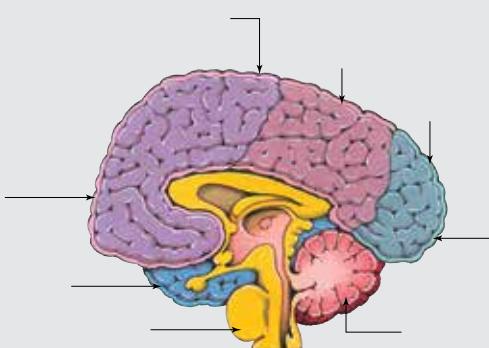
Stimulus	Receptor	Sense organ
		Eye
	Chemoreceptor	
Vibrations, pressure		
	Thermoreceptor	

- Place the following labels in the correct places on the diagrams below.

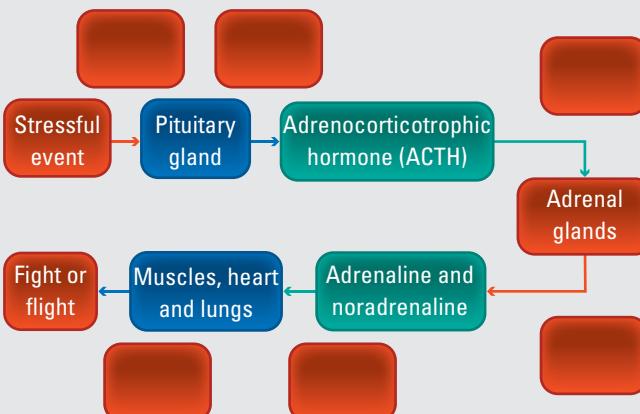
dendrite sensory neurons
nerve cell body effector
axon motor neurons



- Label each of the parts of the brain below and state one of the functions of each.



- Underline the incorrect term in each sentence and replace it with the correct term. Write definitions of the incorrect words you replaced.
 - The neuron carries hormones to target cells.
 - The master gland of the endocrine system is the adrenal gland.
 - The brain and spinal cord make up the peripheral nervous system.
 - Each molecule has tissues which carry out particular functions.
- Construct a table to summarise the differences between the nervous and endocrine systems. Make sure you include the name of the information each system produces, how that information is carried throughout the body, and the speed and length of each system's response.
- Draw a flowchart that outlines what happens when you sit down on a chair that has a sharp object on it. Include both nervous and endocrine responses.
- Construct a continuum to show the following from smallest to largest:
 - nervous system
 - cerebellum
 - molecules
 - brain
 - neurons.
- Describe functions of the following parts of your brain.
 - Cerebrum
 - Cerebellum
 - Brain stem or medulla
- The flowchart below shows a series of events that may occur when you encounter a stressful event. Suggest descriptions or labels for each of the links.

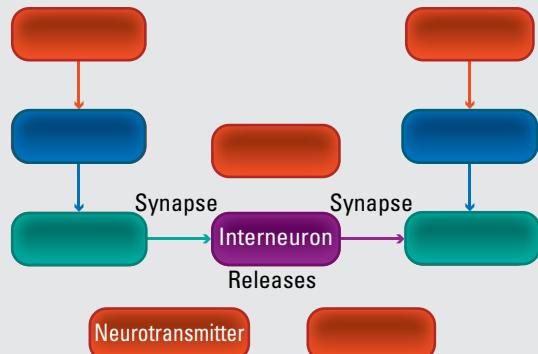


- 11 Match the terms with their appropriate description in the table below.

Term	Description
Central nervous system	Made up of a cell body, dendrites and axon
Motor neuron	Takes messages away from the central nervous system
Nerves	Takes messages to the central nervous system
Neuron	Brain and spinal cord
Neurotransmitter	Chemical messenger that carries messages from one neuron to another across a synapse
Peripheral nervous system	Nerves that connect the central nervous system to the rest of the body
Sensory neuron	Gap between neurons
Synapse	Made up of neurons

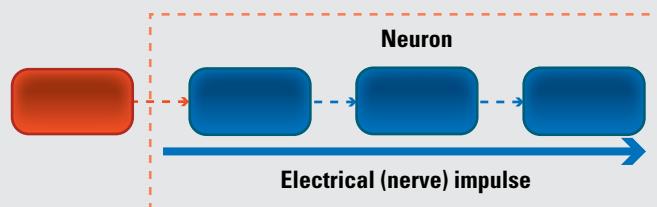
- 12 Suggest how you could link the nervous system terms in the flowchart below.

- Electrical impulse
- Motor neuron
- Sensory neuron
- Response
- Receptor
- Neurotransmitter
- Stimulus
- Effectors



- 13 Place the terms in their appropriate position in the flowchart below:

cell body, axon, dendrite, stimulus



An electrical impulse moves in only one direction through a neuron.

- 14 Describe the relationship between adrenaline, pituitary, adrenal cortex, heart rate, stress.

- 15 Use a diagram to show how blood glucose levels are controlled.

- 16 Recall three endocrine glands and hormones they produce. Describe a function of each of the hormones.

- 17 Provide an example of a negative feedback mechanism.

- 18 Suggest how analogies and metaphors can be useful in helping you connect information that you know to new information. Provide an example.

- 19 Neurolaw? How do you feel about the idea of the determination of guilt or innocence on the basis of a brain scan? There have been suggestions that brain scans (e.g. fMRI) should be used within our legal system. Do you think that these should be allowed as evidence in courts? Discuss and share your opinion with others. Justify your opinion.

- 20 Below are some examples of brain imaging techniques. Match the name of the technique to what it looks like or does.

Brain imaging technique	Description
CAT: Computerised axial tomography	A. Records electrical activity in defined areas, using colour to represent positive and negative locations in the cerebral cortex.
MRI: Magnetic resonance imaging	B. Reports on patterns of electrical transmission within an active brain which are seen as a squiggly line graph.
EEG: Electroencephalogram	C. Image that focuses on soft tissue and can show differences in chemical composition; some MRI techniques can monitor brain activity during cognitive activity.
SQUID: Superconductivity quantum interference device	D. Uses radioactive glucose to monitor blood flow through the brain as areas are activated. Can provide information of how and where an experience is processed in the brain.
PET: Positron emission tomography	E. Responds to small magnetic fields caused by electrical current of firing neurons and can identify source of electrical activity in the brain.
BEAM: Brain electrical activity mapping	F. Shows 3D graphical images of the density of tissue such as bone and tumours.

- 21** When is 'dead enough', good enough? There have been claims in the media that some organ donations have occurred when people were in the process of dying rather than being completely dead. Is near enough, good enough? On the basis of your scientific knowledge, what do you think about this issue? What is your personal opinion on this issue? Does your opinion on this issue match that of your scientific understanding? Discuss this issue with others in the class.
- 22** Tasty words and colourful letters? It is thought that about 4 per cent of the population have their senses crossed and associate letters with a flavour, numbers with a gender or sounds with a colour. This is called synaesthesia. It would be hard for people with synaesthesia to imagine a world without this extra perception. Find out more about this process and suggest how it might lead to the perception of a different world. Imagine having synaesthesia and describe what the world might be like.
- 23** Match the hormone with the appropriate function.

Hormone	Function
Anti-diuretic hormone (ADH)	Causes reabsorption of water in kidneys
Glucagon	Causes testes to produce sperm
Insulin	Causes thickening of the uterine lining
Oestrogen	Controls menstruation cycle and pregnancy
Progesterone	Increases blood glucose levels
Testosterone	Increases metabolic rate of cells
Thyroxine	Lowers blood glucose levels

- 24** Overheating can lead to heat exhaustion. This is your body's response to an excessive loss of water and salt (in your perspiration). If you get too hot, heat exhaustion may lead to heatstroke. When this occurs you may be unable to control your body temperature and death may result.
- (a) The relations diagram at right shows some causes of overheating. In a team, suggest some other possible causes of overheating that could be added to the diagram.
- (b) Construct a mind map of a team brainstorm on symptoms of overheating, heat exhaustion and heatstroke, strategies that could be used to avoid heatstroke, and treatments for heat exhaustion and heatstroke.
- 25** Having extremely low body temperature is also potentially life threatening. This condition is called hypothermia. Find out more about this condition and present your findings in a relations diagram.

- 26** Thermoregulation is the process whereby your body tries to keep your internal body temperature stable. Find out how your voluntary behaviour and your nervous and endocrine systems can help to cool or heat you. Present your findings in a mind map with diagrams or hyperlinks.
- 27** (a) Use the information entitled *Hairy stuff!* below to construct a relations diagram on some causes of hairiness.
- (b) Find out more about one of the disorders or diseases that has increased hairiness as a symptom. Present your findings in a mind map.

Hairy stuff!

Hormonal changes throughout life can cause changes in hair type and how it's produced. For example, prior to puberty, facial hair is a fine, thin type (vellus hair). Hormones released once puberty occurs can transform facial hair into a coarse, pigmented variety (terminal hair). While the growth of vellus hair is not affected by hormones, the growth of terminal hair is.

When females are experiencing menopause, there may be changes in the ratio of male and female hormones (androgens to oestrogen). This hormonal ratio change can produce an increase in facial hair. Heredity can also play a part in facial hair as it determines how thickly hair follicles are distributed throughout your skin.

Some medications and substances can cause hairiness (hirsutism). These include testosterone, steroids, Minoxidil, Rogaine and some blood pressure medication. Hairiness can also be a symptom of a number of disorders or diseases such as adrenal disorders (including Cushing's syndrome), anorexia nervosa, polycystic ovary syndrome and some pituitary disorders.

