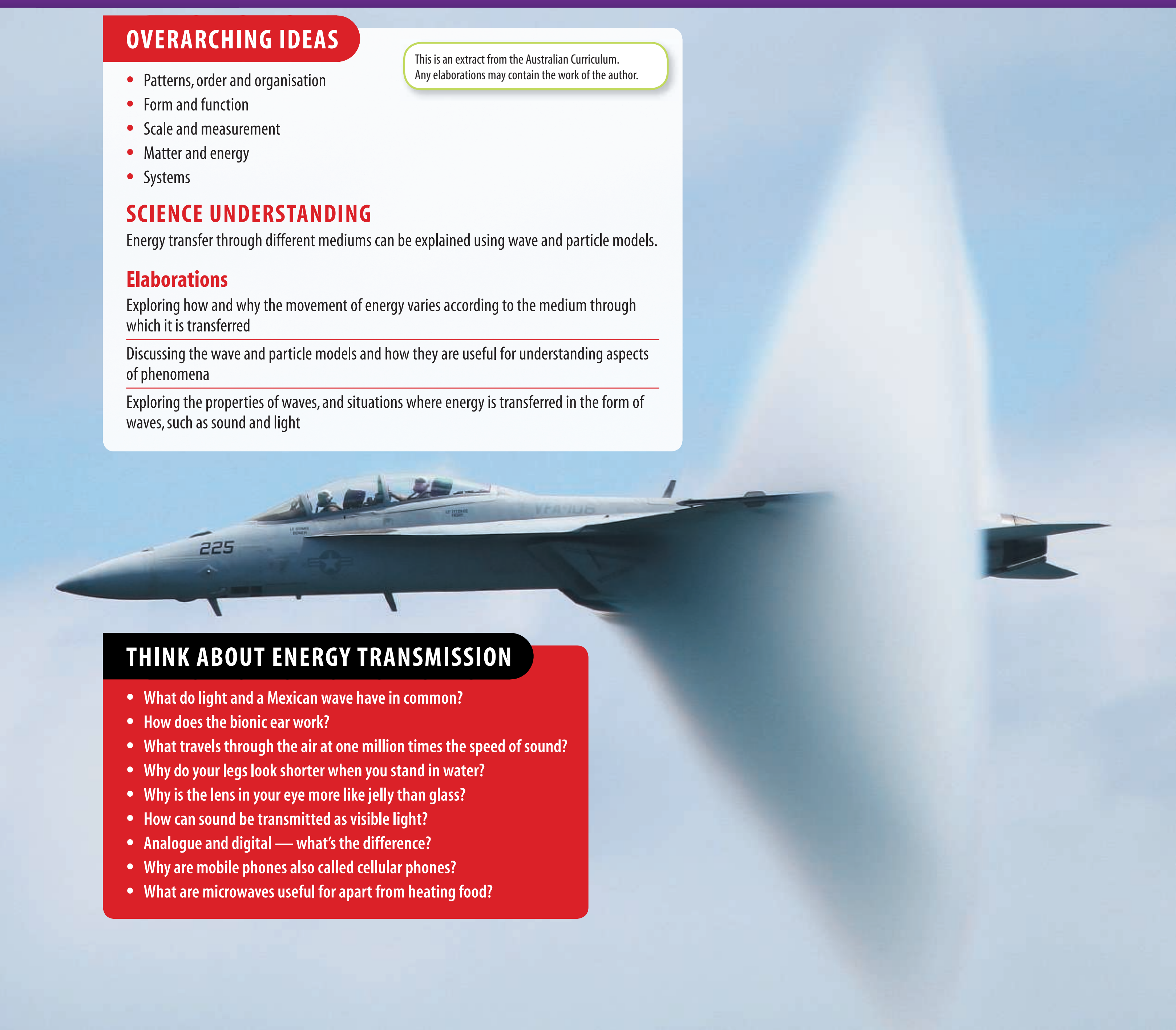
9 Energy transmission

Sound energy is transmitted through the air near sea level at about 1200 km/h. When a jet aircraft reaches the speed of sound, it is said to break the sound barrier. A shockwave known as a sonic boom is heard as the jet crashes through the wall of compressed air that it has created. A lesser-known phenomenon that occurs when planes fly at or near the speed of sound is this cone-shaped condensation cloud.



OVERARCHING IDEAS

This is an extract from the Australian Curriculum. Any elaborations may contain the work of the author.

- Patterns, order and organisation
- Form and function
- Scale and measurement
- Matter and energy
- Systems

SCIENCE UNDERSTANDING

Energy transfer through different mediums can be explained using wave and particle models.

Elaborations

Exploring how and why the movement of energy varies according to the medium through which it is transferred

Discussing the wave and particle models and how they are useful for understanding aspects of phenomena

Exploring the properties of waves, and situations where energy is transferred in the form of waves, such as sound and light

THINK ABOUT ENERGY TRANSMISSION

- What do light and a Mexican wave have in common?
- How does the bionic ear work?
- What travels through the air at one million times the speed of sound?
- Why do your legs look shorter when you stand in water?
- Why is the lens in your eye more like jelly than glass?
- How can sound be transmitted as visible light?
- Analogue and digital — what's the difference?
- Why are mobile phones also called cellular phones?
- What are microwaves useful for apart from heating food?

YOUR QUEST

A matter of communication

In March 1791, Captain Arthur Phillip, Governor of New South Wales, wrote a letter to his employer, King George III in London, asking for some time off work. The only way to get the letter to London was by sailing ship. The letter took eight months to get to King George III, and his reply took a further eight months to reach Sydney.

Today, a reply from London to a request from Sydney for some time off work could be received within seconds by telephone or email. There is no longer any need for matter, such as letters, to be transported. The request and reply travel between Sydney and London via the transmission of energy at the speed of light — 300 000 kilometres per second. Over long distances, there are many advantages of energy transmission without the transmission of matter.

Although more than 200 years later the transmission of matter is a lot faster, it is still relatively slow. A hard copy of the same letter requesting leave sent from Sydney to London by air mail today would take about five days to arrive — and there would be at least another five days to wait for a reply to get back to Sydney.

THINK

1 What has changed since 1791 to reduce the communication time from Sydney to London and back from 16 months to 10 days?

2 What are all of the options now available for sending a request for time off work from Sydney to London?

3 Which options do not require the movement of matter from Sydney to London and back?

4 How long would the sender have to wait for a reply if the fastest method of communication was used?

5 If matter does not move from one place to another when a message is sent over a long distance, what does move?

Even over a short distance the transmission of energy is faster than the transmission of matter. Imagine that you want to warn a couple on the other side of the street that they are about to be hit by an out-of-control shopping trolley. Your options for saving them include:

A yelling at them to get out of the way
B yelling and pointing at the trolley
C waving your arms in the air and pointing
D holding up a sign that says 'Watch out!'
E running across the road to push them out of the way.

THINK

6 Which of the options A–E involves:
(a) the transmission of matter
(b) the transmission of energy
(c) the transmission of both matter and energy?

7 In your opinion, which of the options A–E is the:
(a) fastest
(b) slowest
(c) least safe?

8 Write down as much as you know about the following types of invisible waves. Once you have finished, work with two or three others to write a group report to present to your class.
(a) Sound
(b) Ultrasound
(c) Visible light
(d) Microwaves
(e) Infra-red
(f) Radio waves

Is this the fastest option? How does this message travel from one person to another?

9.1 OVERARCHING IDEA

Matter and energy: Making waves

When a wave is made in a still lake by dropping a rock into it, the wave spreads out. However, the particles of water do not spread out — they just move up and down. A **wave** is able to transmit energy from one place to another without moving any matter over the same distance.

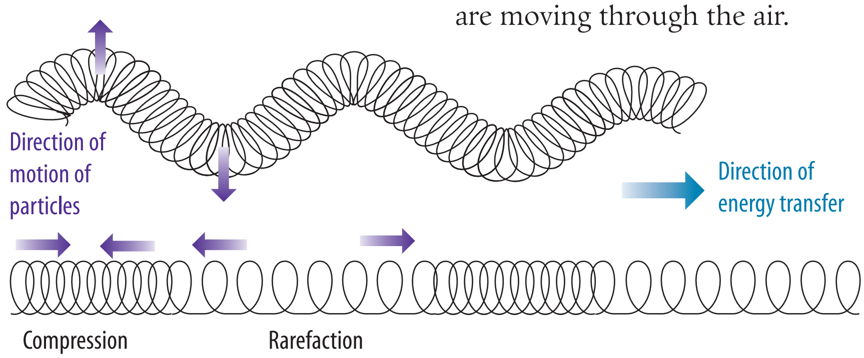
Two types of waves

Waves on water are called **transverse waves**. Transverse waves can also be made on a slinky. As shown in the diagram below, the moving particles in a transverse wave travel at right angles to the direction of energy transfer. The diagram also shows that in a **compression wave**, the moving particles move backwards and forwards in the same direction as the energy transfer. Compression waves are also known as **longitudinal waves**.

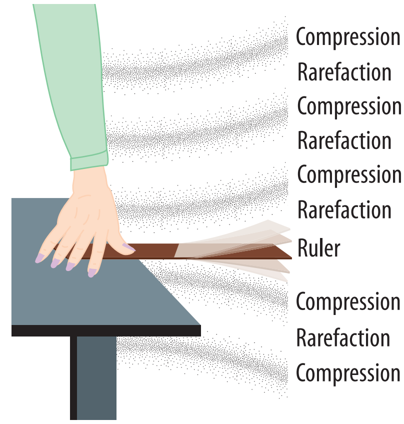
The material through which the waves travel is called the **medium** (the plural is 'media').

Sound waves

Sound is a compression wave. All sounds are caused by **vibrations**. Vibrations cause air to compress like the lower wave pattern shown in the diagram below. The diagram above right shows how a vibrating ruler makes compression waves in air. As the ruler moves up, a **compression** is created as air particles above the ruler are pushed together. Air particles below the ruler are spread out, creating a **rarefaction**. When the ruler moves down, a rarefaction is created above the ruler, while a compression is created below it. Each vibration of the ruler creates new compressions and rarefactions to replace those that are moving through the air.



Two types of energy transfer: a transverse wave (top) and a compression wave (bottom). The transfer of sound energy can be modelled using compression waves in a slinky.



Sound is a compression wave caused by vibrations.

Some jargon to learn

The **frequency** of a vibration or wave is the number of complete vibrations or waves made in one second. The frequency of a sound wave is given by the number of compressions made in a second. The note middle C, for example, creates 256 vibrations, or compressions, every second. Frequency is measured in **hertz** (Hz), a unit named after Heinrich Hertz, the German physicist who, in 1887, was the first to detect radio waves. One hertz is equal to one vibration per second. Therefore, middle C has a frequency of 256 hertz. The frequency of a sound determines its **pitch**. High-frequency vibrations produce high pitch, and low-frequency vibrations produce low pitch.

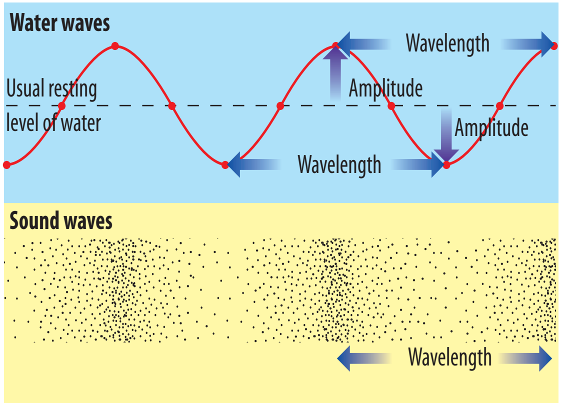
In the case of transverse waves, for example waves on water, the **wavelength** is the distance between two crests, or two troughs, or the distance between any two corresponding points on neighbouring waves. In the case of a compression wave, the wavelength is the distance between the centre of two neighbouring compressions, or two neighbouring rarefactions, as shown in the diagram opposite.

The distance between compressions — the wavelength — of the sound of the note middle C is about 1.3 metres. The wavelength of sound made during normal speech varies between about 5 centimetres and about 2.5 metres.

As the frequency of a sound gets higher — that is, as more compressions are produced per second — the compressions become closer together.

The pitch you hear is higher. Lower frequencies produce longer wavelengths and thus lower-pitched sounds.

The **amplitude** of a wave is the maximum distance that each particle moves away from its usual resting position. The amplitude of two different types of waves is also shown in the diagram below. Higher amplitudes correspond with louder sounds.



Even though sound is a compression wave, it can be modelled with water waves.

INQUIRY: INVESTIGATION 9.1

Moving energy without matter

KEY INQUIRY SKILLS:

- processing and analysing data and information
- communicating

Equipment:

deep tray	*ribbon*
small cork	*slinky*
eye dropper	*water*

- Half fill the tray with water and place a small cork on the water's surface. Use the eye dropper to release drops of water near the cork. Observe the motion of the cork and the motion of the small waves made by the drops.
- Tie a ribbon around a coil near the centre of the slinky. Firmly hold one end of the slinky while your partner, holding the other end, stretches it to about the length of the room. Make a wave by rapidly flicking one end of the slinky to one side. Observe the ribbon as the wave passes.
- Make a different type of wave by pulling about ten coils of the slinky together at one end and then releasing this compressed section. Observe the ribbon as the wave passes.

DISCUSS AND EXPLAIN

1 Describe the motion of the cork on the small waves.
2 Is there any evidence to suggest that any water moves in the same direction as the waves?
3 Describe the motion of the ribbon as the waves made by flicking move along the slinky.
4 Describe the motion of the ribbon as the compression wave moves along the slinky.
5 In each of the slinky waves produced in this experiment, energy is transferred from one end of the slinky to the other.
(a) Where is the ribbon after the wave has passed in each case?
(b) Has any particle on the slinky moved from one end to the other?
6 Which properties of sound waves can be modelled by waves on water?

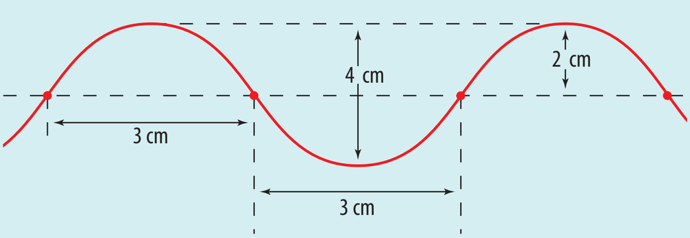
UNDERSTANDING AND INQUIRING

REMEMBER

1 What causes all sound waves?
2 Describe the difference between a compression and a rarefaction.
3 What is the unit of frequency and what does it measure?
4 What quality of sound does the frequency determine?

THINK

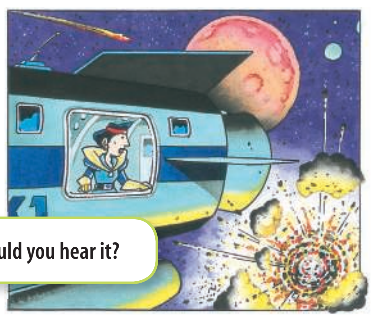
5 Is a Mexican wave, as seen among the crowds at some sporting events, a transverse wave or a compression wave?
6 What is the wavelength and amplitude of the transverse wave shown in the diagram below?



9.2 SCIENCE UNDERSTANDING

Sound waves on the move

Imagine that you are on a spacecraft on the way to Mars and a passing asteroid explodes. Would you hear the explosion before or after you saw it — or would you even hear it at all?



Would you hear it?

The need for particles

Because sound is transmitted as a compression wave, it can travel only through a medium that contains particles that can be forced closer together or further apart. Sound cannot be transmitted in a vacuum because there are no particles to push closer together or spread out.

As sound travels through a medium, some of its energy is absorbed by the particles in the medium and is not transmitted to neighbouring particles. Sound travels more efficiently through materials that are elastic; that is, materials in which the particles tend to come back to their original positions without losing much energy.

Speed of sound

The speed of sound in a particular medium depends on how close the particles are to each other and how easy they are to push closer together. In liquids and solids, the speed is much greater because the particles are more closely bound together. The table below shows the speed of sound in some common substances at 0 °C.

The speed of sound in air is greater at higher temperatures. At sea level in dry air at 0 °C, it is about 330 metres per second. At a temperature of 25 °C, it is about 350 metres per second. The speed of sound in air is lower at higher altitudes. At an altitude of 10 kilometres above sea level, it is about 310 metres per second.

Speed of sound in some common substances

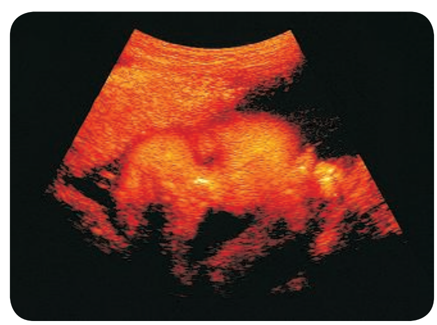
Substance	Speed of sound (metres per second)
Carbon dioxide (at 0 °C)	260
Dry air (at 0 °C)	330
Hydrogen (at 0 °C)	1300
Water	1400
Sea water	1500
Wood	4000–5000
Glass	4500–5500
Steel	5000
Aluminium	5000
Granite	About 6000

Hear an echo?

A knowledge of the speed of sound is used in **sonar**. Sonar (SOund Navigation and Ranging) is used on ships to map the ocean floor, detect schools of fish, and locate other underwater objects such as shipwrecks and submarines. High-frequency sound is transmitted from the ship. By measuring the time taken for the echo to return to the ship, and using the speed of sound in water, the distance to the floor of the ocean or to the underwater object can be calculated.

Sonar is just one example of **echolocation**. Whales, dolphins, porpoises and bats use echolocation to sense their surroundings. They each send out high-frequency sounds. The echo is detected and the animal's brain processes the information to give it a 'sound image' of its surroundings.

The power of ultrasound



Ultrasound has many applications. Here, ultrasound is being used to produce an image of the face of a full-term baby in the womb.

Although called by a different name, echolocation is also used by engineers to locate cracks in metals; and it is used extensively in medicine. The high-frequency sound used in industry and in medicine is called **ultrasound**. Ultrasound has frequencies higher than humans can hear. Echolocation with ultrasound is used in medicine to produce images of unborn babies in the womb during pregnancy, and to search for gallstones, circulation problems and cancers.

Ultrasound also has uses other than echolocation. It is used to remove some cancers, treat an eye condition called glaucoma, shatter kidney stones and gallstones in a process called shockwave therapy, speed up the healing of muscle damage, clean surfaces, mix paint, homogenise milk and cut into glass and steel.

INQUIRY: INVESTIGATION 9.2

Sound in different media

KEY INQUIRY SKILL:

- processing and analysing data and information

Equipment:

ticking watch
metre ruler
teaspoon (or spatula)
cotton thread (or light string)

- Place a ticking watch against your ear and listen to the tick. Have your partner slowly move the watch away from your ear until you can no longer hear the ticking. Measure and record the distance from your ear to this point.
- Place a metre ruler gently against the same ear and rest the watch on it against the ear. Have your partner slowly slide the watch along the ruler to a point where you can no longer hear the ticking. Measure and record the distance from your ear to this point.
- Tie about 80 cm of cotton thread to a teaspoon. Swing the teaspoon slowly so that it gently strikes the side of a bench, wall or cupboard. Listen to the sound made.
- Place the free end of the cotton thread carefully against your ear and again gently strike the teaspoon against the same surface. Listen to the sound made.

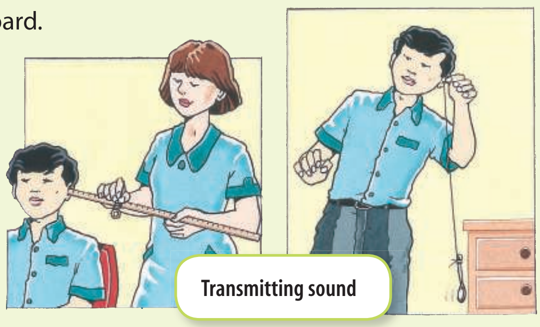
DISCUSS AND EXPLAIN

1 What effect did the ruler have on the distance over which you could hear the sound of the ticking watch?

2 What difference does the cotton thread make to the sound heard when the spoon strikes a surface?

3 Is sound conducted better through air or through solids?

4 What property of the solids do you think makes the difference?



Transmitting sound

UNDERSTANDING AND INQUIRING

REMEMBER

1 Why are sound waves unable to travel through a vacuum?

2 What is ultrasound and how is it useful?

USING DATA

The following questions refer to the data given in the table on the previous page.

3 In general, how does the speed of sound in solids compare with that in liquids and gases?

4 Why do you think such a large range of speeds is given for wood and glass?

5 Suggest a reason why the speed of sound in most woods is generally lower than the speed of sound in steel and aluminium.

6 What does the data suggest about the effect of the density of a gas on the speed of sound?

THINK

7 Answer the question posed at the beginning of this section.

8 Suggest why the speed of sound depends on altitude and temperature.

IMAGINE

9 Imagine that you are one of two astronauts walking on the moon.

(a) Would you be able to conduct a conversation with your partner without radios? Explain why.

(b) Imagine that both of your radios stopped working because you forgot to recharge the batteries. Explain how you would still be able to communicate with your partner.

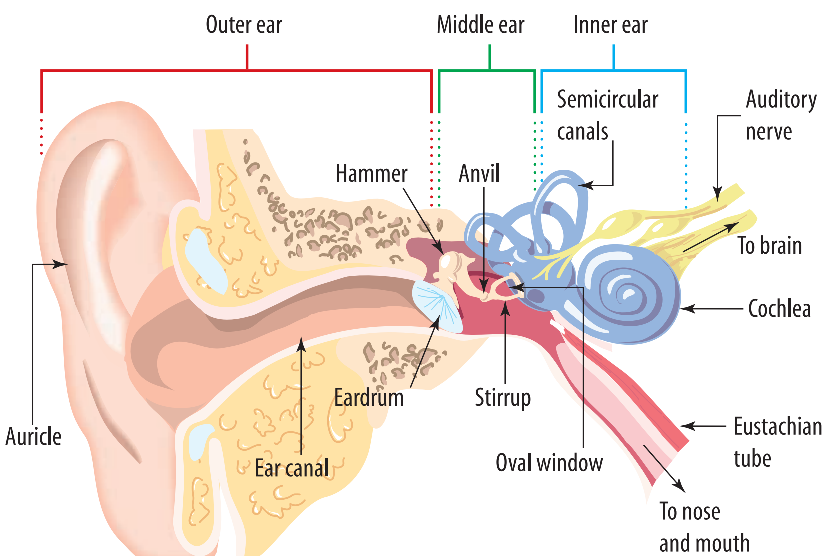
10 Imagine that sounds of different frequencies had different speeds in air. How would that affect what you heard if you were in the back row of a stadium listening to a band?

11 Imagine that you are standing near a steep, rocky cliff. You shout 'Hello' and one second later you hear the echo. The air temperature is about 25 °C, so you estimate that the speed of sound is about 350 m/s. How far are you from the cliff?

9.3 SCIENCE UNDERSTANDING

Hearing sound

The energy of sound waves is transformed by your ear into electrical signals that are sent to your brain. Each of your ears has three distinct parts — the outer ear, middle ear and inner ear. Each part has its own special job to do.



Outer ear

The outer ear funnels the energy of the vibrating air through the **ear canal** to the **eardrum**. The eardrum is a thin flap of skin, or **membrane**, which vibrates in response to the vibrating air particles. The fleshy, outer part of the ear is called the **auricle**.

Inner ear

The inner ear contains the **cochlea** and the **semicircular canals**. The cochlea is a spiral-shaped system of tubes full of fluid. When vibrations are passed through the oval window by the stirrup, the fluid moves tiny hairs inside the cochlea. These hairs are attached to the receptor nerve cells that send messages on their way to the brain through the **auditory nerve**. The semicircular canals also contain a fluid. However, they are not involved in hearing sound. When you move your head, the fluid in the semicircular canals moves hairs that send signals to your brain. The signals provide your brain with information to help you keep your balance.

Middle ear

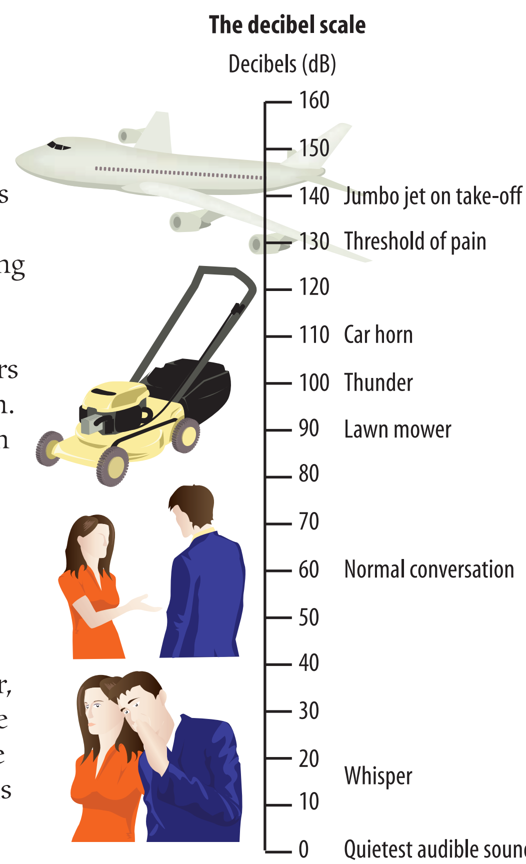
The middle ear contains three small bones called the hammer, the anvil and the stirrup. These three tiny bones (known as the **ossicles**) pass on the vibrations to the inner ear through the **oval window**.

Too loud

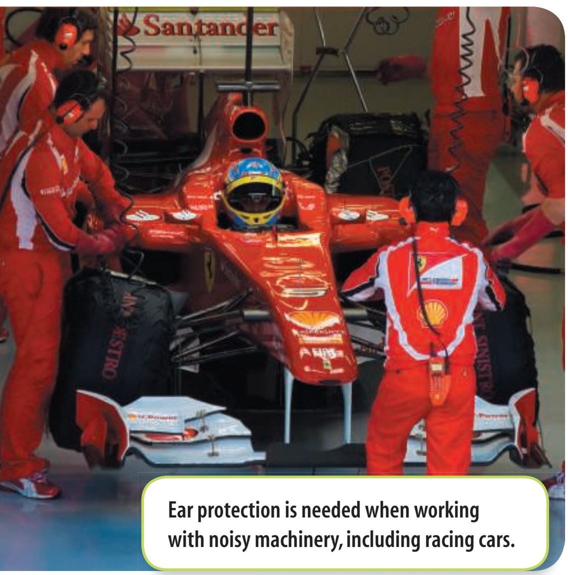
Sound makes your eardrums vibrate. But if the sound is too loud, the vibrations can cause pain and even permanently damage your ear. That's because loud sounds disturb the air — and your eardrums — more than soft sounds.

Although loudness can be a matter of opinion, the disturbance to the air can be measured. The measurement is called the **relative intensity**, or **sound level**. The unit of measurement is the **decibel (dB)**. The number of decibels gives a good indication of the loudness of a sound. It's not a perfectly accurate measure of loudness, because your ear is more sensitive to some pitches than others.

The **threshold of hearing** is the smallest sound level that can be heard when the air is vibrating



at 1000 Hz. For most people it's about 0 dB. Sound levels of more than about 130 dB can cause pain and permanent ear damage. The smallest sound level that causes pain is called the **threshold of pain**. Sound levels of even 80 dB can cause damage to your ears if you are exposed to the sound for long enough.



Ear protection is needed when working with noisy machinery, including racing cars.

HOW ABOUT THAT!

When you are landing or taking off in a plane, your ears 'pop'.

If you climb steeply, the air pressure inside your middle ear remains the same while the air pressure outside drops. The air inside pushes on the eardrum causing an uncomfortable feeling.

The 'popping' is caused as the Eustachian tube, which is normally closed, opens. This allows air to rush out of your middle ear to your nose and mouth. The pressure is then the same on both sides of the eardrum.

When you descend quickly, the 'popping' occurs as the air rushes into your middle ear to balance the increasing pressure outside. If you swallow hard, you can make the 'popping' happen sooner.

NOISE, NOISE, NOISE

One of the 'side effects' of living in an industrialised world is noise. Some of this noise is loud enough to damage your ears. But some of it is just annoying. The offending noises come from sources that include:

- transport, such as aeroplanes, trains, trams, trucks, cars, buses and cars
- heavy machinery, such as tractors, bulldozers, harvesters and jackhammers
- entertainment venues, such as rock concerts, nightclubs and sporting events
- domestic sources, such as mowers, power tools and much, much more.

With good planning and zoning, the noise of traffic, factories and entertainment venues can be kept away from residential areas, hospitals and schools. Sound barriers are built and trees planted beside freeways to reduce the noise heard by nearby residents. Sound barriers are designed to reflect and absorb sound energy. Trees are great natural absorbers of sound energy.

State and local government laws restrict times when you can use mowers, power tools and other noisy items like air-conditioners and swimming-pool pumps. These laws vary from state to state and between local councils.

The effect of freeway noise on nearby residents is reduced by barriers that absorb and reflect sound energy.

Too soft

Hearing aids have been used for many years to make sounds louder for those with impaired hearing. The battery-operated hearing aid that some people wear amplifies the vibrations so that they can reach a properly working cochlea. Another type of hearing

HOW ABOUT THAT!

If you've ever been to a really loud concert, you may have experienced ringing in your ears afterwards. You would also have had trouble hearing. Even after you had gone home to bed and the house was silent, the ringing would still have been there.

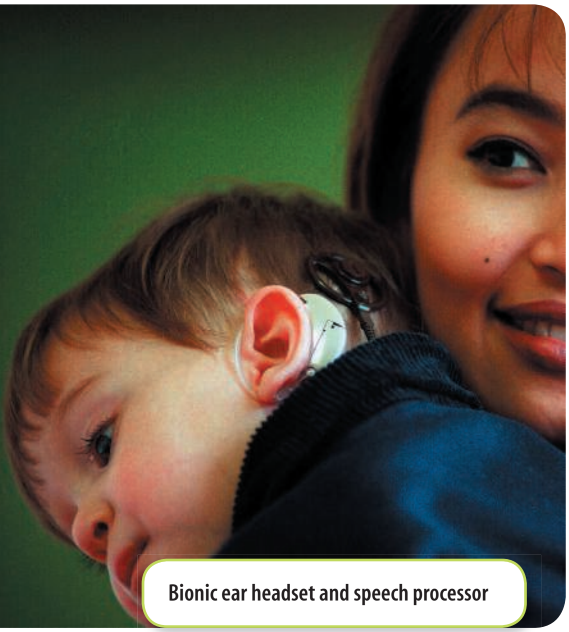
This ringing in your ears is called **tinnitus** (sometimes pronounced tin-eye-tus). Some of the cells in your inner ear — the ones that detect vibrations — have been damaged. Fortunately, your ears are likely to recover. The ringing will stop and your hearing will return to normal — hopefully in a few hours, but maybe in a day or two. If you listen to loud music for too long or too often, the cells don't recover. Your hearing can be permanently damaged. It's a good idea to avoid this by wearing earplugs at loud concerts.

aid 'bends' the vibrations so that they go through a bone behind the ear to the cochlea.

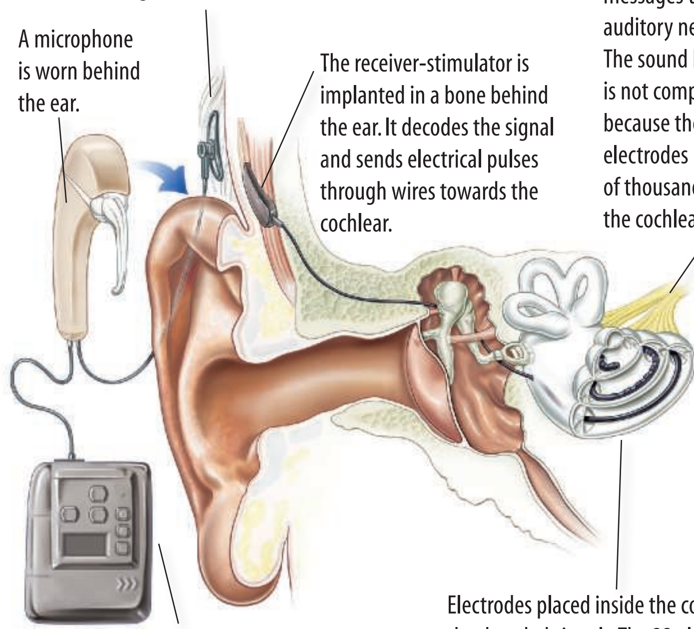
THE COCHLEAR IMPLANT

Many people who have severely or profoundly impaired hearing are unable to benefit from hearing aids. Profoundly hearing-impaired people hear no sounds at all.

Australian scientists have, in recent years, developed a device that has allowed some people who are profoundly hearing impaired to detect sound for the first time in their lives. The **cochlear implant**, or **bionic ear**, is surgically placed inside the ear. A microphone worn behind the ear detects sound and sends a signal to the speech processor (a small computer worn in a pocket or on a belt). It converts the sound into an electrical signal that is sent to a receiver behind the ear and on to the implant in the cochlea. The signal then travels along the auditory nerve to the brain.



Bionic ear headset and speech processor



INQUIRY: INVESTIGATION 9.3

Making it seem louder

KEY INQUIRY SKILLS:

- questioning and predicting
- processing and analysing data and information

Equipment:

ticking watch

sheet of paper, about A4 size

metre ruler

blindfold

- Have your blindfolded partner sit on a chair. Hold a ticking watch close to your partner's right ear. The left ear should be covered with an open palm.
- Move slowly away until your partner indicates that the sound of the ticking watch can no longer be heard.
- Measure and record the approximate distance from the watch to your partner's right ear.
- Make a funnel with a sheet of paper. Place the narrow end of the funnel close to, but not touching, your partner's right ear. Your partner should be able to hold it in place.

CAUTION: Take care not to put the funnel into the ear canal.

- Again, move the ticking watch slowly away from your partner, starting near the wide end of the funnel, until it can no longer be heard. Measure and record the approximate distance between the watch and your partner's right ear.

DISCUSS AND EXPLAIN

1 What difference does the funnel make?
2 How does the funnel work?
3 Look at your own ears. Why do you think they are that shape?

INQUIRY: INVESTIGATION 9.4

Sound proofing

KEY INQUIRY SKILLS:

- planning and conducting
- processing and analysing data and information

Equipment:

variety of materials to test (such as wood, fabric, glass and cardboard)

source of sound (such as an mp3 player)

sound level meter or data logger and sound probe

- Design an experiment to investigate the most effective material to insulate against noise.
- Record your results in a suitable table and graph.
- Analyse your results to draw an appropriate conclusion.

UNDERSTANDING AND INQUIRING

REMEMBER

1 Complete the following table to describe some of the important structures of the human ear.

Structure	Description	Purpose
Eardrum		
	Three small bones in the middle ear	
	An opening into the inner ear	Allows vibrations to pass into the cochlea
Cochlea		Contains receptor cells for hearing
		Allows air to move between the middle ear and the mouth and nose

2 Explain why the sound level measured in decibels is not regarded as a completely accurate measure of loudness.

3 Define the threshold of hearing.

4 Describe tinnitus and explain how it can be avoided.

5 Explain how the bionic ear is different from a normal hearing aid.

THINK

6 When you clap your hands, a sound is heard. Explain how the energy of the sound gets from your hands, through the air, through your ear and finally to your brain.

7 Two astronauts working outside a space station in orbit are unable to hear each other, no matter how loudly they speak or shout. However, when they are inside the space station, even with their helmets still on, they can hear each other easily. Why is there a difference?

8 Explain why luggage handlers who work on the tarmac at airports are required to wear ear protection.

9 Why should you wear ear protection when mowing or trimming the lawn?

10 Explain why trees are good absorbers of sound energy.

CREATE

11 Create a poster to warn people about the dangers of loud noise.

BRAINSTORM

12 Form a group of three or four and brainstorm a list of domestic noises that could damage neighbours' ears, disturb their sleep or annoy them.

INVESTIGATE

13 If a sound level meter is available, measure the sound level at a number of different locations around your school. Create a graph to display your measurements.

14 Find out when the cochlea implant was invented and by whom.

15 Find out more about the following careers that involve using and understanding sound energy.
(a) Audiologist
(b) Acoustic engineer
(c) Audio engineer

work sheet 9.1 Sound energy

9.4 SCIENCE UNDERSTANDING

The electromagnetic spectrum

Isn't it great to be able to sit back in a comfortable chair and use a remote control to change the television channel or skip to your favourite scene on a DVD?

When you push that remote control button, a beam of invisible infra-red radiation travels at 300 million metres per second towards a detector inside your television set or DVD player. The detector converts the energy of the infra-red radiation into electrical energy which, in turn, operates the controls.

Infra-red radiation is just one part of the family of waves that make up the **electromagnetic spectrum**. Let's consider the whole spectrum, starting with the least 'energetic' members and finishing with those that are the most 'energetic'.

Radio waves include the low-energy waves that are used to communicate over long distances through radio and television. They also include radar and the microwaves used in microwave ovens for cooking.

Infra-red radiation, invisible to the human eye, is emitted by all objects and is sensed as heat. The amount of infra-red radiation emitted by an object increases as its temperature increases.

Visible light represents only a very small part of the electromagnetic spectrum. It is necessary for the sense of sight. The process of photosynthesis in green plants cannot take place without visible light.

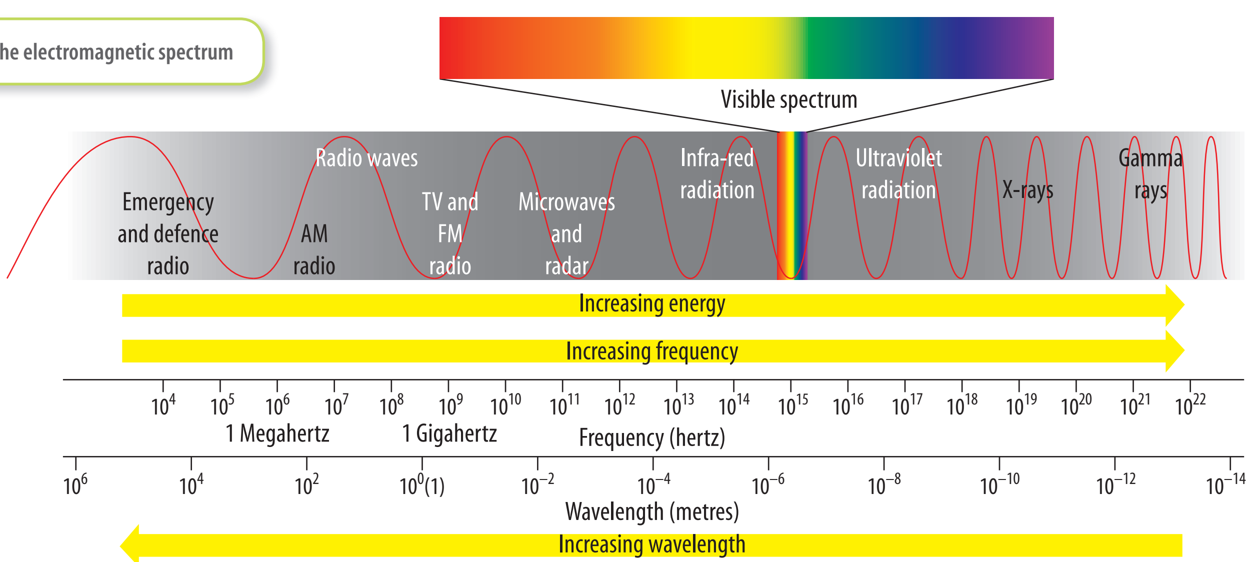
Like infra-red radiation, **ultraviolet radiation** is invisible to the human eye. It is needed by humans to help the body produce vitamin D; however, too much exposure to ultraviolet radiation causes sunburn.

X-rays have enough energy to pass through human flesh. They can be used to kill cancer cells, find weaknesses in metals and analyse the structure of complex chemicals. X-rays are produced when fast-moving electrons give up their energy quickly. In X-ray machines, this happens when the electrons strike a target made of tungsten.

A gentle push of the button sends infra-red radiation to the television set at 300 million metres per second.

Gamma rays have even more energy than X-rays and can cause serious damage to living cells. They can also be used to kill cancer cells and find weaknesses in metals. Gamma rays are produced when energy is lost from the nucleus of an atom. This can happen during the radioactive decay of nuclei or as a result of nuclear reactions.

The electromagnetic spectrum



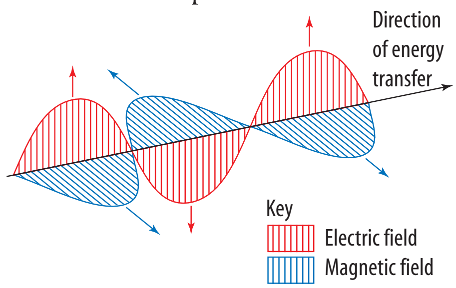
WHAT DOES IT MEAN?

The words *ultraviolet* and *ultrasound* are derived from the Latin term ***ultra***, meaning 'beyond'. Ultraviolet radiation has frequencies beyond those of the colour violet, and ultrasound has frequencies beyond those of sounds we can hear.

Waves without particles

Like all waves, **electromagnetic waves** transmit energy from one place to another. All electromagnetic waves travel through air at 300 000 000 metres per second. Unlike sound waves and water waves, electromagnetic waves can travel through a vacuum. The waves consist of a repeating pattern of electric and magnetic forces. These forces are generated by changes in the speed or direction of moving electric charge. The frequency of electromagnetic waves is a measure of the number of times per second that a new electric or magnetic force is generated.

The wavelength is the distance between adjacent electric or magnetic forces. The diagram below shows that electromagnetic waves are transverse waves. The electric and magnetic forces are at right angles to (that is, across) the direction of motion of the wave. The direction of the electric force is defined as the direction in which it would push on a positive electric charge. The direction of the magnetic force is defined as the direction in which a compass needle would point.



A representation of part of an electromagnetic wave

It's natural

Some electromagnetic radiation is emitted by all objects, including the sun. The higher energy waves, like ultraviolet radiation and X-rays are emitted naturally by stars. Our own sun emits ultraviolet radiation and X-rays. Gamma rays are emitted by radioactive substances and larger stars. All types of electromagnetic radiation can be produced artificially.

What's the difference?

Some differences between sound waves and electromagnetic waves are summarised in the following table.

Sound waves	Electromagnetic waves
Compression (longitudinal) waves	Transverse waves
Travel through all solids, liquids and gases, but are unable to travel through a vacuum	Unable to travel through some substances but travel through a vacuum
Speed in air between about 330 m/s and 350 m/s, depending on temperature	Speed in air about 300 000 000 m/s

UNDERSTANDING AND INQUIRING

REMEMBER

1 Are electromagnetic waves transverse waves or longitudinal waves?

2 List three properties that all electromagnetic waves have in common.

3 List three differences between sound waves and electromagnetic waves.

4 List the types of electromagnetic radiation that have more energy than visible light.

USING DATA

5 The sound of a starting pistol can be heard easily by an observer one kilometre away. From that distance, the sound of the pistol is heard some time after the smoke is seen. Calculate to the nearest second:
(a) how long it takes sound to reach the observer
(b) how long it takes light scattered from the smoke to reach the observer.

6 The speed of sound in air at a temperature of 25 °C is about 350 m/s.
(a) How long would it take for sound waves to travel from Melbourne to Sydney, a straight distance of about 700 km, when the air temperature is 25 °C?
(b) Why doesn't it take this long for the sound to reach you by telephone, television or radio?

THINK

7 Explain why the behaviour of electromagnetic waves cannot be modelled using compression waves in a gas or a slinky.

8 Explain why you always hear thunder after you see the lightning that caused it.

INVESTIGATE

9 Research and report on the use of radiation therapy in the treatment of disease.

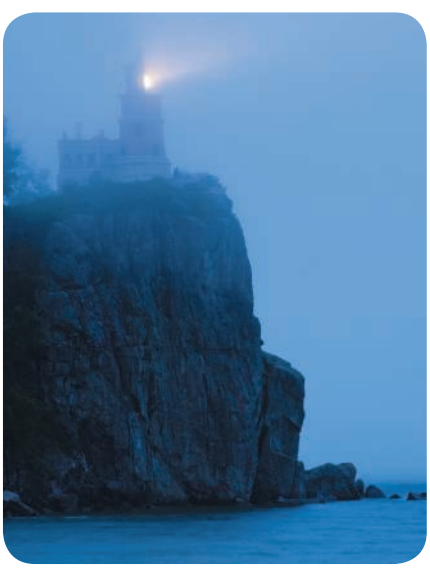
9.5 SCIENCE UNDERSTANDING

Light energy

A ray box. It provides a way of tracing the path of light.

You can get it at the flick of a switch or by striking a match. It travels through space at a speed of about 300 000 kilometres per second. Light from the sun makes life on Earth possible and provides us with some beautiful images such as rainbows and spectacular sunsets.

Light travels in straight lines as it travels through empty space or through a uniform substance like air or water. The lines that are used to show the path of light are called **rays**. You cannot see a single light ray. A stream of light rays is called a **beam**. You can see beams of light only when particles in substances like air scatter the light as shown in the photograph below. Some of the scattered light enters your eye, allowing you to see the particles within the beam.



A beam of light can be seen if there is smoke or fog in the air. Light is scattered by the tiny particles. Some of the scattered light enters your eye, allowing you to see the particles within the beam.

Tracing the path of light

The ray box shown in the photograph above right provides a way of tracing the path of light. It contains a light source and a lens that can be moved to produce a wide beam of light that spreads out, converges or has parallel edges. The light box is placed on a sheet of white paper, making the beam visible as some of the light is reflected from the paper into your eyes.

Black plastic slides can be placed in front of the source to produce a single thin beam or several thin beams. The beams are narrow enough to trace with a fine pencil onto the white paper. The fine pencil line can be used to represent a single ray.

Crossing boundaries

When light meets a boundary between two different substances, a number of things can happen.

ON THE REBOUND

The light may bounce off the surface of the substance. This is called **reflection**, and is what allows you to see non-luminous objects. **Luminous** objects are those that emit light. The sun and the flame of a burning match are examples of luminous objects. Most of the objects that you see are non-luminous.

Light can also be reflected from particles within substances. This is called **scattering** because the light bounces off in so many different directions. Light is scattered by the particles of fog, dust and smoke in the atmosphere. Scattering is also evident in water. A luminous object in very deep or dirty water is not visible from the surface because all of the light is scattered before it can emerge. The same object is more likely to be visible on the surface of shallower or cleaner water because less light would be scattered.

JUST PASSING THROUGH

The light may travel through the substance. Some light is always reflected when light crosses a boundary between two substances. If most of the light travels through the substance, the surface is called **transparent** because enough light gets through for you to be able to see objects clearly on the other side. Some materials let just enough light through to enable you to detect objects on the other side, but scatter so much light that you can't see them clearly. The frosted glass used in some shower screens is an example. Such materials are said to be **translucent**.

eBook*plus* **eLesson**

Twinkle, twinkle
Have you ever wondered why stars twinkle? Find out in this video lesson.
eles-0071

LOST INSIDE

The light may be absorbed by the substance, transferring its energy to the particles in the substance. Substances that absorb or reflect all the light striking them are said to be opaque. Most objects in your classroom are **opaque**.

(a) Transparent, (b) translucent and (c) opaque materials

Reflections

When you look in a mirror you see an image of yourself. If the mirror is a plane or flat mirror, the image will be very much like the real you. If the mirror is curved, the image might be quite strange, like the one in the photograph at right.

The images in mirrors are formed when light is reflected from a very smooth, shiny metal surface behind a sheet of glass. Images can also be formed when light is reflected from other smooth surfaces, such as a lake.

What does this person really look like?

INQUIRY: INVESTIGATION 9.5

Seeing the light

KEY INQUIRY SKILLS:

- planning and conducting
- processing and analysing data and information

Equipment:

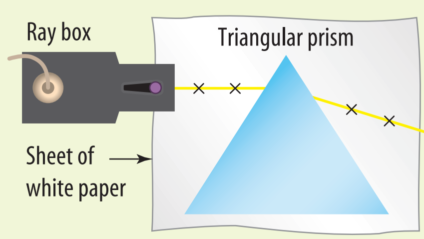
ray box kit

power supply

several sheets of white paper

ruler and fine pencil

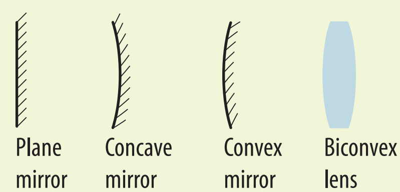
- Connect the ray box to the power supply. Place a sheet of white paper in front of the ray box. Move the lens backwards and forwards until a beam of light with parallel edges is projected.
- Use one of the black plastic slides to produce a single thin beam of light that is clearly visible on the white paper.
- Trace the path of this single beam of light as it meets the lens, prism or one of the mirrors shown in the diagram on the right.



Tracing the path of a beam of light

The path can be traced by using pairs of very small crosses along the centre of the beam before and after meeting each 'obstacle'. Trace and label the shape of each 'obstacle' before you trace the light paths.

- Change the slide in the ray box so that you can project several parallel beams towards each of the 'obstacles'.
- Use a ruler to draw a small diagram showing the path followed by the parallel beams when they meet each of the 'obstacles'.



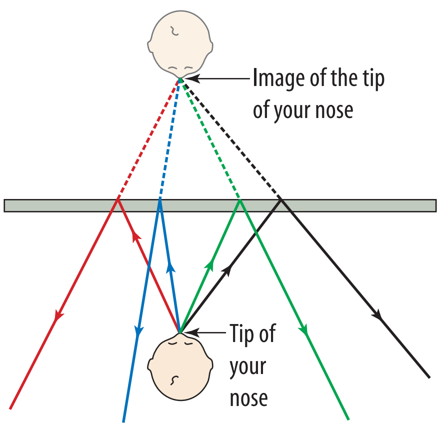
DISCUSS AND EXPLAIN

1. What happens to a beam of light when it meets a perspex surface:
   (a) 'head on'
   (b) at an angle?
2. What happens to a beam of light when it meets a plane mirror surface:
   (a) 'head on'
   (b) at an angle?
3. Describe your observations of the path followed by the three parallel beams when they meet each of the mirrors and the lens.

WHERE IS THE IMAGE?

Whenever light is reflected from a smooth, flat surface, it bounces away from the surface at the same angle from which it came. This observation is known as the Law of Reflection. This law can be used to find out where your image is when you look into a mirror.

The diagram below shows how the Law of Reflection can be used to find the image of the tip of your nose.

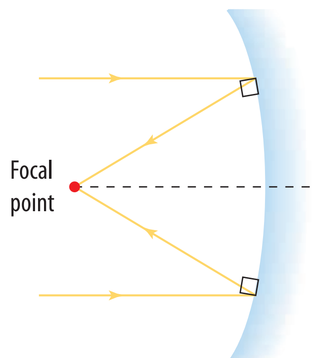


The reflected light appears to be coming from just one place. That's where the image is.

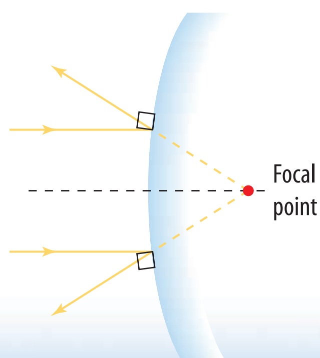
Almost all of the light coming from the tip of your nose and striking the mirror is reflected. (A very small amount of light is absorbed by the mirror.) All of the reflected light appears to be coming from the same point behind the mirror; and that is exactly where the image is. The image of the tip of your nose is the same distance behind the mirror as the real tip of your nose is in front of the mirror.

REFLECTION FROM CURVED MIRRORS

Flat mirrors are commonly found in the home. Curved mirrors have many applications too, including make-up mirrors, security mirrors in shops and safety mirrors at dangerous street intersections. Curved mirrors may be **concave** (curved inwards) or **convex** (curved outwards). Light reflecting from concave and convex mirrors also follows the law of reflection, such that the parallel rays of light are reflected to a **focal point** as shown below.



Reflected light rays converge from a concave mirror.



Reflected light rays diverge from a convex mirror.

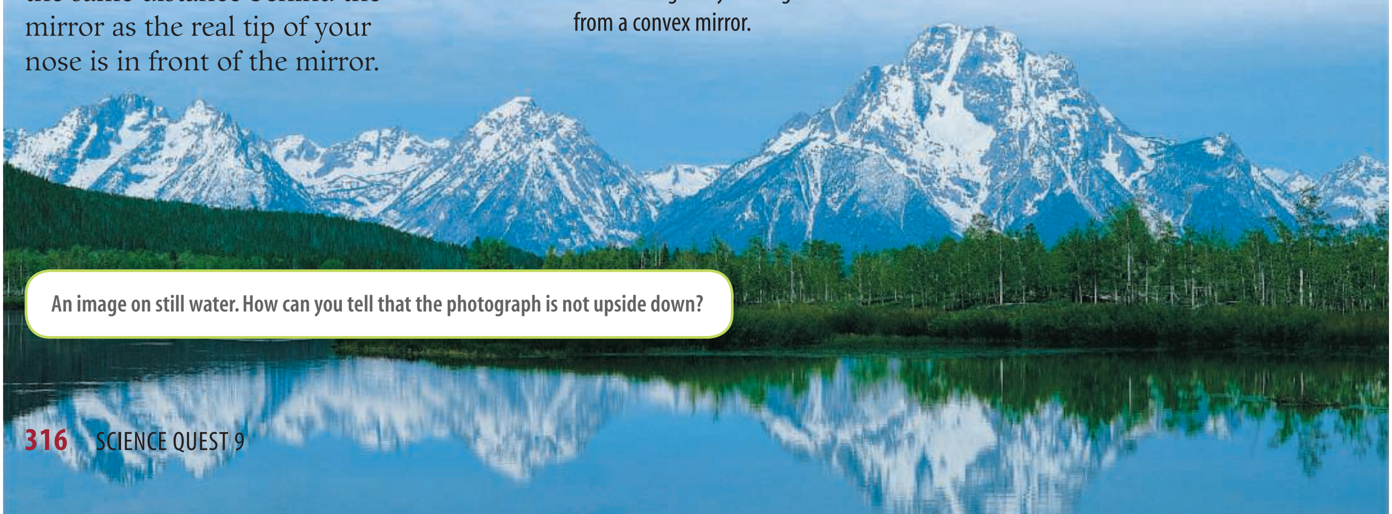
WHY CAN'T YOU SEE YOUR IMAGE IN A WALL?

When you look very closely at surfaces like walls, you can see that they are not as smooth as the surface of a mirror. The laws of reflection are still obeyed, but light is reflected from those surfaces in all directions. It doesn't all appear to be coming from a single point. There is no image.

LATERAL INVERSION

The sideways reversal of images that you see when you look at yourself in a mirror is called **lateral inversion**. The sign on the ambulance in the photograph below is printed so that drivers in front of it can easily read the word 'AMBULANCE' in their rear-view mirrors.

Why is the word 'AMBULANCE' printed in reverse?



An image on still water. How can you tell that the photograph is not upside down?

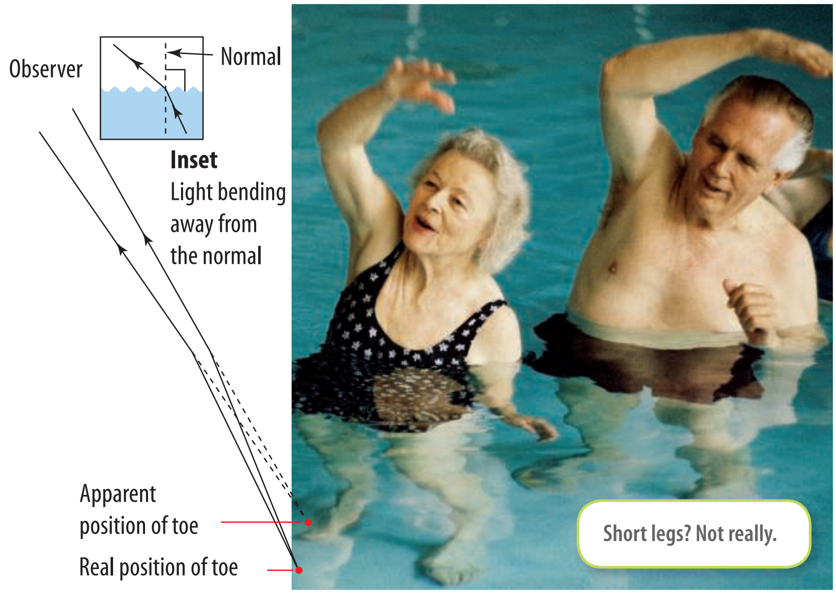
A change of direction

When light travels from one substance into another substance that is transparent or translucent, it can slow down or speed up. This change in speed as light travels from one substance into another is called **refraction**. Refraction causes light to bend, unless it crosses at right angles to the boundary between the substances.

The best way to describe which way the light bends is to draw a line at right angles to the boundary. This line is called the **normal**. When light speeds up, as it does when it passes from water into air, it bends away from the normal. When light slows down, as it does when it passes from air into water, it bends towards the normal.

WHAT HAPPENED TO MY LEGS?

Looks can be deceiving! The people in the photograph below do not have unusually short legs. Everything you see is an **image**. An image of the scene you are looking at forms at the back of your eye.



INQUIRY: INVESTIGATION 9.6

Looking at images

KEY INQUIRY SKILLS:

- questioning and predicting
- processing and analysing data and information

Equipment:

plane mirror

shiny tablespoon or soup spoon

- Look at your image in the back of a spoon. This surface is **convex**. Convex means curved outward. Move the spoon as close to your eyes as you can and then further away. Record your observations in a table like the one below. Is the image small or large? Right-side up or upside down? Is there anything strange about the image?
- Look at your image in the front of the spoon. This surface is **concave**. Concave means curved inward. Move the spoon closer to you and then further away. Record your observations in the table.
- Look at the image of your face in a plane mirror. Wink your right eye and take notice of which eye appears to wink in the image.
- Write the word IMAGE on a piece of paper and place it in front of the mirror so that it faces the mirror. Write down the word as you see it in the image.
- Write down how you think an image of the word REFLECTION would look in the mirror.

DISCUSS AND EXPLAIN

1 Which eye in the plane mirror image appears to wink?
2 Which letters in the image of the word IMAGE look different? Which look the same?
3 Test your hypothesis about the image of the word REFLECTION. Was your hypothesis correct?
4 List some places where you have seen curved mirrors. State whether the mirrors were convex or concave and explain why they are used.

	Observations of image		
	First observation	When you move closer	When you move further away
Convex side			
Concave side			

When light travels in straight lines, the image you see provides an accurate picture of what you are looking at. However, when light bends on its way to your eye, the image you see can be quite different.

The light coming from the swimmers' legs in the photograph bends away from the normal as it emerges from the water into the air. The light arrives at the eyes of an observer as if it were coming from a different direction. The diagram shows what happens to two rays of light coming from the swimmer's right toe. To the observer, the rays appear to be coming from a point higher than the real position of the toe. It can be seen by looking at the diagrams that the amount of bending depends on the angle at which the light crosses the boundary.

INQUIRY: INVESTIGATION 9.7

Floating coins

KEY INQUIRY SKILL:

- processing and analysing data and information

Equipment:

2 beakers

evaporating dish

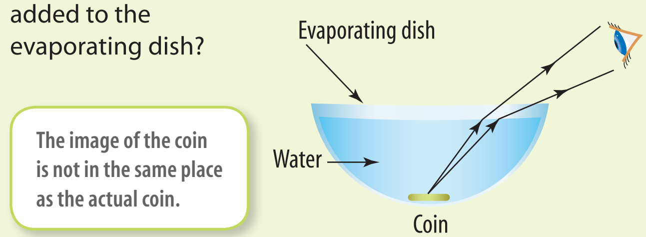
coin

- Place a coin in the centre of an evaporating dish and move back just far enough so you can no longer see the coin. Remain in this position while your partner slowly adds water to the dish.
- Make a copy of the diagram below. Use dotted lines to trace back the rays shown entering the observer's eye to see where they seem to be coming from. This enables you to locate the centre of the image of the coin.

DISCUSS AND EXPLAIN

1 Is the image of the coin above or below the actual coin?

2 What appears to happen to the coin while water is added to the evaporating dish?



INQUIRY: INVESTIGATION 9.8

How much does it bend?

KEY INQUIRY SKILL:

- processing and analysing data and information

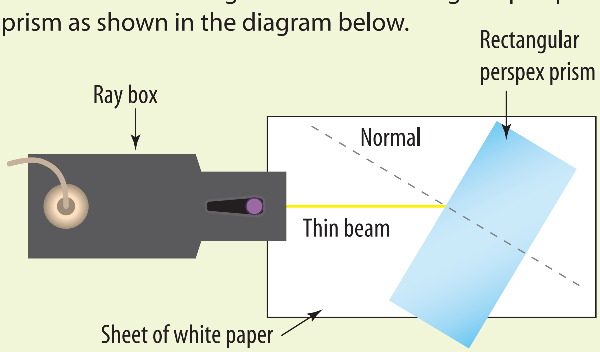
Equipment:

ray box kit

power supply

sheet of white paper

- Connect the ray box to the power supply. Place a sheet of white paper in front of the ray box. Project a single thin beam of white light towards a rectangular perspex prism as shown in the diagram below.



DISCUSS AND EXPLAIN

1 Does the light bend towards or away from the normal as it enters the perspex? (Remember that the normal is a line that can be drawn at right angles to the boundary. It is shown as a dotted line in the diagram. You don't need to draw it — just imagine that it's there.)

2 Imagine a normal at the boundary where the light leaves the perspex to go back into the air. Which way does the light bend as it re-enters the air — towards or away from the normal?

3 Does all of the light travelling through the perspex re-enter the air? If not, what happens to it?

4 Look at the light beam as it enters and leaves the perspex. What do you notice about the direction of the incoming and emerging beam?

5 Turn the prism without moving the ray box so that the light enters the perspex at different angles.

(a) How can you make the incoming light bend less when it enters the perspex?

(b) How can you make the incoming light bend more when it enters the perspex?

UNDERSTANDING AND INQUIRING

REMEMBER

1 You cannot usually see light as it travels through the air. What makes it possible to see a beam of light?

2 What happens to light when it travels through air and meets:
(a) a transparent surface
(b) a translucent surface
(c) an opaque surface?

3 What does a mirror do to light in order to form an image?

4 In which type of mirror can your image be upside down?

5 How is your image in a plane mirror different from the real you?

6 What is refraction?

7 Which way does light bend when it slows down while passing from air into water: towards or away from the normal?

THINK

8 Explain the difference between a ray of light and a beam of light.

9 How is the scattering of light different from the reflection of light by a plane mirror?

10 List one example of each of the following.
(a) A transparent object
(b) A translucent object
(c) An opaque object

11 Why do dentists use concave mirrors to examine your teeth?

12 Which type of mirror is used to help you see around corners?

13 How would the word 'TOYOTA' on the front of a van look in the rear-view mirror of the driver in front of it?

14 The illustration below shows a ray of light emerging from still water after it has been reflected from a fish. Should the spear be aimed in front of or behind the image of the fish? Use a diagram to explain why.

15 The Law of Reflection can be modelled with moving objects (as particles) in a number of sports. List as many of these sports as you can.

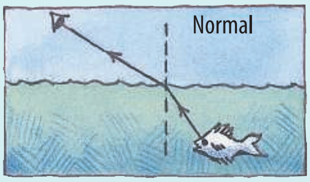
16 When you look down on a coin at the bottom of a glass of water it looks closer to you than it really is.
(a) Draw a diagram to show why it looks closer.
(b) In what other way is the image of the coin different from the real coin?

17 Explain how sound waves can be modelled with water waves, which are transverse waves. Use a diagram to illustrate your answer.

IMAGINE

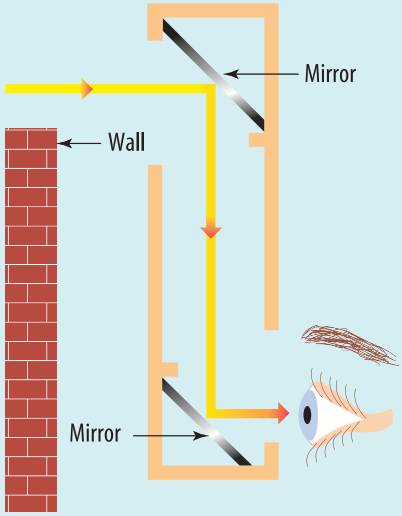
18 Imagine that the world is plunged into darkness by a mysterious cloud of dust. What problems would be caused by the lack of visible light if the cloud lingered for:
(a) one hour
(b) three days
(c) six weeks?

19 Imagine that you are the fish from question 14 in the illustration below.
(a) Will the image of the girl's head be higher or lower than her real head?
(b) Draw a sketch of how the girl might appear to you.



DESIGN AND CREATE

20 Design and build a simple periscope like the one shown in the diagram on the right. You will need stiff card, scissors, two small mirrors, sticky tape or glue, a pencil and a ruler. Explain, with the aid of a diagram, how it works.



A periscope uses mirrors to enable you to see around corners or over objects.

INVESTIGATE

21 Test your knowledge on refraction of light by completing the **Bend it** interactivity in your eBookPLUS. **int-0673**

eBook*plus*

work sheets
9.3 Reflection and scattering of light
9.3 Curved mirrors
9.4 Refraction

9.6 SCIENCE AS A HUMAN ENDEAVOUR

Seeing the light

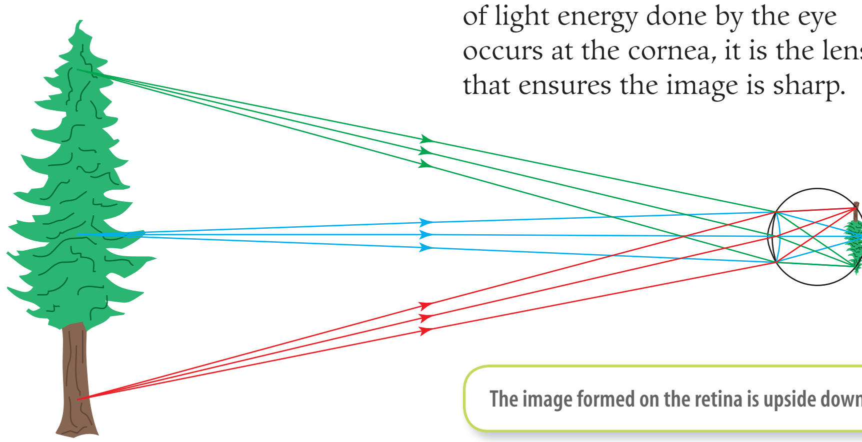
Everything that you see is an image, created when the energy of light waves entering your eyes is transmitted to a 'screen' at the back of each eye.

This screen, called the **retina**, is lined with millions of cells that are sensitive to light. These cells respond to light by sending electrical signals to your brain through the **optic nerve**.

The human eye

Some of the light reflected from your surroundings, along with light emitted from luminous objects such as the sun, enters your eye. It is refracted as it passes through the outer surface of your eye. This transparent outer surface, called the **cornea**, is curved so that the light converges towards the **lens**. Most of the bending of light done by the eye occurs at the cornea.

On its way to the lens, the light travels through a hole in the coloured **iris** called the **pupil**. The iris is a ring of muscle that controls the amount of light entering the lens. In a dark room the iris contracts to allow as much of the available light as possible through the pupil. In bright sunlight the iris relaxes, making the pupil small to prevent too much light from entering. The clear, jelly-like lens bends the light further, ensuring that the image formed on the retina is sharp. The image formed on the retina is inverted. However, the brain is able to process the signals coming from the retina so that you see things the right way up.



Getting things in focus

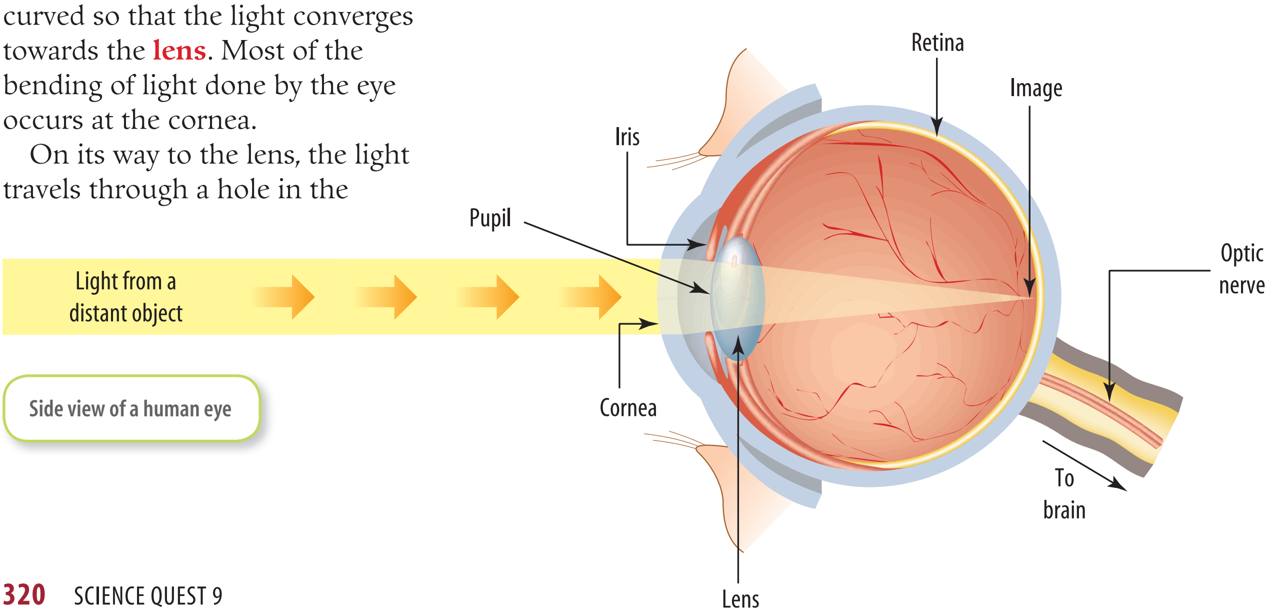
Although most of the bending of light energy done by the eye occurs at the cornea, it is the lens that ensures the image is sharp.

The image formed on the retina is upside down.

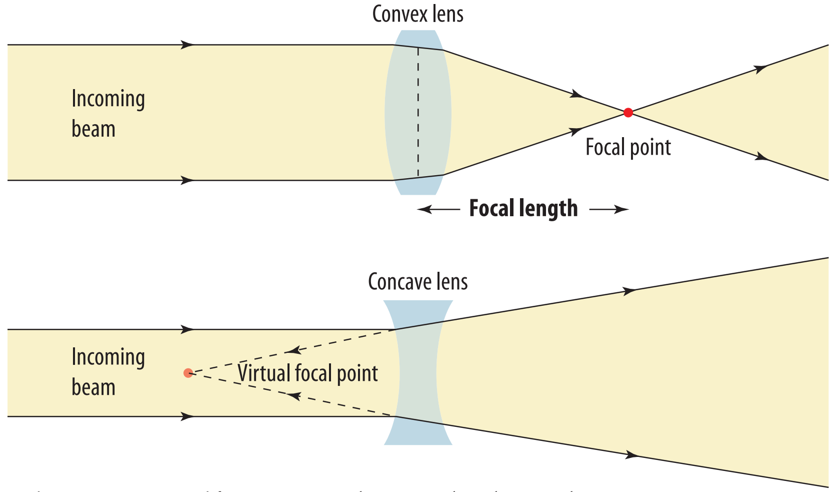
TWO TYPES OF LENSES

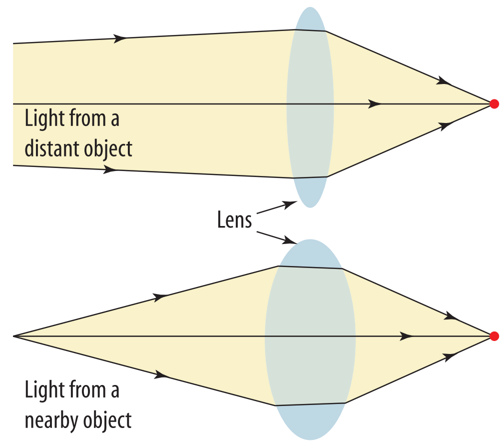
The lens in each of your eyes is a **converging lens**. Its shape is **biconvex** — that means it is curved outwards on both sides. A beam of parallel rays of light travelling through a biconvex lens 'closes in' (converges) towards a point called the **focal point**, or focus.

Another type of lens is a **diverging lens**, which spreads light outwards because of its biconcave shape. A biconcave lens does not have a real focal point. When the parallel light rays emerge from a biconcave lens, they do not converge to a focal



Side view of a human eye





The light coming from a nearby object needs to be bent more than the light coming from a distant object. The lens in your eye becomes thicker when you look at nearby objects.

point. However, if you trace the rays back to where they are coming from, you find that they do appear to be coming from a single point. That point is called the **virtual focal point**, or virtual focus.

INQUIRY: INVESTIGATION 9.9

Focusing on light

KEY INQUIRY SKILLS:

- questioning and predicting
- processing and analysing data and information

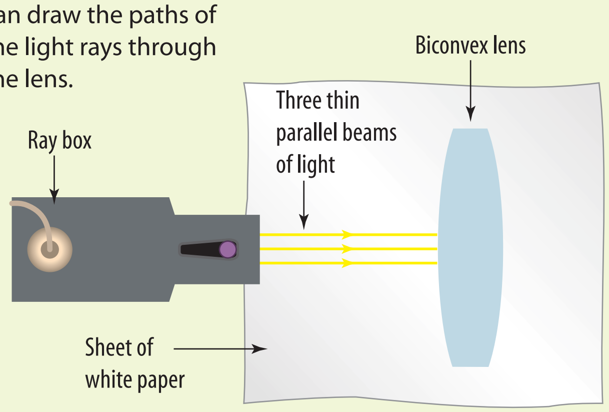
Equipment:

ray box kit	*sheet of white paper*
12 V DC power supply	*ruler and fine pencil*

- Connect the ray box to the power supply and place it on a page of your notebook.

Part A: Biconvex lenses

- Place the thinner of the two biconvex lenses in the kit on the page and trace out its shape. Project three thin parallel beams of white light towards the lens.
- Trace the paths of the light rays as they enter and emerge from the lens. Remove the lens from the paper so that you can draw the paths of the light rays through the lens.



- Replace the thin biconvex lens with a thicker one and repeat the previous steps.

Part B: Biconcave lenses

- Place the thinner of the two biconcave lenses on your notebook page and trace out its shape.
- Trace the path of each of the three thin light beams as they enter and emerge from the lens. Remove the lens from the page so that you can draw the paths of the light beams through the lens.

DISCUSS AND EXPLAIN

1 State the focal length (distance from the focal point to the centre of the lens) for each lens.

2 Which of the biconvex lenses bends light more, the thin one or the thicker one?

3 Explain why the middle light ray does not bend.

4 How many times do each of the other rays bend before arriving at the focal point?

5 Do the diverging rays come to a focus?

6 Do the diverging rays appear to be coming from the same direction? Use dotted lines on your diagram to check.

7 Predict where the diverging rays will appear to come from if you use a thicker biconcave lens. Check your prediction with the thicker biconcave lens in the ray box kit.

ACCOMMODATION

The exact shape of the clear jelly-like lens in your eye is controlled by muscles called the **ciliary muscles**. When you look at a distant object, these muscles are relaxed and the lens is thin, producing a sharp image on the retina. When you look at a nearby object, the light needs to be bent more to produce a sharp image. The ciliary muscles contract and the lens is squashed up to become thicker. This process is called **accommodation**.

WHAT DOES IT MEAN?

The word *accommodation* comes from the Latin term ***accommodatio***, meaning 'adjustment'.

Too close for comfort

As you get older, the tissues that make up the lens become less flexible. The lens does not change its shape as easily. Images of very close objects (like the words you are reading now) become blurred. The lens does not bulge as much as it should and the light from nearby objects converges to a point behind the retina instead of on the retina. You may have to hold what you are reading further away in order to obtain a clear image.

This change in accommodation with age is a natural process. Some people are not inconvenienced at all while others need to wear reading glasses so that they can read more easily and comfortably. The table below shows how the smallest distance at which a clear image can be obtained changes with age. The distances shown are averages and there is a lot of variation from person to person.

How the average smallest distance at which a clear image can be obtained changes with age

Age (years)	Distance (cm)
10	7.5
20	9
30	12
40	18
50	50
60	125

HOW ABOUT THAT!

Each human eye contains just one convex lens. Insects have compound eyes. Each eye contains many lenses. Some types of dragonfly have more than 10 000 lenses in each eye. Each eye can focus light coming from only one direction.

INQUIRY: INVESTIGATION 9.10

Getting a clear image

KEY INQUIRY SKILL:

- processing and analysing data and information

Equipment:

ruler

- Look closely at the **X** printed here from the smallest distance at which you can see it clearly and sharply with comfort. Quickly look away and focus on a distant object for a second or two and then focus on the 'X' again from the smaller distance.
- Try to feel the action of the muscles that allow you to see a sharp image of the 'X'.
- Use the following procedure to estimate the smallest distance at which you can obtain a clear image of a nearby object. (If you are wearing glasses, remove them during this part of the experiment.)
- Hold this book vertically at arm's length from your eyes and focus on it. Move the book to a position about three or four centimetres from your eyes and then gradually move the book further away until you can see the print clearly and sharply.
- Have a partner use the ruler to estimate the distance between the page and your eyes. The ruler should be placed carefully beside your head for this measurement.
- Record the distance measured.
- Collate the results for the whole class and determine the average smallest distance at which a clear image could be obtained.

DISCUSS AND EXPLAIN

1 How does your result compare with the average smallest distance for your class?

2 Write down the highest single result and lowest single result for your class. Comment on the range of results.

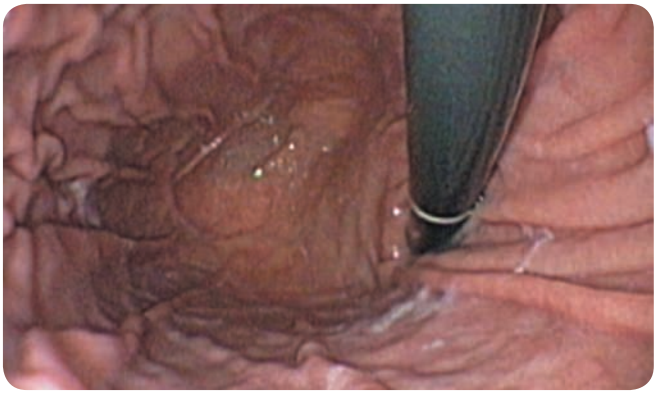
A look inside

The photograph below shows the inside of a human stomach. It has been photographed through a long, flexible tube called an **endoscope**. Inside the endoscope are two bundles of narrow glass strands called **optical fibres**. The glass in optical fibres is made so that light is unable to emerge from the glass.

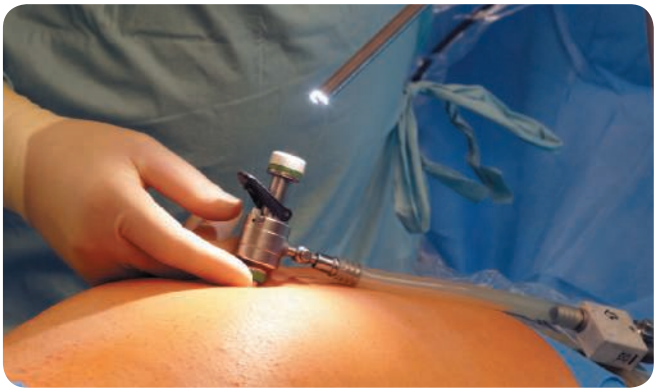
A beam of bright light is directed through one bundle of fibres, illuminating the inside of the stomach. Some of the light is reflected through the other bundle of fibres. A lens at the end of this bundle allows an image to be viewed, photographed or videotaped.

Endoscopes can be used to look at many different parts of the body. Different types of endoscopes include:

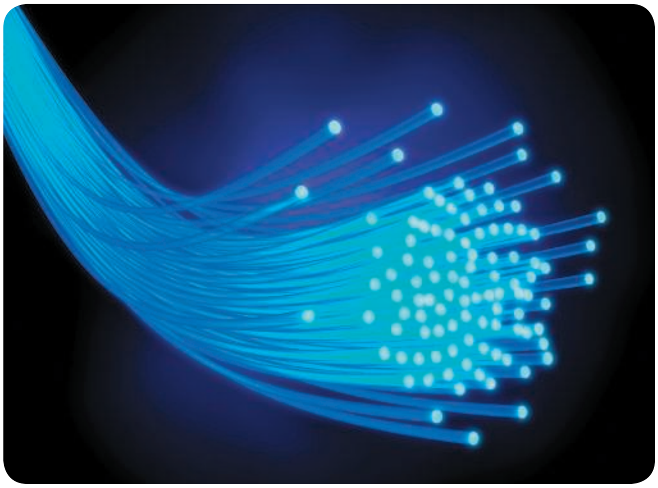
- gastroscopes, which are used to examine the stomach and other parts of the digestive system
- arthroscopes, which are used to search for problems in joints like shoulders and knees
- bronchoscopes, which are used to see inside the lungs.



Optical fibres allow us to see inside the human body via an endoscope.



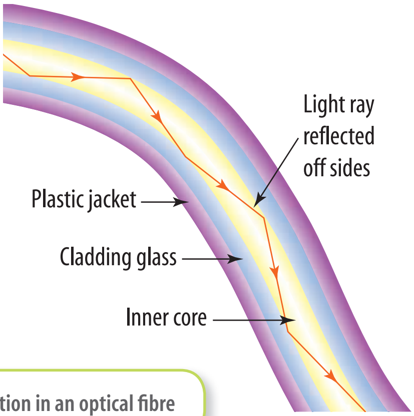
A gastroscope being used to look inside a patient's stomach



A bundle of optical fibres. The light can be seen through the ends.

Endoscopes can also be used in laser surgery. Intense laser beams can be directed into the optical fibres. The heat of the laser beams can be used to seal broken blood vessels or destroy abnormal tissue inside the body.

The glass in optical fibres is made so that light is unable to emerge from the glass. As light travels from a substance such as glass into air, it bends away from the normal (see section 9.5). If the light strikes the boundary at a small enough angle, it bends so much that instead of leaving the glass, it is reflected back into it. This process is called **total internal reflection**. The diagram below shows how total internal reflection occurs in an optical fibre.



Total internal reflection in an optical fibre

eBook*plus* **eLesson**

Light pipes

Watch this video lesson from the ABC *Catalyst* television show about how natural light can be used deep inside dark buildings.

eles-1087

INQUIRY: INVESTIGATION 9.11

Total internal reflection

KEY INQUIRY SKILL:

- processing and analysing data and information

Equipment:

ray box kit

12 V DC power supply

perspex triangular prism

- Connect the ray box to the power supply. Place the ray box over a page of your notebook. Use one of the black plastic slides in the ray box kit to produce a single thin beam of light which is clearly visible on the white paper.
- Place a perspex triangular prism on your notebook and direct the thin beam of light towards it as shown in the diagram on the right. Observe the beam as it passes through the prism.
- Turn the prism slightly anticlockwise, closely observing the thin light beam as it travels from the perspex prism back into the air. Continue to turn the prism until the beam no longer emerges from the prism.

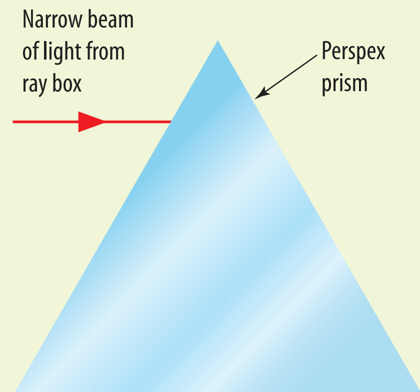
DISCUSS AND EXPLAIN

1 Describe what happens to the thin light beam as it passes from air into the perspex prism and back into the air.

2 What happens to the beam of light when it no longer emerges from the prism?

3 Draw a series of two or three diagrams showing how the path taken by the beam of light changed as you turned the prism.

4 Explain how the amount of light reflected changes as the prism is turned.



Observe the beam of light as it passes through the prism.

INQUIRY: INVESTIGATION 9.12

Optical fibres

This investigation is carried out as a teacher demonstration to minimise the risks associated with the use of lasers.

Equipment:

transparent 2–3 L fruit juice container

large nail

laser (class 1)

demonstration optical fibre cable or light pipe

- Use the nail to poke a narrow 5 mm hole into the front of a fruit juice container approximately 5 cm from the bottom.
- Darken the room.
- Fill the container to the top with water and position it on the edge of a sink so that a thin stream of water flows from the container into the sink.

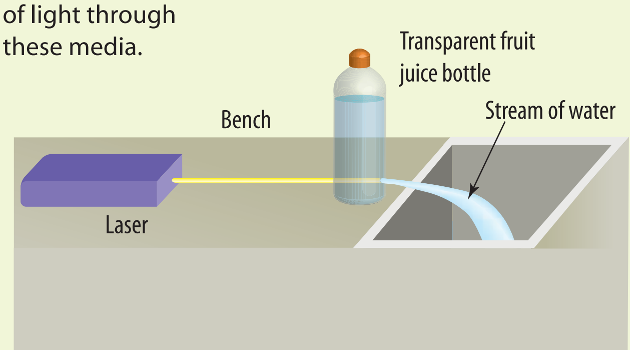
CAUTION: Class 1 and class 2 lasers have a relatively low power output and so are safe for classroom use under direct supervision of the teacher. Laser beams should not be pointed towards others in the room because of the sensitivity of the retina of the eye. Ensure that those viewing this demonstration are positioned on either side of the stream of water to eliminate the possibility of the laser beam being directed towards them.

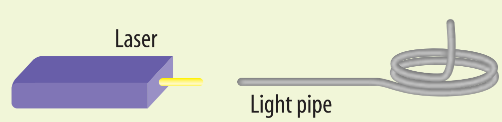
- Direct a laser beam into the container and out through the centre of the stream of water.
- Describe the path of the laser beam.
- Shine a laser beam down a length of 'light pipe' or loop of optical fibre. Describe your observations.

DISCUSS AND EXPLAIN

1 Explain why the laser beam took the path of light observed in these demonstrations.

2 Compare the speed of light in air to that in water or the material making up the optical fibre core. Explain how these demonstrations rely on the difference in the speed of light through these media.





HOW ABOUT THAT!

Diamonds can sparkle with coloured light, each of its surfaces producing a dazzling display. Diamond is the most optically dense, naturally occurring material on Earth. This means that light entering a diamond through each of its facets (or geometrically cut sides) is refracted by a huge angle, causing light inside the gemstone to bounce back and forth several times before it strikes a facet with an angle straight enough to escape. Because the light has travelled so far, the spectrum of colours that make up light have dispersed (or separated) so significantly that a stunning display of colours is produced.

UNDERSTANDING AND INQUIRING

ANALYSE AND EVALUATE

1 Use the data in the table on page 000 to draw a line graph to show how the ability to focus on nearby objects changes with age.
   (a) Use your graph to predict the smallest distance at which a clear image can be obtained by an average person of your age.
   (b) At what age does the decrease in focusing ability appear to be most rapid?

REMEMBER

2 At which part of the human eye does most of the bending of light occur?

3 Describe the function that the iris and pupil work together to perform.

4 Name and sketch the shape of a lens that:
   (a) converges a beam of light to a single point
   (b) makes the rays in a beam of light diverge.

5 What is the focal length of a converging lens a measure of?

6 What is accommodation?

7 What is the name given to the shape of the lens in the human eye?

8 Sketch the shape of the lens in the eye when you are viewing:
   (a) a nearby object
   (b) a distant object.

9 How does the lens change its shape?

10 Why is it common to see older people holding a newspaper at arm's length while they are reading it?

11 How are messages sent from the eye to your brain?

12 Explain how an endoscope works.

13 List three medical uses of endoscopes.

14 Explain how optical fibres allow light to travel along a bent tube.

THINK

15 Does light slow down or speed up when it passes from the air into the cornea? How do you know this? (*Hint:* Refer to section 9.5.)

16 List some commonly used inventions that contain lenses.

17 Explain why the focal point of a diverging lens is called a virtual focal point.

18 Why does the lens need to be thicker for viewing nearby objects?

19 Can total internal reflection occur when light travels from air into glass? Explain your answer.

CREATE AND INVESTIGATE

20 Use two or more lenses and lens holders to make a model microscope or telescope on a laboratory workbench. Investigate the effect of changing the distance between the lenses on the magnification and write a report on your findings.

INVESTIGATE

21 Use the internet to research and report on the development of the bionic eye by Australian scientists. Include in your report information about:
- macular degeneration
- which patients it is designed to benefit
- how it works
- a comparison with the bionic ear.

22 Test your knowledge of the lenses used in common items by completing the **Time Out: 'Lenses'** interactivity in your eBookPLUS. **int-1017**

eBook*plus*

23 Use the **Eye dissection** weblink in your eBookPLUS to view a dissection of a cow's eye.

24 Use the **Colour vision** weblink in your eBookPLUS to learn more about seeing in colour.

work sheet 9.5 The eye

9.7 SCIENCE AS A HUMAN ENDEAVOUR

We’re on the air

Compare the sizes of these transmitting and receiving antennae. Why are they different?

The human desire to continually improve communications seems infinite.

Since the Stone Age, humans have been finding new ways to communicate with more people over greater distances at a greater speed. After the discovery of radio waves by Heinrich Hertz in 1887, and a few years of clever work by the Italian engineer Guglielmo Marconi, it became possible to send messages over long distances at the speed of light.

Riding on a radio wave

Radio waves are emitted naturally by stars. They can also be produced artificially when electrons in a metal rod are made to vibrate rapidly. This metal rod is called a **transmitting antenna** or transmitter. These vibrations cause radio waves to travel through the air (at about 300 000 kilometres per second). The radio waves can be detected by a **receiving antenna**, which is a metal rod just like the transmitter. The radio waves cause electrons in the receiving antenna to vibrate rapidly, producing an electrical signal.

AM RADIO

Each AM radio station has a particular frequency of radio waves on which it transmits sound signals. The sound signal must firstly be changed to an electrical signal. This electrical signal is called an **audio** signal. The waves on which messages are sent are called **carrier waves**. The audio signal is added to the carrier wave, producing a modulated wave, as shown in the diagram on the opposite page. The receiving antenna of your radio detects the modulated wave. Your radio then ‘subtracts’ the carrier wave from the signal, leaving just the audio signal. The audio signal is amplified by an audio amplifier inside the radio and sent to speakers. In the speakers, the changing electric current is used to make the surrounding air vibrate to produce sound.

The carrier signals for AM radio stations have frequencies ranging from about 540 kilohertz up to about 1600 kilohertz. When you tune in your radio, you are selecting the frequency of the carrier wave that you wish to receive. For example, if you tune to ABC Local Radio Melbourne, you are selecting the carrier wave with a frequency of 774 kilohertz.

AM stands for **a**mplitude **m**odulation: the audio signal changes the amplitude of the carrier wave.

FM RADIO

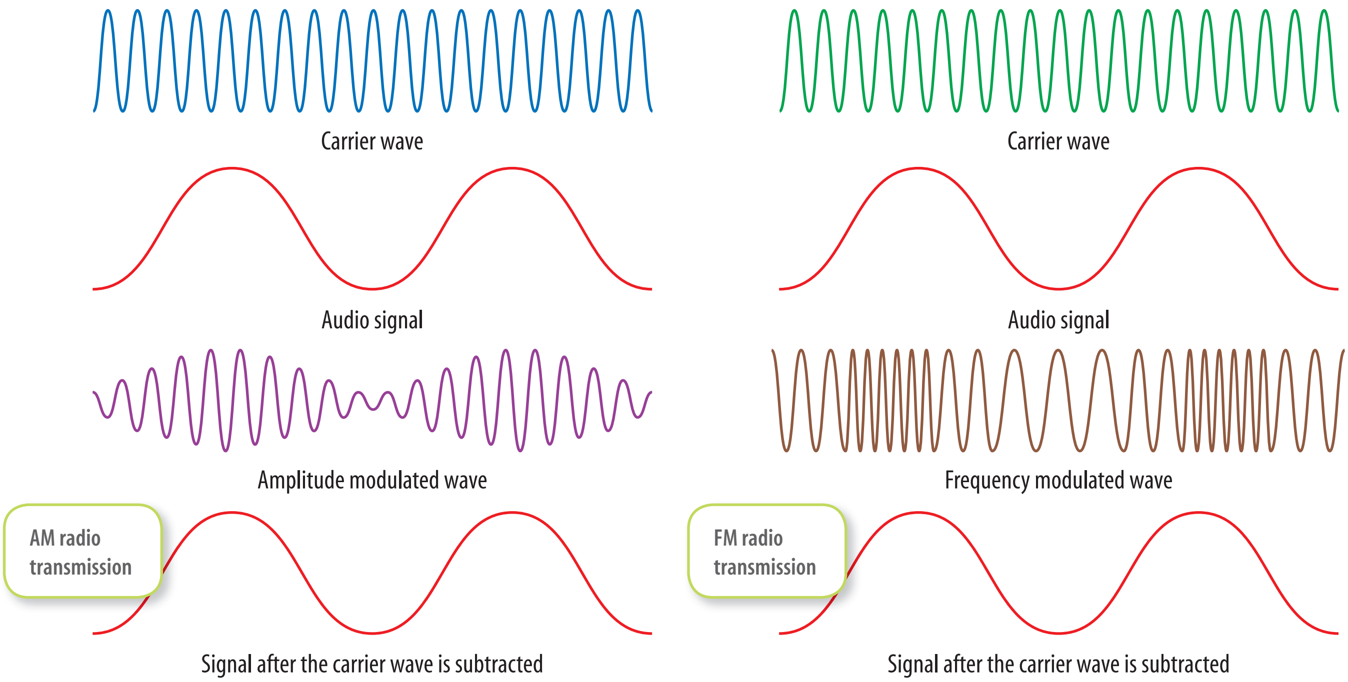
Like AM radio stations, each FM radio station has its own carrier wave frequency. However, the carrier frequencies are much greater — between 88 megahertz and 108 megahertz (1 megahertz equals 1 million hertz). The other major difference between AM and FM radio is the way that the audio signal is carried on the carrier wave. Instead of adding the audio signal to the carrier wave (which changes the amplitude of the wave), the audio signal changes the frequency of the carrier wave as shown in the diagram on the opposite page. FM stands for **f**requency **m**odulation.

As with AM radio, when you tune in your radio to FM you are selecting the frequency of the carrier wave that you wish to receive. For example, if you tune to Triple J in Melbourne, you are selecting the carrier wave with a frequency of 107.5 megahertz.

FM radio waves are affected less by electrical interference than AM radio waves and therefore provide a higher quality transmission of sound. However, they have a shorter range than AM waves and are less able to travel around obstacles such as hills and large buildings.

DIGITAL RADIO

Digital radio began in 2009. Digital signals are different from AM or FM radio signals, and are discussed in section 9.8.



Television

Television signals are transmitted on two separate carrier waves. The visual signal is added onto one carrier wave using amplitude modulation. The audio signal is carried on a separate carrier wave using frequency modulation. When you tune your television set to a particular channel, you are selecting the visual and audio carrier waves that you wish to receive. Your television set then completes the task of removing the carrier waves and translating the signals sent into a picture and sound. This is quite a complex task, as you might imagine!

UNDERSTANDING AND INQUIRING

REMEMBER

1 How are radio waves produced artificially?

2 Sound waves cannot be directly transmitted through the air over long distances. What has to happen to them before they can be transmitted on radio waves?

3 What is a carrier wave?

4 Explain the difference between the way that AM and FM radio waves carry audio signals.

5 List one advantage and one disadvantage of FM radio over AM radio.

6 How are television signals carried by radio waves?

USING DATA

7 Express the frequency of the following radio stations in Hz. (A frequency of 1 Hz corresponds to one complete wave being produced each second.)
(a) Triple M (FM), Melbourne: 105.1 MHz
(b) 3CV (AM), Bendigo: 1071 kHz
(c) Triple J (FM), Shepparton: 94.5 MHz
(d) Triple J (FM), Latrobe Valley: 96.7 MHz
(e) ABC (AM), Sale: 828 kHz

1 kHz = 1000 Hz (or 10^3 Hz)
1 MHz = 1 000 000 Hz (or 10^6 Hz)

8 The wavelength (λ) of a wave is related to the frequency (f) of the wave by the equation:

$v = f\lambda$

where v is the speed of the wave.

The speed of radio waves in air is 300 000 000 m/s.

Use this equation to calculate the wavelength of the carrier waves used by radio stations Triple M, Melbourne, and 3CV, Bendigo.

INVESTIGATE

9 Find out more about how television pictures are transmitted and reproduced on your television screen.

work sheet 9.6 Waves

The digital revolution

Analogue quantities are those that can have any value and can change continually over time. **Digital** quantities are those that can have only particular values and are represented by numbers.

Whereas analogue radio and television signals are carried as continuously changing amplitudes or frequencies, digital signals are carried as a series of 'on' and 'off' pulses. The signals can have only two values — 'on' or 'off'. The original audio and video (sound and vision) are sampled and converted into pulses. Audio signals are sampled about 40 000 times every second. Video signals are sampled more than 13 million times every second. The pulses are added to the carrier waves for transmission.

Out with the old, in with the new

Digital television commenced transmission in Australian capital cities in 2001. The phasing out of analogue signals began in 2010. Once analogue transmissions cease, probably by 2014, a digital TV set-top box can be used to convert the digital signals back to an analogue form. This means that nobody will have to replace their old analogue TV sets with digital TV sets unless they choose to.

The introduction of digital radio began in 2009, but there are no plans to phase out analogue radio services.

What's the advantage?

Both analogue and digital television signals fade away as they travel through the air. Like all other waves, the energy they carry spreads out. So, as they travel over distance their intensity, or strength, decreases. As the continuous analogue becomes weaker, the background radiation and signals from other sources have a greater effect on the amplitude of the wave. It becomes distorted. The result is a fuzzy picture and poor quality sound. Because digital signals can be only 'on' or 'off' pulses, background radiation and signals from other sources cannot interfere with them — even as they become weaker. The rapidly pulsating signals are still either 'on' or 'off' until the 'on' signals have faded away to nothing.

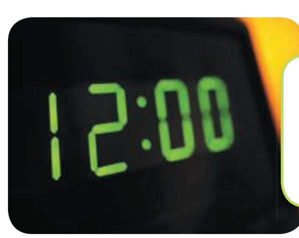
Analogue or digital — smooth or in bits

You can read the time from an analogue clock with hands that continuously rotate, or from a digital clock with LEDs (light-emitting diodes) or liquid crystals that simply turn off and on.

An analogue clock represents time as a quantity that changes smoothly.

All physical quantities such as time, speed, weight and pH can be represented in analogue or digital form. Likewise, invisible waves like sound and radio waves can be transmitted in analogue or digital form.

- Analogue forms change smoothly if the quantity being measured changes smoothly.
- Digital forms display or transmit quantities as a limited series of numbers or pulses. Digital devices are usually electronic. Their displays are made from devices that can only ever be 'on' or 'off'. For example, each number display of a digital measuring device is made up of seven devices. Each of the seven devices can be either 'on' or 'off'. The arrangement of the seven devices allows all of the numbers from 0 to 9 to be displayed.



Each number in this digital display is made up of seven LEDs, each of which can be either 'on' or 'off'.

As a result, digital television has several advantages over analogue television. It provides:

- sharper images and 'ghost free' reception
- widescreen pictures
- better quality sound
- capability of 'surround' sound
- access to the internet and email
- capability of interactive television, allowing the viewer to see different camera views or even different programs on the same channel
- Electronic Program Guides (EPGs) which can provide 'now' and 'next' information about programs.

Going mobile

Since the first major mobile phone service was introduced in Australia in 1987, millions of Australians have purchased mobile phones.

HOW MOBILE PHONES WORK

Domestic and business telephones are connected by cable to the network of microwave and radio links, coaxial cables and optical fibres. Mobile phones transmit signals on radio waves to a **base station**, which consists of several antennas at the top of a large tower or on top of a tall building. The base station is connected to a **switching centre**. Each switching centre is, in turn, connected to many base stations. The switching centre switches the call to other mobile phones through the **cellular system** or the fixed telephone system.

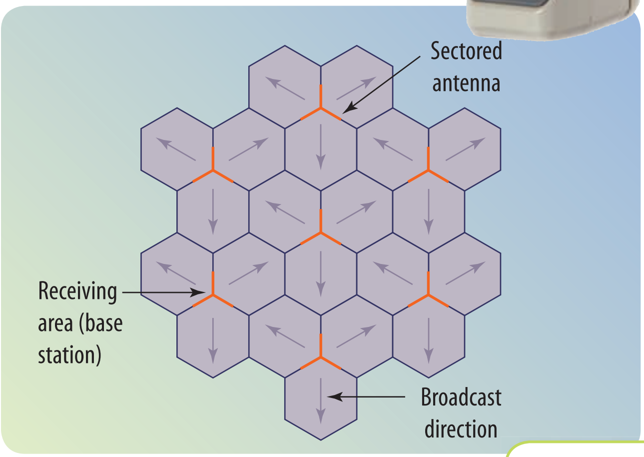
A NETWORK OF CELLS

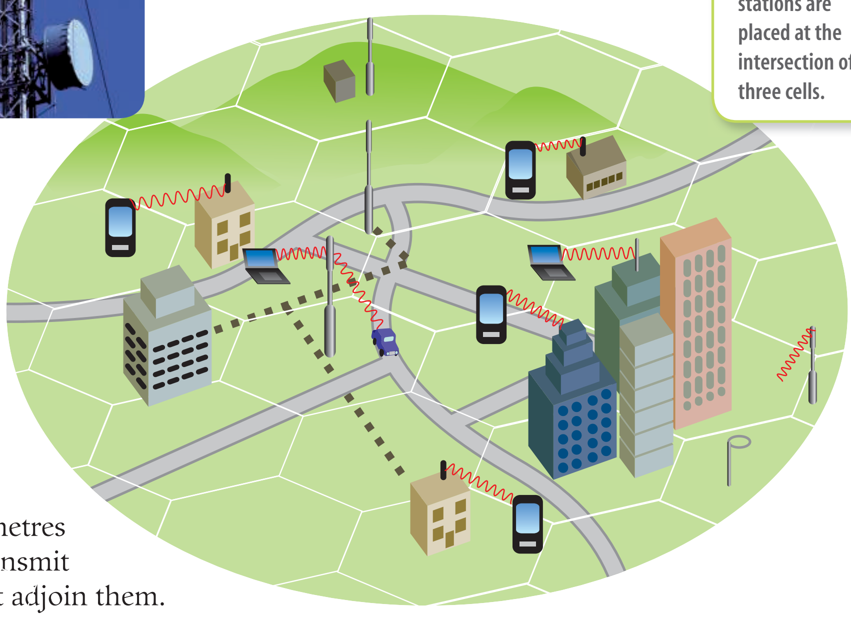
Mobile phones are also called **cellular phones**. That is because the base stations are set up in a network of hexagonal cells as shown in the diagram at right. The cells range in size from 100 metres across to over 30 kilometres across. The base stations receive and transmit mobile phone signals from the cells that adjoin them. A mobile phone signal moves from cell to cell until it reaches its destination base station.

FROM ANALOGUE TO DIGITAL

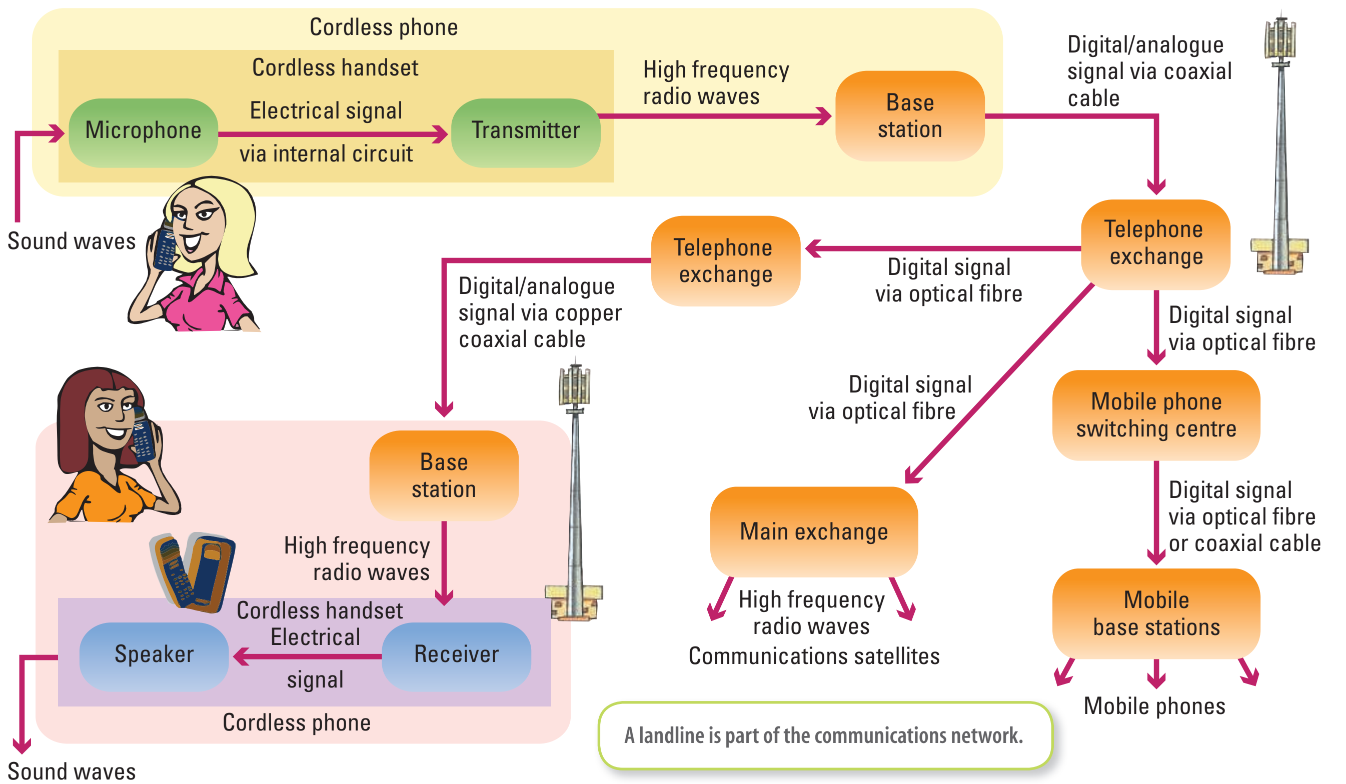
The first mobile phone service operated on an analogue system. The analogue system ceased operating at the end of 1999 and was totally replaced with a digital system. The digital system carries voice signals as a series of 'on' and 'off' pulses that are added to the carrier wave 8000 times every second.

An early mobile phone, used in the late 1980s





The base stations are placed at the intersection of three cells.



A landline is part of the communications network.

UNDERSTANDING AND INQUIRING

REMEMBER

1 Summarise the differences between the digital and analogue signals that are added to carrier waves for television transmission.

2 Will you have to have a digital TV set to watch programs when analogue transmission ceases? Explain your answer.

3 Digital television has several advantages over analogue television.
(a) List five of the advantages.
(b) Explain why digital signals have these advantages.

4 How are all mobile phones different from fixed telephones in the way that they transmit and receive voice messages?

5 Why are mobile phones also known as cellular phones?

THINK

6 Why do digital TV signals provide the capability of interactive TV whereas analogue signals do not?

7 If you could choose an analogue device or a digital device to measure your weight, which would you choose? State the reasons for your choice.

8 Write the name of an analogue device (or substance) that measures:
(a) time
(b) speed
(c) weight
(d) pH.

9 Use a two-column table to list the advantages and disadvantages of mobile phones over fixed lines.

DISCUSS AND REPORT

10 About one in three primary school children now own mobile phones. What do you think about this? In a small group, discuss the reasons for and against primary school children owning mobile phones. After the group discussion, write your own report of approximately 500 words about your opinion on this issue.

INVESTIGATE

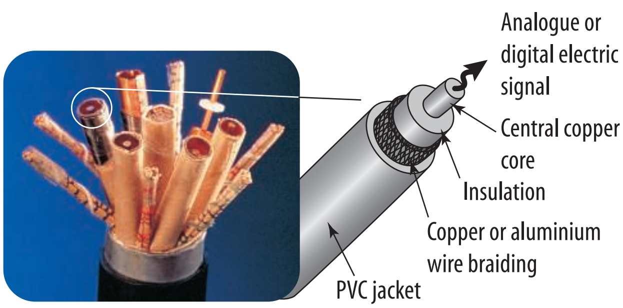
11 Search the internet to find out:
(a) what multichannelling is
(b) the benefits of interactive television.

12 Investigate and report on the way that the use of mobile phones has changed the way people live and work. Your report could be based on interviews conducted with relatives or friends who were at least 10 years old when mobile phones were introduced in 1987.

13 Use the **Analogue vs digital** weblink in your eBookPLUS to learn more about both analogue and digital signals.

eBook*plus*

Long-distance communication



A coaxial cable contains many conducting wires in up to 22 tubes. Coaxial cables can carry television signals as well as telephone calls and facsimile messages. They are designed to minimise interference from outside the cable and to prevent the many signals being carried from interfering with each other.

Australia is covered with a network of microwave and radio repeater towers, coaxial cables, optical fibres and satellite dishes. This network allows us to transmit television and radio signals, telephone calls, facsimiles and computer data across our massive continent.

Wireless technology

Television and radio signals, computer data and telephone messages can be transmitted over long distances using **microwaves**. Microwaves can carry many signals at the same time. However, **repeater stations** need to be used so that the signal does not fade away before it reaches its destination. Antennas on the repeater stations receive the microwave signals and send them on to the next station.

Each repeater tower needs to be within sight of the next one because microwaves, like visible light, travel in straight lines. So, the repeater towers are built on the top of hills wherever possible.

The repeater stations are towers with dish-shaped antennas.

The electric way

Coaxial cables allow sound, pictures and data to be transmitted as pulses of electric current rather than as electromagnetic waves. The signals are carried along conducting wires inside tubes. The thin wire is held in the centre of the tube by a plastic insulating disc. Most Australian coaxial cables contain four, six or twelve tubes. Smaller conductor wires in the cable are used to provide links to small towns along the length of the cable. They are also used to control the system. Coaxial cables are buried under the ground or laid on the ocean floor.

The first major coaxial cable in Australia was laid between Sydney, Melbourne and Canberra in 1962. Coaxial cables can simultaneously transmit many more telephone calls and television signals than earlier cables were able to. As with the microwave system, repeater stations need to be used along the length of the coaxial cable so that the signal does not fade away. Coaxial cable repeater stations need to be even closer together than microwave repeater stations.

The light fantastic

The table below shows that optical fibres can transmit more messages at one time than coaxial cable or microwaves. Electrical signals from a microphone, television camera, computer or facsimile machine are converted into pulses of light. These pulses are produced when an electrical signal is used to turn the light on and off millions of times per second.

Options for long-distance communication over land

Type of link	Number of two-way conversations at once
Copper cable	600
Coaxial cable	2 700
Microwave	2 000
Optical fibres	30 000

The light pulses received at the other end are converted back into electrical signals that can be fed into speakers, a television set, computer or facsimile machine. The messages can also be retransmitted as microwaves or radio waves if necessary.

The idea of using visible light energy to transmit messages over long distances was not feasible until the invention of the laser in 1958. The word 'laser' is an acronym, standing for **l**ight **a**mplification by **s**timulated **e**mission of **r**adiation. A laser produces an intense light beam of one pure colour. As the beam travels through the optical fibre, the glass absorbs some energy. Repeaters are needed every 35 to 55 kilometres along optical fibre cables to boost the signal. The light loses energy less quickly than normal light would, because a laser beam spreads out very little.

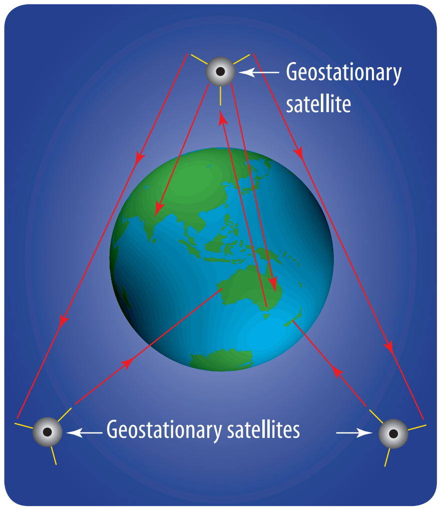
The first successful glass optical fibres were made in 1973. The advantages of optical fibres are so great that Australia already has a network of fibre cables between all capital cities. Optical fibres can be laid under the ground or under water. They are smaller, lighter, more flexible and cheaper than the electrical cables previously used for long-distance telephone, radio and television communication. Light pulses cannot be interfered with by radio waves, so there is no 'static'.

HOW ABOUT THAT!

The first microwave communications system in Australia was opened in 1959. It provided a link between Melbourne and Bendigo. This link signalled the beginning of the end for the overhead telegraph wires that hung between wooden poles.

Satellites

Communications **satellites** allow radio waves and microwaves to be transmitted at the speed of light from continent to continent. In Australia, satellites are used to transmit radio, television and telephone signals from cities to remote areas.



A geostationary satellite relays radio signals to other locations in Australia, or to other continents.

Signals are transmitted to a satellite in **geostationary** orbit. The signals are then sent back to other parts of Australia, or to other satellites which, in turn, transmit the signals to other continents. The energy needed to amplify and retransmit the signals is mostly provided by the sun. Solar panels on the satellite collect solar energy, which is either used straight away or stored in batteries for later use.

A geostationary satellite is one that orbits the Earth once every 24 hours, thus remaining over the same point on Earth at all times. In order for the satellite to orbit at that rate, it must be located about 36 000 kilometres above the equator. Tracking stations on Earth use radio signals to activate small rockets on the satellites to keep them in the correct orbit.

Dish antennas, such as the ones in the photograph below, are aimed at a particular satellite ready to receive signals. The shape of the dish allows for the collection of a large amount of electromagnetic energy, which is focused towards the antenna.

NAVIGATING BY SATELLITE

The Global Positioning System (GPS) makes use of up to 32 satellites orbiting the Earth twice each day. GPS satellites orbit

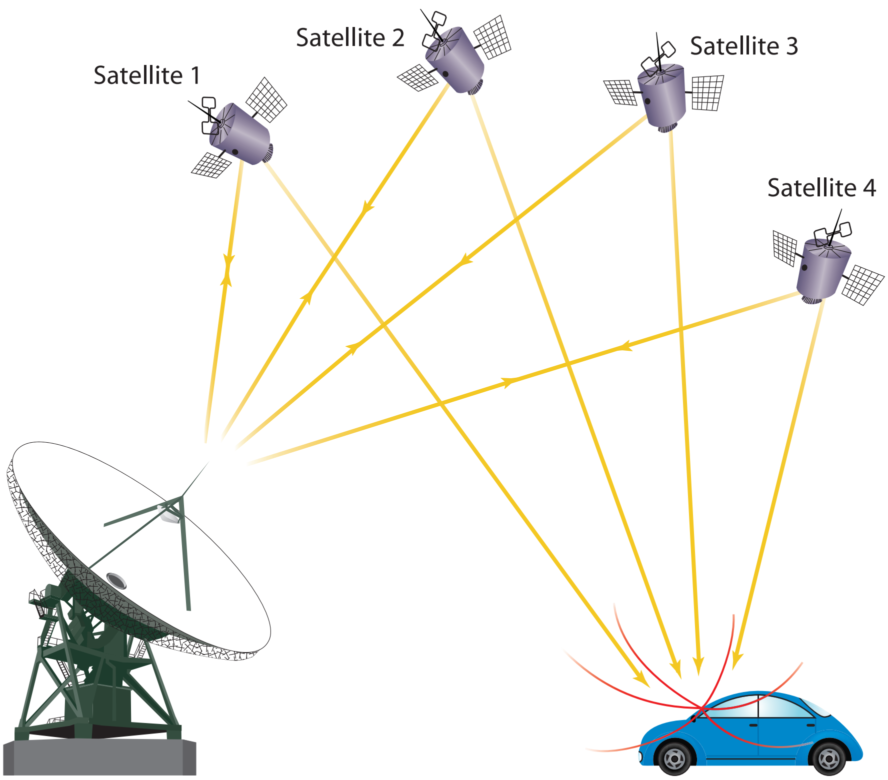
These antennas receive signals that have been retransmitted by a geostationary satellite.

the Earth on different paths, all located about 20 000 kilometres above the Earth's surface. A GPS receiver uses radio signals from at least four of these satellites to accurately calculate and map your position. It can also calculate your speed, direction of movement and the distance to your destination.

Since 1993, the GPS system has been available for use by the public free of charge and has many applications. With a GPS receiver you can now find your way around the road system, locate places of interest and even find lost dogs.

HOW ABOUT THAT!

The GPS system was originally developed for military purposes by the US Department of Defense. The first GPS satellite was launched in 1978 and the general public became aware of its existence when it was used extensively during the Gulf War (1990–1992). It was successfully used by soldiers to locate their own position and that of other soldiers plus tanks and other vehicles.



UNDERSTANDING AND INQUIRING

REMEMBER

1 List the different types of electromagnetic waves that are used for long-distance communication across Australia.

2 Why are repeater stations necessary for the transmission of microwaves and other radio waves?

3 What is total internal reflection?

4 How can light be used to transmit the electrical signals from microphones, television cameras, computers or facsimile machines?

5 From where do communication satellites get the energy required to amplify and retransmit signals from Earth?

THINK

6 Why are repeater stations necessary along coaxial cables?

7 Why are microwaves and other radio waves preferred for communication in the outback rather than optical fibres or coaxial cables?

8 Why are communication satellites placed in geostationary orbit?

9 The term 'global village' has been used to describe the Earth in recent times.
   (a) Why do you think this term has been used?
   (b) How has the development of long-distance communication changed the lifestyles of Australians during the past 40 years?

INVESTIGATE

10 Research and report on how outback Australians communicate with their neighbours and the rest of the world.

work sheets
9.7 Communications
9.8 A step back in time

Super 'scope


The Australian Synchrotron is in the Melbourne suburb of Clayton.

Imagine a microscope that is tens of millions of times more powerful than the best light microscopes. It already exists. It is called a **synchrotron** and it is much, much larger than any light microscope.

There are now more than 50 of them throughout the world, including one in Australia. The Australian Synchrotron in the Melbourne suburb of Clayton is about 70 metres in diameter. The building that houses it is not much smaller than the Melbourne Cricket Ground.

Synchrotron radiation

The energy directed at the target in a synchrotron is, like visible light, electromagnetic radiation. However, it is very different from the light used in a conventional microscope. Synchrotron radiation:

- can range from the low energy, long wavelength infra-red part of the electromagnetic spectrum up to high energy, short wavelength X-rays. The radiation can be 'tuned' to the energy and wavelength most suited for the purpose for which it is being used.
- is hundreds of thousands of times as intense as the radiation produced by conventional X-ray tubes. Intensity is a measure of the amount of power delivered to the target.
- is usually emitted in short pulses that last less than a billionth of a second
- is highly polarised).

Together, these characteristics allow a synchrotron to produce data describing objects as small as a single molecule.

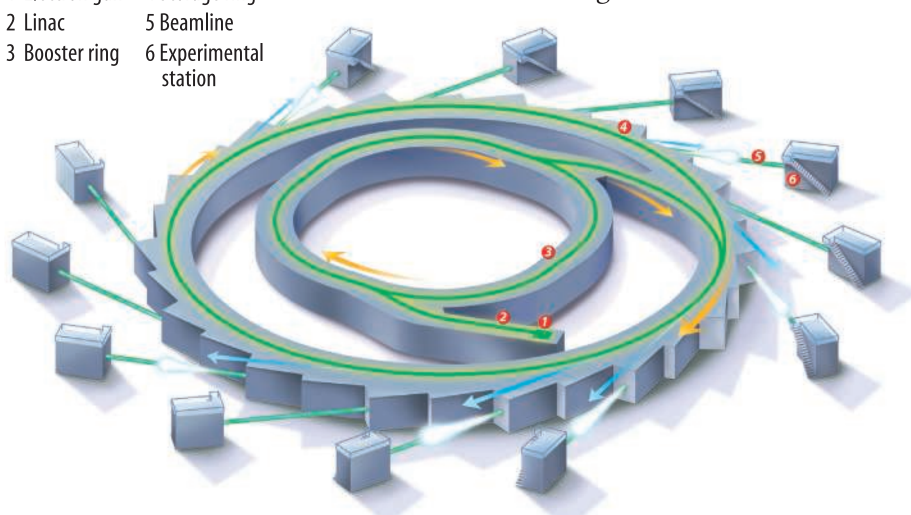
Unlike a conventional microscope, you can't actually see an image. The image has to be created from the data obtained when the radiation strikes the target with the aid of computers.

eBook*plus* **eLesson**
Australian synchrotron
Find out how the Australian synchrotron works.
eles-1088

How it works

1. Electrons are fired from a heated tungsten filament with the aid of a voltage of 90 000 volts. They reach a speed of about 159 million metres per second, 53 per cent of the speed of light.
2. The **linear accelerator** (linac) uses an even higher voltage (100 million volts) to accelerate the electrons to a speed of 99.9987 per cent of the speed of light.
3. The booster ring is used to increase the energy of the electrons before they are transferred into the storage ring.
4. In the storage ring, large magnets are used to steer the electrons. As the electrons change direction, they emit electromagnetic radiation for many hours. Magnetic fields are used to replace the energy lost by the electrons during each 'lap' of the ring.
5. The synchrotron radiation is directed into a **beamline**. The beam passes through a silicon **monochromator**, which allows only the required wavelengths to pass through.
6. The experimental station contains the target object, which is rotated so that a complete, clear image is obtained.

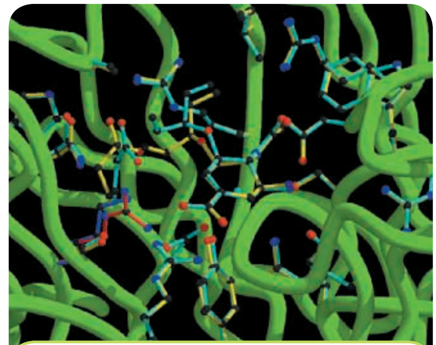
Key
1 Electron gun
2 Linac
3 Booster ring
4 Storage ring
5 Beamline
6 Experimental station



The benefits of a super 'scope

Synchrotron radiation has a wide range of applications in many areas of science and technology, including medicine, nutrition, environmental science, mining, materials, transportation, forensic science and archaeology. Some examples of the use of synchrotrons are:

- imaging proteins in the influenza virus to help develop a drug to stop it from multiplying
- the development of an artificial substance to coat the lungs of premature babies so that they can breathe more easily
- producing X-ray images of human tissue that have much more detail than conventional X-ray images. These images are being used in the fight against heart disease, breast cancer, brain tumours and many other diseases.
- the detection of weaknesses and cracks in materials used in aircraft and spacecraft
- the analysis of drill core samples in mineral exploration
- assisting in criminal investigations by more accurately identifying substances such as biological fluids, poisons, fibres and paint pigments
- identifying substances in archaeological finds such as ancient armour
- imaging molecules in chocolate to help in the production of smoother, creamier chocolate with a longer shelf life.



Images like this were used to develop the drug Relenza™, which is effective in the fight against all known strains of influenza, including bird flu.

HOW ABOUT THAT!

A synchrotron was used to help solve the mystery of the death of the German composer Ludwig van Beethoven (1770–1827). During his lifetime, Beethoven suffered from loss of hearing, cramps, fevers, chronic abdominal pain, irritability and depression. Following his death, a 15-year-old fellow musician cut off a small lock of Beethoven's hair. After many years of changing hands, the lock of hair was found in a London auction house, where it was bought by the American Beethoven Society, who allowed it to be examined at a synchrotron in Chicago. It was discovered that Beethoven's hair contained about 100 times more of the heavy metal lead than today's normal level. Beethoven's symptoms were consistent with severe lead poisoning. No-one knows where the lead came from, but it could have been from the lead that was used in serving dishes, flasks and crystal glasses during Beethoven's lifetime.

UNDERSTANDING AND INQUIRING

REMEMBER

1 Which parts of the electromagnetic spectrum can synchrotron radiation consist of?

2 Apart from having a wider range of wavelengths, how is synchrotron radiation different from visible light?

3 From where do the electrons used to produce synchrotron radiation come?

4 In the Australian Synchrotron, what is the main purpose of the:
(a) linear accelerator (linac)
(b) booster ring
(c) silicon monochromator?

5 What happens to electrons in the storage ring of the Australian Synchrotron?

THINK

6 What makes the synchrotron such a useful tool in the fight against diseases such as influenza?

CALCULATE

7 According to the US National Institute of Standards and Technology, the speed of light in a vacuum is 299 792 458 metres per second. In a synchrotron, electrons reach a speed of 99.9987 per cent of the speed of light in the booster ring.
(a) Calculate this speed in metres per second.
(b) How much slower, in metres per second, than the speed of light are the electrons travelling?

INVESTIGATE

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8 Use the internet to search for case studies on the use of synchrotrons. Make a list of examples of the use of the synchrotron other than those mentioned on this page. Use the **Australian Synchrotron** weblink in your eBookPLUS to start your research.

Plus, minus, interesting charts and target maps

1. Draw a box and write your topic or problem in it.
2. Draw three long boxes underneath your topic or problem box.
3. Fill in the three long boxes with good things and bad things about the topic, and things that you find interesting but are neither good nor bad.

why use?

To encourage you to look at optional viewpoints before making a decision

question

How can I prepare myself to make a decision on something? What are the pluses, minuses and interesting points of this problem or topic?

also called

Pros, cons and interesting points

PMI chart

Topic/theme/idea

Plus	Minus	Interesting
• • • • • •	• • • • • •	• • • • • •

comparison

Target map

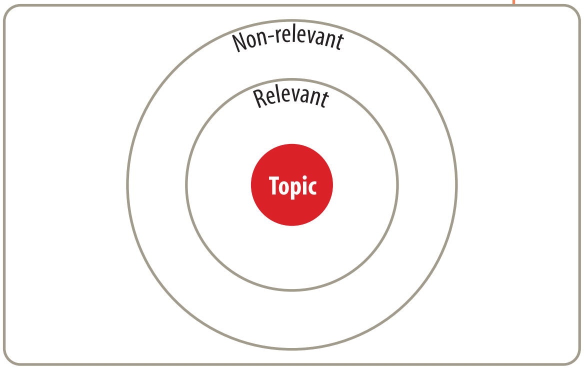
Similarity

Both help you to think about ways to classify ideas related to the topic.

Difference

Target maps sort out relevant from non-relevant material; PMI charts show your opinions.

example



UNDERSTANDING AND INQUIRING

THINK AND CREATE

1 With a partner or in a small group, discuss the positive, negative and interesting aspects of each of the following forms of energy transmission. Work together to create a PMI chart for each type of energy transmission to summarise your discussions.
   (a) Sound
   (b) Light
   (c) Microwaves
   (d) X-rays

2 Create a PMI chart to illustrate the positive, negative and interesting aspects of each of the following methods of communication.
   (a) 'Snail' mail
   (b) Mobile phones

3 Create a target map on each of the following topics using the words in the box at right and at least three additional words that are relevant.
   (a) Sound
   (b) Radio waves
   (c) Long-distance communication
   (d) Medical diagnosis or treatment

4 Work with a partner or in a small group to create a large target map on the topic of digital communication using both words and images. Start by brainstorming a collection of words and pictures related to both digital and analogue communication.

'Snail mail' may be slow, but it has some advantages over the faster methods of sending and receiving information such as phone, email and chatting over the internet. Creating PMI charts can help you reflect on the different ways of communicating.

5 Create a timeline to illustrate the development of communication by electromagnetic radiation, beginning with the discovery of radio waves by Heinrich Hertz in 1887.

light longitudinal waves reflection
pitch cochlea ultraviolet infra-red
sound waves
retina Lens compression
300 000 km/s rarefaction
transverse waves X-rays
particles
ultrasound frequency wavelength
microwaves
gamma rays AM radio FM radio

HOW ABOUT THAT!

- The African elephant's ears enable it to hear low-pitched sounds from other elephants over four kilometres away. They also use their giant ears to release heat, sometimes flapping them to cool down more quickly.
- Some insects have ears but they are not on their heads. The ears are membranes like eardrums on the surface of their bodies. A cricket has an ear just below the knee of each of its front legs. A grasshopper has an ear on each side of its body just below the wing. Most insects, however, do not have ears but detect vibrations with sensitive hairs on their antennae or other parts of their bodies.

HOW ABOUT THAT!

The human ear is capable of detecting frequencies between about 20 Hz and about 20 000 Hz. Dogs have a much greater range of hearing and can detect frequencies between 15 Hz and 50 000 Hz. Cats can hear even higher frequencies — up to 60 000 Hz.

STUDY CHECKLIST

ENERGY TRANSMISSION IN WAVES

- describe examples of the transmission of energy without the transmission of matter
- compare the transmission of waves through different media

SOUND ENERGY

- distinguish between transverse waves and compression (longitudinal) waves
- describe the transmission of sound energy
- relate the pitch and loudness of sound to the properties of sound waves
- explain how sound is transmitted through the human ear and detected by the brain

ELECTROMAGNETIC ENERGY

- describe the properties and uses of the waves that make up the electromagnetic spectrum
- identify light as part of the electromagnetic spectrum
- describe the transmission, reflection and refraction of light
- explain how light is transmitted through the human eye and detected by the brain
- outline the effect of biconvex and biconcave lenses on the transmission of light
- describe the use of total internal reflection in optical fibres

ENERGY FOR COMMUNICATION

- describe the transmission of radio waves in terms of carrier waves and audio and visual signals
- describe the advantages of digital over analogue signals
- explain the basic operation of the digital mobile phone network
- compare methods of long-distance communication, including microwaves, coaxial cables, optical fibres and satellites

SCIENCE AS A HUMAN ENDEAVOUR

- describe examples of the use of ultrasound by engineers and in medicine and industry
- describe the decibel scale
- explain the operation and impact of the cochlear implant
- describe the use of endoscopes in medical diagnosis
- outline the impact on daily life of communication technology, including mobile phones and the GPS
- examine the application of radiation in the Australian Synchrotron to science and technology

ICT

eBook plus Summary

ELESSONS

Twinkle, twinkle

Have you ever wondered why stars twinkle? Find out in this video lesson.

Searchlight ID: eles-0071

Australian Synchrotron

Learn more about the Australian Synchrotron.

Searchlight ID: eles-1088

Light pipes

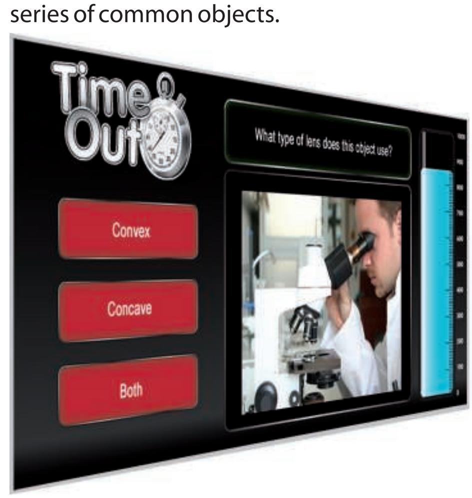
Watch an ABC *Catalyst* video about how natural light can be used deep inside dark buildings.

Searchlight ID: eles-1087

Interactivities

Time Out: 'Lenses'

Use this exciting interactivity to test your ability to identify different types of lenses as convex, concave or both, in a series of common objects.



Searchlight ID: int-1017

Bend it

Test your knowledge of the refraction of light and see if you can predict whether it slows down or speeds up and which way it will bend once it hits the surface of the water.

Searchlight ID: int-0673

INDIVIDUAL PATHWAYS

eBook plus

Activity 9.1
Revising energy transmission

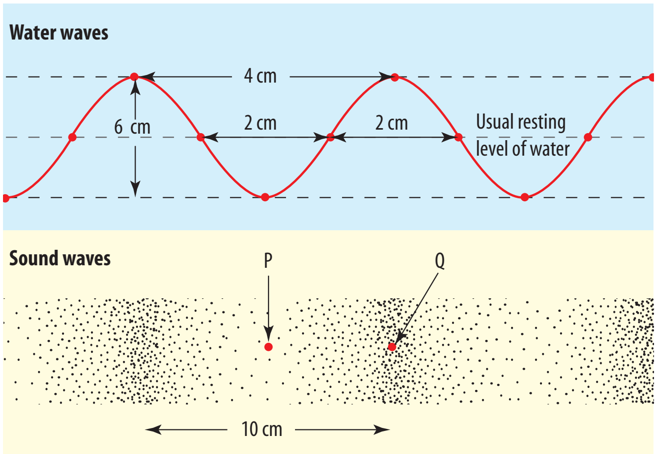
Activity 9.2
Investigating energy transmission

Activity 9.3
Investigating energy transmission further

LOOKING BACK

1 Explain the difference between a transverse wave and a compression wave. List two examples of each type.

2 Refer to the water wave and sound wave shown in the figure below to answer the following questions.
(a) What is the amplitude of the water wave?
(b) What is the wavelength of the water wave?
(c) What is the wavelength of the sound wave?
(d) Which of the points P and Q is in the centre of a rarefaction?



3 How are ultrasound waves different from the sound waves that you can hear?

4 List some of the uses of ultrasound.

5 Replace each of the following descriptions with a single word.
(a) Regions of air in which the particles that sounds bring closer together than usual
(b) Regions of air in which the particles that sounds are moved further apart than usual
(c) The effect of sound reflected from a hard surface over and over again
(d) What you see when you look in a mirror — even when you are not directly in front of it

6 When an object vibrates faster, what happens to the pitch of the sound it produces?

7 Explain why a hearing aid is of no use to some hearing-impaired people.

8 (a) Copy and complete the table below.

Electromagnetic wave type	Wavelengths (m)	Properties
Infra-red radiation		
Gamma rays		
Ultraviolet radiation		
Light		
X-rays		
Radio		

(b) State three differences between sound waves and all of the waves listed in the table.
(c) What two properties do all of the waves listed in the table have in common?
(d) To which type of electromagnetic waves listed in the table do microwaves belong?
(e) Which of the electromagnetic waves listed in the table:
(i) can be produced artificially
(ii) transmits the most energy?

9 Which aspect of sound and light can easily be modelled with both particles and waves?

10 Which type of electromagnetic radiation is used in remote control devices?

11 What is the major use to society of:
(a) X-rays
(b) ultraviolet radiation
(c) gamma rays?

12 If there were no visible light coming from the sun, it is obvious that we wouldn't be able to see. But the lack of visible light would cause a much greater problem. What is that problem?

13 Explain the difference in the meaning of each of the following pairs of words.
(a) Ray and beam
(b) Reflection and scattering

14 When a light ray passes from air to glass and back into air again, how does its speed change when it:
(a) enters the glass
(b) emerges back into the air?

15 Use a diagram to explain why your legs appear to be shorter when you stand in clear, shallow water.

16 Describe the role of each of the following parts of the eye.
(a) Cornea
(b) Iris
(c) Lens
(d) Retina
(e) Ciliary muscles

17 Use labelled diagrams to explain how visible light is used to transmit sound along optical fibres.

18 Describe how digital radio signals are different from analogue radio signals.

19 What does the digital transmission of television signals have in common with the analogue transmission of television signals?

20 Although electromagnetic radiation has many uses in society, there are also dangers associated with it.
(a) What danger does ultraviolet radiation pose to the human body and what measures should be taken to protect against it?
(b) Find out what precautions must be taken by the operators of X-ray equipment in hospitals.

21 What is synchrotron radiation and how is it 'created'?

22 List some examples of how images obtained through the use of a synchrotron can benefit medical science.

work sheet 9.9 Invisible waves: Summary

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Did you hear that?

SEARCHLIGHT ID: PRO-0109

Scenario

Since the invention of the Walkman — a portable cassette tape player — in 1979, through to the modern iPod, we have loved to carry our favourite music around with us everywhere we go. Wherever you look, you'll see people walking the dog, riding the bus, going for a run, hitting the books or just sitting around hooked in to an audio device of some form. With more than 220 million iPods alone sold since their release in 2001 and the increasing affordability of personal music players in general, more and more people are spending time plugged in. But for every person who loves their mp3 player, there's another who'll be warning them that channelling all that sound directly into their ears will have long-term effects on their hearing.

Your fifty-year-old principal wonders whether there aren't short-term effects as well, because she finds it difficult to hear her mobile ringing for about ten minutes after she has stopped listening to music on her iPod. She comes to your science class (known for their cleverness) for some possible answers. One clever classmate suggests that maybe the type of music she was listening to had lots of high frequency sounds in it and that this had somehow affected her ear's ability to pick up the high frequencies of her mobile ring tone. Another clever classmate thinks that maybe she had the volume up too high on her iPod and that this might have caused some temporary deafness. A cheeky classmate suggests that maybe she can't hear it because she's old! Somewhat grumpy with that last comment, your principal decides that maybe she should just ban all personal music players in the school unless you can provide her with some thorough scientific evidence that something other than age can have short-term effects on hearing range after iPod use.

Your task

Using personal music players and online hearing tests, your group will perform a series of scientific investigations to explore the short-term effects of personal music players (such as iPods) on hearing range. You will then present your findings in the form of a scientific report suitable for sending to the principal.

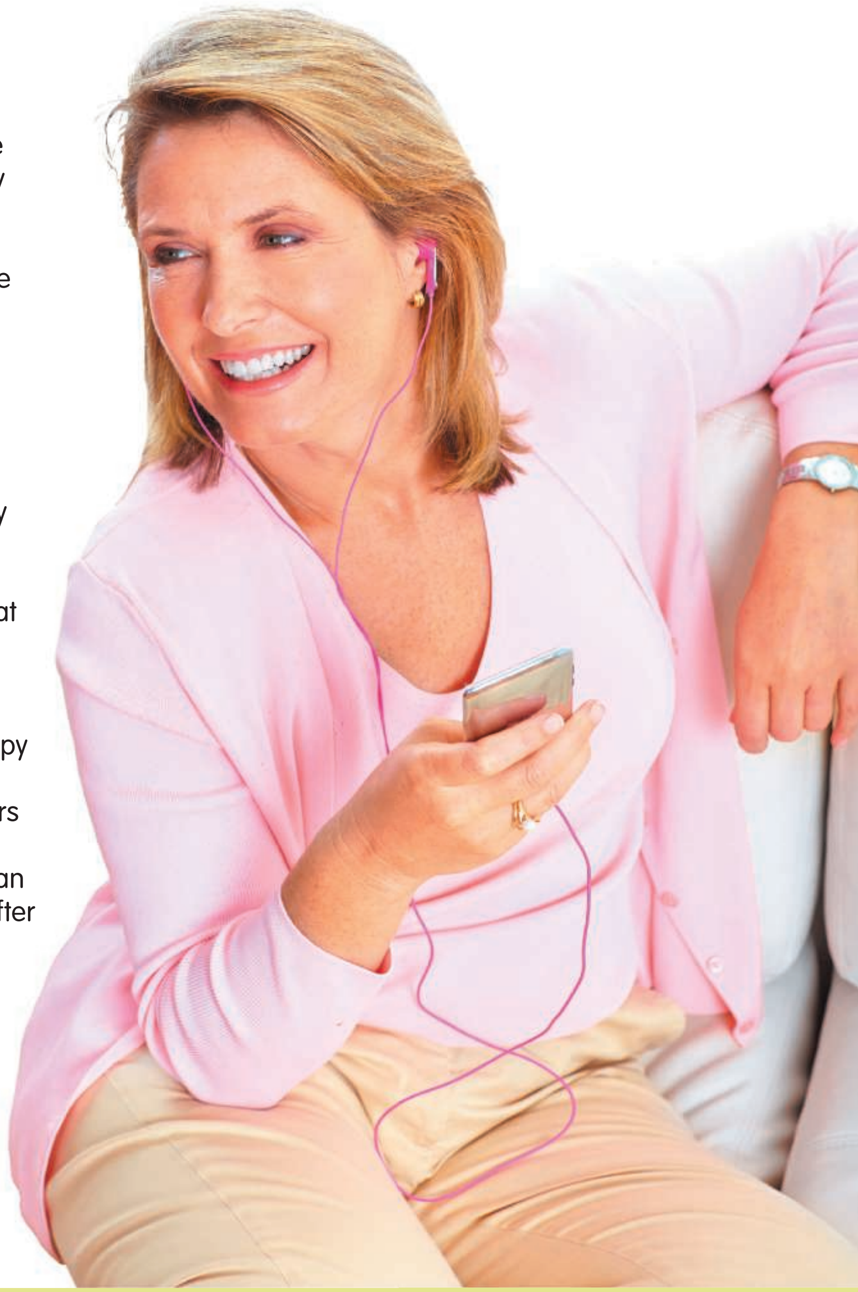
Suggested factors to consider include:

- volume used
- hearing range differences between males and females
- type of music (for example, classical, jazz, R&B or pop).

Note that you will need to minimise any risk of permanently causing damage to the hearing of your human subjects by ensuring that the volume does not exceed 90 dB and limiting trial durations to a few minutes.

Process

- Open the ProjectsPLUS application for this chapter located in your eBookPLUS. Watch the introductory video lesson and then click the 'Start Project' button to set up your project group. You can complete this



project individually or invite other members of your class to form a group. Save your settings and the project will be launched.

- Navigate to your Research Forum. Here you will find a number of topic headings that you can use to start your research to help you in your investigation. As you find more information and different research topics suggest themselves, you may add new topic headings.
- Start researching. Make notes of information that you gather that will provide background for your investigation and direct its design. Enter your findings as articles under your topic headings in the Research Forum. You should each find at least three sources (other than the textbook, and at least one offline such as a book or encyclopaedia) to help you discover extra information about human hearing and the factors that might influence a person's hearing range. You can view and comment on other group members' articles and rate the information that they have entered. When your research is complete, print out your Research Report to hand in to your teacher.
- Design your investigation by determining what will be the dependent, independent and controlled variables, establishing the use of controls and repeated measurements, and deciding what factors you will test and how you will measure the hearing range of your subjects. Your Media Centre include links to websites through which you can access online hearing tests.
- Perform your investigation. Take photographs during your investigation for inclusion in your report.
- Visit your Media Centre and download the report template to help you build your experimental report. In each section of the template, you will find directions as to what information should be included in each report section. Delete these directions as you complete each section. Your Media Centre also includes images that you may like to use in your report, as well as links to useful websites.

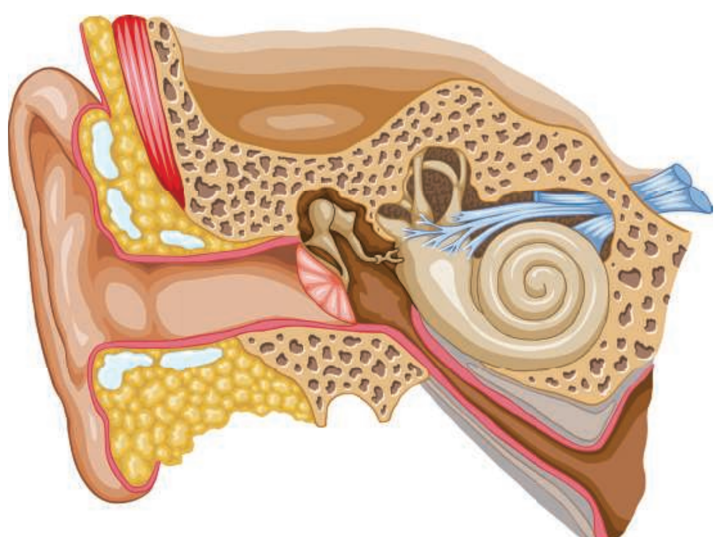
MEDIA CENTRE

Your Media Centre contains:

- a report template
- a selection of images
- a selection of useful weblinks
- an assessment rubric.

SUGGESTED SOFTWARE

- ProjectsPLUS
- Word or other word-processing software
- Internet access
- Computer with soundcard
- Excel or other spreadsheet software



Your ProjectsPLUS application is available in this chapter's Student Resources tab inside your eBookPLUS. Visit www.jacplus.com.au to locate your digital resources.