CHAPTER 10

Light and sound

You will discover

How we see and hear
The differences between sound and light
How mirrors work
Different ways to measure sound

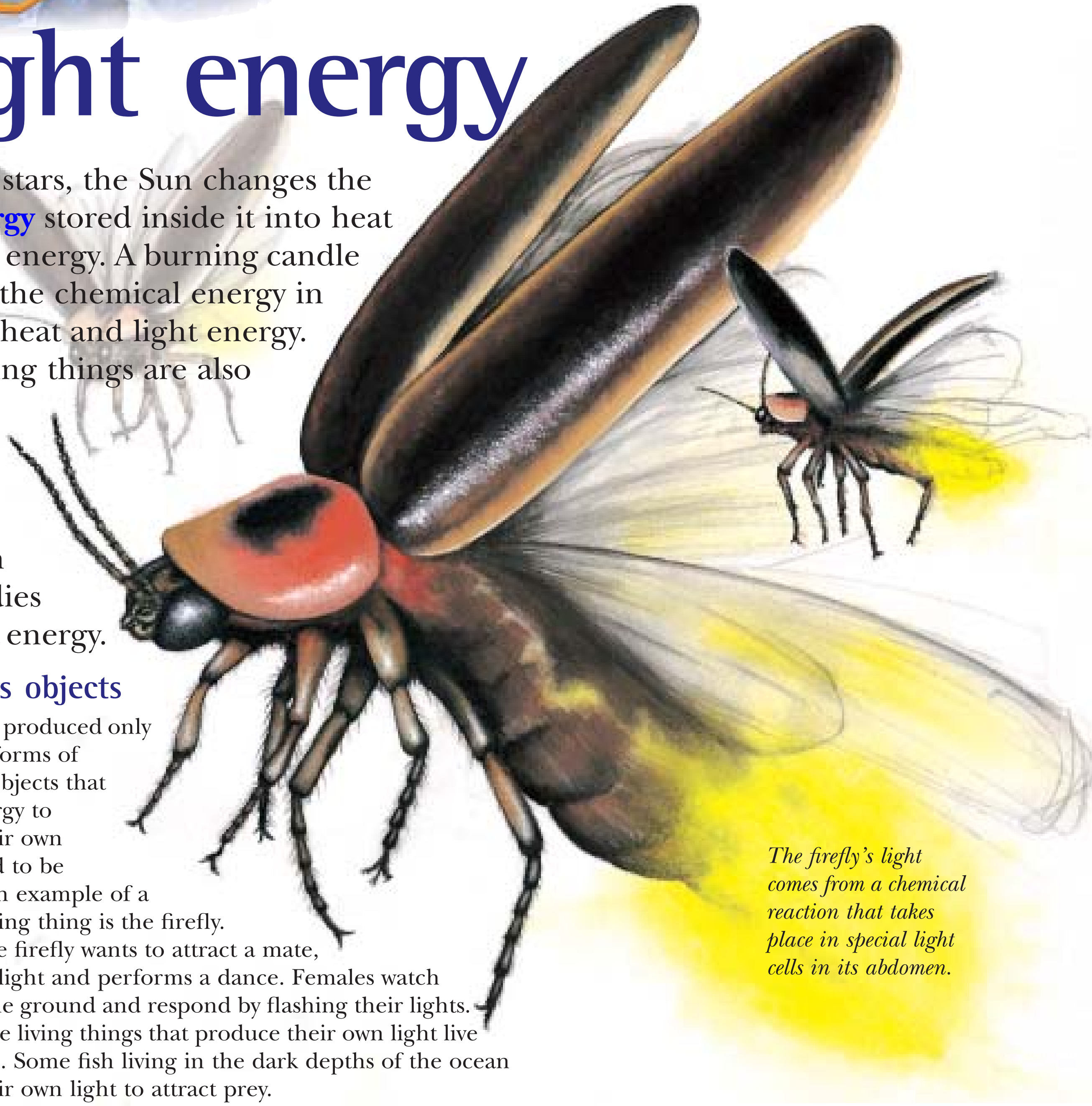
Lights are flashing and the music is so loud that you can feel the vibrations. The band has been playing for only 15 minutes and your ears are beginning to ring. Maybe you should have brought along some earplugs. But the atmosphere is electric. The lights move with the music — and the music is just what you came to hear.

When the concert is over, your ears are still ringing. You're also having trouble hearing. Even after you go to bed and the house is silent, the ringing is still there. The ringing in your ears is called tinnitus (pronounced tin-eye-tus). Some of the cells in your inner ear — the ones that detect vibrations — have been damaged. Fortunately, they 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.

1 What caused the vibrations I could feel?
2 How loud does the sound have to be to cause ringing — or even pain?
3 Why did the singer's lips start moving before I heard the sound?
4 How come I could see the light beams?

Light energy

Like all stars, the Sun changes the **energy** stored inside it into heat and light energy. A burning candle converts the chemical energy in wax into heat and light energy. Some living things are also able to change the chemical energy in their bodies into light energy.

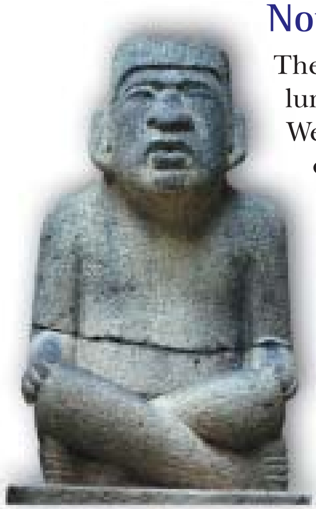


The firefly's light comes from a chemical reaction that takes place in special light cells in its abdomen.

Luminous objects

Light can be produced only from other forms of energy. All objects that convert energy to produce their own light are said to be **luminous**. An example of a luminous living thing is the firefly. When a male firefly wants to attract a mate, it flashes its light and performs a dance. Females watch from near the ground and respond by flashing their lights.

Most of the living things that produce their own light live in the ocean. Some fish living in the dark depths of the ocean produce their own light to attract prey.



Non-luminous objects

The Moon (on the right) and the statue (on the left) are not luminous. In fact, most things that you see are not luminous. We see **non-luminous** objects because light from luminous objects bounces from them. The bouncing of light from an object is called **reflection**. You see the Moon because it reflects light from the Sun — and some of that reflected light enters your eyes. You see the statue because it reflects light from the Sun or (if it were indoors) the lights in the room.

We are able to see things when light coming from them enters our eyes. The light energy is then changed into electrical energy by special **cells** called **receptors** at the back of each eye. That energy is then sent to the brain so that we know what we are looking at.

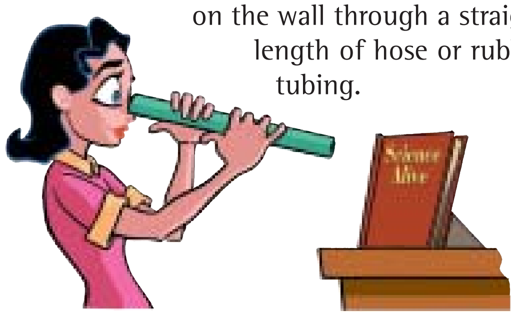
Glowing in the dark

Glow-in-the-dark stickers and toys are made with a chemical called phosphor, which **absorbs** light energy. It then slowly releases the light energy as one colour — usually green. Because the light energy is released more slowly than it is absorbed, when you turn off the lights in your room, the sticker or toy continues to release light for quite some time. This process of absorption and slow release is called **phosphorescence**.

Does light travel in straight lines?

You will need:
small length of hose or rubber tubing.

- Look at a few letters on this page or a poster on the wall through a straight length of hose or rubber tubing.



- Bend the hose or rubber tubing slightly until you can no longer see the letters.

1. What do you see when you bend the tubing?
2. Explain in words why you can no longer see the letters.
3. Draw a diagram to show why you can't see the letters.
4. Does the light reflected from the letters travel in straight lines?

Activities

REMEMBER

1. How is light energy produced?
2. What type of energy is used to produce light in a firefly?
3. Why do fireflies need light energy?

THINK

4. Which of the following objects are luminous?
   (a) the Sun
   (b) the Moon
   (c) a human eye
   (d) an unlit candle
   (e) a burning candle
5. You can see luminous objects in the dark. Why can't you see most non-luminous objects in the dark?
6. Name at least two non-luminous objects that you can see in the darkness of night and explain why you can see them.
7. What form of energy allows light to be produced in a glow-in-the-dark sticker?
8. Light energy travels through empty space and air at a speed of 300 000 km/s. How long does light take to travel the 150 million km from the Sun to the Earth?

INVESTIGATE

9. Find out what the word 'incandescent' means. Make a list of luminous objects that are incandescent.

CONNECT

10. Light produced by living things is called **bioluminescence**. Go to www.jaconline.com.au/science/weblinks and click on the Living Lights link for this textbook to find out more about the many fascinating creatures that use chemicals in their body to produce light.

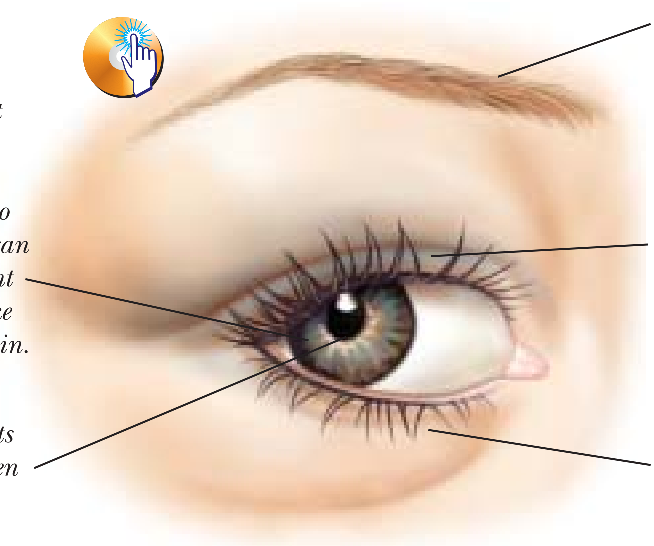
checklist

I can:
- ☐ describe light as a form of energy
- ☐ explain how light is produced
- ☐ explain how we see objects that don't produce their own light.

Seeing things

Your eyes are light detectors. They collect light from **luminous** and **non-luminous** objects. Your eyes form **images** of these objects which they then send to your brain. Your brain makes sense of the images so that you can see.

Look into my eye



Iris
*The coloured part of the eye that opens and closes to let the right amount of light into the eye. In dark conditions, the **iris** opens to allow more light in so that you can see as much as possible. In bright conditions, the iris closes to make sure that not too much light gets in.*

Pupil
The hole through which light gets into the eye. Its size changes when the iris opens and closes.

Eyebrow
Helps stop dust and other small particles from getting into your eye. The eyes are set back below your eyebrow. This helps stop water and sweat from dripping into your eye.

Eyelid
Your eyelids close to protect the eye from wind, dust and very bright light. They also keep your eye moist. Every time you blink, your eyelids spread liquid over the surface of your eyes.

Eyelashes
Short hairs that trap dust and other small particles that could damage your eye

What gives an eyeball its shape?

The part behind the lens is filled with a completely clear, jelly-like substance. This substance is what gives the eyeball its shape. It is as clear as glass, which is how it got its name — vitreous humour. Vitreous comes from the Latin word for glassy. Humour comes from the Latin word for moisture. The substance at the front of the eyeball is also clear, but more watery. It's called aqueous humour.

Light from a distant object

Light comes directly from luminous objects or is **reflected** from non-luminous objects.

Cornea
*The clear outer surface of the front of the eye. It is curved so that it bends light through the **pupil**.*

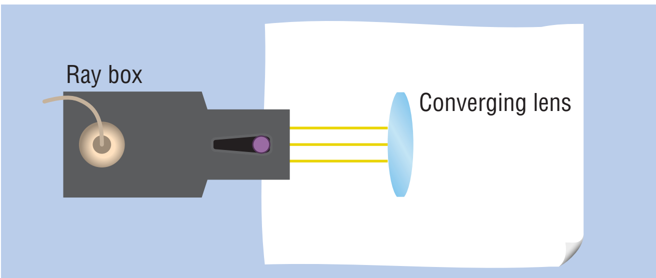
Lens
*Bends light towards the **retina**. The **lens** is clear and flexible. It is connected to muscles that change its shape to make it thinner or thicker. The lens changes shape so that you can get sharp **images** whether you are looking at distant or nearby objects.*

What does a lens do to light?

You will need:

ray-box kit
sheet of white paper
pencil.
12 V power supply
ruler

- Place the ray box on the edge of a sheet of white paper and connect it to the power supply.



- Put a thin convex lens about 5 cm in front of the ray box.

A convex lens

- Use a pencil to trace the shape of the lens and mark the paths of the **light rays** on both sides of the lens. Remove the lens and complete your ray diagram by showing the path of the rays through the lens. Use a ruler to draw the rays.

1. How does the thin convex lens change the path of the light rays?

- Replace the thin convex lens with a thicker convex lens. Trace the shape of the lens and the light rays on a different part of the white paper.

2. What difference does it make to the path of the light rays when they pass through a thicker convex lens?

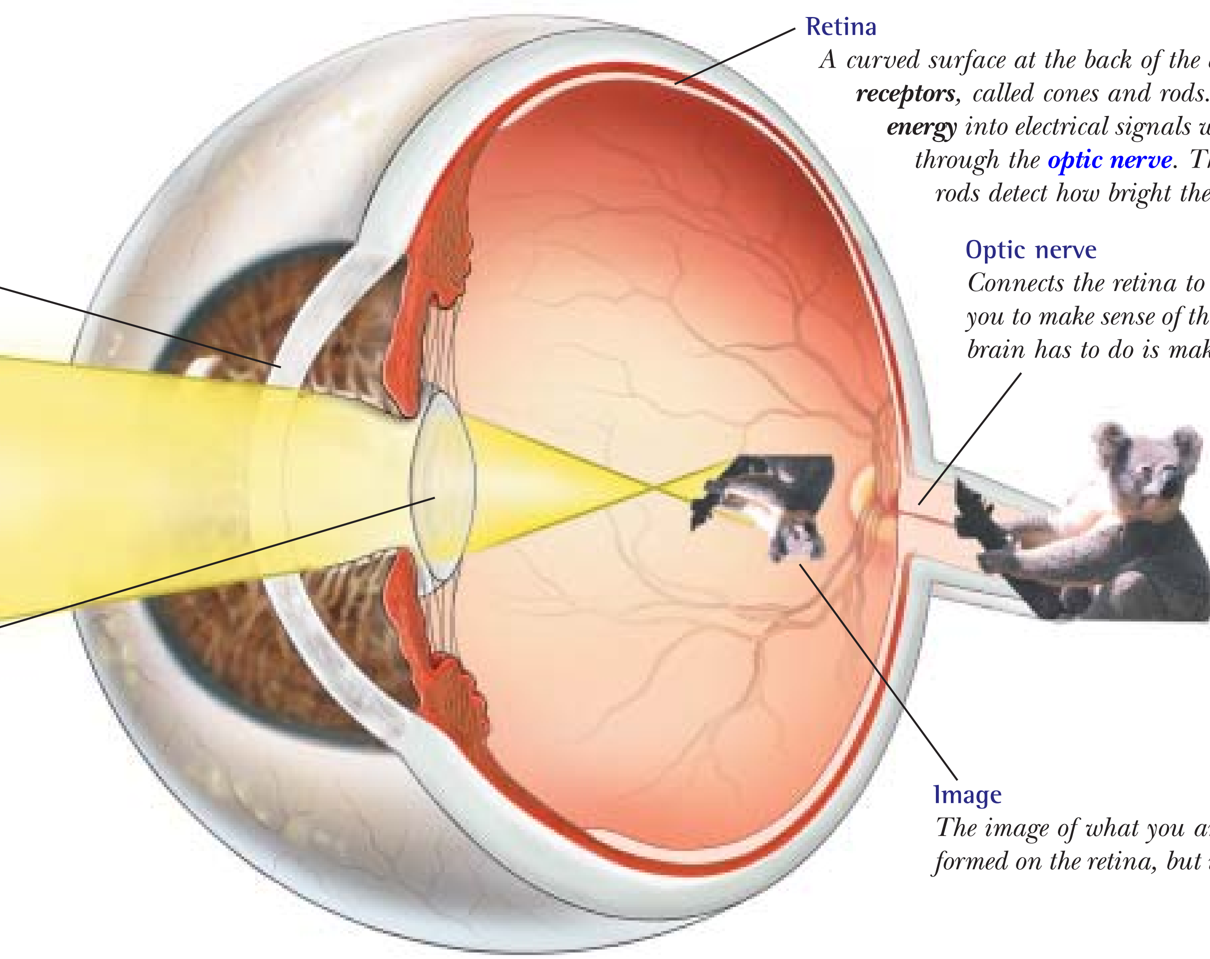
- Repeat the steps above with a thin concave lens.

3. How does a thin concave lens change the path of the light rays?

A concave lens

- Replace the thin concave lens with a thicker concave lens.

4. What difference does the extra thickness make to the path of the light rays?



Retina
*A curved surface at the back of the eye. It is lined with the sight **receptors**, called cones and rods. The receptors change light **energy** into electrical signals which are then sent to the brain through the **optic nerve**. The cones detect colour and the rods detect how bright the light is.*

Optic nerve
Connects the retina to the brain. The brain allows you to make sense of the image. One of the things the brain has to do is make the image 'right-side up'.

Image
The image of what you are looking at is formed on the retina, but it is upside down.

What's in a bullock's eye?

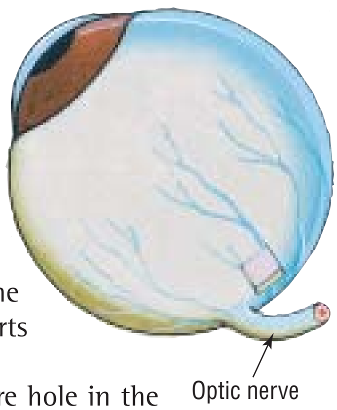
You will need:

- safety glasses
- fresh bullock's eye
- newspaper
- sharp-nose scissors
- disposable gloves and lab coat or apron
- dissection board
- paper towel
- forceps.

!CAUTION: Before beginning this experiment, make sure you read all of the initial instructions below.

1. Before beginning the experiment, make a list of safety rules that you should follow.

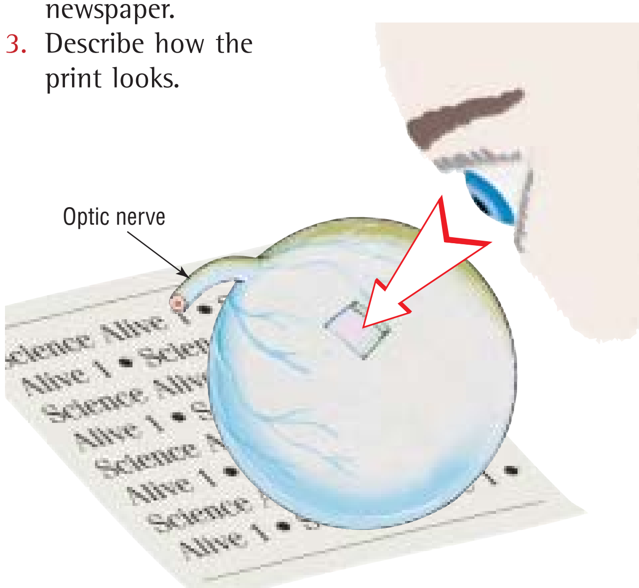
- Put on a lab coat or apron, gloves and safety glasses.
- Cover a dissection board with newspaper. Place a sheet of paper towel on the newspaper.
- Place the bullock's eye in the centre of the paper towel.
- Find the optic nerve, the cornea, the iris and the pupil.



2. Draw a diagram of the eye, labelling the parts that you found.

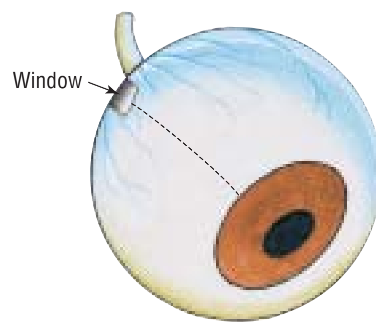
- Carefully cut a square hole in the white coating at the back of the eye near the optic nerve.
- Hold the eye just above some newspaper with the pupil facing some words on the paper. Look through the square hole and try to read the newspaper.

3. Describe how the print looks.



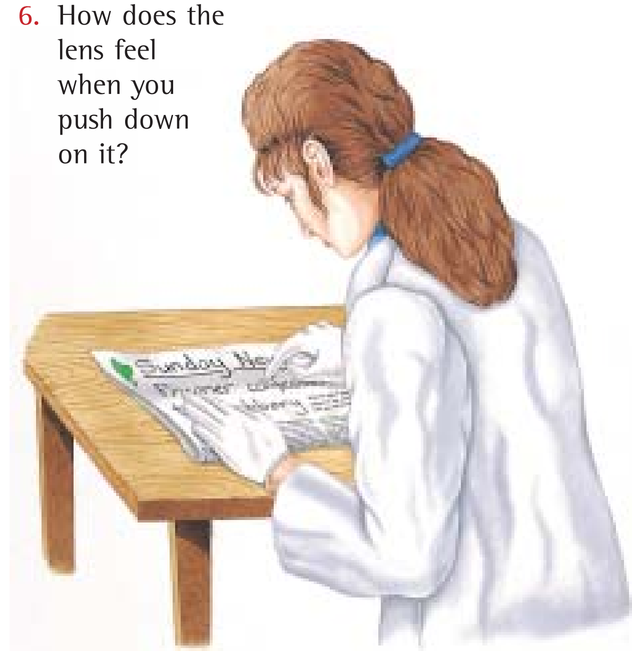
- Carefully cut from the edge of the square hole to the iris.
- Peel back the white coating and use the forceps to remove the lens and wash it with water.

4. Describe the appearance of the lens.



- Place the lens on the newspaper and look through it at some of the printed words.
- Push down gently on the lens with your finger and look for changes in the way the print looks.

5. Describe how the look of the words changes as you push down on the lens.
6. How does the lens feel when you push down on it?



Meeting new substances

When light energy travelling through the air meets a new substance, three things can happen to it:

1. it can be **transmitted**; that is, it can travel through the substance
2. it can be reflected from the surface of the substance, or reflected (scattered) from small particles inside the substance
3. it can be **absorbed**; that is, the light energy is **transferred** to the particles inside the substance.

All substances can be described by what happens to light energy when it meets them. Substances can be **transparent**, **translucent** or **opaque**.

This sheet of glass is transparent. You can see Mick through the glass because the light reflected from his face travels through the glass. That is, the glass transmits light. You can also see an image of something in the glass. That's because some of the light striking the glass is reflected — just as it would be from a mirror.

This sheet of glass is translucent. Tiny particles inside the glass scatter the light reflected from Mick's face in many directions. However, because some of the light gets through the glass without being scattered, you can still see the general shape of Mick's face.

This piece of wood is opaque. None of the light reflected from Mick's face travels through the wood. Opaque objects absorb or reflect light. Dark-coloured objects absorb more light than light-coloured objects made from the same material.

Can you see a torch beam?

You can't usually see light as it travels through the air. You don't usually see beams of light rays coming from the Sun or the lights in a room. But you can sometimes see a torch beam on a dark night. When there are lots of tiny droplets of water in the air (called fog) or small particles of smoke or dust in the air, the light from the torch hits the droplets or particles and is reflected in all directions. This type of reflection is called **scattering**. Some of the scattered light reaches your eyes. You are not actually seeing the light. You are seeing the small droplets or particles. Those droplets or particles show you the path taken by the light.

Go to worksheet 46

MI VERBAL/LINGUISTIC

Activities

Go to worksheet 47

MI VISUAL/SPATIAL

REMEMBER

1. What important job does your eye do?
2. Which three features near your eye protect it from dust and other small particles?
3. Which two parts of the eye bend light?
4. What does the iris do when you walk from bright light into a dark room?
5. What is the main job of (a) the pupil and (b) the optic nerve?
6. What special name is given to the reflection of light from many tiny particles?
7. Describe what can happen to light travelling through the air when it meets a new substance.
8. What type of substance allows the least amount of light through to the other side — transparent, translucent or opaque?

THINK

9. Why can't you usually see a beam of light from a torch at night?
10. The image on your retina is upside down. Why do you actually see things 'right-side up'?
11. How do you know that the piece of wood held by 'Mick' in the figure above left reflects some of the light that strikes it?

✓ checklist

I can:

- ☐ describe the parts of the eye
- ☐ describe how the eye forms an image of an object
- ☐ explain how light behaves when it meets a new substance.

Mirror, mirror

When you look in a mirror, you see an **image** of yourself. That's because light from the Sun or other **luminous** object bounces off your body. If some of that light is **reflected** from a smooth surface, like a mirror, you see an image of yourself. But are you seeing yourself exactly as others see you?

Flat mirrors like this are also known as **plane mirrors**. When you look at yourself in a plane mirror, you see an image.

The image in the photo above is formed because light coming from the baby is reflected from a smooth, shiny surface behind a thin sheet of glass.

The image is the same size and shape as the baby. But the way the baby sees himself in the mirror is not exactly the same as the way others see him. For example, when you look at the baby directly, his right arm is touching the mirror. When you look at the image in the mirror, it looks like his left arm is touching the mirror. His image is **laterally inverted**. In other words, it is reversed sideways.

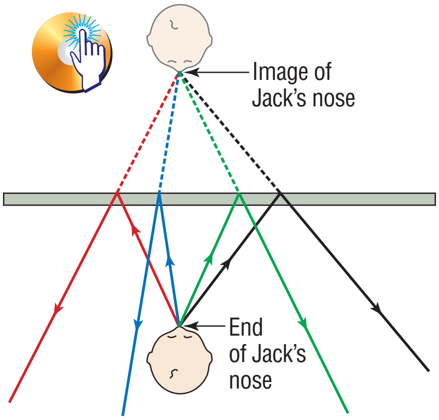
The Law of Reflection

Jenny needs to hit the centre ball with the white ball without disturbing the black ball. Luckily, she has remembered the Law of Reflection — anything that bounces from a surface comes away at the same angle from which it went in. Jenny has to work out which part of the cushion to aim for so that the 'in' angle and 'out' angle are the same.

The same law applies to light **energy** — and anything else that bounces, or is reflected from a surface.

Two kinds of reflection

You see a painted wall when you look at it because light is reflected from it. So, why can't you see an image of yourself in the wall like you can in a mirror? To answer this question you need to look very, very closely at the wall.



Light energy from the lights in the room bounces from baby Jack's nose. It is reflected from the shiny, smooth, back surface of the mirror.

The light reflected from the mirror all appears to be coming from one place. And that is exactly where the image of Jack's nose is.

*This type of reflection is called **regular reflection**.*

This type of reflection is called regular reflection.

Go to worksheet 48

HOW IT WORKS

One-way mirrors

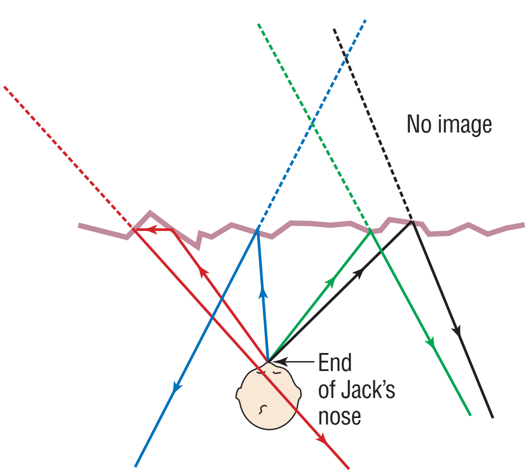
You may have seen TV shows in which a criminal is being questioned while detectives watch through a ‘one-way’ mirror.

A ‘one-way’ mirror is made from a darker type of glass than a normal mirror. The metal coating on the glass is much thinner than the coating on a normal mirror. It allows half of the light to go through. The other half is reflected. If the rooms on both sides of the mirror are well lit, you can actually see through it from both sides. The mirror becomes a one-way mirror only when the lighting is right.

The interview room is brightly lit. There is plenty of light bouncing off the suspect, the two detectives and everything else in the room. Enough reflected light goes through the mirror to allow the detectives in the viewing room to see what’s happening.

The rest of the light is reflected from the mirror. This allows the people in the interview room to see a clear image of themselves.

The viewing room on the other side of the mirror is only dimly lit. There is very little light bouncing off the detectives and the room. So these detectives can’t see themselves in the mirror. More importantly, there is not enough light going through the mirror to allow the suspect in the interview room to see who’s watching.



This type of reflection is called diffuse reflection.

Light energy from the lights in the room bounces from Jack’s nose. It is reflected from the surface of the painted wall. Notice that the Law of Reflection is obeyed wherever light meets the surface.

Because the surface is not smooth, the light is reflected in all directions. It doesn’t all appear to be coming from a single point behind the wall. There is no image of Jack’s nose.

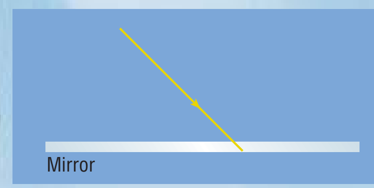
This type of reflection is called ***diffuse reflection****.*

MI LOGICAL/MATHEMATICAL

Activities

REMEMBER

1. Copy the diagram and complete it by carefully drawing the path of the light after it is reflected from the mirror.



2. Why can’t you see your image when you look at a painted wall even though it reflects light?

THINK

3. The image of the baby is formed because some of the light coming from him is reflected from the mirror. Where does this light originally come from?
4. Which of the baby’s ears is visible in the photo — left or right?
5. Write down three capital letters of the alphabet that (if you wrote them on a piece of card and held it up to a mirror) would not look any different in the mirror.
6. Why is the word ‘fire’ on the fire truck shown below printed in two different ways?

checklist

I can:
- ☐ describe images in plane mirrors
- ☐ draw a diagram to illustrate the Law of Reflection
- ☐ explain why mirrors produce images while most other surfaces do not.

Mirrors with a curve

Curved mirrors can produce some very strange **images**. If you stand in front of a curved mirror, your image can be large, small or even upside down. Some curved mirrors even allow you to see around corners. Curved mirrors obey the Law of Reflection — just as flat mirrors do. But their shape causes the image they produce to be quite different from a flat-mirror image.

Mirrors that are curved outwards are called **convex mirrors**. These mirrors collect light from a wide angle and **reflect** it towards your eyes. The images in convex mirrors are smaller than those in a plane mirror. But there is one other difference. What is it?

Mirrors that are curved inwards are called **concave mirrors**. The images in concave mirrors can be large, small or upside down. Dentists use a concave mirror on a handle to get a magnified view of your teeth. A dentist's mirror is not curved as much as this soup spoon.

Describing mirror images

You will need:
convex and concave mirror or a polished spoon
2 plane mirrors
glue stick or similar small object.

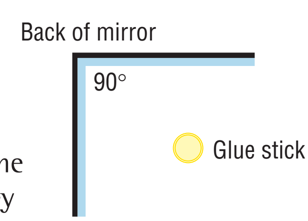
- Look at an image of yourself in a convex mirror. Move the mirror towards yourself and then further away to see how the image changes.

1. How is the image in the convex mirror different from your image in a plane mirror?

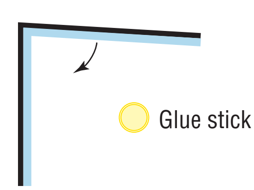
- Repeat the same observations with a concave mirror.

2. How is the image in the concave mirror different from your image in a plane mirror?
3. How does the image in a concave mirror change as your face gets closer to the mirror?

- Place two plane mirrors at right angles to each other and stand a glue stick between them. Look at the images of the glue stick.



4. How many images are there?
5. Are all of the images exactly the same? If not, explain how they are different.
6. Why do you think there are more than two images? (You'll need to think hard about this one!)

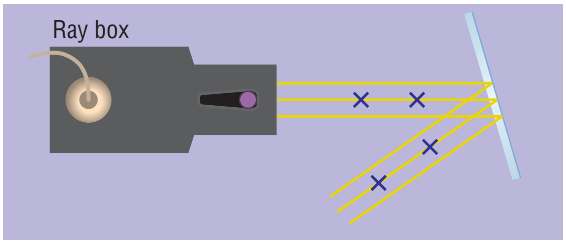


- Move the mirrors to gradually make the angle between them smaller.

7. What happens to the number of images as the angle between the mirrors gets smaller?

How does light behave when it meets different mirrors?

You will need:
ray-box kit
12 V power supply
sheet of white paper
ruler
pencil
protractor.



- Place the ray box on the edge of a sheet of white paper and connect it to the power supply.
- Put a plane mirror about 5 cm in front of the ray box.
- Draw a pencil line on the paper to show where the back of the glass part of the mirror is. You will need to move the mirror while you do this. Make sure that you put it back in exactly the same place.
- Use the pencil to mark two points on one **light ray** going into the mirror. Do the same for the ray as it goes away from the mirror.
- Remove the mirror and complete your ray diagram by drawing the path of the rays towards and away from the mirror. Use a ruler to draw the light rays.
- Use a protractor to measure the angle between the incoming ray and the mirror. Then use it to measure the angle between the outgoing ray and the mirror.

1. Are the angles the same? Is the Law of Reflection obeyed? If the angles are not the same, explain why you think they are different.

- Turn the sheet of paper over. Replace the plane mirror with a convex mirror and observe how the three rays are reflected.
- Look closely at where each ray meets the surface of the mirror.

2. Does it look like the Law of Reflection is obeyed at the surface of the convex mirror?

- Replace the convex mirror with a concave mirror.
- Again, look closely at where each ray meets the mirror surface.

3. Does it look like the Law of Reflection is obeyed at the surface of the concave mirror?
4. Trace the shape of the front of the concave mirror and the paths of the rays towards and away from the mirror.

- The point where the reflected rays meet is called the **focus**, or focal point. Label the focus on your diagram. The **focal length** of the mirror is the distance between the mirror and the focus. Measure the focal length of the concave mirror and write it down on your diagram.
- Replace the concave mirror with another one that is either more curved or less curved.

5. What happens to the focus if you use a concave mirror that is more curved?

- Turn off the light box and let it cool down while you answer the next two questions.

6. Which shaped mirror reflects light energy so that it spreads out?
7. If a mirror were used to reflect sunlight to cook a sausage, what shape would it need to be — plane, convex or concave?

Activities

REMEMBER

1. In which shaped mirror/s:
   (a) can you see an upside-down image of yourself?
   (b) can you always see an image that is smaller than the image in a plane mirror?
   (c) is the image always right-side up?
   (d) is the Law of Reflection obeyed?
2. Which shaped mirror:
   (a) spreads light out?
   (b) brings light rays together?
3. What is special about the focus, or focal point, of a concave mirror?

THINK

4. Describe the shape of the mirror in the photo at the top of the previous page.
5. Which shaped mirror could be used:
   (a) to make a solar reflector to heat food?
   (b) to allow you see around corners?
6. Why is a convex mirror used at the worksite shown at far left instead of a plane mirror?
7. A searchlight is designed to produce a beam that does not spread out. The lamp of a searchlight is placed in front of a large curved mirror. Would you expect the mirror of a searchlight to be concave or convex?

checklist

I can:
- ☐ describe the images in convex and concave mirrors
- ☐ list some uses of convex and concave mirrors, and relate their use to the way they reflect light.

Sound energy

In 1883, the Indonesian island of Krakatoa was blown apart by a volcanic explosion. The sound of the explosion was probably the loudest that human ears have ever detected. It was heard as far away as South Australia. That's over 3000 kilometres away! How did the sound travel such a huge distance?

Vibrations everywhere

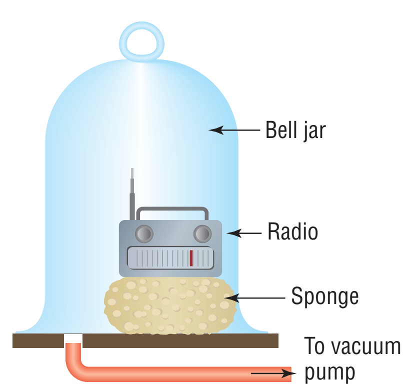
Sound is caused by fast, back-and-forth movements called **vibrations**. When you strike a drum, the drumskin vibrates. The movements of the drumskin cause air particles to be pulled back and spread out. A fraction of a second later, the air particles are pushed together. This pulling and pushing of air particles continues until the drumskin stops vibrating. The energy of the vibrating drumskin is **transferred** to the nearby air particles. So the air particles vibrate just as quickly as the drumskin vibrates.

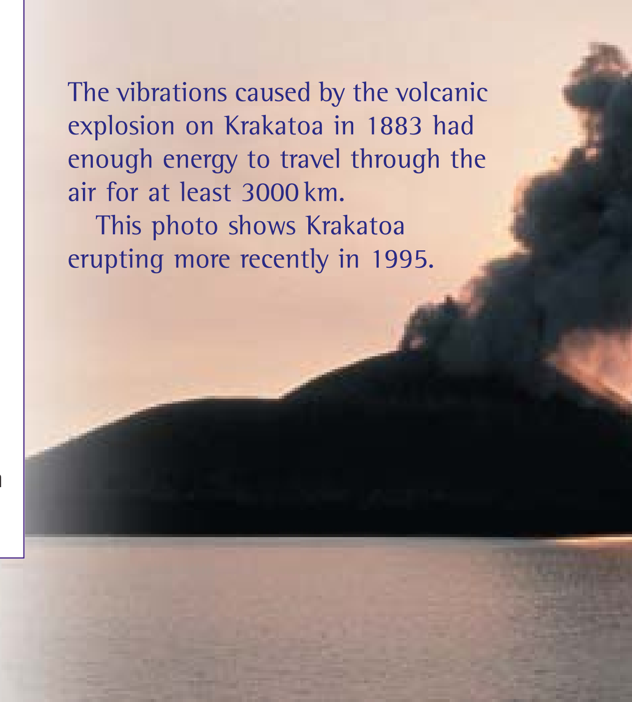
The vibrating air particles bump into other air particles, making them vibrate as well. If there is enough **energy** in the vibrating air, the vibrations are passed on all the way to your ear. If the vibrations reach your ear, you hear sound.

Sound silenced

HOW ABOUT THAT!

When a loud radio is played in a bell jar, the sound can be heard clearly. When the air in the bell jar is sucked out by a vacuum pump, the sound fades. If all of the air is removed, no sound can be heard at all. Sound cannot travel through empty space. The energy of vibrating objects can travel only by making particles vibrate. In empty space, there are no particles to vibrate. Unlike sound, light can travel through empty space. It doesn't need particles. So you can still see the radio, even if you can't hear it.





The vibrations caused by the volcanic explosion on Krakatoa in 1883 had enough energy to travel through the air for at least 3000 km.

This photo shows Krakatoa erupting more recently in 1995.

When lightning strikes during a thunderstorm, a giant electric spark heats the air around it. The hot air quickly expands, crashing into the cold air around it. The sound of that crash is thunder. So why do you always hear thunder AFTER you see the lightning? The answer lies in one of the differences between sound energy and light energy. Sound travels through air at a speed of about 340 m/s. Light travels through air at a speed of 300 000 km/s.

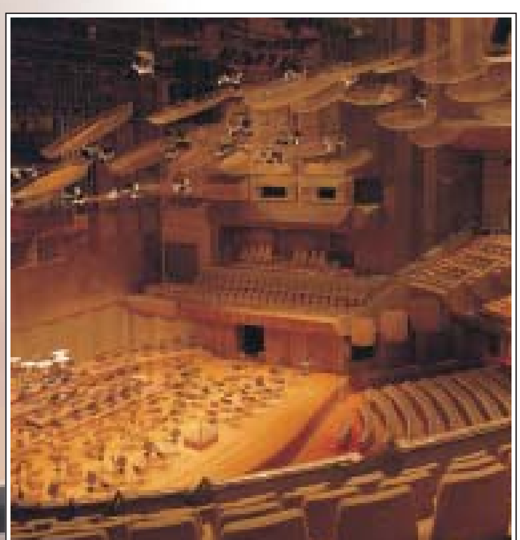
The delay between seeing lightning and hearing thunder is about three seconds for each kilometre that you are away from the lightning.

Sounding great

Like light, sound can be **transmitted**, **reflected** and **absorbed**:

- All materials transmit some sound, some better than others. That's why you can sometimes hear conversations from another room through the walls.
- Sound is reflected by hard surfaces like the tiles in bathrooms and showers. Each note that you sing in the shower lasts longer because its sound is reflected. This effect is called **reverberation**.
- Soft materials, like curtains and carpet, absorb much more sound than walls of tiles or plaster.

The Melbourne Concert Hall is designed to control the transmission, reflection, and absorption of sound. The inner walls are designed to make sure that unwanted noise is not transmitted from outside. The 30 perspex plates above the stage control how much sound is reflected to different parts of the hall. To control the amount of sound absorbed there are 22 woollen banners around the hall. The banners are lowered to allow more sound to be absorbed. Heavy curtains behind the audience can also be closed to increase the amount of sound absorbed.



Activities

REMEMBER

1. What causes sound?
2. Why can't sound travel through empty space?
3. Which form of energy travels faster in air — light or sound?
4. What types of surface cause reverberation?

THINK

5. When sound energy reaches a wall, there are three things that can happen to it.
   (a) What are those three things?
   (b) Which one or more of these things can also happen to light energy?
6. If you see lightning, then hear thunder 9 seconds later, how far are you from the lightning strike?
7. How could two astronauts repairing the outside of a space shuttle talk to and hear each other without using radios?
8. Imagine if light could not travel through empty space. What would you observe if air was removed from a bell jar containing a radio playing loudly?

INVESTIGATE

9. You can feel your vocal cords vibrate if you place your hand gently over your throat while you talk. Say a long 'hummmm' in a deep voice and feel the vibrations. How do the vibrations change when you say 'hummmm' in:
   (a) a louder voice?
   (b) a higher voice?

✓ checklist

I can:

- ☐ explain how sound is produced and how it travels through the air
- ☐ describe two differences between the way light and sound travel
- ☐ give examples of the transmission, reflection and absorption of sound.

Your ears and hearing

The main job of your ears is to detect sound. They collect the **energy** of vibrating air and change it into electrical signals that are sent to your brain. Each ear has three main parts — the outer ear, the middle ear and the inner ear. Each part has its own special job to do.

Middle ear

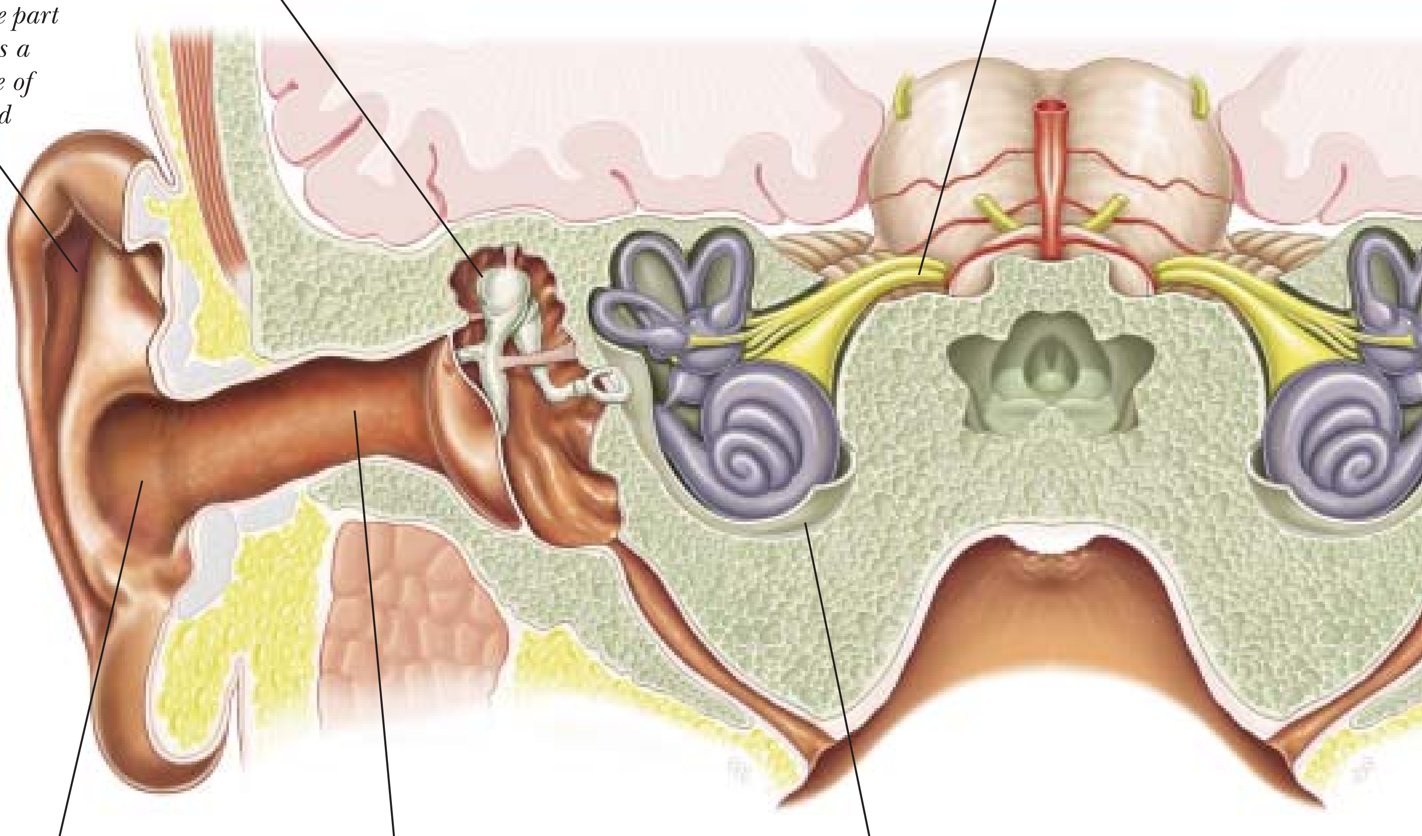
*The middle ear contains the three smallest bones in your body. Together, they are known as the **ossicles**. These tiny bones send **vibrations** from the **eardrum** to the inner ear. They also make the vibrations larger. One of the ossicles (the stirrup) presses against a thin layer of skin called the **oval window** at the entrance to the inner ear.*

Auditory nerve

*Nerves from the **receptors** in the **cochlea** merge together to form this large nerve that sends signals to the brain.*

Auricle

The outside part of the ear is a spongy type of tissue called cartilage.



Outer ear

*The outer ear collects the energy of the vibrating air and funnels it along the **ear canal**. The air along the ear canal vibrates. That makes the eardrum vibrate. High-pitched sounds make the eardrum vibrate quickly. Low-pitched sounds make the eardrum vibrate slowly.*

Ear canal

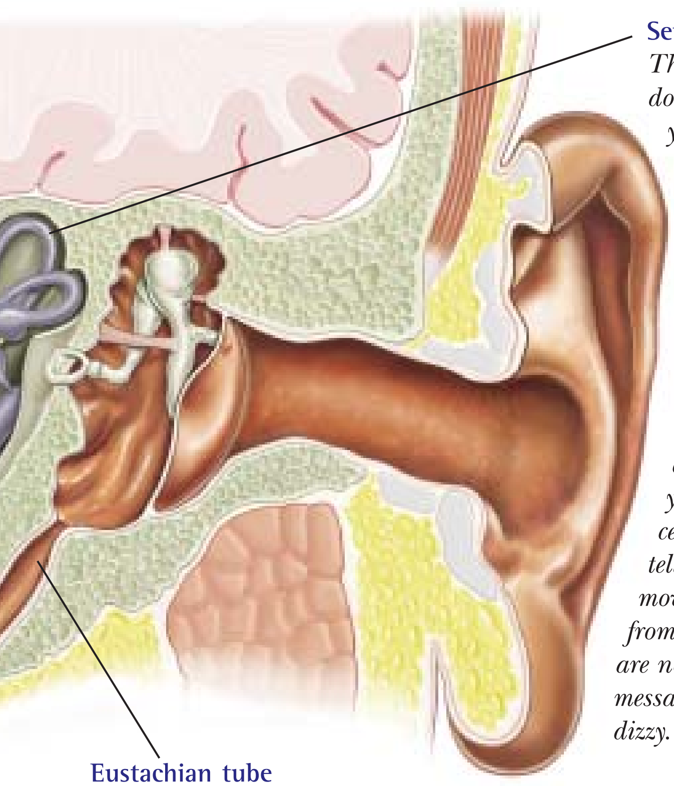
Contains wax and tiny hairs to trap dust so that it doesn't get to your eardrum. Don't try to remove the wax. It's there to protect your eardrum. If it builds up enough to block your ear canal, a doctor can remove it for you.

Inner ear

*The inner ear is filled with fluid. The vibrations are passed along the fluid into a snail-shaped tube called the cochlea. The inside of the cochlea is lined with millions of tiny hairs. Each hair is attached to a receptor. When the fluid vibrates, the hairs move. The receptors change the energy of the moving hairs into electrical energy and send signals through the **auditory nerve** to the brain. You interpret those signals as sound.*

Aye-aye

The aye-aye is a rare animal that lives on the island of Madagascar. It feeds at night and has goggle eyes and huge ears. The aye-aye searches for food by tapping one of its stick-like fingers on tree trunks. It listens to the sound as vibrations go through the wood. The sound tells it where gaps, cracks and hollows are under the bark and where tasty grubs are hiding. Then it chews through the wood and hooks out the grub with its long middle finger.



Semicircular canals

These three tubes have nothing to do with hearing. They control your sense of balance. When you move, fluid in the tubes flows past cells that sense the movement. These cells send signals to the brain. The signals tell you when you are moving and whether you are up, down or on your side. When you move around in circles quickly, the fluid moves quickly — even for a while after you stop. The messages from the cells in the ***semicircular canals*** *tell your brain that you are still moving. However, the messages from your eye tell the brain that you are not moving. These mixed messages to the brain make you feel dizzy.*

Eustachian tube

This tube joins the middle ear to the nose and throat. It is usually closed. When the air ***pressure*** *on the eardrum is not the same on both sides, the tube opens. Air then moves either into or out of the middle ear until the pressure is balanced again.*

When the air pressure on one side of the eardrum changes quickly, you can feel a 'pop' as the ***Eustachian tube*** *opens and air rushes through it. This happens when you are in a plane that is climbing steeply. The air pressure in the plane becomes less than the air pressure in your middle ear. The Eustachian tube then opens and some air moves from the middle ear to the nose and throat so that the air pressure on your eardrum is balanced. You can also feel the 'pop' just before you land, because the air pressure in the plane increases. The tube opens again and air rushes into your middle ear from your nose and throat to balance the pressure outside your eardrum.*

Activities

REMEMBER

1. Why does the ear canal contain wax and hairs?
2. What is the job of the outer ear?
3. How do the ossicles change vibrations?
4. In which part of the inner ear are the receptors for hearing?
5. How do receptors in the inner ear detect the vibrations that arrive from the outer ear?
6. Part of the inner ear has nothing to do with hearing:
   (a) Which part is it?
   (b) What important job does this part do?

THINK

7. Why shouldn't you try to remove wax from your ear canal yourself?
8. Why do you think there are three semicircular canals rather than just one?

SKILLBUILDER

9. Design an experiment to find out the direction from which a sound is coming. Try your experiment with high-pitched sounds and low-pitched sounds to see if the pitch makes any difference.

INVESTIGATE

10. Apart from the aye-aye, what animals have big ears? What are they used for apart from hearing?

checklist

I can:

- ☐ describe the main parts of the human ear and what they do
- ☐ explain how the human ear changes the energy of vibrating air into signals that we hear as sound.

Measuring sound

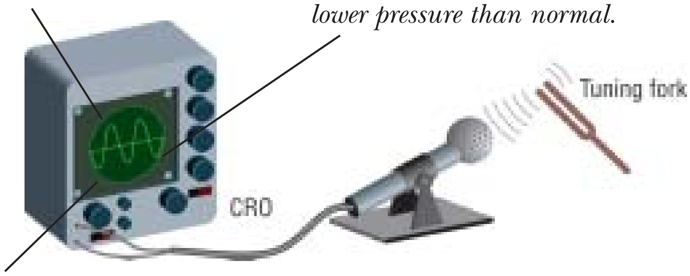
You can't see sound, but that doesn't mean you can't measure it. Fortunately, sound **energy** can be converted into electrical energy. That means that we can measure how quickly it makes the air **vibrate** and how much the air is squashed up as sound passes. These measurements tell us how high or low a sound is and how loud it might sound.

Pictures of sound

A **cathode ray oscilloscope** (CRO) changes sound energy into electrical energy. The shape on each screen is called a **waveform**. It shows how the air **pressure** changes when the sound passes the microphone.

This peak represents air that has been compressed (squashed up). It is at a higher pressure than normal.

This trough represents air that is spread out. It is at a lower pressure than normal.



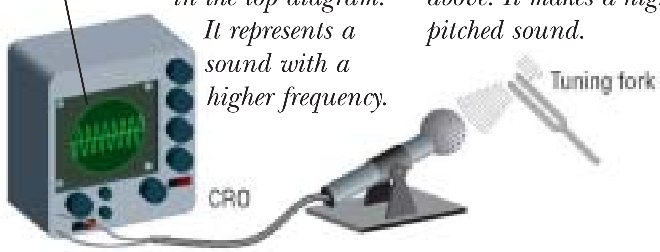
Taller waveforms represent louder sounds. That's because louder sounds change the air pressure more than soft sounds do.

The **pitch** of a sound depends on how quickly it makes the air vibrate. High-pitched sounds make the air vibrate quickly, so the air pressure changes quickly. As a result, they produce 'bunched-up' waveforms. Low-pitched sounds make the air vibrate less quickly, so the air pressure changes more slowly. The waveforms are more spread out.

The number of times that a sound makes air vibrate every second is called its **frequency**. Frequency is measured in a unit called **Hertz** (Hz). Higher frequencies sound more highly pitched than low-frequency sounds.

This waveform is more 'bunched-up' than the waveform in the top diagram. It represents a sound with a higher frequency.

This tuning fork vibrates faster than the one above. It makes a higher pitched sound.



How does the size of vibrating objects affect the sound they make?

You will need:
ruler
2 clean, different-sized test tubes.

- Hold a ruler firmly over the edge of a table so that about half of it overhangs the table. Flick the ruler so that it vibrates.
- Change the position of the ruler so that less of it overhangs the table and flick it again.

1. What happens to the pitch of the sound when the length of the vibrating part of the ruler becomes shorter?

- Blow across the mouth of a large, empty test tube and listen to the sound.

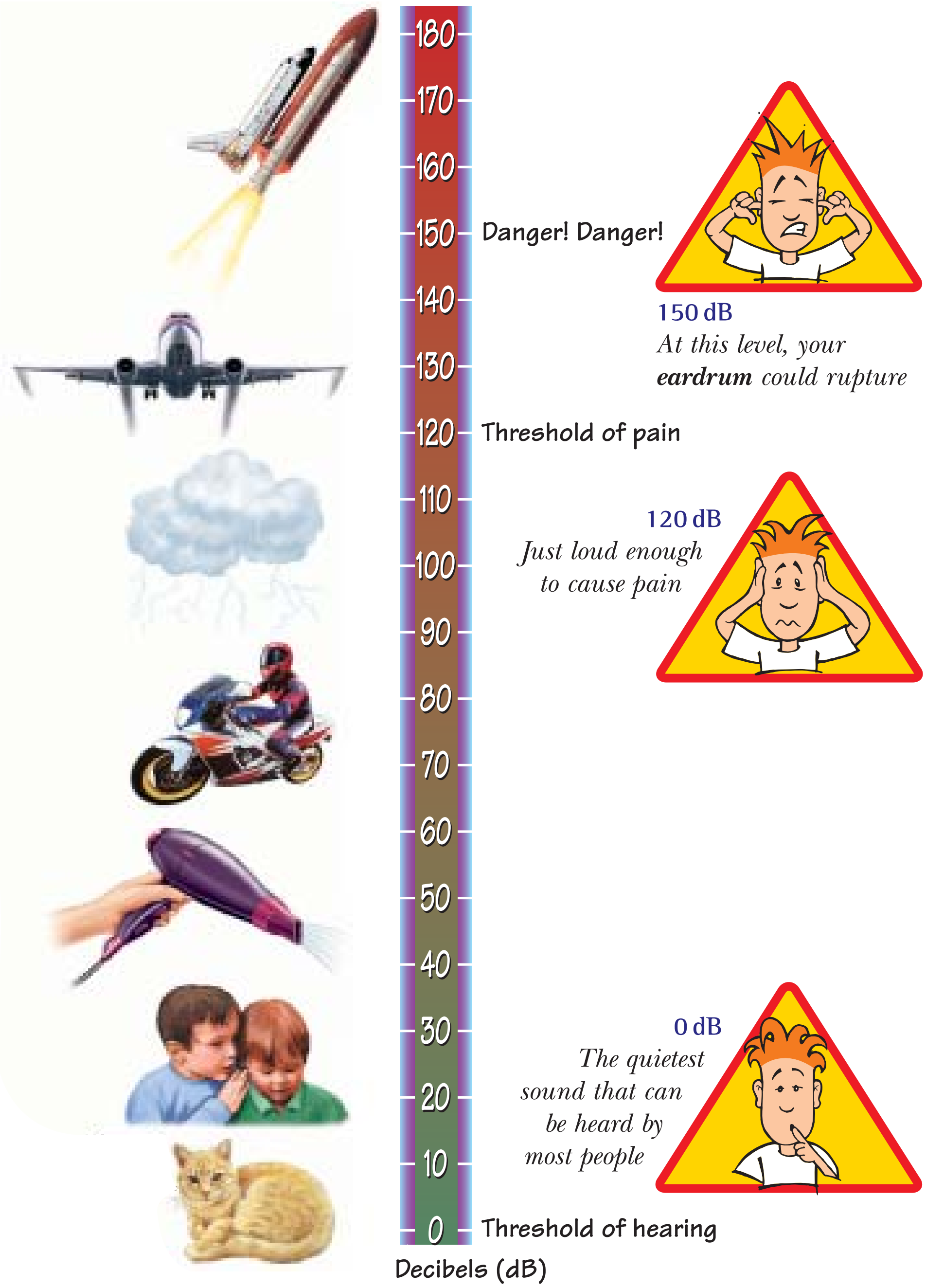
2. What happens to the air inside the test tube when you blow across its mouth?

- Blow across the mouth of a smaller test tube.

3. How is the sound of the small test tube different from that of the larger test tube?
4. How does the size of vibrating objects appear to affect pitch?

Turn that music down!

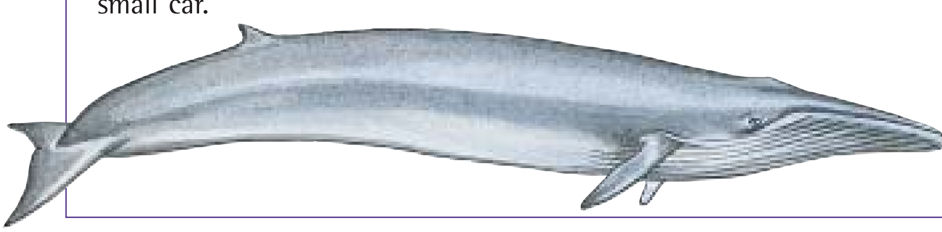
The loudness of a sound is sometimes a matter of opinion. But there is a way to measure how much the air is disturbed by a sound. This measurement, called **sound level**, is made in **decibels** (dB). The number of decibels gives a good indication of loudness.



Very loud noises (greater than 120 dB) can cause pain and damage your ear. Even long periods of listening to noise with a sound level more than about 80 dB can damage your inner ear. You should always wear earmuffs when using noisy machines like chainsaws.

HOW ABOUT THAT!

The calls of the blue whale can be even louder than the launch of a space shuttle, with sound levels of more than 180 dB. That's not surprising when you consider that its tongue can weigh more than an elephant and its heart can be the size of a small car.



Go to worksheet 49

MI MUSICAL/RHYTHMIC

Activities

REMEMBER

1. Why do louder sounds produce taller waveforms on the screen of a cathode ray oscilloscope?
2. What is the unit of frequency?
3. What happens to the pitch of a sound when its frequency is increased?
4. What is the name of the quantity that is measured in decibels?
5. What is the sound level of the softest sound that most people can hear?

THINK

6. Which of the two waveforms (top or bottom) displayed on the cathode ray oscilloscope screens in the figures on the far left is caused by:
   (a) the loudest sound?
   (b) the highest pitched sound?
7. If a dog barks to produce a sound with a frequency of 400 Hz, how many times does the air near the dog vibrate every second?
8. The sound level of chainsaws is below the threshold of pain. Why is it necessary to wear ear protection while using a chainsaw?

SKILLBUILDER

9. Use a sound-level meter to measure the sound level in decibels at a range of places and times around your school. Your results could be displayed in a graph like the one on this page.

checklist

I can:

- ☐ use a variety of equipment to measure sound
- ☐ explain what is meant by the frequency of a sound
- ☐ recognise situations in which ear protection is necessary.

Checkpoint

Sound technology

We all know that sound **energy** allows us to hear, but did you know that we can use sound to look inside things — including the human body? **Ultrasound** is used to treat muscle injuries and other medical problems. We also use sound to map the depths of the ocean floor.

Ultrasound

Sound with **frequencies** higher than those that humans can hear is called ultrasound. This **image** of an unborn baby was produced with ultrasound. To produce images like this, ultrasound is sent through the mother's body. Some of it is **reflected** from the baby. A computer is used to change the reflected ultrasound into an image. The images are used to check for problems during pregnancy.

Ultrasound is also used to check for cracks in metal; drill holes in glass and steel; and join metals together.

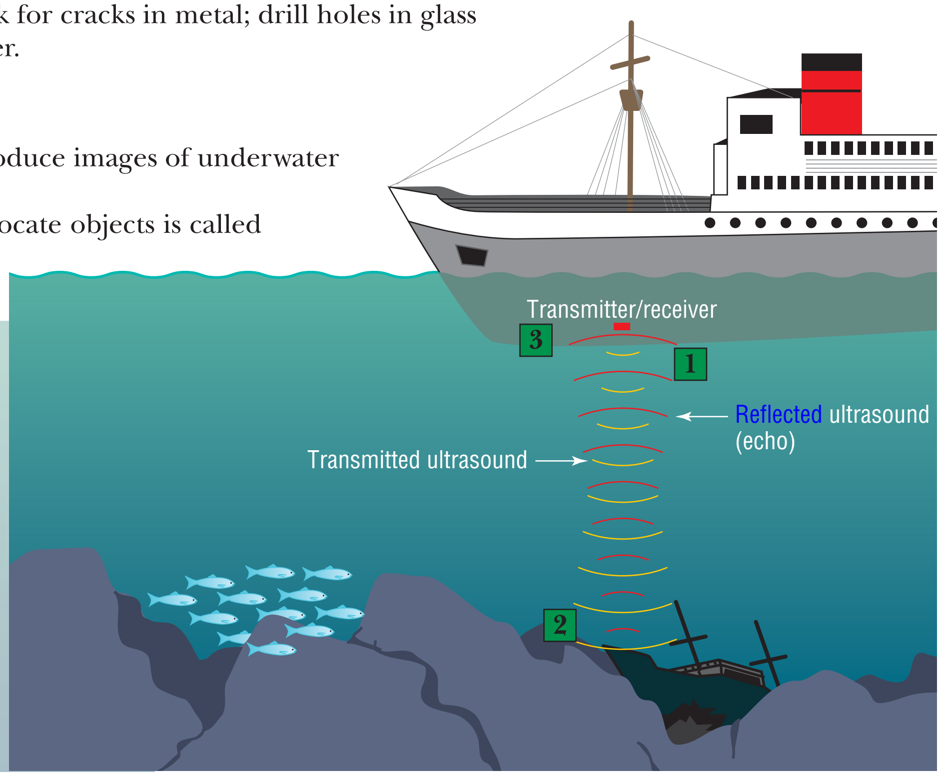
Catching prey in the dark

Bats use ultrasound to find their prey in the dark. The ultrasound they emit from their nostrils is reflected from insects. Bats can tell from the reflected ultrasound, or **echo**, exactly where their prey is. The further away the insects are, the longer it takes the echo to return to the bat. The echo from more distant insects is also fainter. This use of echolocation by bats is called **biosonar**.

Seeing without seeing

Ultrasound is used in **sonar** to produce images of underwater objects or the ocean floor.

The use of reflected sound to locate objects is called **echolocation**.



1 *Ultrasound is sent down into the water.*

2 *Objects under the water (and the ocean floor) reflect some of the ultrasound.*

3 *A receiver detects the reflected ultrasound.*

A computer uses the time taken for the reflected ultrasound to return to the ship to calculate the depth of objects in the water. It can also map the ocean floor.

Go to worksheet 50

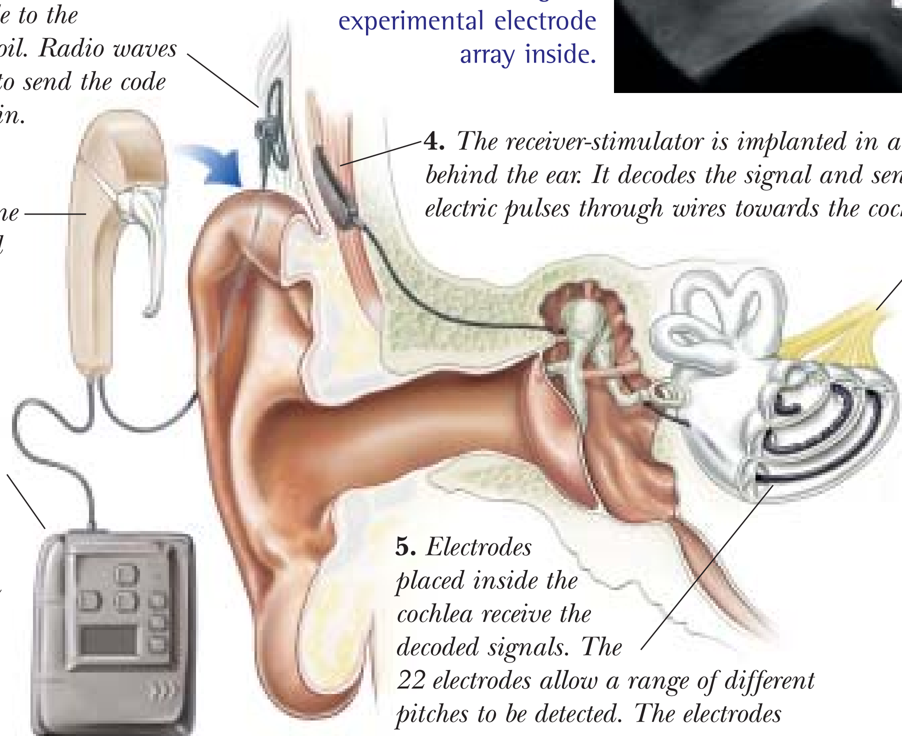
MI INTERPERSONAL

HOW IT WORKS

The bionic ear

The **cochlear implant**, also known as the bionic ear, has allowed some people with inner-ear problems to hear sound for the first time. When deafness results from serious inner-ear damage, no sounds are heard at all. Normal hearing aids that make sound louder will not help because the **cochlea** cannot detect the **vibrations**. However, in many cases, the cochlear implant can help. The cochlear implant changes sound energy from outside the ear into electrical signals that can be sent to the brain.

An enlarged X-ray of the cochlea showing the experimental electrode array inside.



1. *A microphone is worn behind the ear.*

2. *The speech processor changes the sound into an electrical code. It can be worn on a belt or a smaller version can be built into the microphone and worn behind the ear.*

3. *The electrical code is sent through a cable to the transmitting coil. Radio waves are then used to send the code through the skin.*

4. *The receiver-stimulator is implanted in a bone behind the ear. It decodes the signal and sends electric pulses through wires towards the cochlea.*

5. *Electrodes placed inside the cochlea receive the decoded signals. The 22 electrodes allow a range of different pitches to be detected. The electrodes stimulate the* ***hearing receptors****.*

6. *The hearing receptors send messages through the* ***auditory nerve*** *to the brain. The sound heard by the user is not completely natural because there are only 22 electrodes replacing the tens of thousands of hair cells in the cochlea of a normal ear.*

Activities

REMEMBER

1. What is the difference between sound that we hear and ultrasound?
2. List two medical uses of ultrasound.
3. How does ultrasound enable bats to locate insects?
4. What do the electrodes in the cochlear implant replace?

THINK

5. Why is the use of sound to locate objects called echolocation?
6. In the case of bats, which sense does the use of biosonar replace?
7. Why can't hearing aids help people with a seriously damaged cochlea?

CONNECT

8. Go to www.jaconline.com.au/science/weblinks and click on the Bionic Ear link for this textbook to find out more about the cochlear implant.

checklist

I can:
- ☐ describe ultrasound and list some of its uses
- ☐ explain what is meant by echolocation
- ☐ explain how the bionic ear works.

Solar System Gazette

MONDAY 9 SEPTEMBER 1999 WEATHER: JUPITER SURFACE — COLD, –140 °C

Extra-terrestrial life?

Washington: Scientists have released evidence of what they think could be life on Europa, the fourth largest moon of the planet Jupiter. Until 1979, when the *Voyager* space probes photographed Europa, little was known about its surface. But recent photographs taken by NASA's *Galileo* spacecraft have provided enough detail to make scientists think that there could be an ocean, and maybe even life, under the sheet of ice.

NASA is planning to launch a new space probe to try to solve the mystery of what is below the icy surface of Europa. The probe, called *Europa Orbiter*, is due to leave Earth in 2008. After a three-year journey from Earth, *Europa Orbiter* will go into orbit around Europa. It is not designed to land on the surface. It will begin by finding out whether the ocean exists, how deep it is and how thick the sheet of ice is.

If water is found beneath the ice on Europa, NASA is likely to send space probes that can land. They would carry special robots. A cryobot, an ice-melting robot, would drill down into the ice. Then a hydrobot with a camera and chemical sensors would explore the mysterious ocean.

If there is water on Europa, it is possible that there might be some form of life. Every year more and more unusual micro-organisms are discovered living in unexpected places on Earth. Some found near the vents of hot, underwater volcanoes live without sunlight or oxygen, at temperatures of 105 °C. Not that long ago, people thought this was impossible. Perhaps similar life exists on the strange and distant moon of Europa?

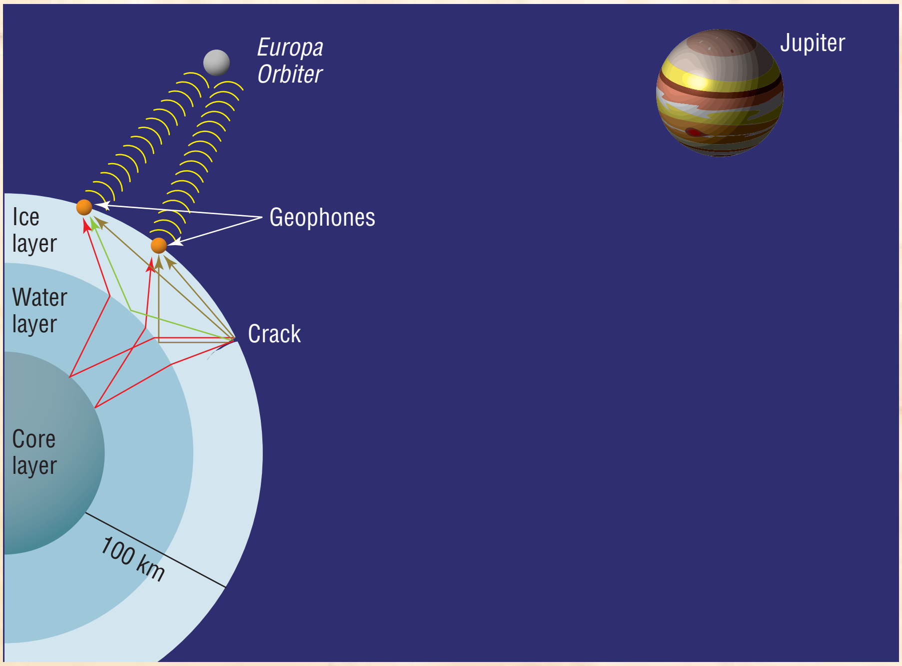
Eavesdropping from 680 million km

The challenge facing NASA scientists is how to find out if there is water under a sheet of ice that could be 10, 50 or even 100 km thick. Even on Earth that would be difficult. But Jupiter and its moons are 680 million kilometres away!

Europa Orbiter's first task will be to use radar to find out if there is water under the ice. If it does find water, the next part of the challenge begins. It must explore a thick sheet of ice and the ocean below it without landing.

Exploring with sound

Giant cracks appear in the ice on the surface of Europa about twice every minute. Each crack creates a very loud noise on the surface. The sound then travels down through the ice. Some of it bounces back when it reaches the ocean, causing an **echo** at the surface. Some of the sound bounces back when it reaches the moon's hard core, causing a second echo. The amount of time that passes between the original cracking sound and the two different echoes can be used to work out the thickness of the ice and the depth of the ocean.



There will be two echoes — one from the bottom of the ice and another from the bottom of the ocean.

To listen to these echoes, scientists will put special microphones (called geophones) in the ice on Europa's surface. Because the *Europa Orbiter* will not land on Europa, the geophones will probably be carried to the surface by rockets.

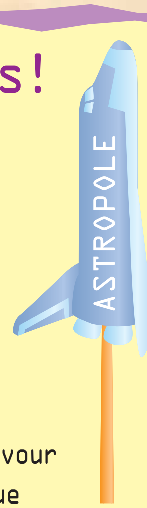
Astronomically delicious!

Icy poles delivered to your home —
all the way from Europa, Jupiter

All natural, all pure ice

Available in three taste sensations
* Surface bliss
* Shallow mallow
* Deeply delicious

The deeper its icy origins, the deeper the flavour
Non-stick astropoles — gentle on your tongue



Activities

REMEMBER

1. Where on Europa is the ocean believed to be?
2. How long will it take the space probe *Europa Orbiter* to travel from Earth to Europa?
3. Explain how sound is used to measure the thickness of the ice on Europa and the depth of the ocean beneath it.
4. What is a geophone?

THINK

5. How many loud noises will a geophone detect each time the ice surface cracks?
6. What discoveries on Earth make scientists more hopeful of finding life on Europa?

INVESTIGATE

7. Radar will be used to check if there is an ocean under Europa's ice before geophones are sent down to detect sound. Radar uses radio waves rather than sound.
   (a) Find out what radar is and how it works.
   (b) What is the difference between radar and sonar?

CONNECT

8. Go to www.jaconline.com.au/science/weblinks and click on the Jupiter link for this textbook to find out more about the discoveries about the moons and rings of the planet Jupiter made by the *Galileo* space probe.

✓ checklist

I can:
- ☐ explain how sound waves can show what lies beneath thick ice
- ☐ describe the surface of Europa
- ☐ explain why scientists think that Europa could support life.

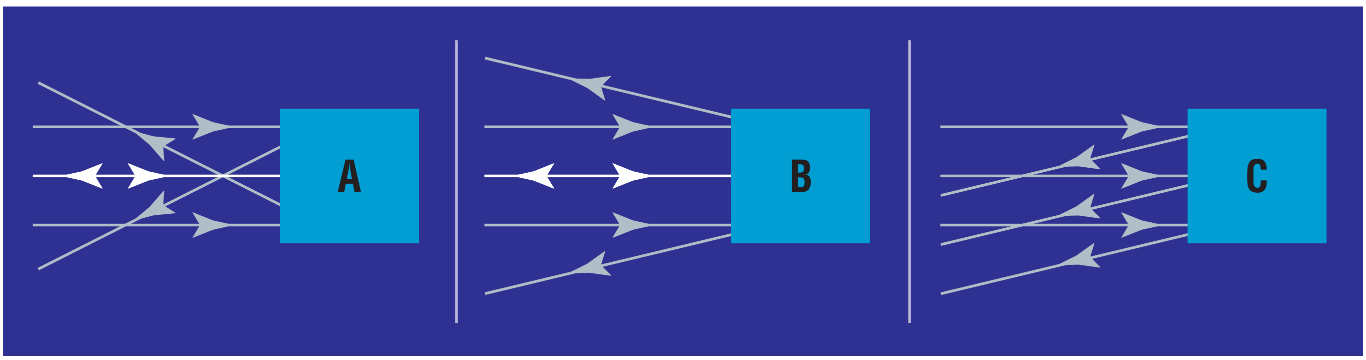
Check and challenge

LIGHT AND SOUND

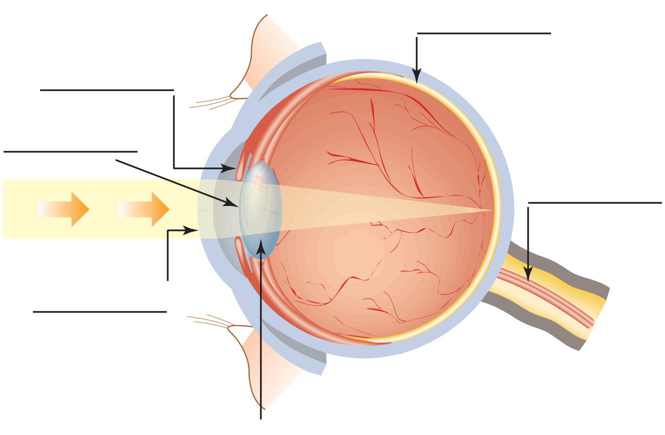
Check

Changing the path of light

1. Three narrow beams of light are directed at some mystery objects. The objects are covered with a card so light can get in and out, but you can't see them. There is only one object under each square. Name and describe the object under each square.



2. (a) Why is a concave mirror useful as a solar reflector?
   (b) Use a diagram to show how a convex mirror can be used to see around corners.
3. Identify the parts of the eye that enable you to see images of the objects you look at.

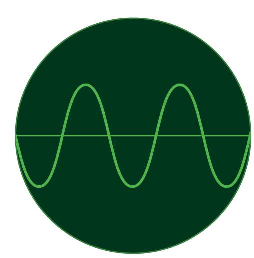


Looking at images

4. Write your own name in capital letters so that it would read correctly when you are looking at it in a plane mirror. Test it to see if you wrote it correctly.
5. Explain why you see images in a mirror while you can't see images in most other flat surfaces.
6. Which shaped mirror (plane, concave or convex) can produce images that are:
   (a) upside down compared to the object in front of the mirror?
   (b) always smaller than the object in front on the mirror?
   (c) the same shape and size as the object in front of the mirror?
   (d) larger than the object in front of the mirror?

Sound

7. The waveform shown has been produced by plucking a string on an electric guitar.
   (a) Make a copy of the waveform.
   (b) In another circle of the same size, draw a waveform that shows a louder sound.
   (c) In another circle of the same size, draw a waveform that has a higher pitch than the original waveform.



8. (a) What quantity is a measure of the number of times an object vibrates every second?
   (b) How does a sound change when this quantity increases?
9. What is ultrasound?
10. List at least five uses of ultrasound.

Comparing light and sound

11. Copy and complete the table below and use ticks to show which statements refer to light and which refer to sound. Some of the statements apply to both light and sound.

	Light	Sound
Travels through empty space at 300 000 km/s		
Can be reflected		
Always caused by vibrating objects or substances		
Can travel through transparent substances		
Cannot travel through opaque objects		
Can be measured in decibels		
Can only be produced from another form of energy		
Is detected by receptors in the human body		
Travels faster than a speeding bicycle		

Seeing and hearing

12. How do we see objects that don't produce their own light?
13. When you blow across the top of a plastic drinking straw, you hear a sound. What could you do to the straw to make a more highly pitched note?
14. Copy and complete the table below to describe the main parts of the eye and ear and what they do.

Part	Eye or ear?	What it looks like	What it does
Auditory nerve			
Auricle			
Cochlea			
Cornea			
Eardrum			
Iris			
Lens			
Optic nerve			
Ossicles			
Pupil			
Retina			

Where is it?

1. Where is your image in a plane mirror? Stand in front of a mirror and hold a length of measuring tape or ruler to the mirror. Look at the image of you AND the measuring tape or ruler. How far behind the mirror is your image? Compare this to how far in front of the mirror you are.

The issue of speed

2. (a) How far does light travel through empty air in one hour?
   (b) How far does sound travel through empty air in one hour?
3. How could you persuade someone that light travelled much faster than sound? Include at least two examples of evidence in your answer.

Two kinds of waves

Read the paragraph below before answering questions 4–7.

Light and sound energy travel as waves. That means that energy travels from one place to another, but no material moves from one place to another. Sound waves are made up of vibrating particles. But the particles only move backwards and forwards 'on the spot'. They don't actually go anywhere. Light travels as electromagnetic waves. That is, light is made up of electric and magnetic pushes and pulls. Light waves can travel through empty space because those electric and magnetic pushes and pulls can happen in empty space.

4. When you want to attract someone's attention you could yell out 'hey you' or walk over to them and tap the person on the shoulder.
   (a) Which method is an example of energy travelling in waves?
   (b) Why is the other method NOT an example of energy travelling in waves?
5. Why are sound waves sometimes called compression waves?
6. Why can't sound waves travel through completely empty space?
7. Why are light waves able to travel through empty space?

Summary of key terms

absorb: take in something such as light, sound or heat energy. The energy taken in can be stored or released as a different form of energy.
aqueous humour: the clear substance at the front of the eyeball between the lens and the cornea
auditory nerve: a large nerve that sends signals to the brain from the hearing receptors in the cochlea
auricle: the outside part of the ear
bioluminescence: the release of light energy from a living thing
biosonar: the use of echolocation by living things
cathode ray oscilloscope: an instrument with a small screen that can be used to display the waveform of a sound. It does this by converting sound energy into electrical signals.
cells: the tiny units that make up all living things. There are many differently sized and shaped cells in the human body.
cochlea: the snail-shaped part of the inner ear. It is lined with tiny hairs and the hearing receptors.
cochlear implant: a device inserted in the ear to allow vibrations caused by sound to reach receptors in the inner ear. Also known as the bionic ear.
concave mirror: a mirror with its reflecting surface curved inwards
convex mirror: a mirror with its reflecting surface curved outwards
cornea: the clear, curved outer surface of the front of the eye
decibels: the unit of sound level. Abbreviation is dB. The sound level is measured with a sound-level meter.
diffuse reflection: the type of reflection that happens at a surface that is not smooth. Diffuse reflection does not produce an image.
ear canal: the tube that leads from the outside of the ear to the eardrum
eardrum: a thin piece of stretched skin and muscle that vibrates when sound energy reaches it
echo: a sound that is heard a second time when it is reflected
echolocation: the use of sound to locate objects by detecting echoes
energy: there are many forms of energy, including light, sound and heat. All forms of energy can cause change or make things happen.
Eustachian tube: a tube that joins the middle ear to the throat. It opens and closes to make sure that the air pressure is the same on both sides of the eardrum.
focal length: the distance between the centre of a curved mirror or lens and the focus
focus: the point at which light rays coming from one direction meet after being reflected or bent
frequency: the number of vibrations each second
hearing receptor: tiny cell in the cochlea that detects vibrations caused by sound and sends signals to the brain
Hertz: the unit of frequency. Abbreviation is Hz. One Hertz is equal to one vibration each second. So, for example, 500 Hz is equal to 500 vibrations each second.
image: a view of an object
iris: the coloured part of the eye that opens and closes to control the amount of light that gets into the eye
laterally inverted: reversed sideways
lens: a transparent curved object that bends light towards, or away from a point called a focus
light ray: very thin beam of light
luminous: releasing its own light
non-luminous: describes objects that don't give off their own light. Non-luminous objects can only be seen because they reflect light.
opaque: describes substances that don't allow any light to pass through
optic nerve: a large nerve that sends signals to the brain from the sight receptors in the retina
ossicles: a set of three tiny bones that send the vibrations from the eardrum to the inner ear. They also make the vibrations larger.
oval window: an egg-shaped hole covered with a thin tissue. It is the entrance from the middle ear to the inner ear.
phosphorescence: the slow release of light of one colour from a chemical after it is exposed to light
pitch: the highness or lowness of a sound. The pitch that you hear depends on the frequency of the vibrating air.
plane mirror: a flat mirror
pressure: the amount of push, or force, on a certain area
pupil: the hole through which light gets into the eye
receptors: special cells that detect energy and convert it to electrical energy that is sent to the brain
reflect: bounce off
regular reflection: the type of reflection that happens at a smooth, shiny surface, like glass or a flat mirror. Regular reflection produces an image.
retina: the curved surface at the back of the eye. It is lined with the sight receptors.
reverberation: the longer lasting sound caused by repeated reflection from hard surfaces
scattering: reflection of light in many directions from small particles or droplets
semicircular canals: three large, curved tubes in your inner ear that control your sense of balance
sonar: the use of reflected sound waves to locate objects under water
sound level: a measurement of how much the air is disturbed by a sound. Sound level is measured in decibels.
transferred: moved from one place to another
translucent: describes a substance that scatters some light and allows some light to pass through. It is possible to make out large shapes through translucent substances, but it isn't possible to see clearly through them.
transmitted: the passing through of something, for example, light or sound
transparent: describes a substance that allows most light to pass through. You can see clearly through transparent substances.
ultrasound: sound with frequencies too high for humans to hear
vibrations: repeated back-and-forth movements
waveform: a graph that shows how the amount of energy a sound has changes with time