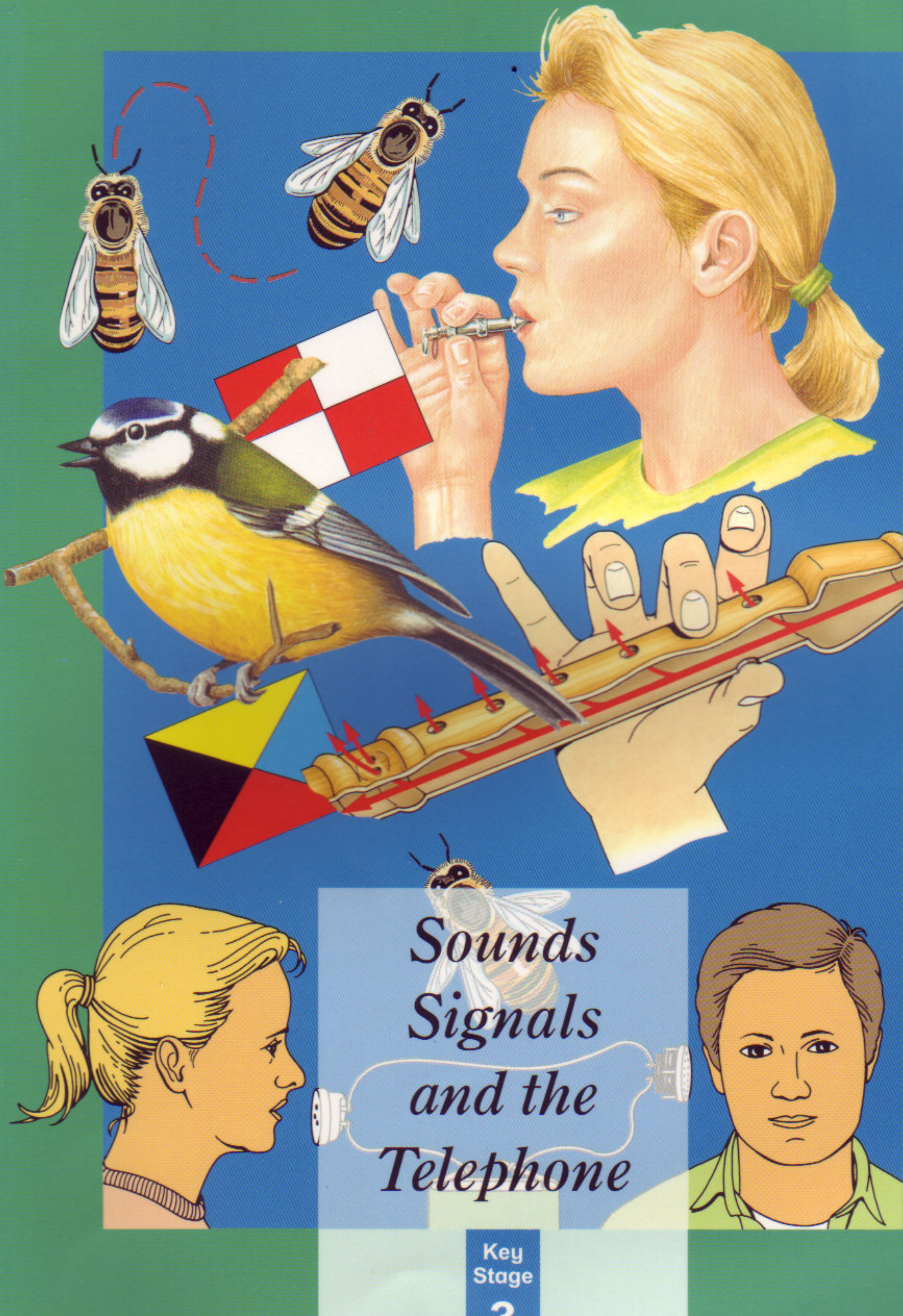


Sounds Signals and the Telephone

Key Stage 3

5–14

A teaching resource for science and physics

BT

UNDERSTANDING COMMUNICATIONS

Sounds, signals and the telephone

Book One

ISBN 0 948 257 81 4
 Produced by BT Education Service
81 Newgate Street, London EC1A 7AJ.

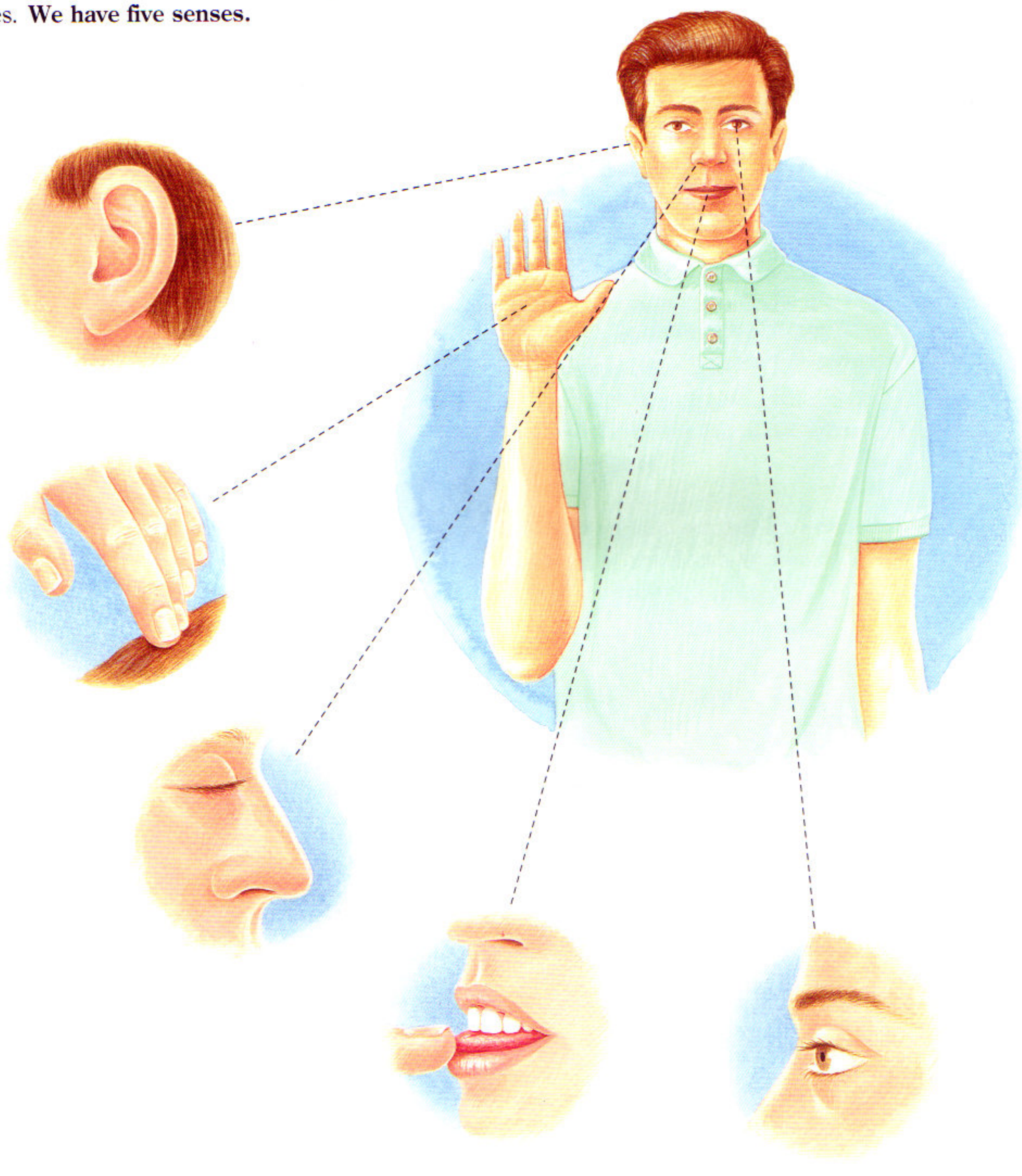
"Understanding Communications" Book One has been based on material written by Ian Johnstone of Haberdashers Aske's Girls' School, London SE14, and Terry Ward of the London Nautical School, London SE1.

Edited by Brian Nicholl and Jenny Selfe.
NS Education Partnership, Mews House, 2a Chelverton Road, Putney, London SW1S 1RH.

Contents

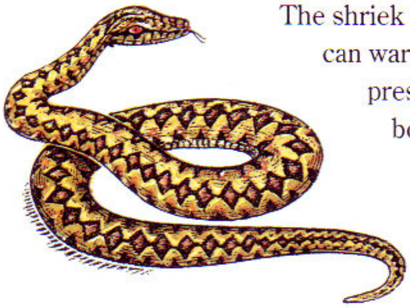
Knowing about the world

We are aware of the world around us through our senses. **We have five senses.**



These senses can be used to pass a message, or some other information, from one person to another. Passing on information in this way is called **communication**.

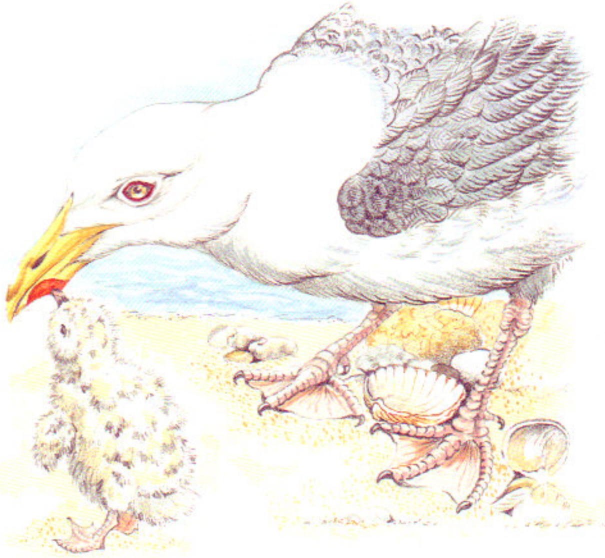
Why is communication important?



The shriek of a bird in the garden can warn other birds of the presence of a cat. The bold pattern of a snake can warn other creatures to keep out of its way.

These animals are sending warning signals.

Bright colours on animals are not only used as warning signals. The red colour on the underneath of a gull's beak has a special purpose. It is there to help the young. They know that if they tap this area the mother will supply them with food.



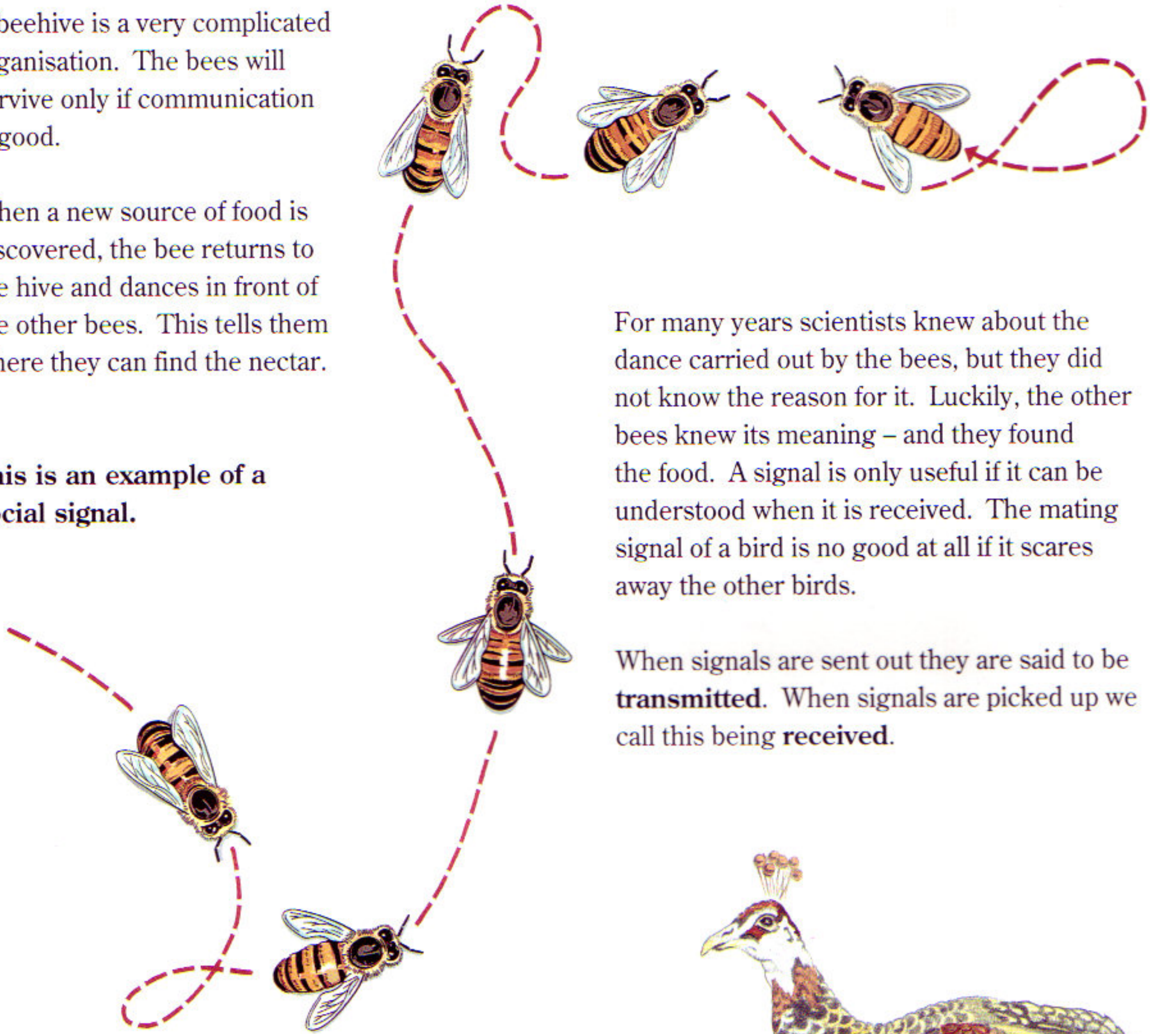
Male and female animals have to attract each other's attention. Some animals, and insects too, communicate by performing special dances.

Communicating by signals

A beehive is a very complicated organisation. The bees will survive only if communication is good.

When a new source of food is discovered, the bee returns to the hive and dances in front of the other bees. This tells them where they can find the nectar.

This is an example of a social signal.



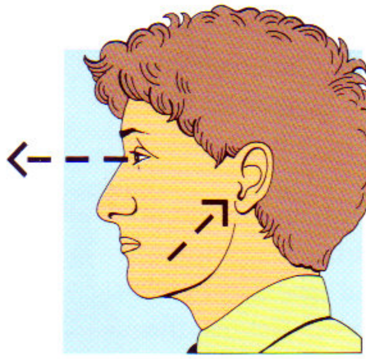
For many years scientists knew about the dance carried out by the bees, but they did not know the reason for it. Luckily, the other bees knew its meaning – and they found the food. A signal is only useful if it can be understood when it is received. The mating signal of a bird is no good at all if it scares away the other birds.

When signals are sent out they are said to be **transmitted**. When signals are picked up we call this being **received**.

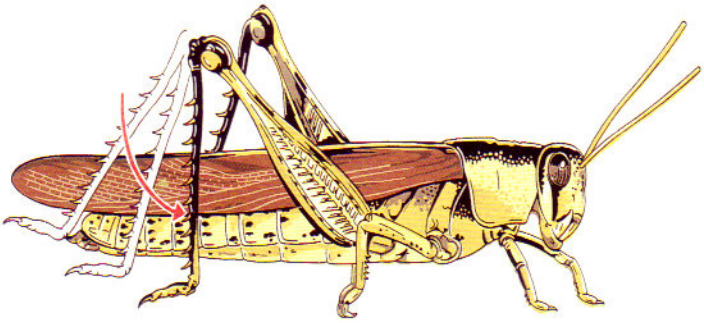
Brightly coloured tail feathers of a peacock are displayed to attract the attention of a peahen.

The two main senses used in communication are sight and hearing.

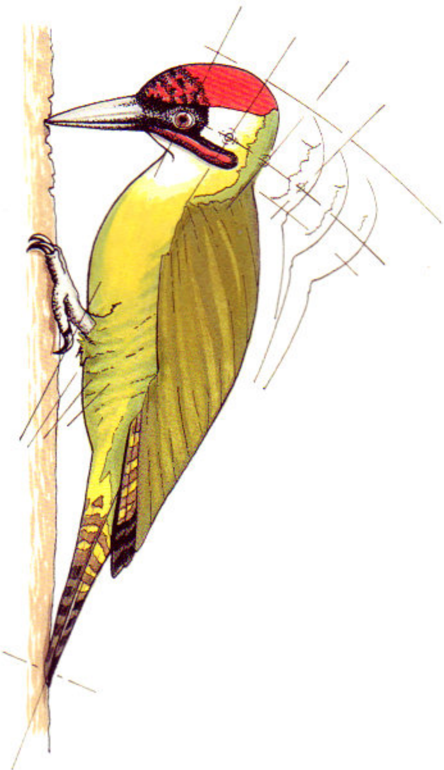
Highly organised animals, such as human beings, have very well-developed hearing and vision. Signals that can be heard are called **audio signals**. The bird warning other birds is an example of one of these. Signals that can be seen are called **visual signals** and the snake's pattern is an example of these.



There are many other kinds of signals that animals and insects use. Make a list of as many signals as you can and the animals and insects that use them. Say why you think they use these signals.



The common green grasshopper 'sings' by moving its hind-legs to and fro to attract a mate.



A woodpecker establishes its territory by rapidly hammering on a tree, although the Green Woodpecker does this less than the other two species found in Britain.

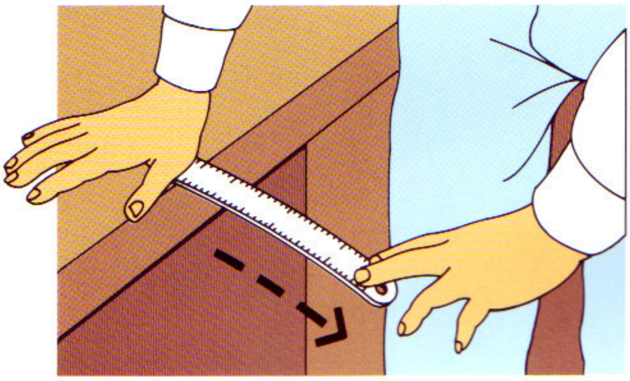
Once animals are able to transmit, receive and understand social signals, they are able to communicate with each other. Sometimes it is important to be able to send signals over a long distance, but this is not always easy. If we want to be able to communicate over a long distance, we must first learn something about **sound** and **light**.

Sound

Making sounds

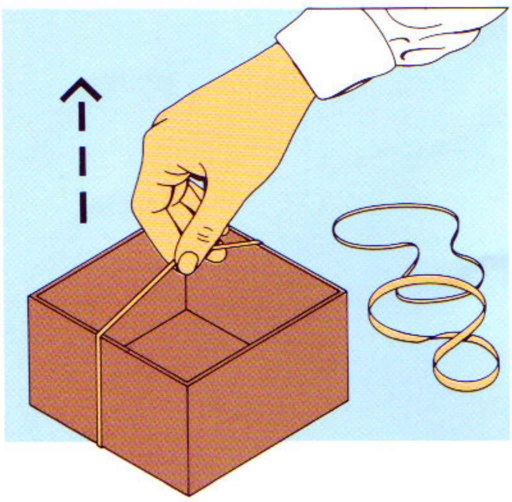
Sounds are produced by making something vibrate. Try these experiments.

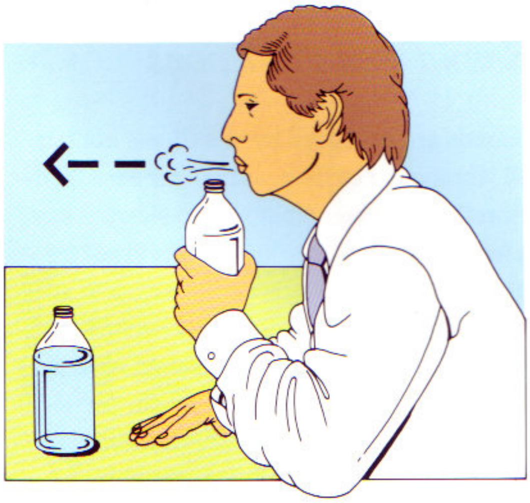
1. Place a ruler at the edge of a table and flick it. The vibration of the ruler makes a sound. Try changing the length of ruler hanging over the edge of the table. Listen how the sound changes.



2. Place an elastic band over an empty, open box and pluck the elastic band. What do you hear as you tighten the band? Does it make any difference if you use a thicker band?

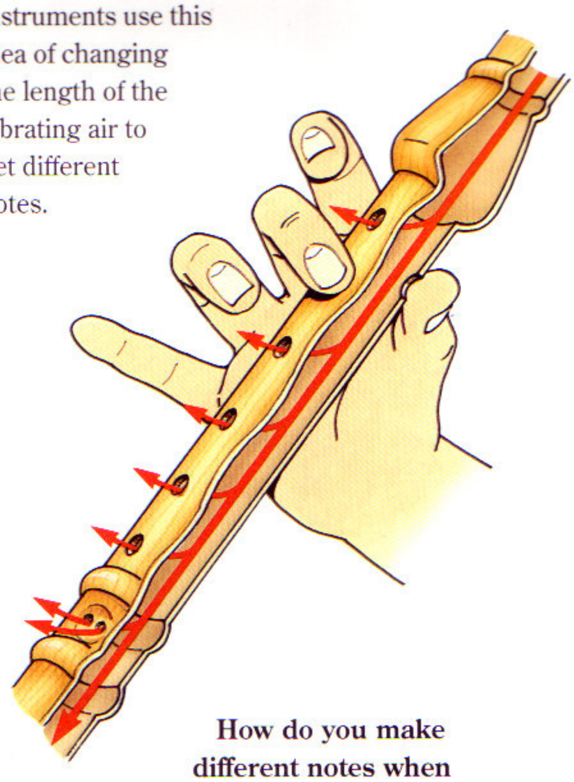
Try and think of as many musical instruments as you can that work in this way.





3. Blow across the mouth of an empty bottle. If you do this gently you should hear a loud sound. Try filling the bottle with water and see what difference this makes to the sound produced.

Musical wind instruments use this idea of changing the length of the vibrating air to get different notes.

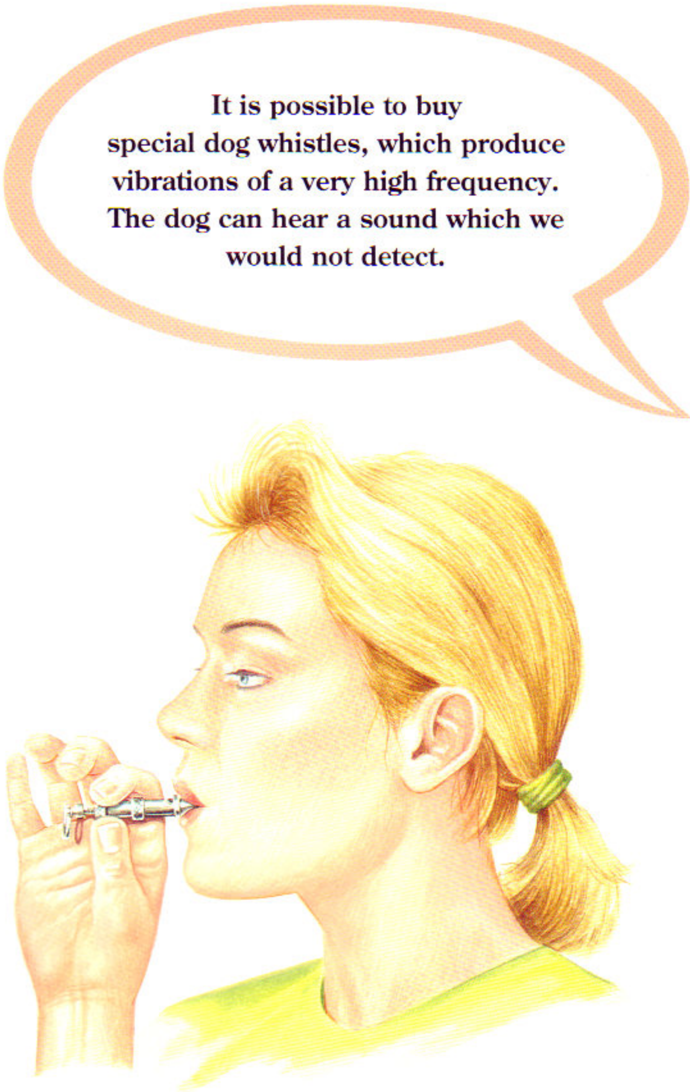


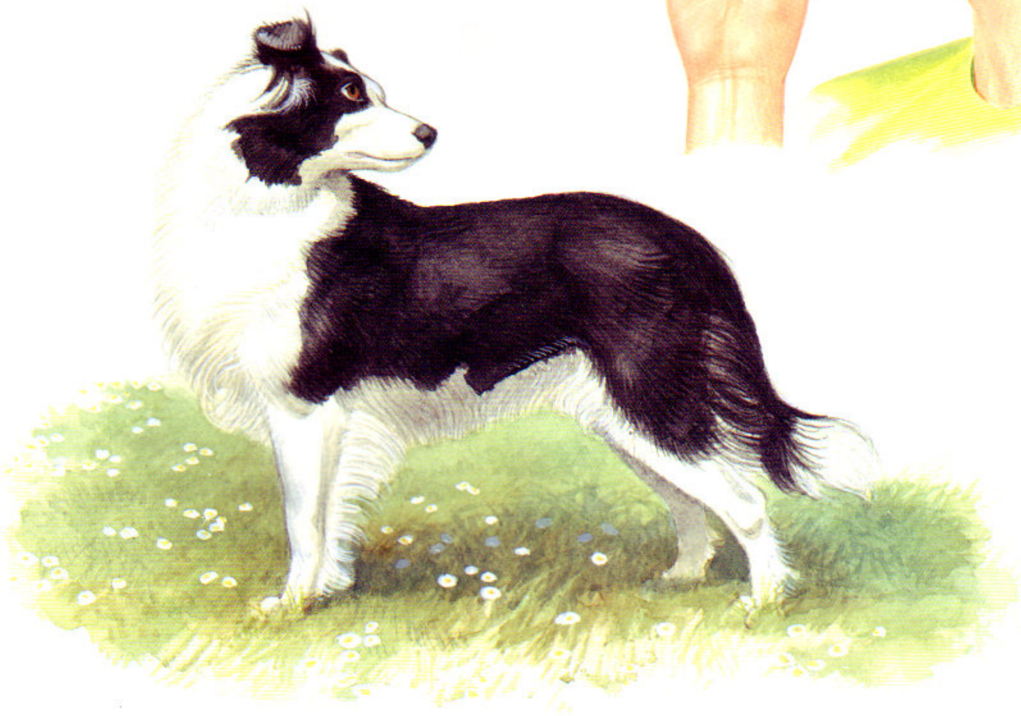
How do you make different notes when playing a school recorder? How does this change the length of the vibrating air?

Sound and vibrations

Sounds are produced by vibrations, but not all vibrations can be heard by our ears. If the vibrations are being made very slowly – say a few every second – the sound will not be heard. If the vibrations are being made at more than about 20,000 times a second, the human ear will not hear this sound either. The number of vibrations made per second is called the **frequency** of the vibration. Sounds with a frequency between the above extremes are usually heard by most human ears.

Other animals can hear vibrations which cannot be heard by humans. For instance, a dog can hear sounds having a frequency much higher than 20,000 vibrations per second.

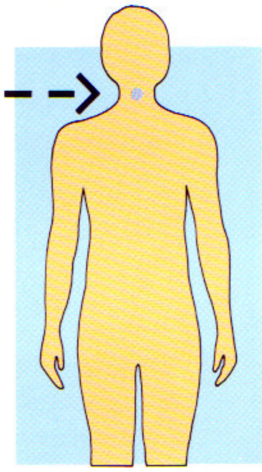


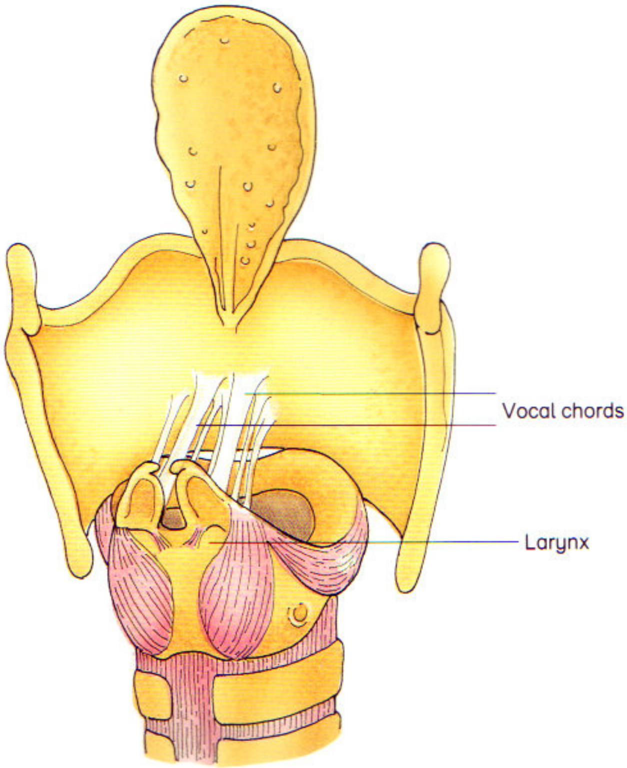


The human voice

The sounds we make are formed in the back of the throat, in what is sometimes called the **voicebox**. The correct name for this is the **larynx**.

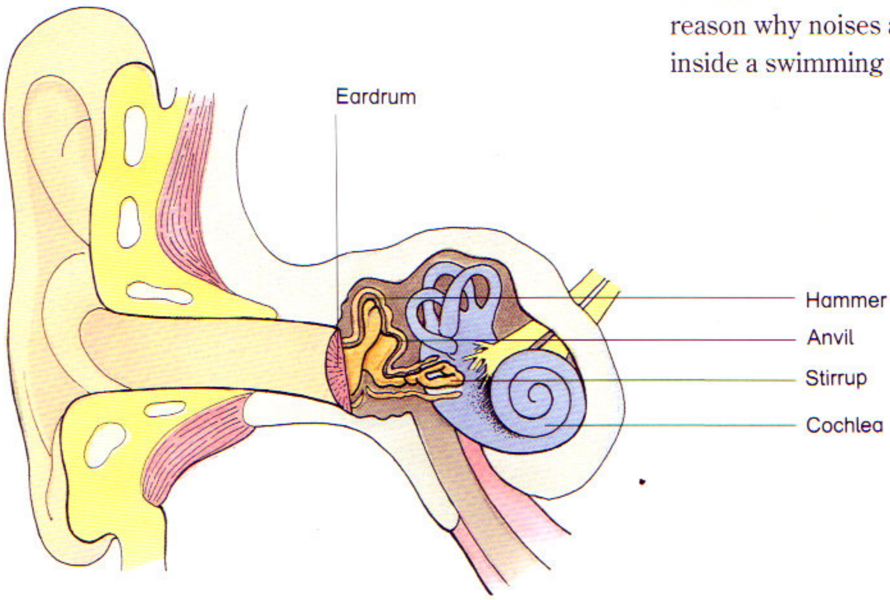
Air from the lungs passes through the larynx and makes the **vocal chords** vibrate. The sound produced is then formed into words by the tongue, teeth and lips. In this way we transmit a sound.





Hearing sounds

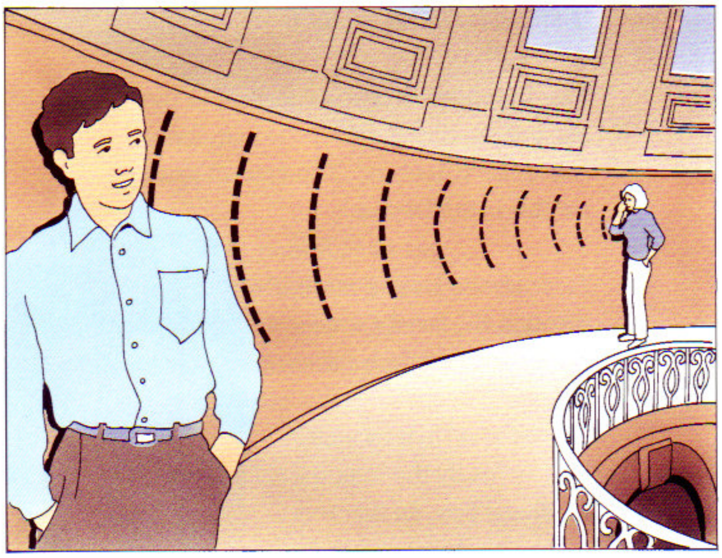
We hear sounds with our ears. The tiny vibrations which make up a sound strike the **eardrum**. This is a piece of skin stretched across the entrance to the ear. The vibrations of the eardrum are amplified by a series of bones and transmitted to the brain. Here they are received as signals which the brain interprets and translates into sounds which we can understand.



Why do you think it is difficult to hear someone speaking when there is a lot of background noise?

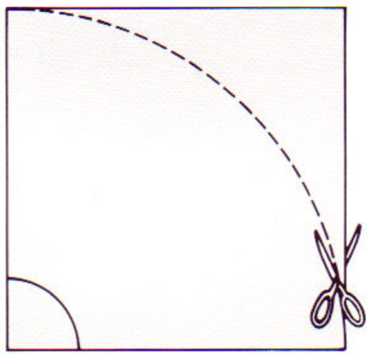
Sound does not carry very far in air. It spreads out in circles, getting fainter as it travels. Sound travels better over water because the water acts like a mirror and reflects the sound on its way. This is one reason why noises always sound louder inside a swimming pool.

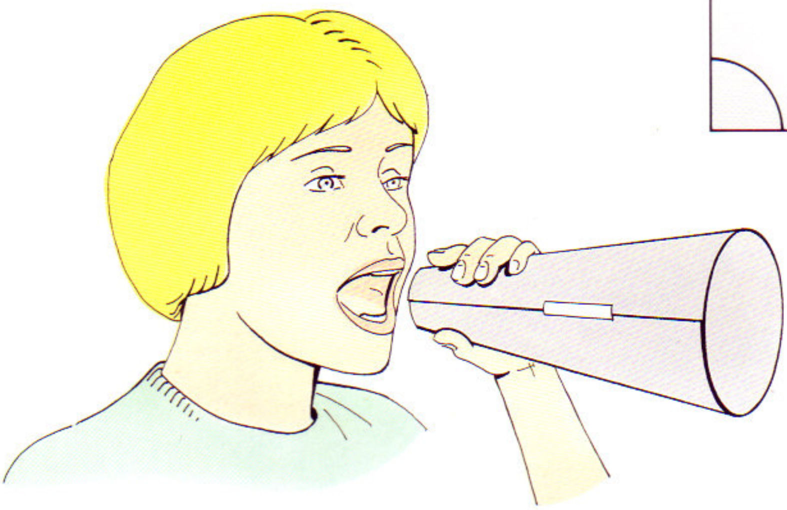
The Whispering Gallery in St Paul's Cathedral, in London, is another example of sound being reflected. Even very quiet whispers made at one side of the gallery are reflected by the walls of the dome and can be heard distinctly at the other side.

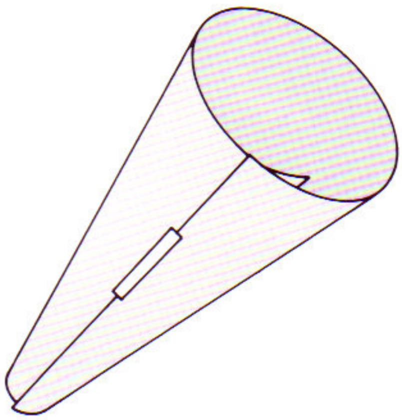


Sounds can also be magnified by other artificial means. If we cup our hands round our mouth, the sound will carry much further. A megaphone is sometimes used to make sounds seem louder.

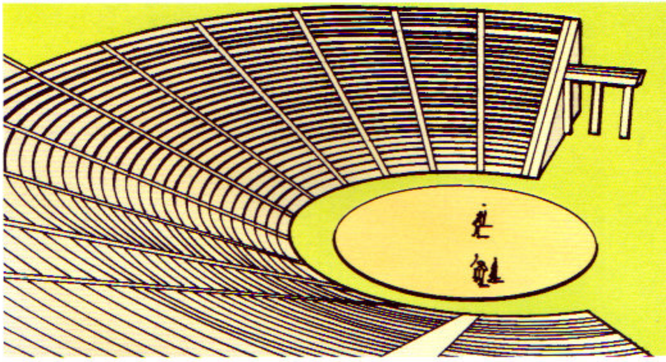
Using a large sheet of paper, try to make a megaphone for yourself.







Concert halls and theatres have to be specially designed so that lots of people can hear the performers – even at a great distance away from the stage. The control of the sound within a building like a theatre is called the **acoustics** of the building.



Some ancient Greek theatres, built over 2,000 years ago, were designed to have superb acoustics.

Carrying sounds

As mentioned earlier, air is not a very good sound carrier. Most other substances, such as water, metal and wood, are much better at carrying sounds. Whales communicate with each other under water using sounds. Even though they may be many miles apart, the vibrations are carried by the water. Prisoners are said to communicate with each other by tapping messages on walls or through pipes.

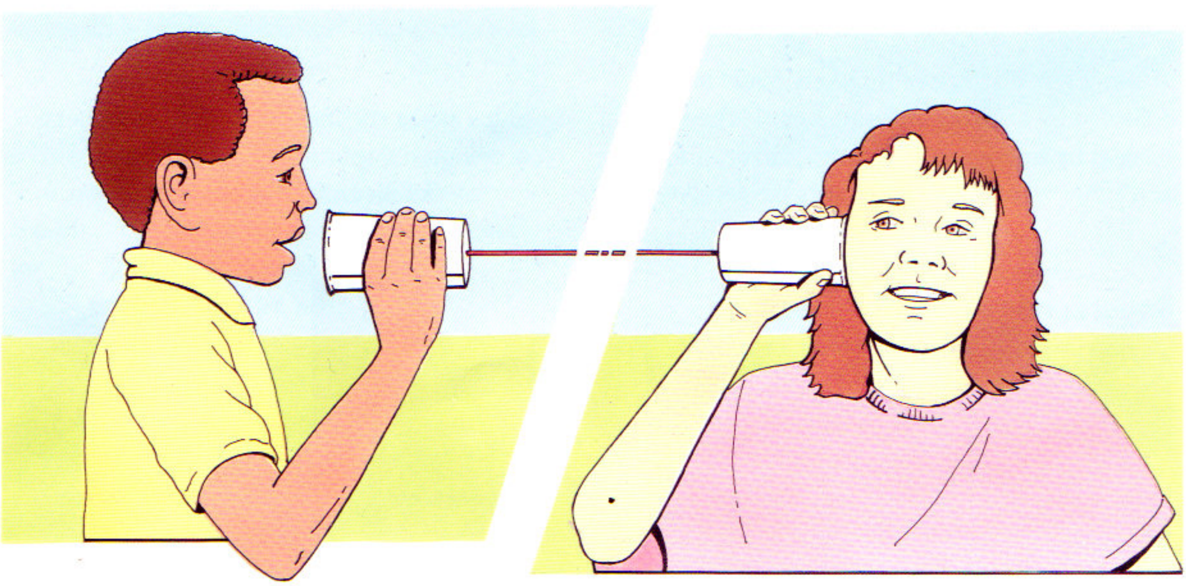
We can demonstrate how sound travels by means of a simple telephone experiment.

It is easy to make your own simple telephone. Connect together two plastic cups – using a long length of string. Working with a partner, stretch out the string so that you are as far apart as possible and the string is stretched tight. If one of you speaks into the cup at one end, the person at the other end will hear the message.

Will the telephone work if the string is:

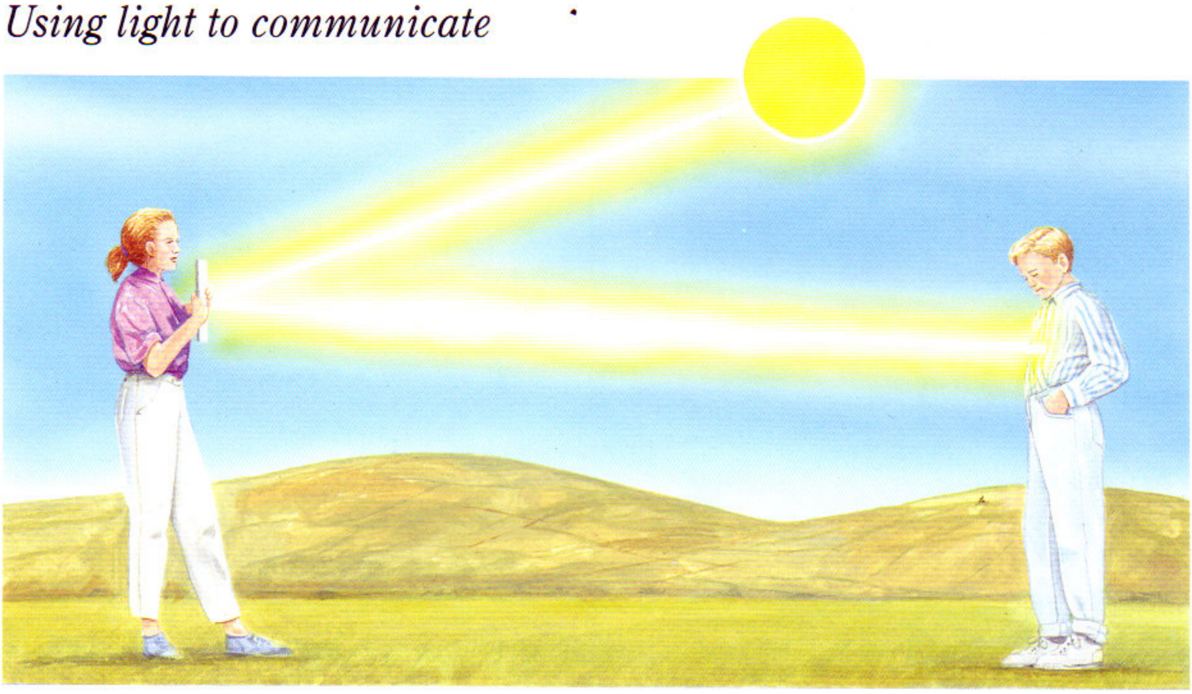
a. Slack?

b. Bent round a corner?



Light

Using light to communicate



Light signals have been used to communicate messages for a very long time. The arrival of the Spanish Armada off the coast of England was signalled across the country by lighting large bonfires. If you look at a map of Britain you will see many places called Beacon Hill. These were points where large fires were lit to pass on the message that an important event had happened. They were usually placed on high ground. **Why do you think this was so?**

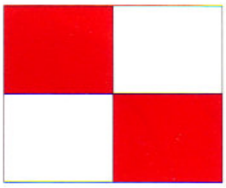
When it was discovered that light could be reflected by a mirror, messages could then be sent by **heliograph**. Using a mirror, the sun's rays were directed towards the receiver.

By moving the reflected ray of light towards, and then away from, the receiver, messages could be sent. This needed some kind of code which could spell out the information. One kind of code will be described later in this book.

Try to design a simple, practical way in which the heliograph could send these light signals.

Ships at sea still use a special arrangement of coloured flags to spell out messages. Some examples are shown below.

I require a tug.



You are running into danger.

Man overboard.

I require assistance.

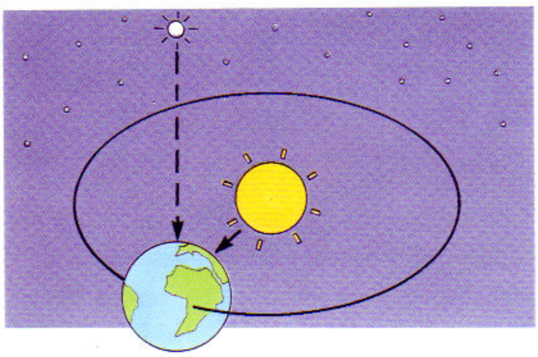
All these methods of visual communication depend on two things:

1. Having a source of light.

2. Being able to see the light.

The sun often produces the light by which we see things. A variety of artificial sources of light have been invented during the ages. Electricity is probably the most common one used today.

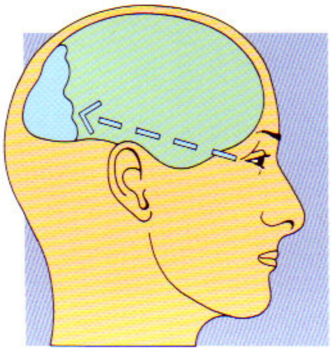
Unlike sound, light travels very quickly and over very long distances. Light which comes to us from the sun has to travel a distance of almost 150 million km (93 million miles). It makes the journey at a speed of about 300,000 km (186,000 miles) every second. When we see the stars at night, the light which we see has travelled very long distances. The nearest star to us is almost 10 million million km away.



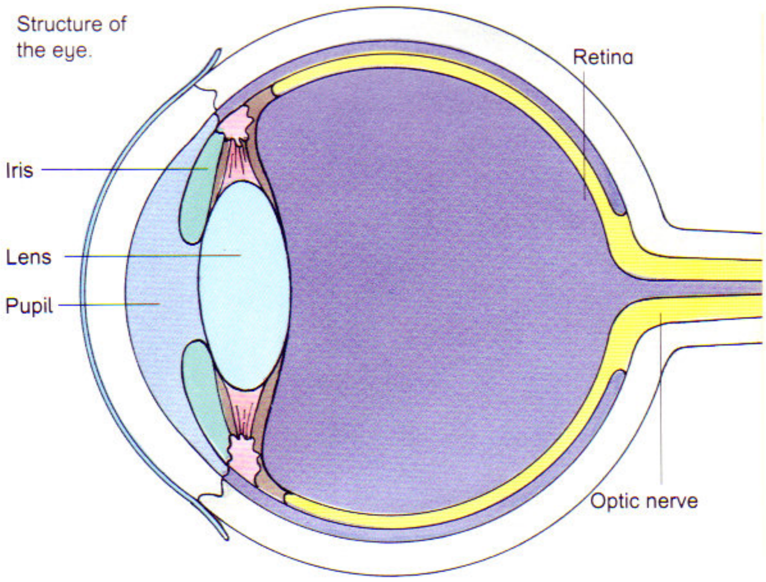
You now know the speed at which light travels. Calculate how long it must take for the light from this nearest star to travel to Earth and be seen by us.

Our eyes enable us to receive light signals which our brain converts into messages.

Light passes into the eye through the **pupil**. The **lens** focuses the light onto the back of the eye. Here the **retina** converts the light into electrical signals which are passed via the **optic nerve** to the **brain**.

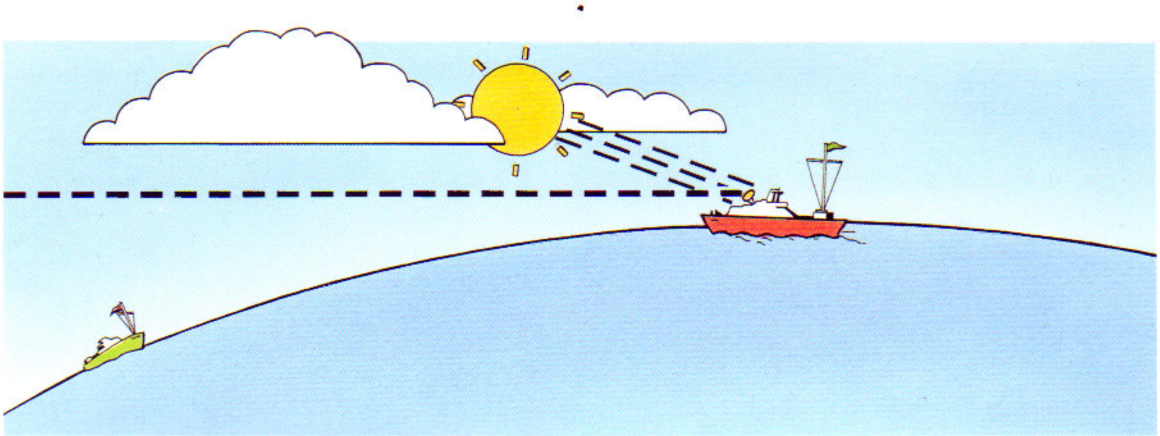


Structure of the eye.



Most animals have two eyes like we have. But there is one kind of spider which has a total of eight eyes. This enables it to see in all directions at once. This must be very convenient.

Electric telegraphy

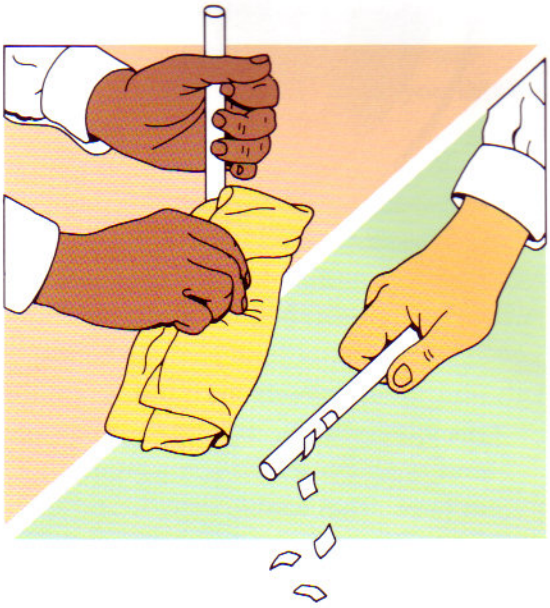


There are problems in trying to communicate using audio or visual signals. Sound does not travel very far. Light usually travels in straight lines.

Because the Earth's surface is curved, ships at sea cannot use visual signals over a distance of about 48km. The heliograph could be used only when the sun was shining.

Long-distance communication became possible when scientists began to understand the physics of magnetism and electricity. Centuries ago, the ancient Greeks knew that some rocks had magnetic properties which could be used for direction finding. The rocks contain mainly **magnetite** and this gives us the name **magnet**. The Greeks also knew that some substances, when rubbed, could be made to attract other substances.

You can repeat this experiment yourself.



Take a glass rod, or strip of plastic (some rulers are made of plastic) and rub it up and down with a piece of cloth. Use one end of the rod to pick up small pieces of paper. The rod is said to be electrically charged. If you rub a balloon on a woollen jumper, you can make it stick to the wall. The balloon is electrically charged.

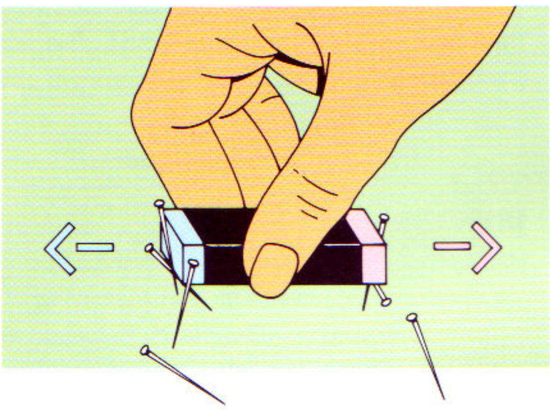
From the seventeenth century onwards, scientists began to make many important discoveries. Some of these, which were important in the development of communications, are described in the following pages.

1600

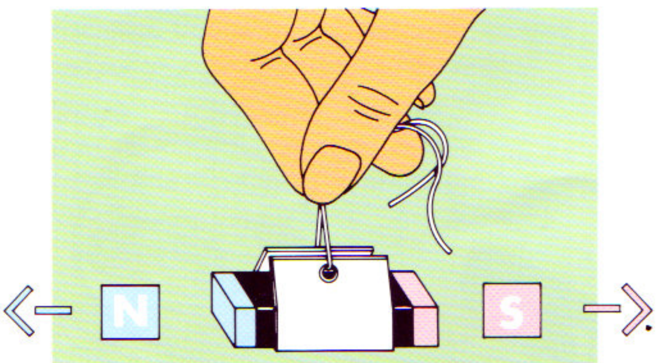
It was in this year that a scientist called **William Gilbert (1540–1603)** discovered something special about a magnet.

You can repeat his experiment yourself as shown in the diagrams below.

Dip a magnet into a pile of steel pins. (Iron filings will do instead – but they are a bit messy.) What do you notice about the attraction of the magnet to the pins? The magnet seems to be strongest at each end. These are called the poles of the magnet.

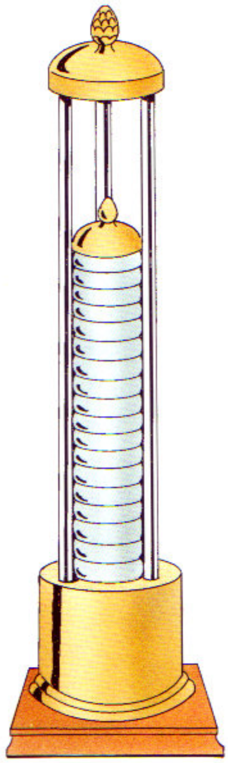


Now hang your magnet on a thread. Leave it for a little while. You will find that it will come to rest always pointing in the same direction – north and south. This explains why two poles of a magnet are called the north and the south pole.



1800

Another step forward was made in this year. An Italian professor, **Alessandro Volta (1745–1827)**, announced his invention of the **Voltaic Pile**, the first electric battery. This consisted of a number of pairs of silver and zinc discs, separated by discs of cardboard soaked in a salt solution. It enabled electric charges to be moved along metal wires – what we now call an **electric current**.

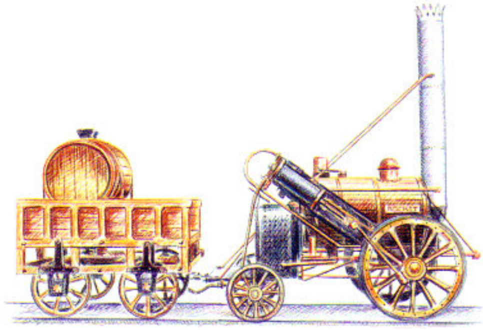


Voltaic Pile.

Alessandro Volta.

It was these inventions and discoveries, amongst others, that made electric telegraphy possible.

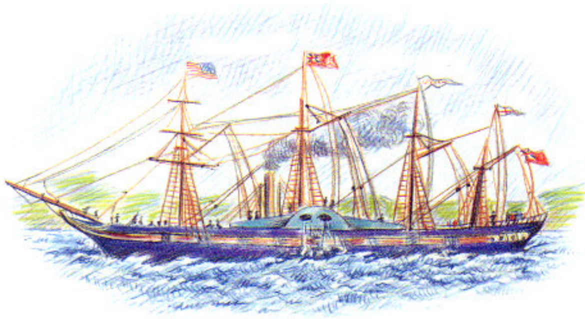
The nineteenth century was a time of great social and technological change. Society in Europe was changing quickly. The Industrial Revolution was under way.



As long ago as 1753, a Scotsman, **Charles Morrison**, had predicted the electric telegraph and suggested a way in which it might be worked. However, over 80 years passed before a practical system was demonstrated. A number of discoveries and inventions had to be made before electrical telegraphy became possible.

1829

James Watt (1736–1819) had developed the steam engine so that it could drive a wheel. This led to the invention of the railway locomotive. In 1829, **George Stephenson's** famous **Rocket** won a competition by travelling between Liverpool and Manchester, reaching a speed of 35mph. In 1830, the Liverpool–Manchester railway was opened and started the great railway age. By 1870 there were over 100,000km (65,000 miles) of railway track in Europe.



Great Western.

1816

Alongside the development of steam railways, engineers were building steamships. In 1816, the first sea-going steamship, the **Hibernia**, was launched. It sailed between Holyhead and Dublin.

1838

Brunel's famous steamship **Great Western** sailed from Bristol to New York in 15 days.

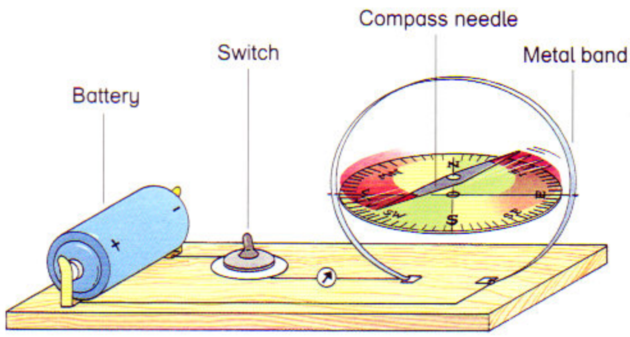
This revolution in transport speeded up communication in Europe. People could travel more easily and cheaply. This brought with it the need for a more efficient and reliable means of communicating information. Faster moving railways needed a better system of signalling. Ships at sea needed to keep in contact with shore-based stations.

1819

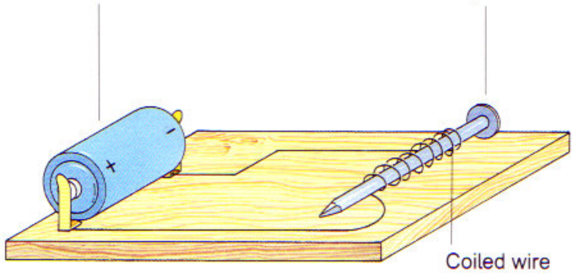
Hans Christian Oersted (1777–1851) of Copenhagen showed that a wire carrying an electric current would deflect a magnetic compass needle.

The illustration below shows how you can repeat his experiment.

When there is no electric current in the wire, the magnetic compass needle does not move. Now switch on the circuit. What happens to the compass needle?



This idea led to the invention of the first electromagnet in 1825. The illustration on the right shows how you can make a simple electromagnet.



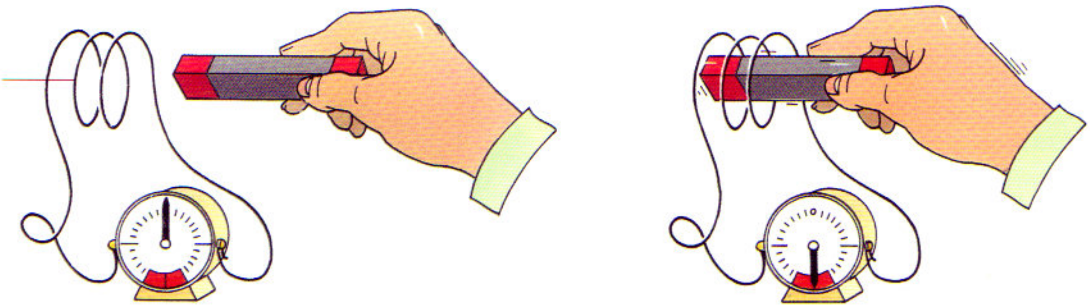
Scientists now knew that electricity could affect a magnet and that electric currents could create one. One more principle remained to be discovered before the electric telegraph system finally became possible.

1831

In this year, **Michael Faraday (1791–1867)**, a very famous British scientist, made this important discovery. He found that a coil of wire placed in a changing magnetic field produces an electric current in the coil. The diagram below shows how you can demonstrate this.

Stationary magnet

Magnet moving into coil

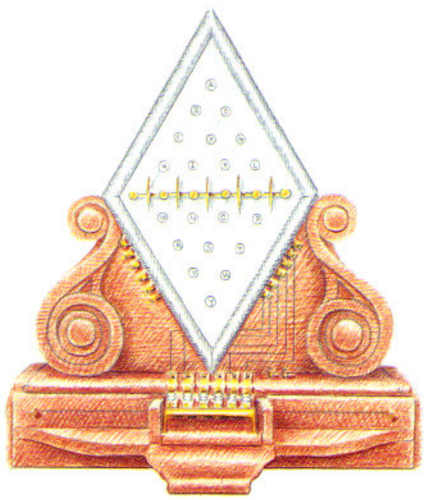


No electric current

Electric current flowing

1837

The way was now clear and in **1837** two scientists, **Cooke** and **Wheatstone**, patented and successfully demonstrated the first electric telegraph. This worked on the principle of five magnetic needles and five conducting wires and is shown on the right.

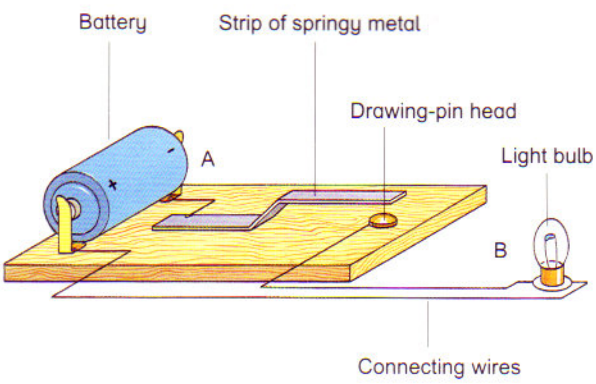


1839
The world's first commercial telegraph line using the five-needle system was built between Paddington and West Drayton. This was also the first commercial use of electricity.

1843
In this year **Samuel Morse (1791–1872)** used the same principles of magnetism and electricity to send a message from Washington to Baltimore (USA). He used a different kind of code which is now known as the **Morse code**. In this, the letters of the alphabet and the numbers 0–9 are represented by a series of dots and dashes as shown on the right.

Using an electric circuit, he was able to transmit the dots and dashes as a series of long and short electric impulses. At the receiving end, the electric impulses could be converted back to dots and dashes using an electromagnet.

You can build your own Morse code system using the circuit shown below.



This system will work in one direction only (from A to B). Can you design a system so that A could send a message to B, and B could reply?

A •–	S •••
B –•••	T –
C –•–•	U ••–
D –••	V •••–
E •	W •––
F ••–•	X –••–
G ––•	Y –•––
H ••••	Z ––••
I ••	1 •––––
J •–––	2 ••–––
K –•–	3 •••––
L •–••	4 ••••–
M ––	5 •••••
N –•	6 –••••
O –––	7 ––•••
P •––•	8 –––••
Q ––•–	9 ––––•
R •–•	0 –––––

The telephone

The early systems of electric telegraphy were a wonderful step forward in methods of communication, but they had one major drawback. Converting messages into code at the transmitter and decoding at the receiver all took time. However skilful the operator (and some telegraph operators could send Morse code messages at a very high speed) this still remained a slow method of transmitting large quantities of information.

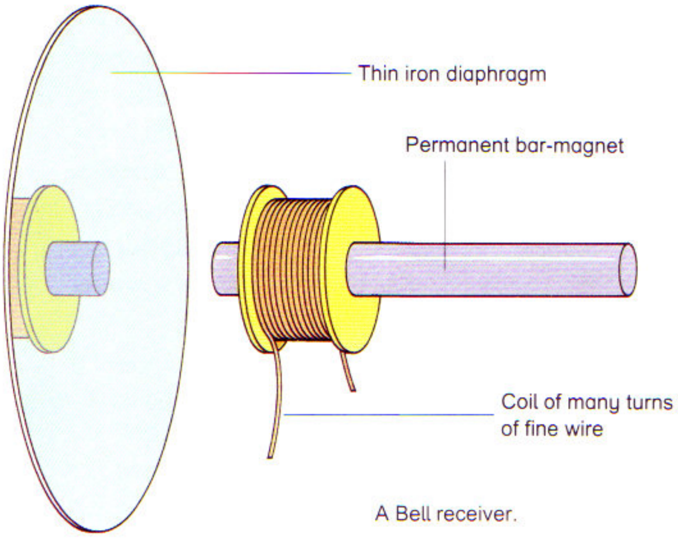
What was needed was a system which could send and receive verbal communications.

1876

Alexander Graham Bell (1847–1922), a Scotsman who had emigrated to America, transmitted the first spoken sentence by telephone, in Boston USA.

There is a story that Bell was working on his telephone transmitter when he spilled some battery acid on his clothes. He shouted to his assistant, who was working in an adjacent room, "Mr Watson, come here – I want you." Mr Watson heard the message through the receiver of the telephone. So the first transmitted telephone message had been an emergency call.

Bell used the same instrument as a transmitter and a receiver. The sound message was converted into electric currents which changed in size according to the vibrations of the voice. As a receiver, the instrument worked very well; but as a transmitter it was less successful.



A Bell receiver.

The diagram of the Bell receiver shown above can be used to explain its action. A permanent bar magnet was mounted with one end near to a circular diaphragm. This was made of very thin iron and was held firmly round its circumference. The diaphragm was sufficiently flexible to allow it to bulge inwards at its centre. A coil of wire was placed over the magnet very near to the diaphragm. As the changing electric currents produced by the transmitter passed through the coil, the combined permanent/electromagnets became more or less magnetic and caused the diaphragm to vibrate. This reproduced the sound of the voice speaking into the transmitter.

Alexander Graham Bell.

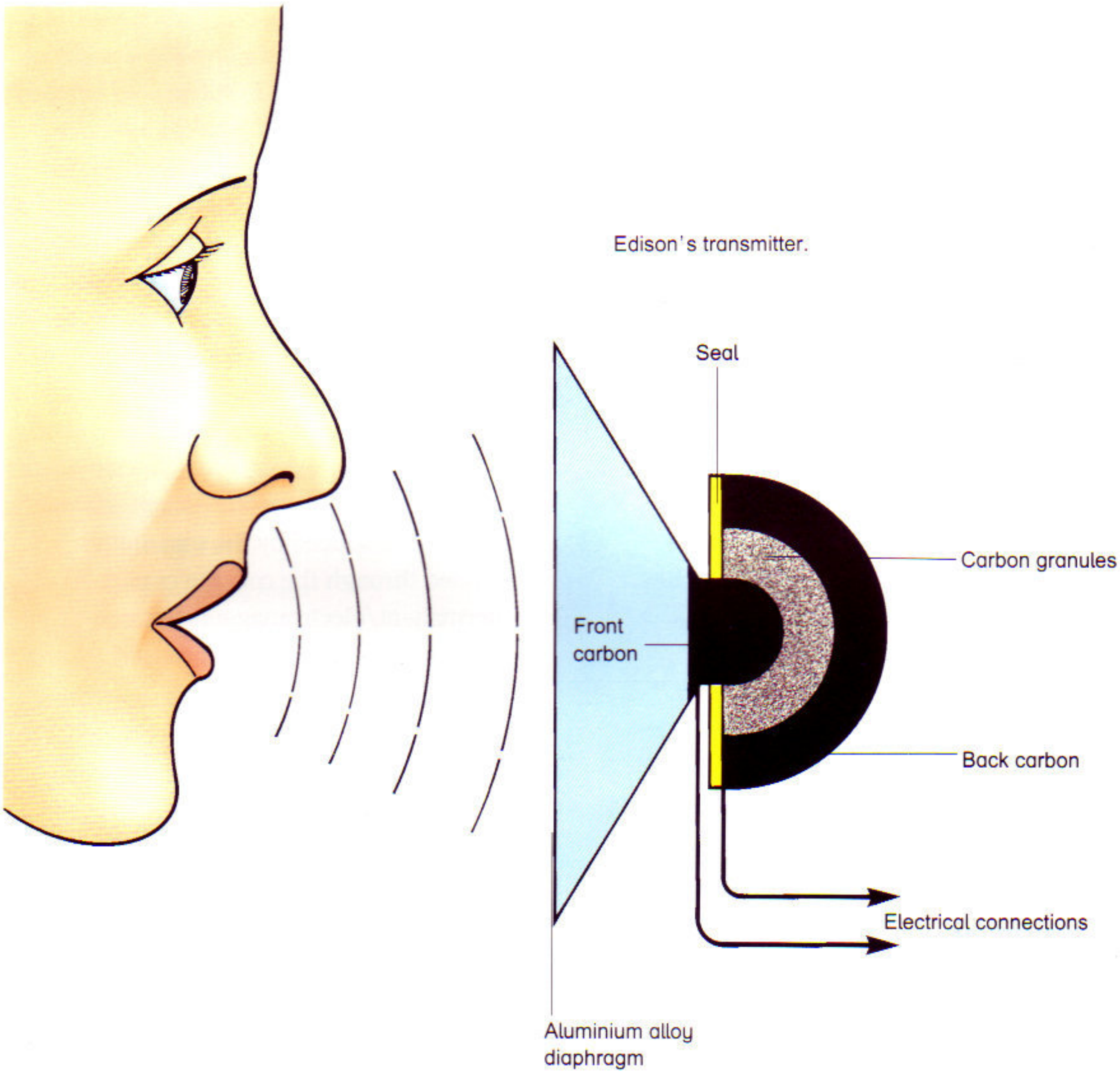
1877

In the following year, another American inventor – **Thomas Alva Edison (1847–1931)** – produced a transmitter that was much more efficient. The combination of Bell's receiver and Edison's transmitter formed the basis of telephone design almost to present times.

Edison's transmitter depended on the changing resistance of carbon granules caused by pressure from a diaphragm. The tiny carbon granules are held in place by two carbon blocks.

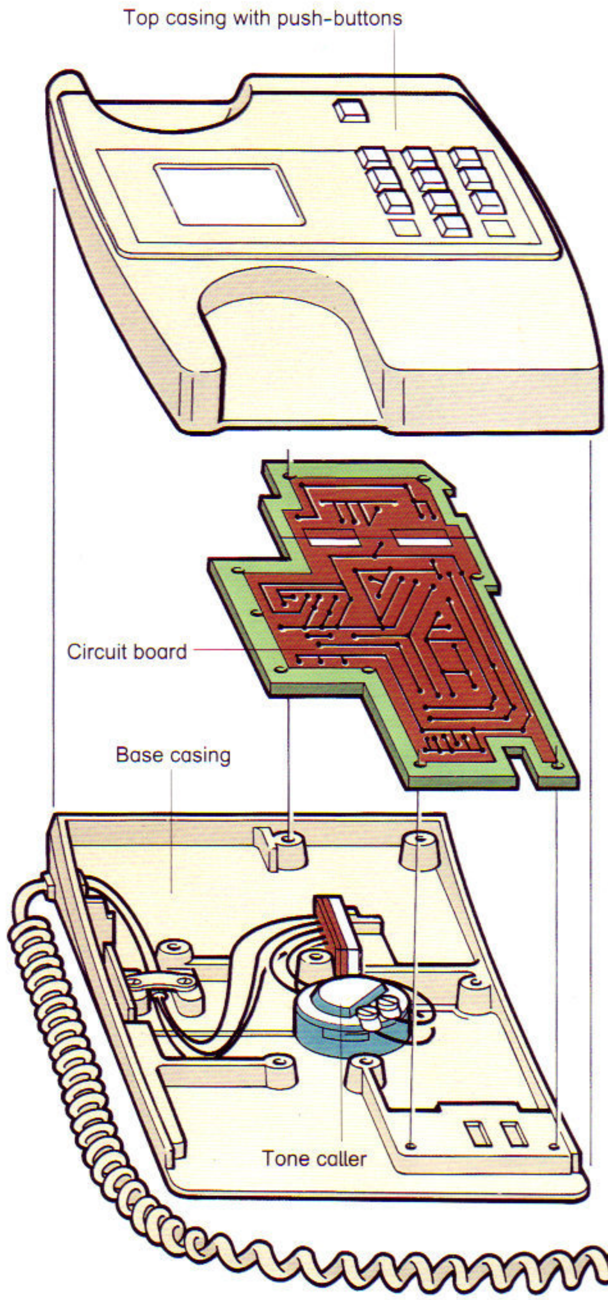
The front block (which is dome-shaped) is attached to the diaphragm and can move backwards and forwards. The cup-shaped back carbon is fixed. Electrical connections are made to each carbon block. Changing air pressure from the vibrations of the voice makes the diaphragm vibrate.

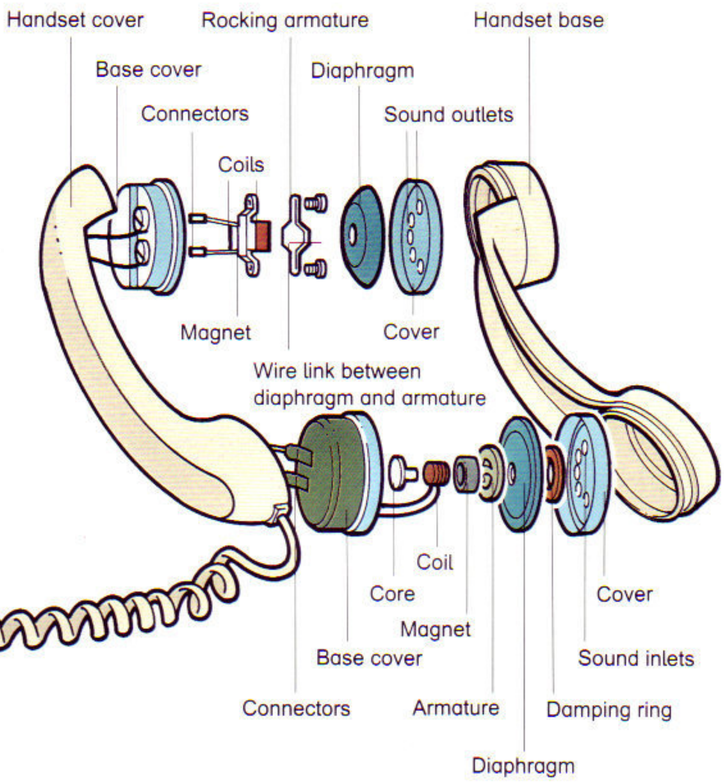
Edison's transmitter.



The vibrations are passed into the carbon granules and this causes them to be compressed or released as the pressure increases or decreases. This alters the resistance of the carbon granules, so changing the size of the electric current passing through them. The electric current varies in time with the changes of air pressure on the diaphragm and so enables the original sounds to be reproduced at the receiver.

Modern telephones use electromagnets at both the transmitter and receiver. This diagram shows an arrangement of a modern instrument.





Rocking armature receiver.

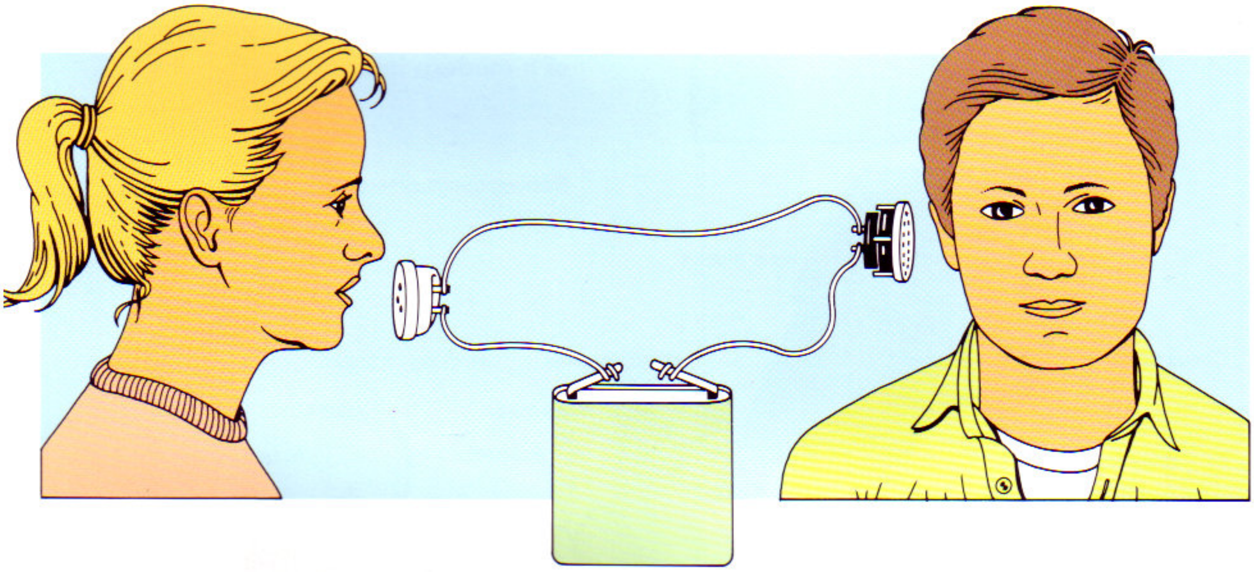
Moving iron transmitter.

Making your own telephone

You will need

Two scrap telephones (or two transmitters and two receivers), battery – about 4.5V, large nail, fine insulated wire – as much as you can get.

A very simple telephone can be made by connecting a transmitter, battery and receiver in a circuit.



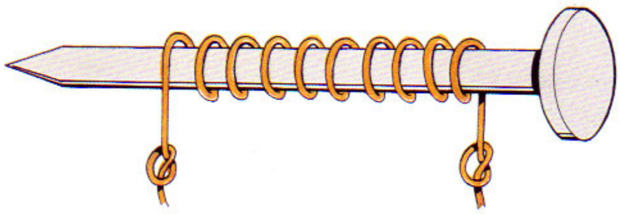
Two circuits like this will allow two people to talk to each other – but only over very short distances. This is because the current has to flow all the way round the circuit, through the transmitter and the receiver. In a long circuit, the electrical resistance is high and the current in the circuit very small. Changes in the current caused by the sound vibrations in the transmitter will be small and the sounds in the receiver will be faint.

To overcome this difficulty, two circuits are used; one to carry the current through the transmitter and a second circuit to carry the current to the distant receiver. This requires the use of a transformer.

You will remember that Michael Faraday made a very important discovery which we described earlier. He found that a changing electric current could produce a magnetic field while a changing magnetic field could generate electric currents.

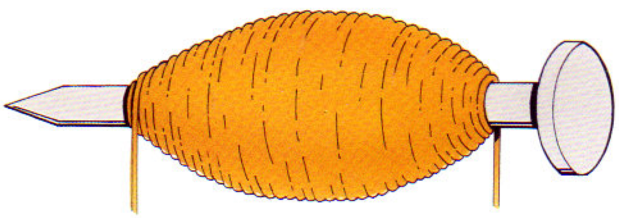
This is the basis of a transformer. You can now build your own transformer.

Wrap ten turns of wire around a large iron nail. Leave about 0.5 metre of wire free at each end. It will help you later if you make a small knot in each of these free ends.

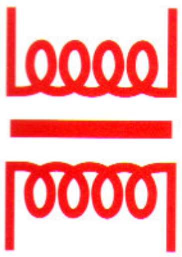


If a current is passed through the wire the nail becomes a magnet. This is called an electromagnet. The magnetic field will disappear when the current ceases to flow. Any changes in the current will cause changes in the magnetic field.

Using a longer piece of wire, wind 100 turns round the nail and on top of the first coil. Again, leave about 0.5 metre of free wire at each end but do not tie knots in these wires.



The first winding of wire is called the primary coil and the second winding, the secondary coil.



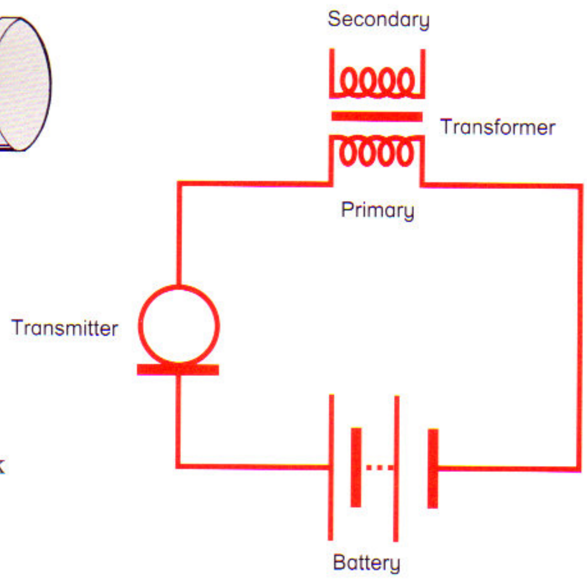
Your transformer should now look like the picture above.
On the left you can see how a transformer is drawn in a circuit diagram.

Building the telephone circuit

To make a long distance telephone call you will need two sets of equipment. Each one is built up as follows:

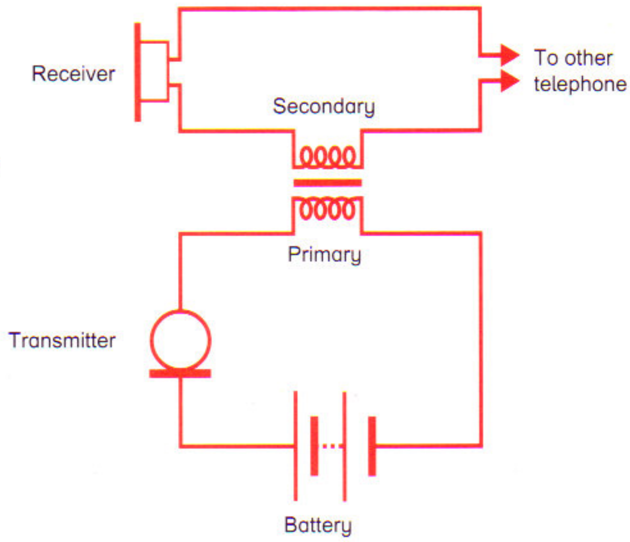
The transmitter circuit

The diagram below shows you how to connect up the circuit. Remember that the primary coil of your transformer is the one with knots in the wires. A 4.5V battery should work well.



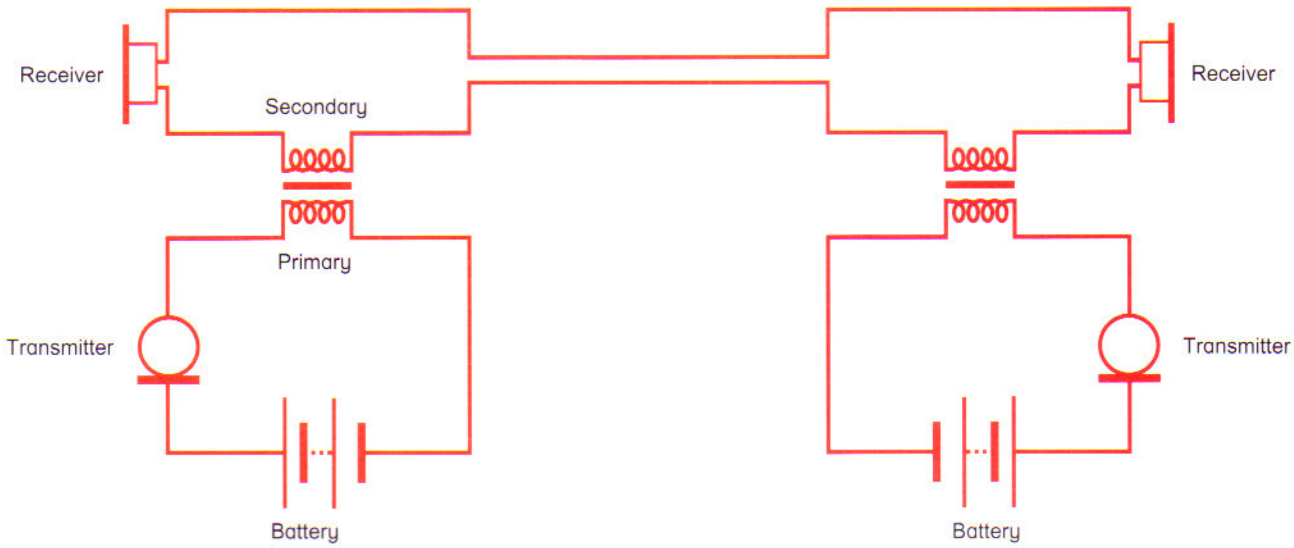
The receiver circuit

The diagram on the right shows you how to connect up the receiver part of the circuit.



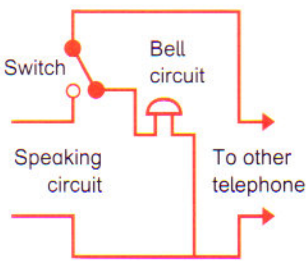
The complete telephone

Connect the second telephone circuit in the same way and then join the two circuits together. If you can get some two-core wire, you need to run only one length of wire between the two instruments. If you have only single-core wire, then you will have to run two lengths.



Your system can now be used to speak to someone a long distance away. You must remember to disconnect the batteries when they are not being used, otherwise they will run down.

Here is a design problem for you to tackle.



Try to devise a system that leaves the batteries connected but not working when the telephone is not being used, and another system which allows a bell to ring when the telephone is not being used. This diagram gives you a clue.

This all seems a long way from bees dancing and birds shrieking. In this book we have tried to explain the business of communication, and how modern telephones have been developed from a basic understanding of the principles of physics.

BT Education Service
ES72 (1.94)

Printed by Vitesse Printing Company Ltd

ISBN 0 948 257 81 4