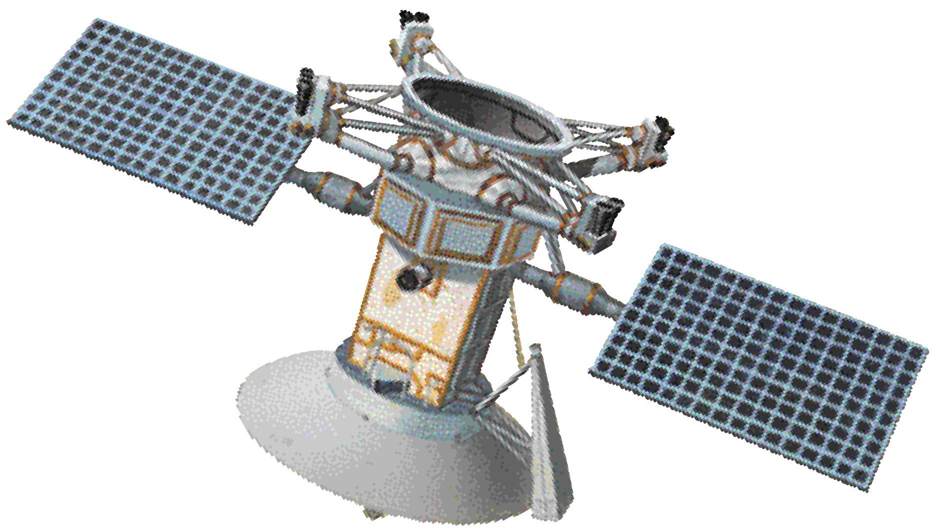
children's illustrated encyclopedia

The World of Technology



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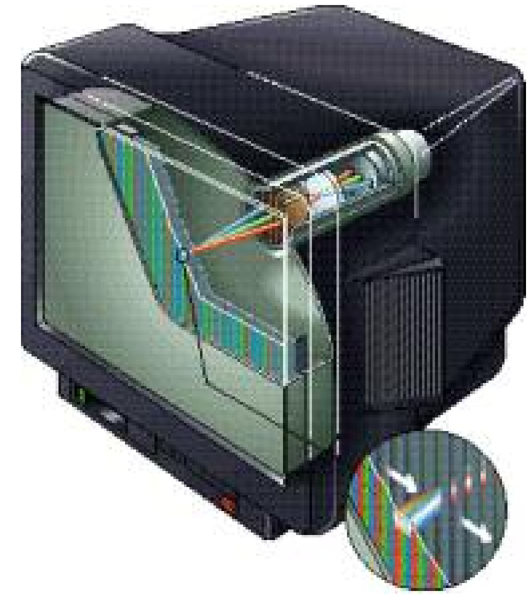
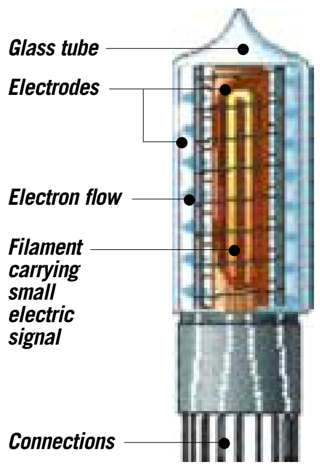


USING LIGHT

ELECTRONICS

ELECTRONS are tiny particles that are parts of atoms. An electric current is a flow of electrons. Electronics is the study of how electrons behave and how they can be controlled so that they can do useful jobs. Nearly all the machines we use in our everyday lives—from radios, calculators and television remote controls to telephones, computers and cars—contain electronic circuits that make them work. Electronics are especially important in information technology *(see page 9)* and communications *(see page 12)*.



A thermionic triode valve was designed to amplify (strengthen) electric signals. A central electrode is heated inside a glass tube. Electrons flow from it to another, outer electrode. A small electric signal causes large changes to this electron flow, producing a more powerful electric signal.

The study of electronics began at the end of the nineteenth century, and had its first practical use in the early 20th century in the development of radio communications *(see page 16)*. The first electronic devices were called thermionic valves. These included the diode valve, which allowed current to flow through it one way but not the other, and the triode *(above),* in which a small current could be used to control a much larger current. The parts of thermionic valves, some of which glowed red hot, had to be enclosed in a glass tube with the air removed to create a vacuum.

In the 1950s valves were quickly replaced by semiconductor devices. A semiconductor is a material that can act as both a good conductor of electricity and an insulator. Semiconductor devices are much simpler, smaller and more reliable than valves.

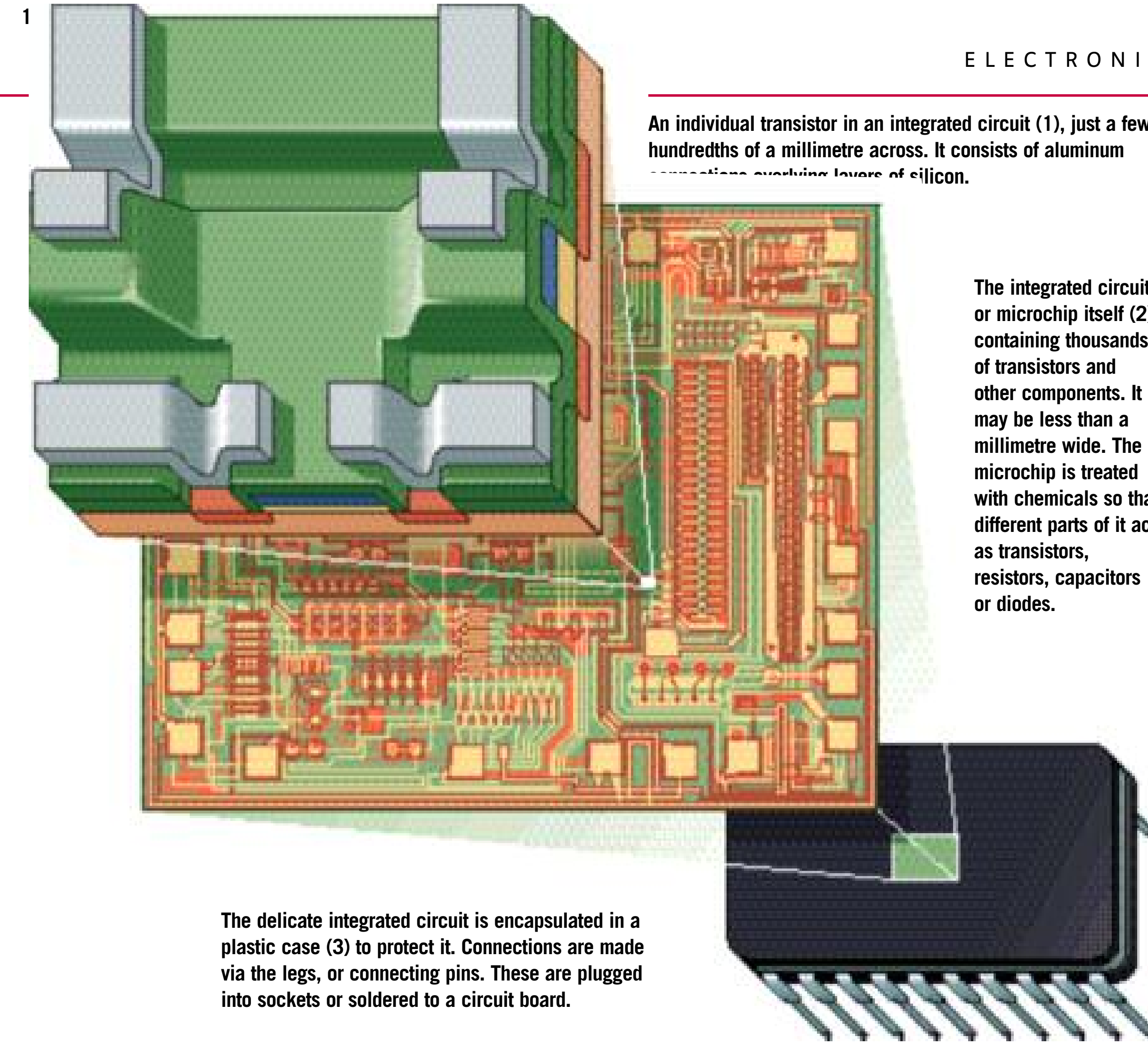
Examples of electronic components: *(clockwise, from top left)* resistor, capacitor, light-emitting diode and transistor. The metal legs connect them to the circuit.

There are dozens of different **electronic components,** but the most common ones are resistors, capacitors, diodes and transistors. A resistor restricts the flow of current in a circuit. Capacitors store electric charge. Current can flow into them until they are full, and out of them until they are empty. A diode allows current to flow one way but not the other. A transistor can act as a switch or an amplifier. It has three connections. The current flowing between two connections is controlled by a tiny current flowing into the third.

An **electronic circuit** is made up of components linked together by wires around which an electric current flows. By combining different components and connecting them in different ways, it is possible to make electronic circuits which do almost any job. In an electronic circuit, the components of the circuit itself control the current. For example, in a security light, the electric current is turned on or off by an electronic device that detects whether it is dark and whether anybody is moving nearby.

Calculators, personal computers, camcorders and portable media players all contain complex electronic circuits that control how they work.

ELECTRONICS



An individual transistor in an integrated circuit (1), just a few hundredths of a millimetre across. It consists of aluminum connections overlying layers of silicon.

The integrated circuit or microchip itself (2), containing thousands of transistors and other components. It may be less than a millimetre wide. The microchip is treated with chemicals so that different parts of it act as transistors, resistors, capacitors or diodes.

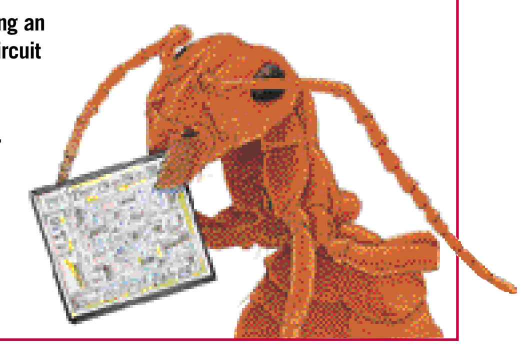
The delicate integrated circuit is encapsulated in a plastic case (3) to protect it. Connections are made via the legs, or connecting pins. These are plugged into sockets or soldered to a circuit board.

INTEGRATED CIRCUITS

Single electronic components are normally soldered (connected by metal) on to a circuit board by their legs. Metal tracks on the board connect the components together. Circuits that require hundreds or thousands of components would be enormous. Modern circuits use integrated circuits, or microchips, in which microscopically small components and the connections between them are built into a wafer of semiconductor material, which is normally silicon. This is why integrated circuits are often called silicon chips. There are thousands of different integrated circuits. Some, such as amplifier chips or timing chips, contain a few dozen components. Others, such as computer processors or memory chips, contain hundreds of thousands or even millions.

The first integrated circuit was built in 1959 in the USA by Texas Instruments. Since then the number of components that can be fitted on to a chip has increased rapidly. An integrated circuit starts life as thin wafer of semiconductor material. The components are built into it by adding and removing layers of semiconductor material, conductors and insulators, using complex chemical and photographic processes.

An ant holding an integrated circuit containing hundreds of components.



ELECTRONICS

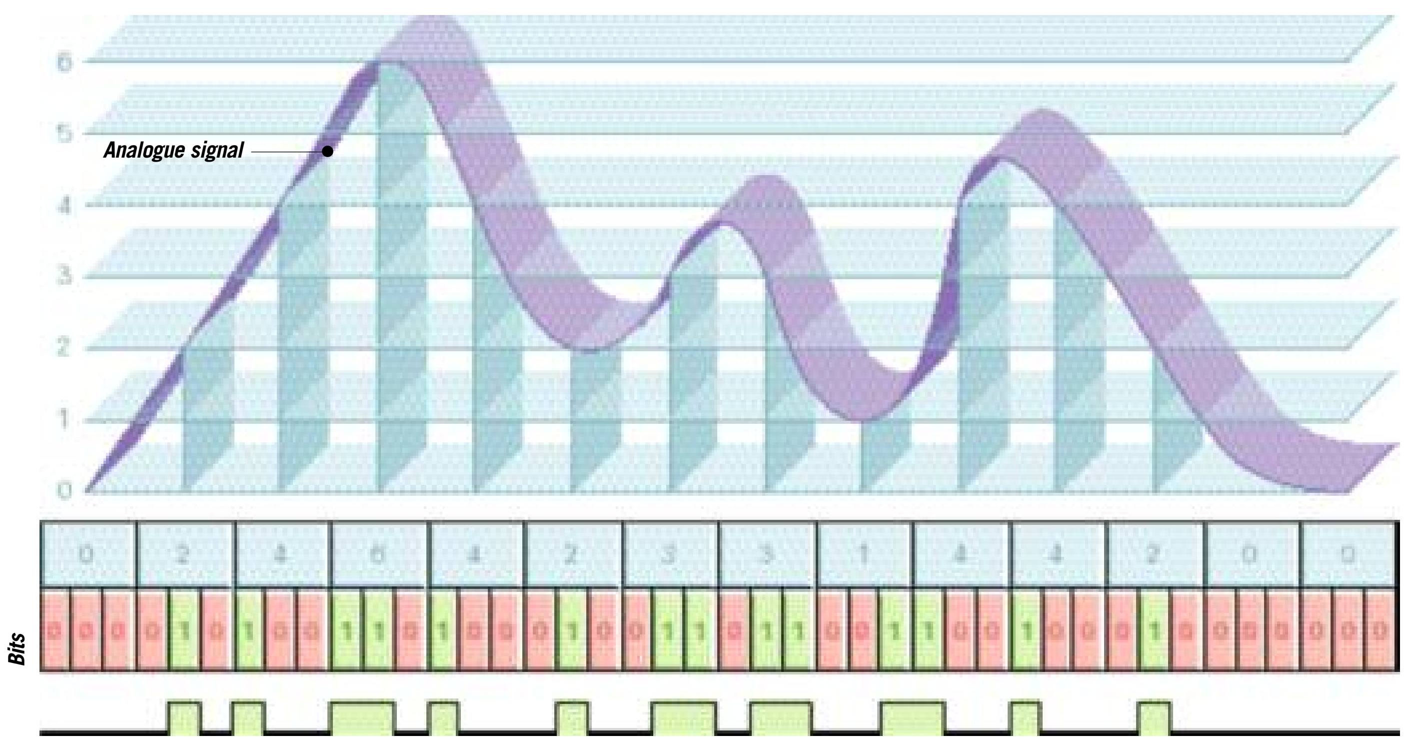
Digital Electronics

In many electronic circuits, such as those in radios, the current can be of any strength. These circuits are called analogue circuits. In digital circuits, the current can have only two strengths—on and off. Digital circuits are used in devices in which the flow of electricity represents information, such as computers.

BINARY					DECIMAL
16	8	4	2	1	
0	0	0	0	0	0
0	0	0	0	1	1
0	0	0	1	0	2
0	0	0	1	1	3
0	0	1	0	0	4
0	0	1	0	1	5
0	0	1	1	0	6
0	0	1	1	1	7
0	1	0	0	0	8
0	1	0	0	1	9
0	1	0	1	0	10
0	1	0	1	1	11
0	1	1	0	0	12
0	1	1	0	1	13
0	1	1	1	0	14
0	1	1	1	1	15
1	0	0	0	0	16

Numbers are represented in digital circuits using the **binary number system.** This uses only the digits 0 and 1 and so can easily be represented in electronic circuits by turning currents on or off. In the decimal system (numbers we use in everyday life: 1, 2, 3, etc.), the digits of a number represent ones, tens, hundreds and so on. In the binary system *(see illustration below left),* the digits represent ones, twos, fours, eights and so on. In digital circuits, each 0 or 1 is called a bit. A four-bit binary "word" can represent decimal numbers up to 15 (one 8, one 4, one 2 and one 1).

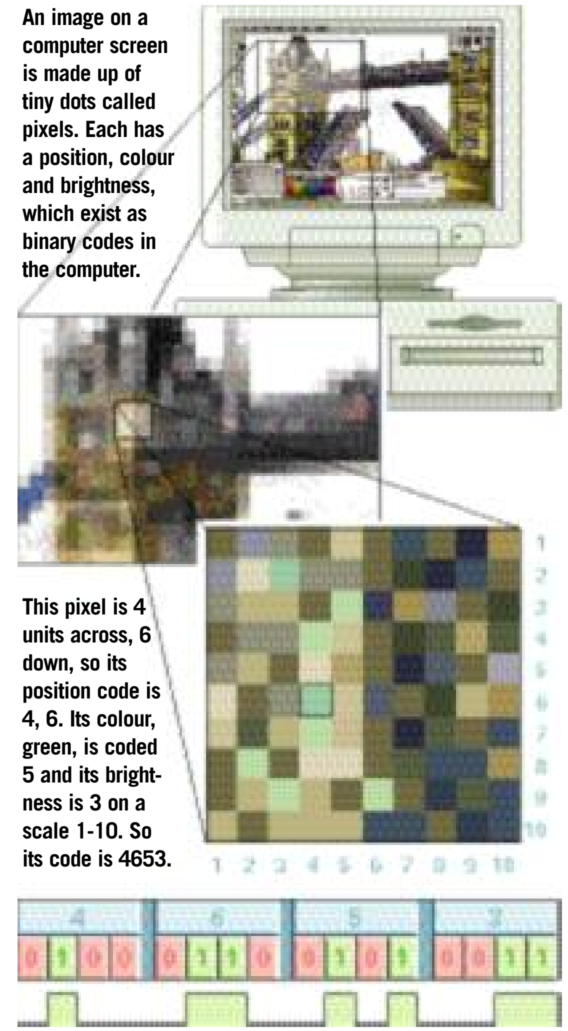
Many types of analogue information must to be turned into digital form before they can be handled by digital circuits. This process is called digitization *(see illustration below).* For example, in a microphone, a sound, which is created by waves of air pressure, is turned into a changing electric current, called an analogue signal, that represents the changes in pressure. This is turned into a digital signal by an electronic circuit called an analogue-to-digital converter. It repeatedly measures the analogue signal, turning it into a continuous stream of binary numbers.



An analogue electrical signal is converted to a digital one. The bits become electrical pulses: on (1) or off (0).

Almost any sort of information (from simple letters to complex moving images) can be represented by numbers, which in turn can be represented in binary form. This means that any sort of information can be represented in digital electronic circuits. Computers *(see page 8)* rely on this fact to store numbers, words, pictures and sounds. They use circuits called logic circuits to process and manipulate the information.

In telephone systems *(see page 12),* the sound of your voice is digitized, normally at the telephone exchange, before it travels across the telephone network. Before it arrives at the telephone of the person you are talking to, it is turned back to an analogue signal (which is needed to work the speaker) by a digital-to-analogue converter. The same thing happens in a CD player, because sound is recorded in digital form on a CD *(see page 28).*



An image on a computer screen is made up of tiny dots called pixels. Each has a position, colour and brightness, which exist as binary codes in the computer.

This pixel is 4 units across, 6 down, so its position code is 4, 6. Its colour, green, is coded 5 and its brightness is 3 on a scale 1-10. So its code is 4653.

The pixel code is stored as a binary number, which, inside the computer, exists as electrical signals. 1 means an electrical pulse, 0 means no electrical pulse.

Digital Pictures

Anything that appears on a computer's monitor is called computer graphics. These can be as simple as plain white text on a black screen, or as complicated as animated three-dimensional images. Whatever the graphics are, they are made up of small coloured squares called pixels (short for picture elements) in a grid pattern.

The concentration of pixels in a picture is called resolution. High-resolution graphics can be viewed on a large screen without the pixels being visible. Graphics can have a different range of colours, too. In eight-bit graphics, each pixel is represented by eight bits, and so can be any one of 256 colours.

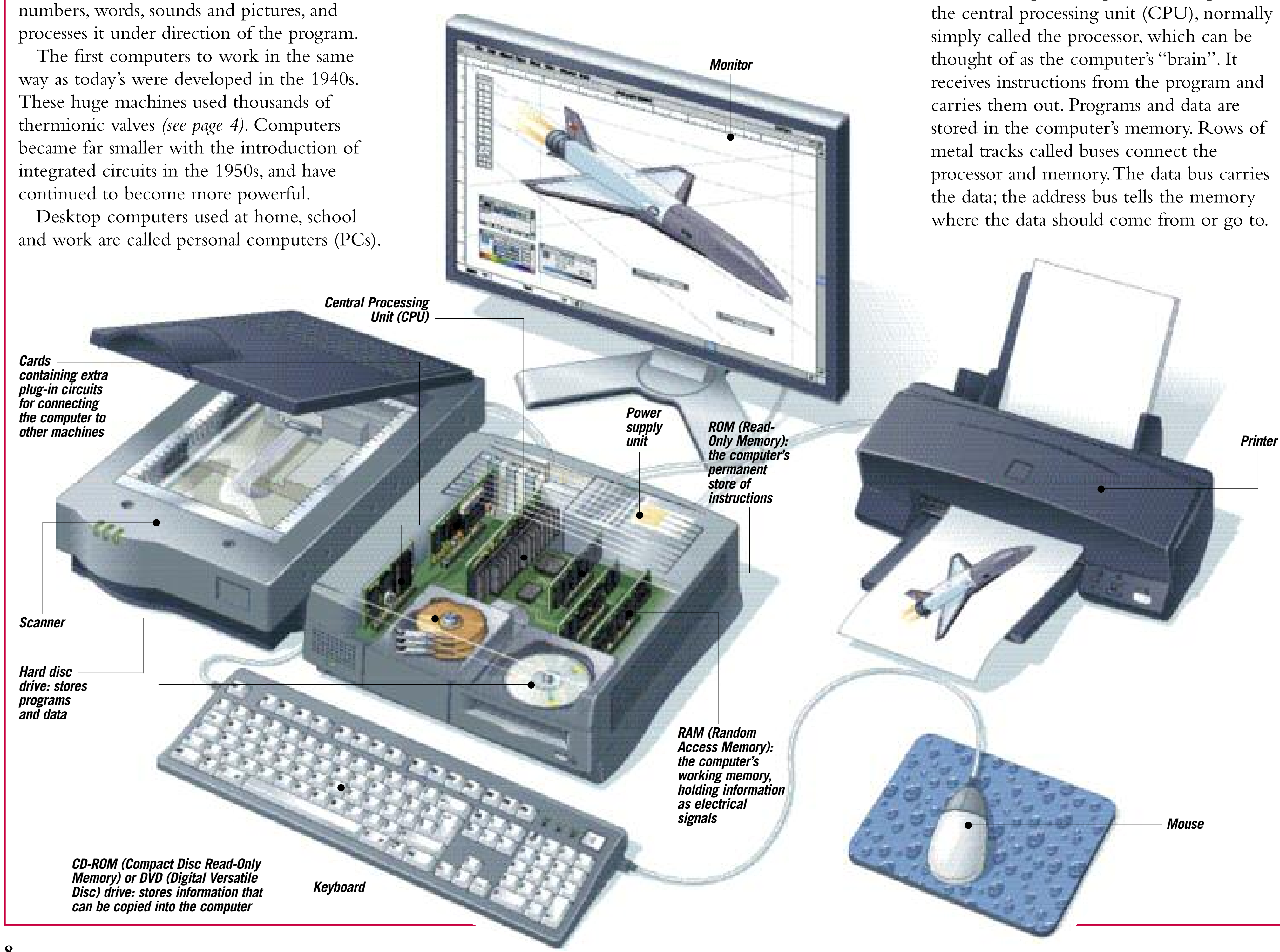
COMPUTERS

COMPUTERS do hundreds of different jobs, from word processing to flying aircraft. A computer can perform different tasks because it is a general-purpose electronic machine, controlled by a computer program. Change the program and the computer does a new job. A computer stores data such as numbers, words, sounds and pictures, and processes it under direction of the program.

The first computers to work in the same way as today's were developed in the 1940s. These huge machines used thousands of thermionic valves *(see page 4)*. Computers became far smaller with the introduction of integrated circuits in the 1950s, and have continued to become more powerful.

Desktop computers used at home, school and work are called personal computers (PCs). Other types include mainframes, used by large companies for data processing, and supercomputers, for doing complex scientific calculations extremely quickly.

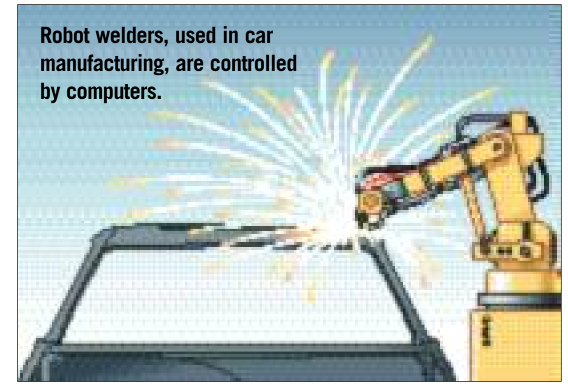
The central processing unit of a PC is contained on a single large integrated circuit called a microprocessor. It has two units—one that carries out calculations and other operations, and another that receives instructions and data from memory.



PARTS OF A PC

A computer is made up of hardware, its physical parts, and software, made up of the data and programs it stores and uses. The hardware is made up of the computer itself and peripherals, such as monitors and printers, that attach to it.

The main part of a personal computer is the central processing unit (CPU), normally simply called the processor, which can be thought of as the computer's "brain". It receives instructions from the program and carries them out. Programs and data are stored in the computer's memory. Rows of metal tracks called buses connect the processor and memory. The data bus carries the data; the address bus tells the memory where the data should come from or go to.


Robot welders, used in car manufacturing, are controlled by computers.

COMPUTER APPLICATIONS

There are two main types of computer software—system software and application software. System software does the computer's "housekeeping" jobs, such as controlling a printer, or writing data to disc drives. Application software makes the computer do specific jobs.

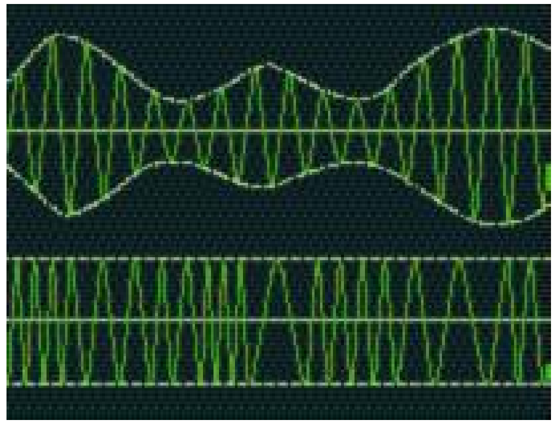
Most personal computers have application software such as a word processor (for preparing letters and reports), a database (for storing and retrieving information), a web browser (for surfing the internet) and e-mail software. Games and educational programs are also applications. Office computers may also have software for doing calculations (called spreadsheets), for processing orders, for accounts, for planning projects and for making presentations. Book and magazine designers use publishing software to design and edit pages before they are printed. Engineers and designers use computer-aided design (CAD) software to help them design new products, which they can view on-screen before making the real thing. Details of the parts can be sent to computers that control the manufacturing machines that make the parts.

In most offices, computers are linked together into networks so that they can share programs and data, which are stored on a computer called a server.

Many computers do just one specific job. Examples of these dedicated computers are games machines, in-car navigation computers, and the computers that help to fly airliners and fighter aircraft.

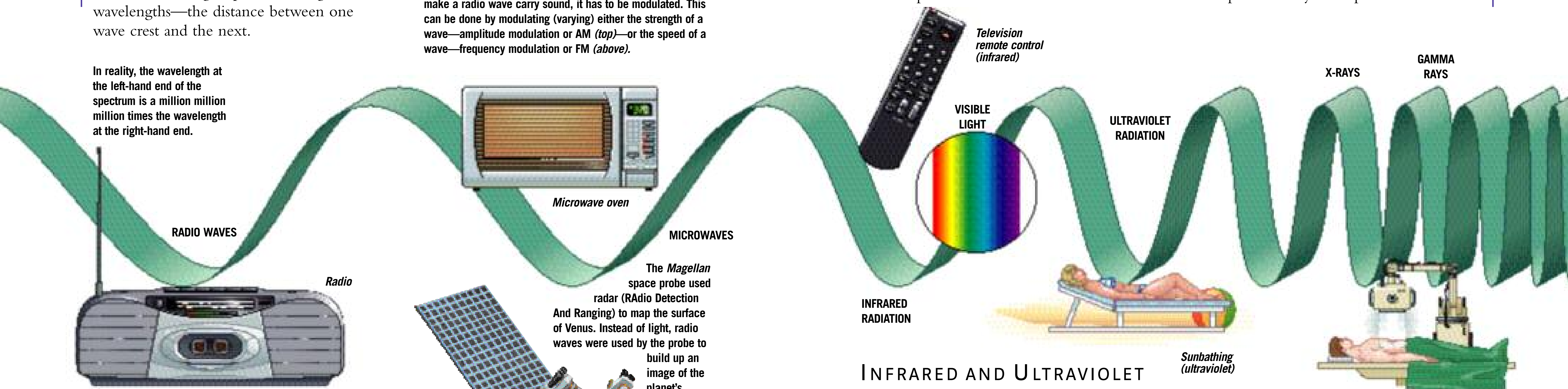
Electromagnetic Radiation

RADIO WAVES, microwaves, light and X-rays have different characteristics, but they are all forms of electromagnetic radiation. Together with other forms, they make up a family called the electromagnetic spectrum. These forms of radiation can also be thought of as waves moving through space, in the same way as waves move across the surface of water. They all travel at the speed of light. Forms of electromagnetic radiation can be grouped according to their wavelengths—the distance between one wave crest and the next.



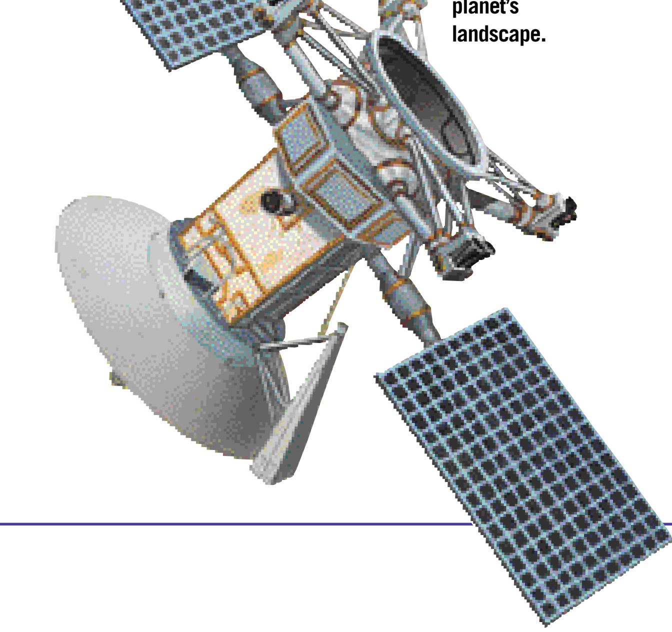
Electromagnetic waves have an amplitude and a frequency. Amplitude is the height or strength of a wave. Frequency is the number of wave crests that pass a point every second. To make a radio wave carry sound, it has to be modulated. This can be done by modulating (varying) either the strength of a wave—amplitude modulation or AM *(top)*—or the speed of a wave—frequency modulation or FM *(above).*

In reality, the wavelength at the left-hand end of the spectrum is a million million million times the wavelength at the right-hand end.



Radio Waves

The longest waves of the electromagnetic spectrum are radio waves. They have wavelengths ranging from more than 100 kilometres down to less than a metre. Radio waves are produced when an electric current changes strength or direction. Radio waves are important in communications through air and space. Microwaves are high-frequency radio waves also used in communications. Some microwave frequencies can be used in cooking.



The *Magellan* space probe used radar (RAdio Detection And Ranging) to map the surface of Venus. Instead of light, radio waves were used by the probe to build up an image of the planet's landscape.

Light

In the middle of the electromagnetic spectrum is a small group of waves that our eyes detect, which is called visible light. It has wavelengths of around a thousandth of a millimetre. Waves with slightly different wavelengths appear as different colours, which together make up the colour spectrum. Light, and especially laser light *(see page 28)*, is very important in modern communications. Where practical, it is used in place of electricity and radio waves, because it can carry far more information without problems of interference.

X-rays and Gamma Rays

To the right of ultraviolet radiation are two more forms of electromagnetic radiation—X-rays and gamma rays. They both have very short wavelengths (less than a millionth of a millimetre) and extremely high frequencies (more than a million million million cycles per second). This means that X-rays and gamma rays have extremely high energies, and they can pass right through some solids. This makes them useful for investigating what is inside solid objects, such as human bodies, or closed suitcases at an airport security checkpoint.

Infrared and Ultraviolet

To the left of visible light on the spectrum is infrared (IR) radiation. This is the radiation you feel as heat from hot objects. It is one of ways in which heat energy travels. Infrared radiation is used for short-range communications, such as in television remote controls, video camera autofocus and remote locking in cars.

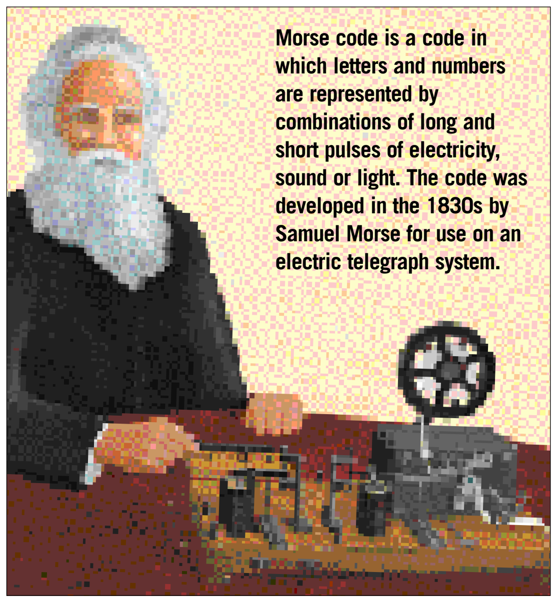
To the right of visible light on the spectrum is ultraviolet (UV) radiation. It carries more energy than visible light. Ultraviolet radiation from the Sun is mostly absorbed by the atmosphere, but it still causes tanning of the skin and sunburn.

X-rays were discovered by the German physicist Wilhelm Röntgen in 1895. They have a wide range of applications. In medicine, they are used to see the structure of bones and other organs by placing the patient between an X-ray source and a photographic film or camera. X-rays and gamma rays are also used in radiotherapy for treating cancers. However, in high doses they can damage tissues. X-rays are given off by high-energy, distant objects in space. X-ray telescopes can detect them.

COMMUNICATIONS

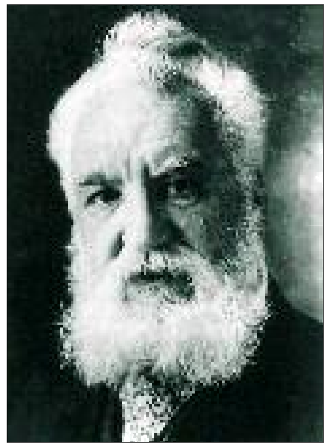
TELECOMMUNICATIONS

TELECOMMUNICATIONS is the sending and receiving of information using electricity, radio waves or light. The information can be sound, television pictures or computer data (which itself can be numbers, words, sounds and images). Forms of telecommunications include the telephone, fax, two-way radio, television and radio broadcasting, and the Internet. Most of these forms of communication require transmitting and receiving machines, and a network to link them together.



Morse code is a code in which letters and numbers are represented by combinations of long and short pulses of electricity, sound or light. The code was developed in the 1830s by Samuel Morse for use on an electric telegraph system.

The first telecommunications device was the **telegraph.** Messages travelled along wires from a sending device to a receiving device as pulses of electricity, using some sort of code that both the sender and receiver understood. Practical telegraph systems were developed in the first half of the nineteenth century, and were first used for railway signalling. Early systems needed several connecting wires, but the system that eventually became standard, developed in the USA by Samuel Morse, needed just one wire. A network of telegraph lines, including undersea cables across the Atlantic, was quickly established right around the world.



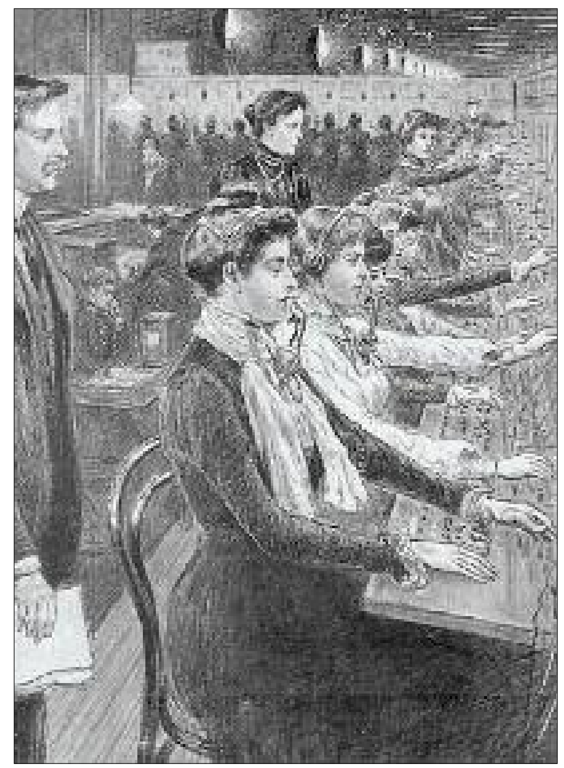
British-born American Alexander Graham Bell gave the first demonstration of the telephone in 1876, and founded the Bell Telephone Company the next year. Bell developed the telephone in his time off from working with deaf children as a speech therapist.

In the early 1900s the telegraph was automated so that machines turned the message into code and back again. The sender could type messages on a keyboard and they would be printed out at the receiver's end. To send a telegraph message, people had to visit a telegraph office. The message arrived at another office and was delivered by hand to the recipient.

The next major step in the development of telecommunications was the invention of the **telephone,** which could transmit speech, allowing people far apart to talk to each other. The first telephone receiver (the part that you talk into and listen to) was patented in 1876 by Alexander Graham Bell. This device both turned the sound of the user's voice into an electrical signal, and an incoming signal into sound, which meant that the user could not talk and listen at the same time.

Early telephones had a separate mouthpiece and earpiece, known as "butterstamps".

When the telephone was invented, there was no telephone network to link telephones in different places, but one soon grew up. All the telephone lines in an area meet at a **telephone exchange,** where they can be connected to one another, or to a line to another area's exchange. The first exchange, opened in 1878 in Connecticut, USA, had just 21 lines. Like all early exchanges, it was operated by hand. A subscriber had to tell the operator which line he or she wanted to be connected to. The automatic exchange, which allowed people to dial numbers, was invented in the USA by Almon Strowger, and started working in 1897. Meanwhile, complex telephone networks grew in large cities. It took longer for different cities and countries to be linked, and until the middle of the twentieth century, the telegraph was still used for long-distance communication.



A telephone exchange in 1902. In early exchanges, only callers attached to the same exchange could be automatically connected. Long-distance calls between cities and countries required three or four operators to connect them.

HOW A TELEPHONE WORKS

All telephone receivers *(see illustration below)* are linked to a telephone exchange by a telephone line (1). When you lift or turn on the receiver, electronic circuits at the exchange detect it and wait for a number to be dialled. As you dial the number, the receiver sends signals to the exchange, which uses them to make a connection to the line of the person you are calling. The exchange makes the other telephone ring, and when it is answered, it connects the two lines together.

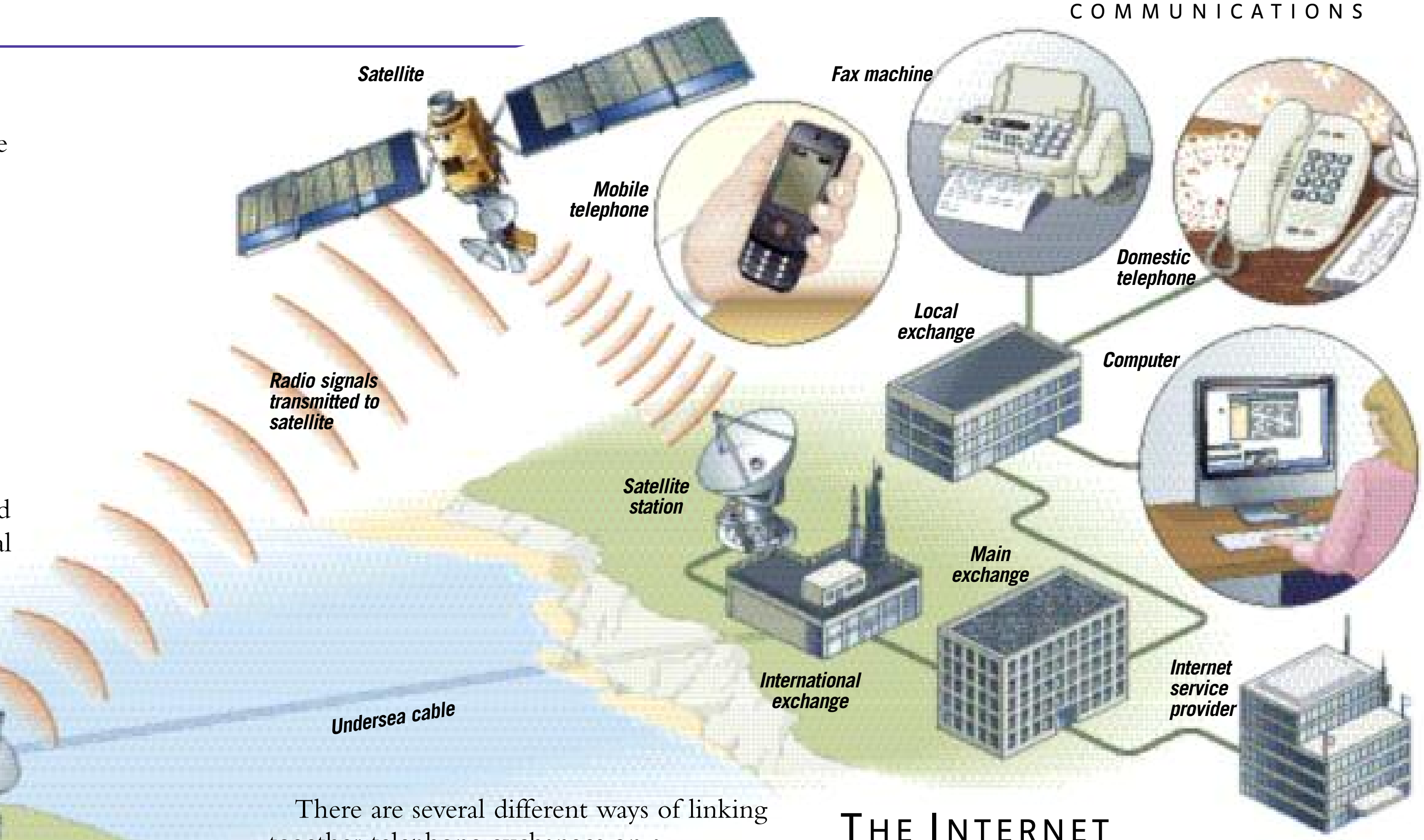
When you speak into the receiver's mouthpiece (2), the sound makes a thin metal plate called a diaphragm vibrate. This movement affects the strength of an electric current, creating an electrical copy of the sound, which is called a signal. The signal travels through the connections in the telephone network to the other receiver, where it operates a tiny speaker in the earpiece (3), recreating the sound.

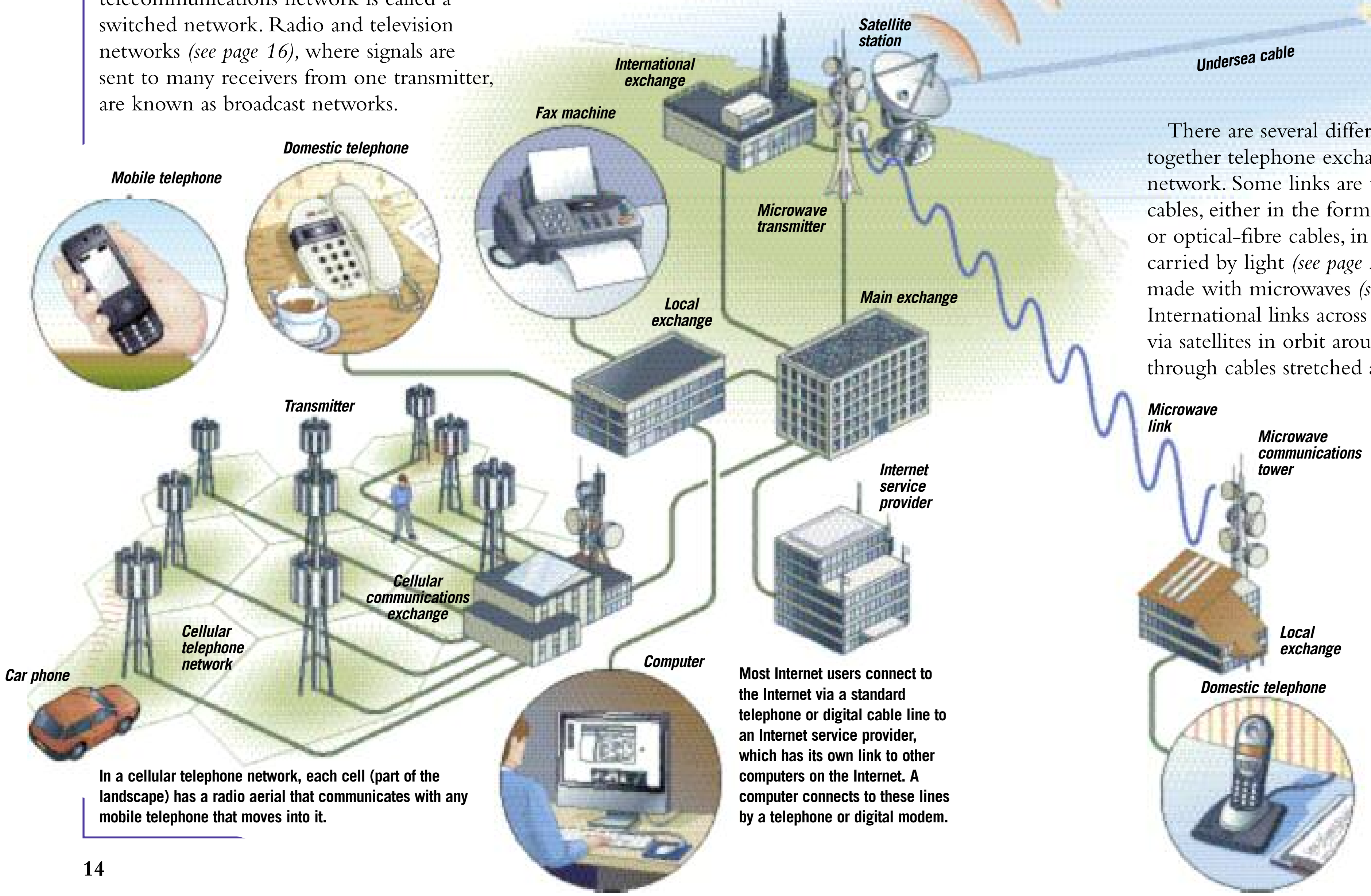
The signal travels in digital form *(see page 6)* for most of its journey through the network.

Communications Networks

TELEPHONE CALLS, fax messages, e-mails, computer data—and often radio and television signals as well—all travel from place to place through a complex, worldwide telecommunications network. All the different forms of telecommunications are turned into signals that can travel through the network. They always travel between two points in the network (for example, two telephone receivers or fax machines), and are directed through it by electronic circuits at telephone exchanges. This sort of telecommunications network is called a switched network. Radio and television networks *(see page 16),* where signals are sent to many receivers from one transmitter, are known as broadcast networks.

All the telecommunications devices (telephones, fax machines and home computers) connected to normal telephone lines are linked by the lines to a local telephone exchange. Each line has its own unique telephone number which the exchange uses to find it. All the local exchanges in one area are linked to a main exchange, which in turn is linked to other main exchanges to form a national network. Also linked into the network are special exchanges for mobile telephones, and Internet service providers *(see opposite).* Most information (speech, fax messages and computer data) travels to and from the local exchange in analogue form and between local exchanges in digital form.





In a cellular telephone network, each cell (part of the landscape) has a radio aerial that communicates with any mobile telephone that moves into it.

Most Internet users connect to the Internet via a standard telephone or digital cable line to an Internet service provider, which has its own link to other computers on the Internet. A computer connects to these lines by a telephone or digital modem.

Microwaves carry signals between hill-top transmitters and receivers, to and from communications satellites. Microwave transmitters and receivers are dish-shaped aerials. A transmitter focuses the microwaves into a narrow beam, which is aimed at a receiver that collects the waves. The microwaves are modulated (shaped) so that they can carry information.

There are several different ways of linking together telephone exchanges on a network. Some links are underground cables, either in the form of electrical cables or optical-fibre cables, in which signals are carried by light *(see page 28).* Some links are made with microwaves *(see below).* International links across oceans are made via satellites in orbit around the Earth, and through cables stretched across the sea bed.

The Internet

The Internet is a vast computer network that stretches right around the world, made up of hundreds of millions of computers. Data can travel from any computer on the network to any other computer. The Internet began in the 1960s, when research agencies in the USA built their own communications network. Other organizations, such as universities, gradually joined. As home computers became cheaper and more popular in the 1990s, the Internet began expanding rapidly, with anybody being able to use it via a telephone line.

Internet use falls into two main areas—e-mail and the World Wide Web. With e-mail, it is possible to send a text message (with other data files, such as photographs, attached if needed) almost instantly to any other Internet user at their e-mail address. The World Wide Web (the "Web") is a huge information-gathering system. It allows one computer connected to the Internet to ask for and copy files from another computer. The files are stored in standard form so that any computer can read them.

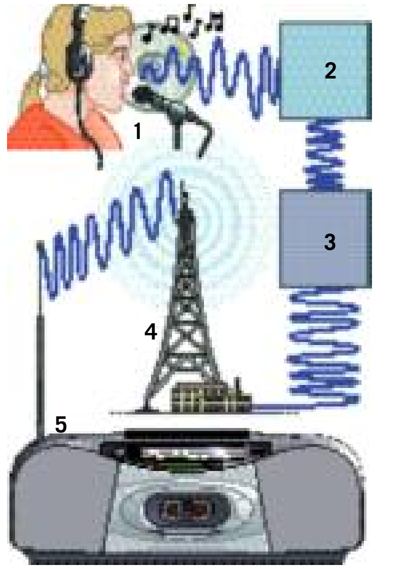
Radio

THE WORD "radio" means communicating with radio waves. These are part of the electromagnetic spectrum *(see page 10)*. Radio has a huge range of applications. It is used in the telephone network *(see page 14)* for mobile telephones and links in the network, for broadcasting, for two-way radio communications as used by the emergency services, and for remote control of machines. "Radio" also means the media of radio, in which music and speech from radio stations are transmitted by radio waves or digital signals, and are picked up by radio or digital receivers.

The existence of radio waves was confirmed in 1888 by the German physicist Heinrich Hertz, but it was the Italian Guglielmo Marconi who, in 1896, was the first to make long-distance radio transmissions. In 1901 he transmitted Morse code *(see page 12)* across the Atlantic. Two-way radio communications using Morse code began in the early twentieth century, and radio broadcasting began in the 1920s.

Italian radio pioneer Guglielmo Marconi with his radio equipment.

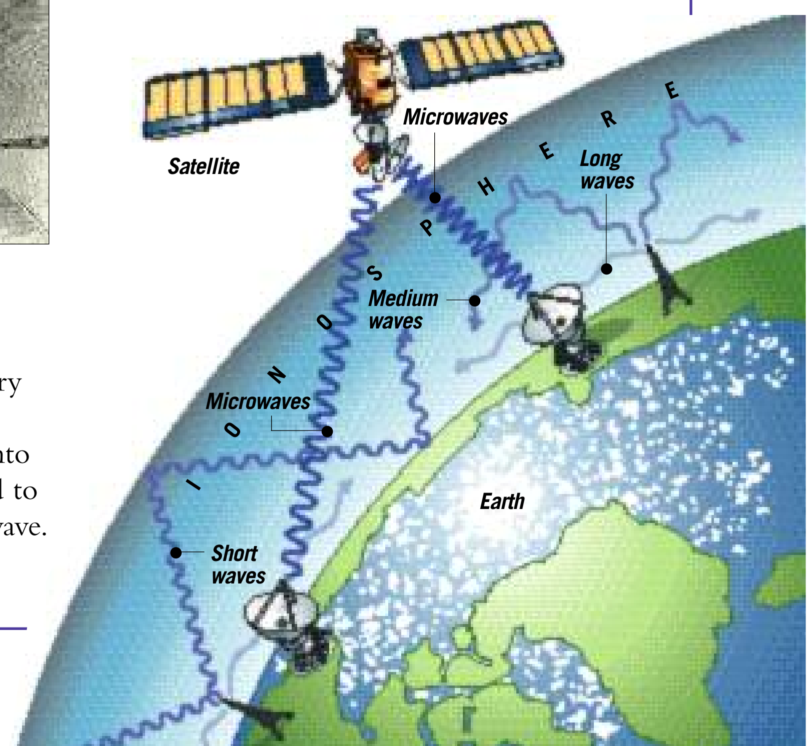
On their own, radio waves do not carry any information. To make an electrical signal, such as one representing sound, into a radio signal, the electrical signal is used to shape another signal, called the carrier wave. The shaped carrier signal is sent to a transmitter, where it creates radio waves.



At a radio station, electrical signals from microphones, tape machines and music decks are combined to create a signal for transmission (1). This is then modulated (2), amplified to increase its power (3), and then sent to a transmitter (4). From here radio waves spread out in all directions. They are detected by radio receivers (5).

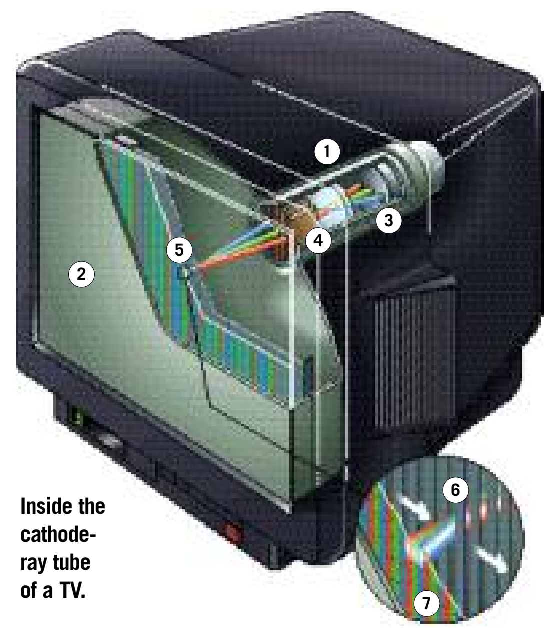
The shaping process is called modulation *(see page 10)*. So that radio signals from different transmitters do not interfere with each other, they are sent using carrier waves with different frequencies. The whole family of radio waves is divided into sections called wavebands. Each waveband is reserved for a different form of communication. A radio receiver detects radio waves of the right frequency and demodulates them to get back the original electrical signal.

Radio waves travel through the air, bounce off a layer of the atmosphere called the ionosphere, or are relayed by satellite.



Television

The first fully electronic television system was developed in the 1930s in the USA by Vladimir Zworykin. A simple TV system needs a camera at the scene, a way of transmitting the images *(see page 19)*, and a receiver where the images appear. A television camera takes 25 or 30 electronic photographs (called frames) of a scene every second and creates an electric signal that represents the colours in the frames. The receiver uses this signal to display the frames in quick succession on a screen, which creates the illusion of smooth movement because our brains merge the frames together.

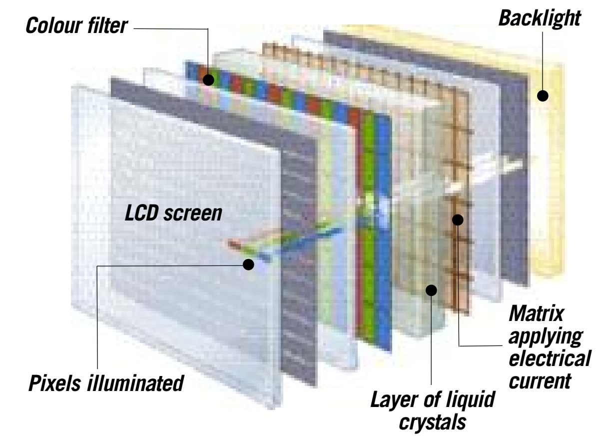


Inside the cathode-ray tube of a TV.

How a TV Set Works

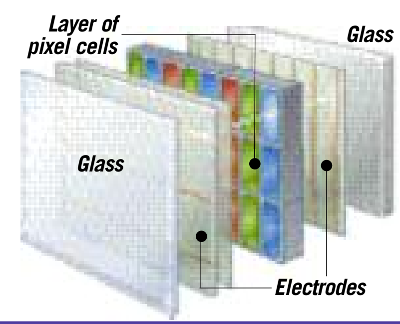
A television builds each frame of the moving picture line by line using the electrical or digital signal originally created by the camera. In older televisions, the picture is created by a cathode-ray tube, but modern flat-screen TVs use liquid crystal display (LCD) or plasma display panels (PDP).

The cathode-ray tube in a television receiver has a narrow neck (1) and a flat base that forms the screen (2). The air is pumped out to create a vacuum. At the back of the tube are three guns (3) that fire beams of electrons (for red, green and blue light) at the screen. Electromagnets (4) make the beams scan quickly across the screen line by line, while the picture signal controls their strength. Where the beams hit a special coating on the inside of the screen, it gives off light (5). Just behind the TV screen is a plate with holes in it called a shadow mask (6). It ensures that the beams hit the screen only behind filters of their own colour (7). Filters make the light produced by the three beams appear red, blue or green. These add together to form the picture colours.

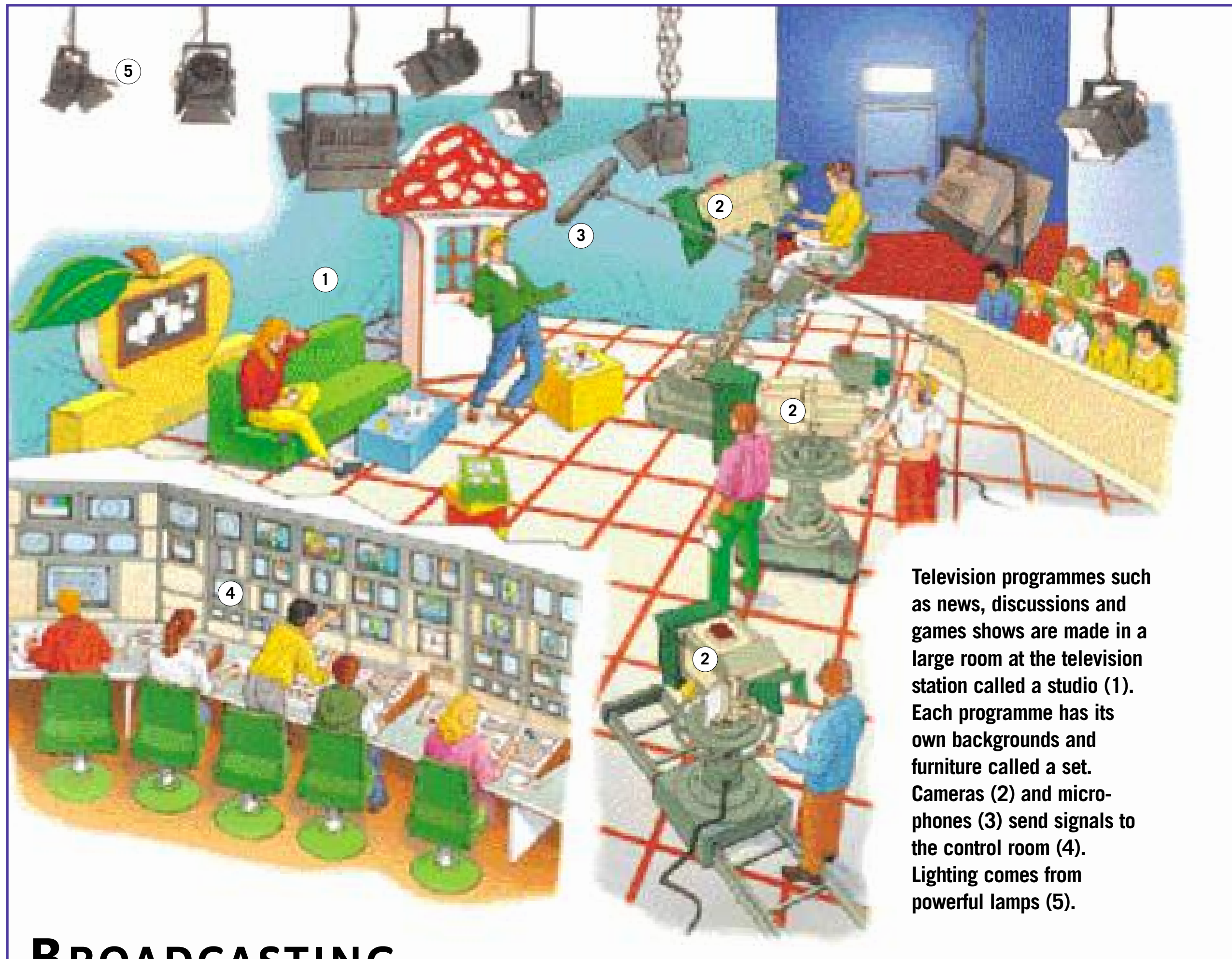


LCD Screens

Computer laptops and many flat-screen TV receivers use LCDs. An LCD screen contains many thousands of tiny pixels *(see page 7)*, each made up of red, green and blue elements. White light from a backlight passes through a layer of liquid crystals and various filters to illuminate the pixels. When an electric current is passed through the liquid crystal layer, the rod-shaped molecules act as a kind of shutter for the pixels, varying the amount of light that each transmits. The changing pattern of illumination, controlled by the electrical or digital TV signal, produces the moving images.



In a plasma screen TV there is a layer consisting of many thousands of pixel cells. An electric current causes gas inside each cell to give off energy and illuminate the pixels by varying amounts.



Television programmes such as news, discussions and games shows are made in a large room at the television station called a studio (1). Each programme has its own backgrounds and furniture called a set. Cameras (2) and micro-phones (3) send signals to the control room (4). Lighting comes from powerful lamps (5).

BROADCASTING

THERE ARE thousands of different television channels around the world, broadcasting entertainment, news, information and sport. Television programmes are created at television stations. Each station normally broadcasts several separate channels. Some programmes, such as news and sports, are broadcast live, which means the viewers see action as it happens. Most programmes are recorded on videotape and broadcast at a later date. Some programmes are a combination of live and recorded action.

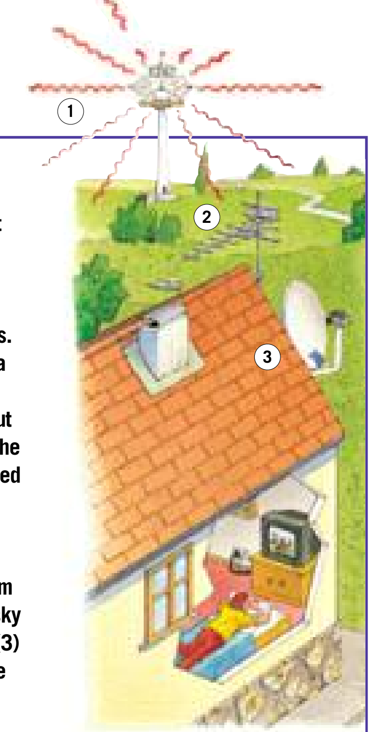
A television camera electronically divides an image of the scene it is pointing at into hundreds of narrow horizontal lines, each made up of hundreds of small dots of colour. It creates a electrical signal that represents the colours of all the dots. It repeats this process 25 or 30 times a second to create a continuous picture signal.

Pictures from the cameras in a television studio, and from cameras at outside broadcasts, such as sporting events, are fed to a control room, where they appear on screens. Here, live pictures from cameras, pictures from videotape (such as short news reports) and computer graphics are mixed to create the signal for the pictures that will be broadcast. Sound from studio microphones or audio tape is also added.

There are several ways of broadcasting signals. In each case, the signal is modulated *(see page 10)* before it is sent, with different channels using different carrier signals. The receiver tunes in to the signal from the channel the viewer wants to watch. Many signals now travel in digital *(see page 6)* rather than analogue form. This allows many more channels to be broadcast, and eliminates the interference that often makes pictures sent using analogue signals fuzzy.

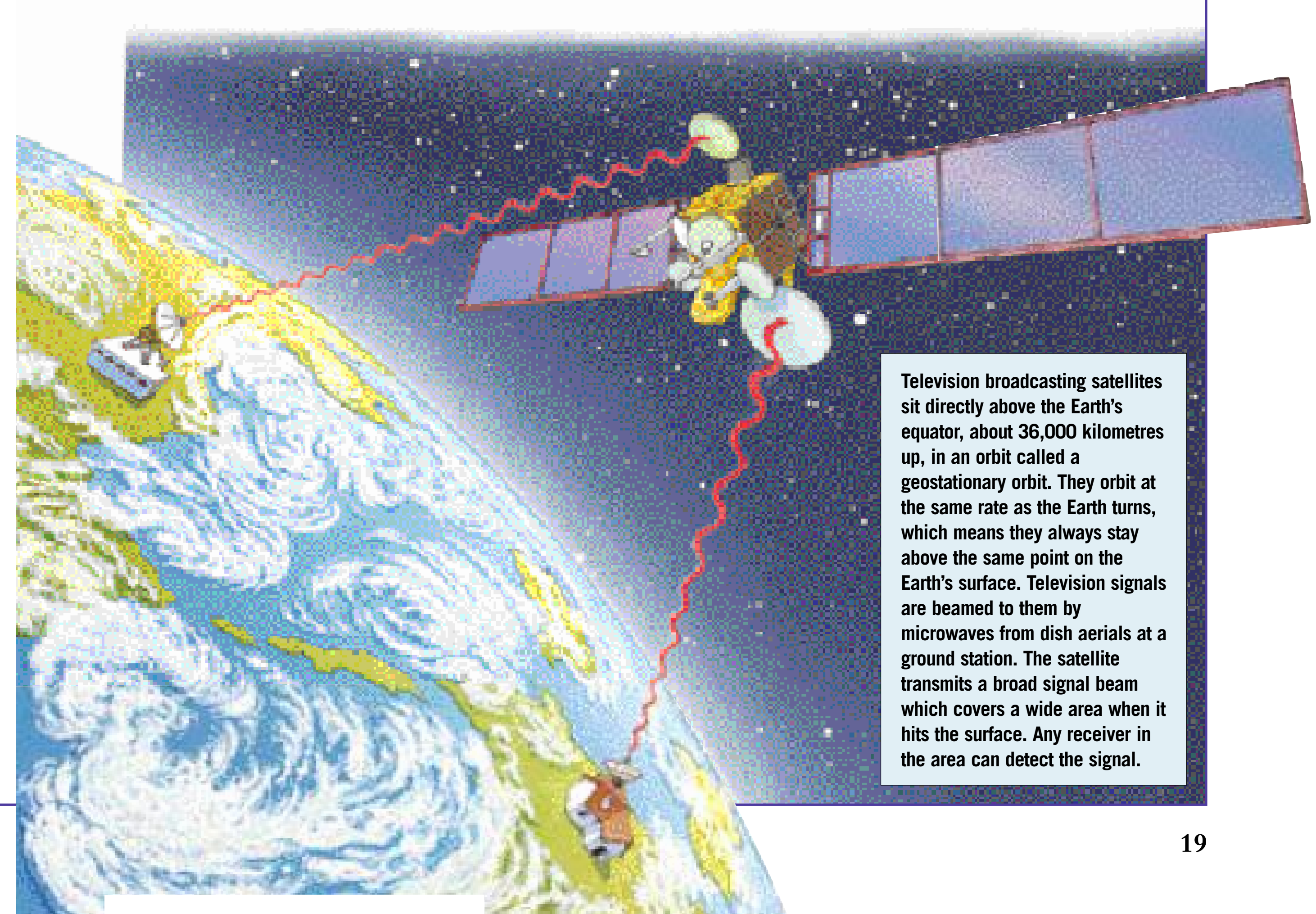
In terrestrial television, the signal goes to a transmitter where it is turned into a radio signal that is spread out in all directions. The signal can be detected by an aerial of any receiver within range of the transmitter. In cable television, the signal travels from a cable television station through a network of underground cables that link directly to receivers connected to the network. In satellite television, the signal is beamed by microwaves to a satellite high above the Earth. The satellite detects the signal with its own aerial and re-transmits it so that it can be picked up by receivers on the Earth's surface. In webcasting, television and video pictures are transmitted over the Internet *(see page 15)*. The pictures are first converted into a digital video format and then made available on a website.

In closed-circuit television (CCTV), signals are not broadcast at all. Instead, they go directly from the camera to a receiver. CCTV is used for security systems, with the pictures being recorded as well as viewed.



Terrestrial television signals are broadcast from transmitters (1) at the top of tall masts, often on hill tops, and detected by aerials (2) placed high up on roofs. This gives the signals a clear route from transmitter to aerial. But in mountainous areas the signals are often blocked by hills. This is not a problem with satellite television, where the signals come down from a satellite high in the sky to small aerial dishes (3) aimed accurately at the satellite.

Interactive television is television in which the viewer can send information back to the television station, normally via a telephone or digital cable line. The combination of digital television and a telephone line also allows viewers to access the Internet *(see page 15)*.



Television broadcasting satellites sit directly above the Earth's equator, about 36,000 kilometres up, in an orbit called a geostationary orbit. They orbit at the same rate as the Earth turns, which means they always stay above the same point on the Earth's surface. Television signals are beamed to them by microwaves from dish aerials at a ground station. The satellite transmits a broad signal beam which covers a wide area when it hits the surface. Any receiver in the area can detect the signal.

COMMUNICATIONS

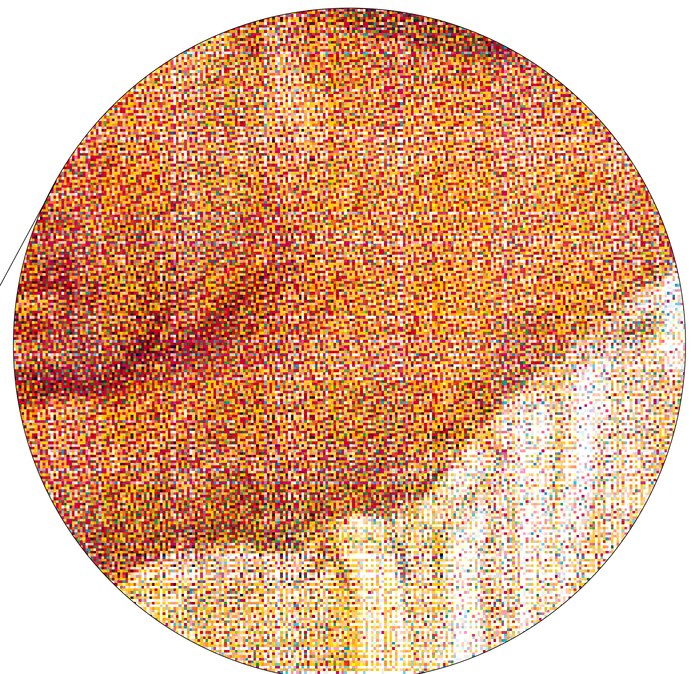
PRINTING

PRINTING is the process of making many copies of a document or a picture. Printing is normally done on paper, but it can also be done on fabrics, and sheets of plastic or metal. Books such as this one are printed on a machine called a printing press. The text and pictures start as patterns on a plate. In the press, the plate is inked so that these areas become ink-covered, and are pressed on to the paper via a rubber-covered drum. A fast printing press can make several prints a second because each print is made by one simple operation.

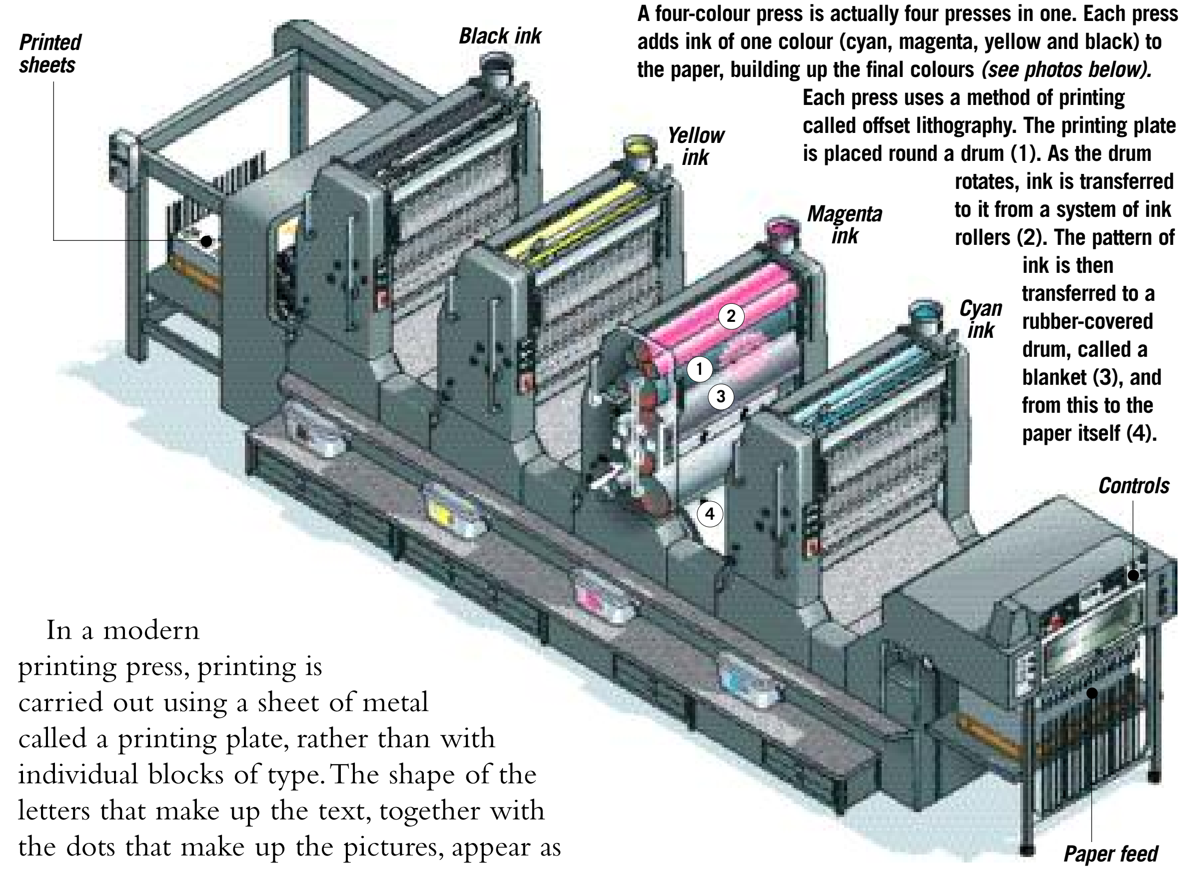
One of the first methods of printing was wood-block printing, where the images to be printed were carved in reverse into wooden blocks. The blocks were then inked and pressed onto paper to make a print. Ink from the raised areas was transferred on to the paper. Simple block printing is still used for hand-printed textiles.

Two of the most important inventions in printing were moveable metal type (which allowed words and paragraphs to be built up from individual metal blocks with letters on them) and the printing press. In Europe, these were both developed in the fifteenth century by the German printing pioneer Johannes Gutenberg. They allowed books to be printed in large quantities, whereas before each book had to be hand-copied.

On a printed colour page such as this one, the text is normally solid black ink, while the pictures are made up of tiny dots of coloured—and black—ink.



In an early printing press a screw was turned to press the paper firmly down on to inked type.



A four-colour press is actually four presses in one. Each press adds ink of one colour (cyan, magenta, yellow and black) to the paper, building up the final colours *(see photos below).* Each press uses a method of printing called offset lithography. The printing plate is placed round a drum (1). As the drum rotates, ink is transferred to it from a system of ink rollers (2). The pattern of ink is then transferred to a rubber-covered drum, called a blanket (3), and from this to the paper itself (4).

In a modern printing press, printing is carried out using a sheet of metal called a printing plate, rather than with individual blocks of type. The shape of the letters that make up the text, together with the dots that make up the pictures, appear as patterns on the surface of the plate. The plates are prepared using photographic and chemical processes.

Type and pictures for a book, magazine or leaflet are nowadays usually designed and laid out on a computer using desktop publishing software. The files from the computer may then be sent to the printer, which uses them to make four printing plates, one for each colour of ink on the printing press.

For most publications, the paper needs to be printed on both sides. Some presses can do this but on others the paper has to be sent through the press twice. Several pages of the final book or magazine are normally printed on each sheet of paper. The sheets then go for print finishing, where machines fold, collate (sort), staple or sew, and trim the sheets to create the finished product.

Most colour printing is done with just four colours of ink: cyan, magenta, yellow and black. By printing dots in varying sizes, the first three colours combine to create almost any other colour *(right).* In practice, all three mix to create brown, so black is used to darken some areas.

Cyan only

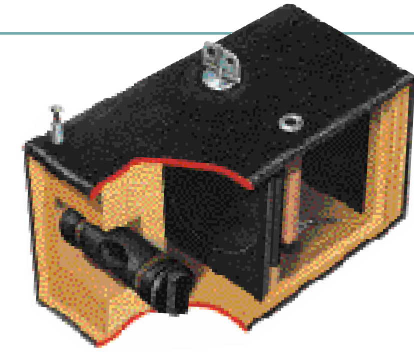
Cyan and magenta

Cyan, magenta and yellow

Cyan, magenta, yellow and black

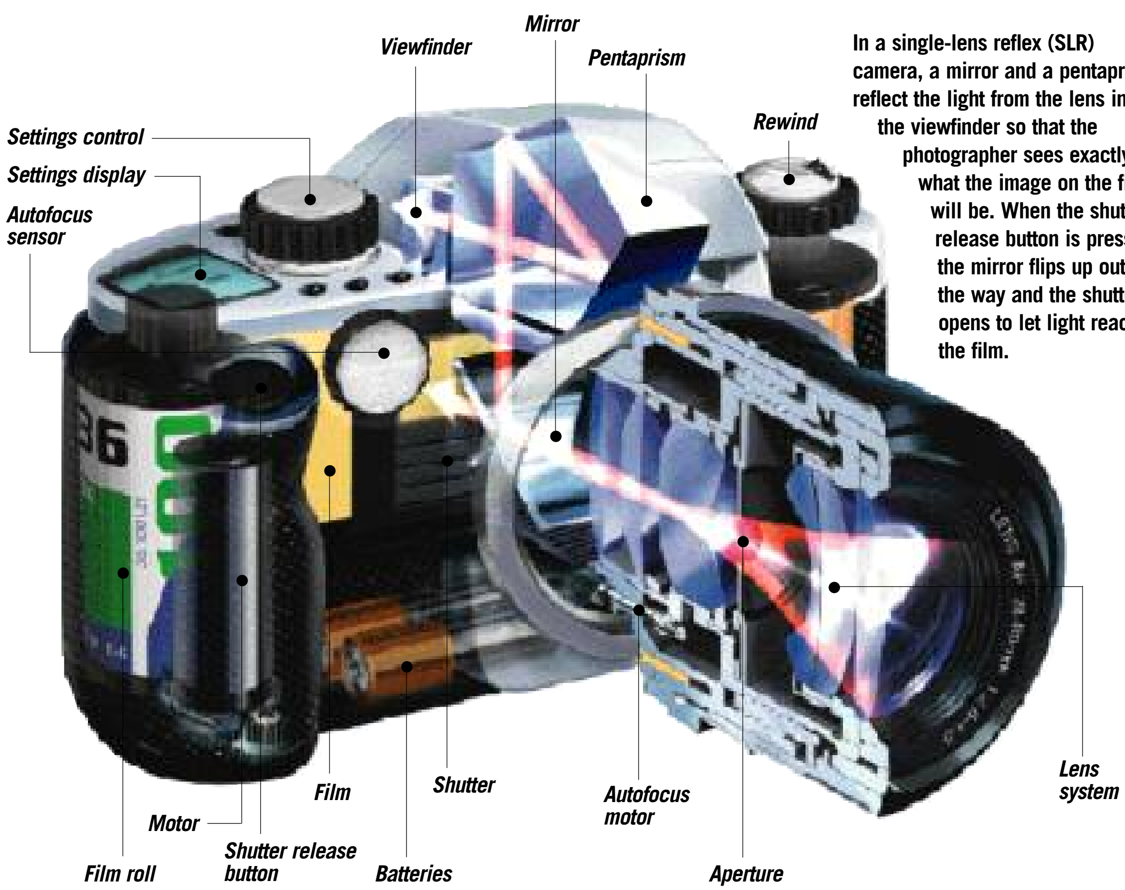
CAMERAS AND PHOTOGRAPHY

A CAMERA is a device that records an image of a scene, either on photographic film or electronically as a digital photograph. Its main features are a light-proof body, a lens and a shutter. The lens gathers rays of light from the scene that the camera is pointed at and bends them so that all the rays from one point on the scene are focused to meet at the same place at the back of the camera. In this way it makes a small copy of the scene called an image. The shutter opens to allow light from the lens to reach the film or light sensors. Photographic film must be exposed to just the right amount of light in order to create a clear image on the film. The exposure is controlled by adjusting how long the shutter opens for (called the shutter speed) and the size of an opening behind the lens called the aperture.



In 1888 American inventor George Eastman introduced the first Kodak box camera. It helped to make photography a popular hobby because the films could be sent away for developing.

The forerunner of the camera was the camera obscura, used by artists, which made images with a lens, but could not record them. The earliest surviving photograph was taken by Frenchman Joseph Niépce in 1827. It was recorded on a metal plate coated with chemicals that changed very slowly where the image was light but not where it was dark. Photographic processes were soon improved by Frenchman Louis Daguerre, and Englishman William Fox Talbot. Talbot developed the negative-positive process, where the image is recorded as a negative in the camera, and is used to print positive photographs.



In a single-lens reflex (SLR) camera, a mirror and a pentaprism reflect the light from the lens into the viewfinder so that the photographer sees exactly what the image on the film will be. When the shutter-release button is pressed, the mirror flips up out of the way and the shutter opens to let light reach the film.

RECORDING AN IMAGE

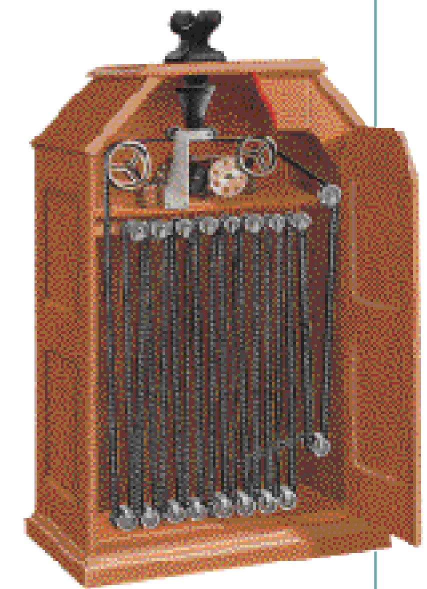
Photographic film consists of a plastic strip coated on one side with a layer of light-sensitive chemicals. When light from a scene is focused on to the film in a camera, the chemicals in the bright areas of the image begin to change. The brighter the light, the greater the change. The chemicals remain unchanged in the dark areas. At this stage, the image is simply a pattern of chemicals. It only becomes visible when the film is processed. Colour film contains three layers of chemicals, one to record each of the primary colours of light, which are red, green and blue.

The Imacon high-speed research camera takes photographs just one billionth of a second apart. It can reveal what happens when a bullet hits its target.

DIGITAL PHOTOGRAPHY

A digital camera is a camera in which photographs are stored electronically in digital form rather than on traditional film. The lens focuses light on to a special microchip called a charge-coupled device (CCD). This divides the image into pixels *(see page 6)*, measures the brightness and colour of each one and digitizes the readings. The digitized image is stored in memory chips or on a disc. The photographs are transferred to a computer, where they can be viewed on screen, edited, added to documents, used to make greetings cards, or attached to e-mails.

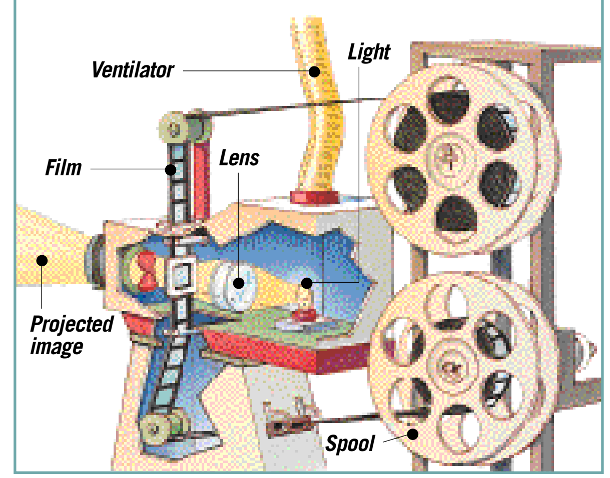
MOVIE CAMERAS



American inventor Thomas Edison built his kinetoscope *(right)* in the late 1891 to show films shot by his kinetograph, which was one of the first movie cameras. The viewer watched the movie, which was on a continuous loop of film, through a slot in the top of the kinetoscope.

A MOVIE FILM is made up of thousands of photographs called frames on a long roll of film. The frames are taken in quick succession by a movie camera (or cine-camera). A revolving shutter opens to let light hit the film, creating the image for a frame. Then it closes and the film is moved into position for the next frame. This sequence is repeated again and again to photograph 24 frames every second.

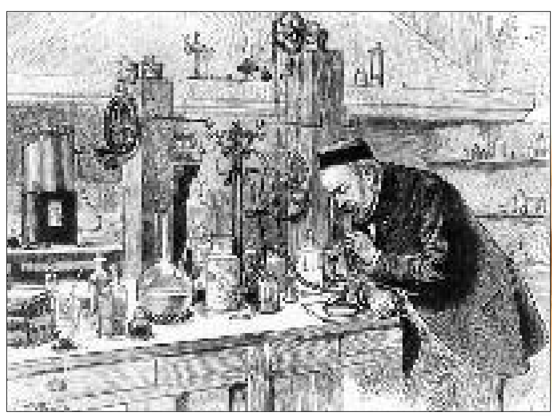
A movie projector *(below)* does the reverse of a camera. It shines a bright light through the film and focuses the rays onto a screen, creating an enlarged image. It shows the frames in quick succession, which creates the illusion of movement.



MICROSCOPES

A MICROSCOPE is an instrument that magnifies very small objects, allowing the viewer to see detail in the object that is invisible to the naked eye. Microscopes are used mostly, but not only, in biology and medical research.

There are two main types of microscope—optical microscopes and electron microscopes. In an optical microscope, the image of the object is created by light. The simplest optical microscope is a magnifying glass, which contains a single lens. The lens gathers and bends light coming from the object, making the object look larger than it really is. Compound microscopes have more than one lens. A standard compound microscope has two groups of lenses. The first group, called the objective, gathers light from the object and focuses it to create a magnified image of the object. The second group, called the eyepiece, magnifies this image.



French microbiologist Louis Pasteur *(above)* studies bacteria under a microscope.

The first compound microscope was probably built by Dutch spectacle-maker Zacharias Janssen in about 1590. Early microscopes had poor-quality lenses and gave blurred images. In the 1670s another Dutchman, Anton van Leeuwenhoek, began making simple, single-lens microscopes. He was the first person to see microorganisms, such as bacteria and amoebae.

KEY
1 *Eyepiece lenses*
2 *Adjustment controls*
3 *Objective lenses*
4 *Multiple nosepiece*
5 *Specimen on slide*
6 *Stage*
7 *Condenser (focuses light beam)*
8 *Condenser control*
9 *Light beam*
10 *Mirror*

A typical compound optical microscope with three inter-changeable objective lenses, providing magnifications from about 50 times to about 200 times.

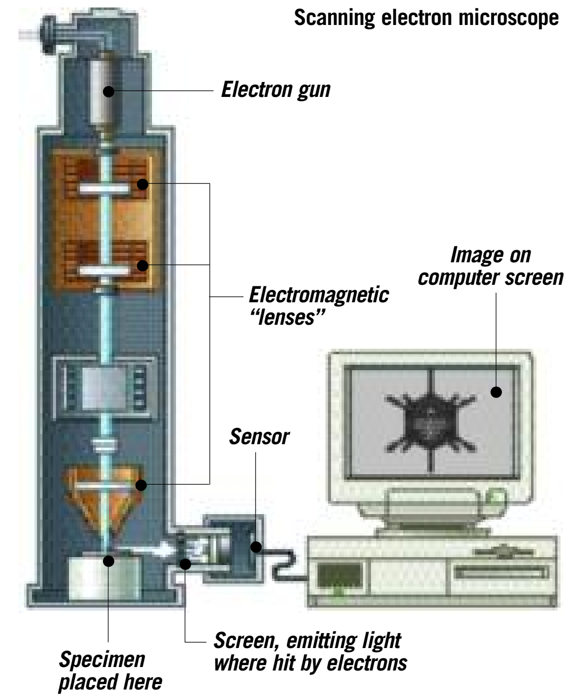
ELECTRON MICROSCOPES

Optical microscopes can only magnify objects up to 2000 times. Greater magnifications do not reveal any more detail. Electron microscopes can magnify objects more than a million times. In an electron microscope, a beam of tiny particles called electrons does the same job as light in an optical microscope. It is fired at the object and then focused by electromagnetic "lenses" on to a screen that emits light where the electrons hit it.

This SEM image of the head of a fruit fly, enlarged about 135 times, has been coloured so that its features can be seen clearly.

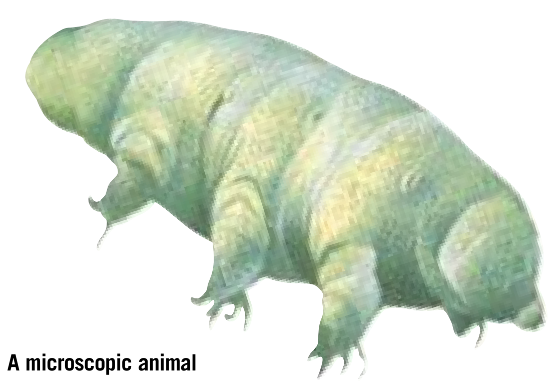
There are two main types of electron microscope. In a transmitting electron microscope (TEM), the beam of electrons is fired through an extremely thin slice of the specimen under investigation. In a scanning electron microscope (SEM), a very narrow beam of electrons is fired at the surface of the specimen. The beam scans across the surface of the specimen and a sensor detects the electrons bouncing off. In this way, a three-dimensional image of the specimen is gradually built up.

Scanning electron microscope



The images created by electron micro-scopes are called electron photomicro-graphs. An example of one is shown here *(left)*. They may be viewed on television screens using video cameras, or digitized and viewed on computer screens.

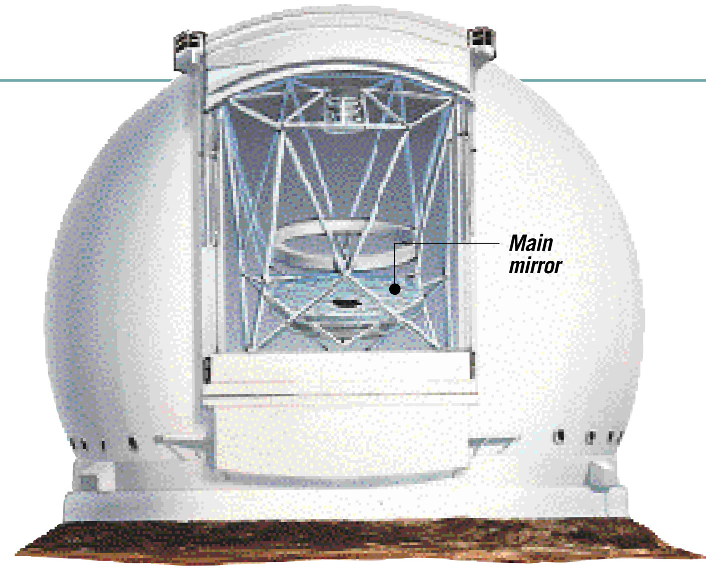
The first electron microscope, which could magnify objects up to 400 times, was built in 1932 by German engineers Ernst Ruska and Max Knoll. The newest type of electron microscope is the scanning tunnelling electron microscope (STM). It can magnify up to 100 million times, which is enough to see individual atoms.



A microscopic animal called a water bear, magnified about 150 times with an scanning electron microscope.

Telescopes

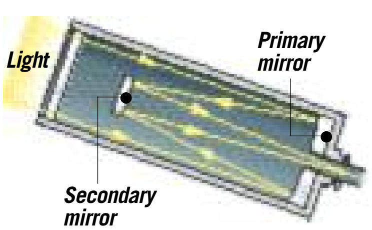
A TELESCOPE is an instrument that makes distant objects appear closer, allowing the viewer to see details that are not visible with the naked eye. Terrestrial telescopes are used for spotting wildlife (binoculars are made up of two telescopes, one for each eye), on gun sights and in periscopes. Astronomical telescopes are used to study objects in space. Terrestrial telescopes and most astronomical telescopes are optical telescopes, which collect light coming from distant objects and use it to produce images of the objects.



The Keck telescope in Hawaii has a main mirror 10 metres across. It is housed in a special building called an observatory.

Italian scientist Galileo used the first astronomical telescope in 1609, with which he discovered moons around Jupiter.

There are two main types of optical telescope—refracting telescopes and reflecting telescopes. In a refracting telescope, a convex (bulging) lens collects light from the distant object and focuses it to form an image of the object. This image is very small, but is much larger than the image formed in the human eye. In a reflecting telescope, a concave (dish-shaped) mirror collects the light from the object and focuses it to form the image. Larger telescopes are nearly always reflecting telescopes because large mirrors are easier to manufacture than large lenses.



In a reflecting (Cassegrain-type) telescope, light is focused by a large primary mirror and a small secondary mirror.

The larger the lens of a refracting telescope or the mirror of a reflecting telescope, the brighter the image of the object observed, and the fainter the objects that can be seen with the telescope. The image is viewed with an eyepiece lens, which works like a magnifying glass to make it appear much larger.

A radio telescope *(below)* can be turned to collect rays from any part of the sky.

Radio Telescopes

Objects in space, such as stars and galaxies, do not just give off light. They also give off radiation from other parts of the electromagnetic spectrum *(see page 10)*, such as infrared radiation, radio waves, X-rays and ultraviolet radiation. These can show up objects that are otherwise invisible. They cannot be seen with ordinary optical telescopes, so special telescopes are needed.

Radio telescopes have a huge dish that acts as a reflector, collecting radio waves and focusing them on to a detector. Radio astronomy has allowed the discovery of new celestial objects, such as pulsars.

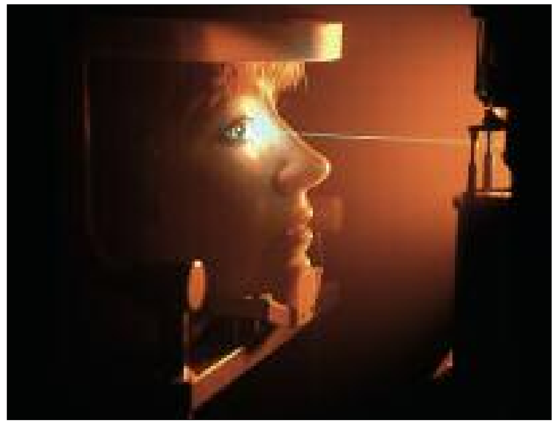
Space Telescopes

The Earth's atmosphere stops many types of radiation from reaching the surface. To study these sorts of radiation, space telescopes must be launched into Earth orbit. They need special mirrors to reflect and focus the radiation, and electronic detectors to record the images formed, which are radioed back to Earth. Optical telescopes also benefit from being in orbit because the atmosphere distorts light rays as they pass through it. The Hubble Space Telescope, launched by space shuttle in 1990, is the most complex space telescope so far. It can detect visible light, infrared and ultraviolet rays.

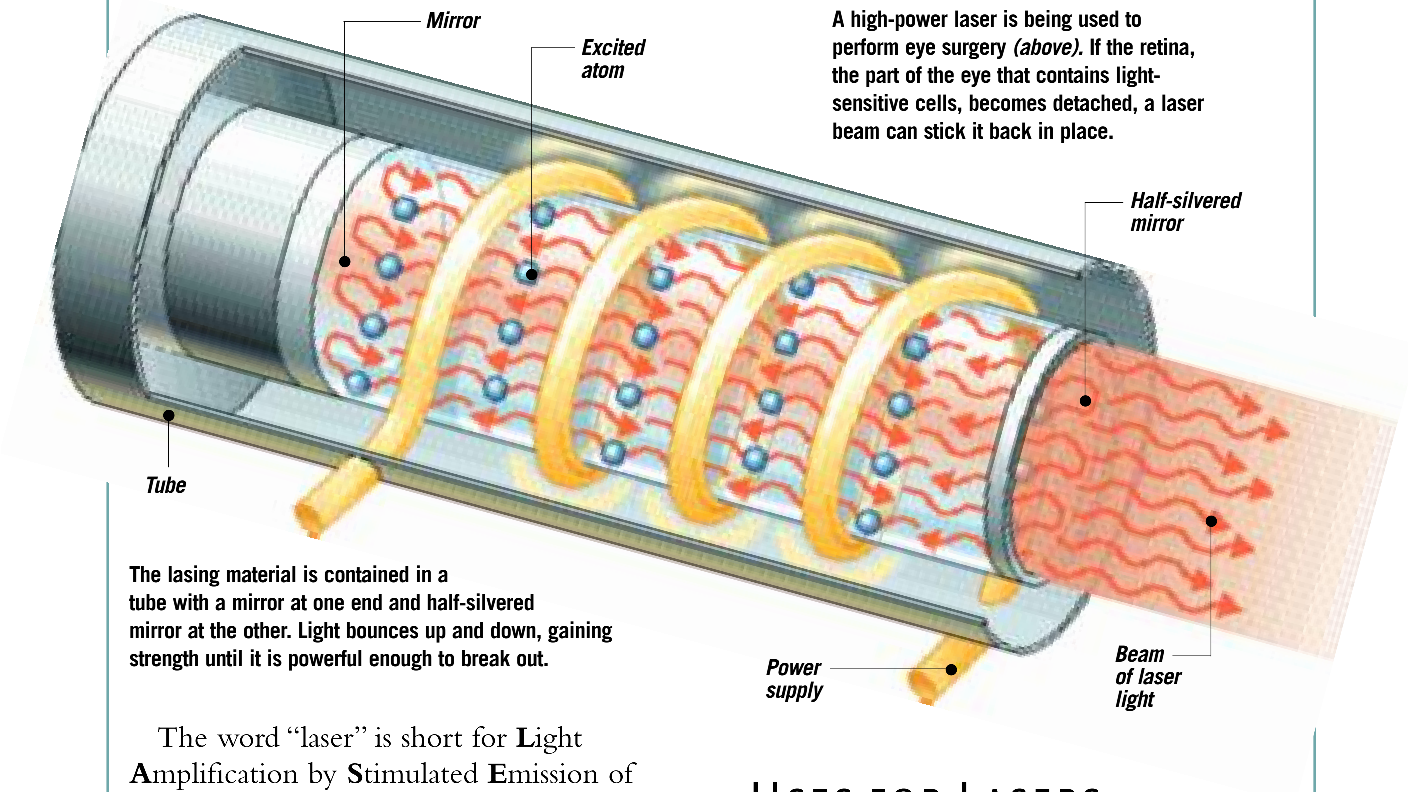
The Hubble Space Telescope can see 10 times more detail than Earth-based telescopes and objects 50 times as faint. Solar panels provide its power. Images are transmitted via antennae.

LASERS

A LASER is a device that creates an intense beam of light called a laser beam. A laser beam is monochromatic: it is made up of light of just one colour of the spectrum. This means that all the light waves in it have the same wavelength *(see page 10)*. Just as importantly, all the waves are "in phase", which means that as they leave the laser, their crests and troughs all line up with each other.



A high-power laser is being used to perform eye surgery *(above)*. If the retina, the part of the eye that contains light-sensitive cells, becomes detached, a laser beam can stick it back in place.



The lasing material is contained in a tube with a mirror at one end and half-silvered mirror at the other. Light bounces up and down, gaining strength until it is powerful enough to break out.

The word "laser" is short for **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation. Inside the laser is lasing material, which can be a solid, a liquid or a gas. The atoms of the material are excited or "stimulated" by giving them energy, either in the form of light or electricity. This makes them emit light (a type of radiation), which in turn makes other atoms emit light of the same wavelength. This process creates an intense laser beam. The wavelength, and so the colour, of a laser beam depends on the lasing material. Some lasers produce ultraviolet or infrared radiation rather than visible light. The first working laser was built by American physicist Theodore Maiman in 1960.

USES FOR LASERS

The most common uses of lasers are playing compact discs *(see page 29)* and reading bar codes. These lasers are normally red lasers that use semiconductor lasing materials. They are low-power lasers, but they are still dangerous to look at directly. Low-power lasers are also used in communications, where they send signals along optical-fibre cables, in laser printers, in surveying, and for light shows. High-power lasers can be focused to create intense heat in materials. They are used in manufacturing for accurate cutting and in medicine for delicate surgery *(top)*.

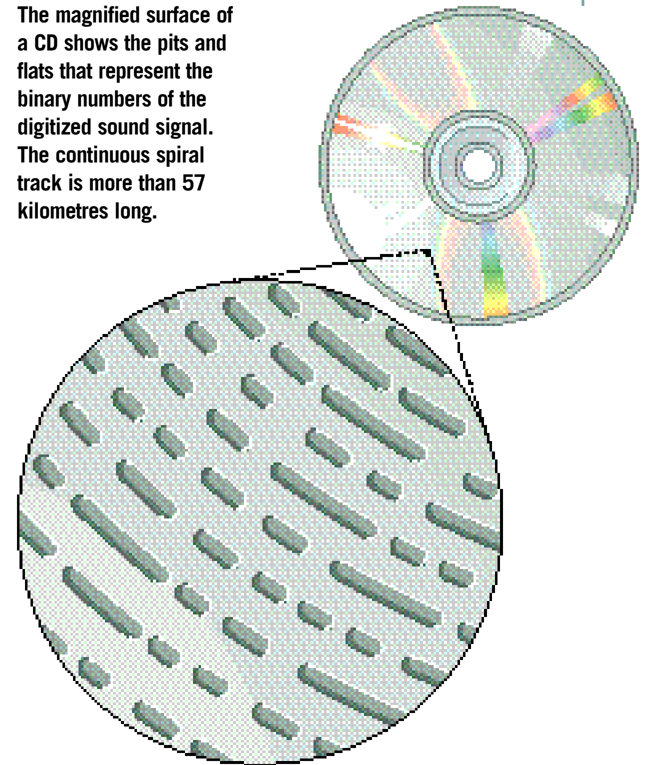
RECORDING

TO RECORD SOUND, the pattern of vibrations in the air must be turned into a form that can be stored. The gramophone was the first sound-recording device. To record, the sound was made to vibrate a needle, which cut a wavy groove in a foil surface. To play back, the needle moved along the groove, making a diaphragm vibrate to reproduce the sound. In the electric gramophone, introduced in the 1920s, the vibrating needle created an electrical signal, which was amplified to drive a loudspeaker.

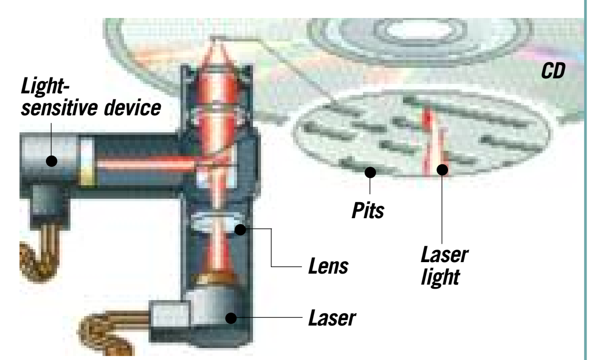
The first type of gramophone was the phonograph, invented in 1877 by the American inventor Thomas Edison.

Tape recording was developed in the 1940s. To record on to tape, the electrical signal from a microphone is sent to an electromagnet, which creates a pattern in the tiny magnetic particles that coat the tape. This pattern recreates the signal as the tape plays, and the signal is amplified before going to a speaker.

The magnified surface of a CD shows the pits and flats that represent the binary numbers of the digitized sound signal. The continuous spiral track is more than 57 kilometres long.



Most sound recording is now done digitally. A microphone turns the sound into an analogue electrical signal, which is then digitized *(see page 6)* more than 44,000 times a second to create a long string of binary numbers. The binary numbers can be stored in a computer's memory or disc drives, in a portable media player, or on a compact disc (CD). On a CD, the binary digits 0 and 1 are represented by flat areas or shallow pits in the surface. In a CD player, these are detected by a laser as the disc spins and reflected to a light-sensitive device *(below)*. Electronics rebuild the original electric signal, which is amplified and sent to speakers. Computer CD-ROMs and DVDs work in the same way.



GLOSSARY

GLOSSARY

Amplifier An electronic circuit that increases the strength of an electrical signal.

Amplify To make larger.

Amplitude The strength of a wave.

Analogue Describes information that can have any value in a range, such as the height of a person.

Binary A number system that uses only the digits zero and one.

Carrier signal An electrical or radio wave that is shaped by modulation to create a signal for transmission.

Condense To turn from gas to liquid.

Diesel engine A type of internal combustion engine that ignites its fuel (diesel oil) by compressing it with air.

Digital Describes information made up of binary numbers only.

Digital electronics Electronic circuits in which information is represented in binary using currents that are either on or off.

Diode A semiconductor device that allows an electric current in one direction only.

Electrical or **electronic signal** An electric current that represents information, such as sound, by continuously changing in strength and direction.

Electrode A device on an electronic circuit, made of carbon or metal, that releases or accepts electrons.

Electron A extremely tiny particle that is part of an atom. An electric current is a stream of electrons.

Electronic circuit An electric circuit in which the flow of current is controlled by the circuit's components.

Electronics The study of how electrons (which make up electric currents) behave and their application in electronic circuits.

Filter A coloured, transparent piece of glass or plastic that allows light of its own colour to pass through but stops other colours.

Frame An individual image or photograph in a series of images or photographs that makes up a moving picture, such as a television picture or movie film.

Frequency The number of wave crests that pass a point every second.

Friction A force that resists (acts against) the movement of one surface against another.

Generator A device similar to an electric motor, but which turns rotary movement into an electric current.

Hardware The physical parts of a computer, such as the electronic circuits, the disc drives, keyboard and monitor.

Image A picture of an object or scene formed by focusing the rays of light coming from the object or scene.

Infrared radiation Invisible radiation similar to light which lies just to the left of visible light on the electromagnetic spectrum.

Insulator A material that reduces or stops the flow of heat or electricity.

Integrated circuit A complete electronic circuit consisting of microscopic electronic components built into a small piece of semiconducting material. Also known as a microchip or a silicon chip.

Internal combustion engine A type of engine in which the fuel, such as petrol or kerosene, is burned inside the engine rather than outside.

Internet A huge computer network that links millions of computers around the world.

Jet engine An engine in which the burning fuel spins a fan (called a turbine) that creates a stream of hot gases from the rear of the engine.

Laser A device that creates an intense, parallel beam of light known as a laser beam.

Lens A shaped piece of glass or plastic that is used to focus light.

Microphone An electronic device that turns the pattern of a sound wave into an electric signal.

Liquid Crystal Display (LCD) Screen display technology used in flat-screen televisions, computer screens, watches and clock displays. Rod-shaped molecules in the screen reflect and bend light when energized by electricity to form the picture.

Microwaves High-frequency radio waves used in communications and for cooking.

Modulation The shaping of a wave, such as a changing electric current, radio wave or beam of light so that it represents information.

Monitor The screen of a computer, where text and graphics appear.

Petrol engine A type of internal combustion engine that ignites its fuel (diesel oil) by compressing a mixture of fuel and air.

Pixel Short for picture element, which is one of the tiny coloured dots that make up an image on a computer monitor.

Propeller A fan-like object that pushes against water (on a boat) or air (on an aircraft) as it spins at high speed.

Radar (RAdio **D**etection **A**nd **R**anging) A system that detects objects by transmitting radio waves and receiving the "echoes".

Radiation The emission and transfer through space of electromagnetic waves, including light, radio, X-rays, etc.

Radio The use of radio waves for communication. Also the general broadcasting of sound and music.

Radio waves Invisible waves that are part of the electromagnetic spectrum and which travel at the speed of light.

Receiver A device that detects signals, such as radio waves.

Rocket engine An engine that creates a stream of hot gases by burning fuel in a chamber.

Satellite A spacecraft that orbits the Earth. Communications satellites relay radio signals between ground stations on the Earth's surface.

Semiconductor A substance that can act both as a conductor of electricity and as an insulator.

Software The programs and data that a computer uses and stores.

Steam engine An engine that uses pressurized steam from a boiler to make its pistons move.

Telecommunications Communications systems that use electricity, radio waves or light to work.

Telegraph A communication system that uses coded pulses of electricity to represent letters and symbols.

Telephone exchange A place where telephone lines meet and can be linked to each other.

Thermionic valve An electronic device contained in a evacuated glass tube.

Transistor A semiconductor device that can act as an electronic switch.

Transmitter A device that gives out signals, such as radio waves.

Ultraviolet radiation Invisible radiation similar to light which lies just to the right of visible light on the electromagnetic spectrum.

Vacuum A space that contains nothing, not even air.

Wavelength The distance between two crests or two troughs on a train of waves.

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