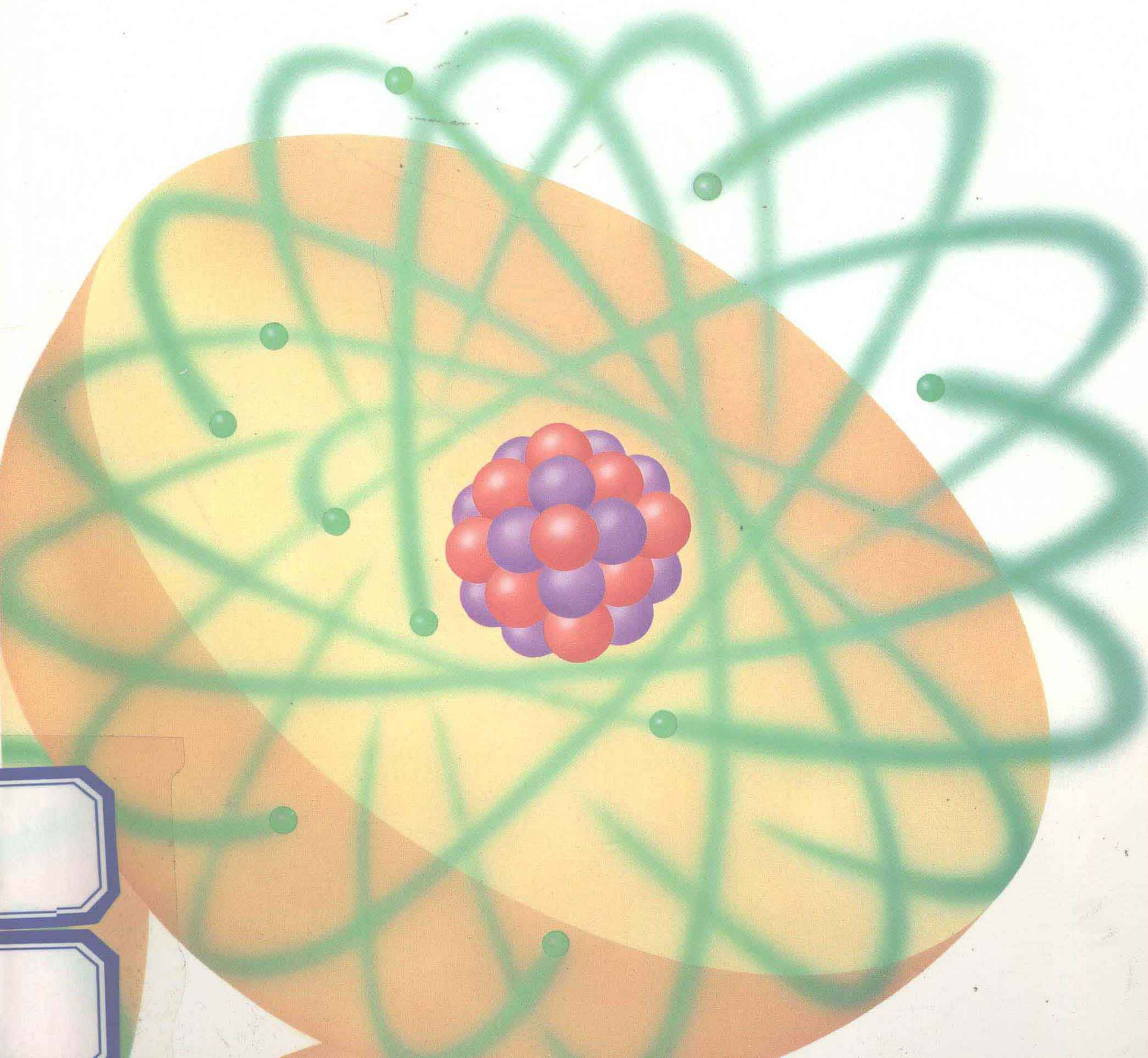
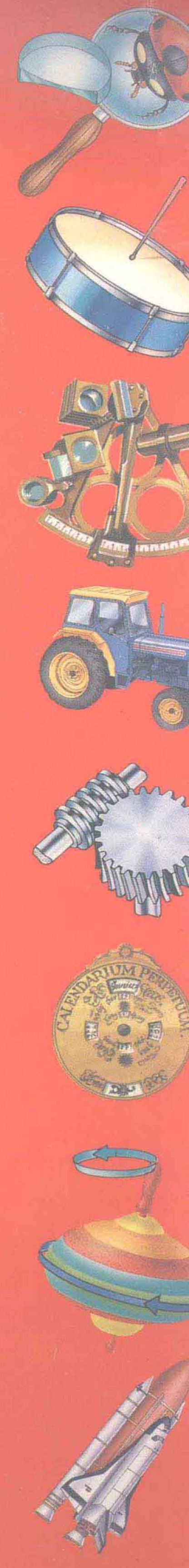
*Visual Factfinder*

# SCIENCE AND TECHNOLOGY

BRIAN WILLIAMS





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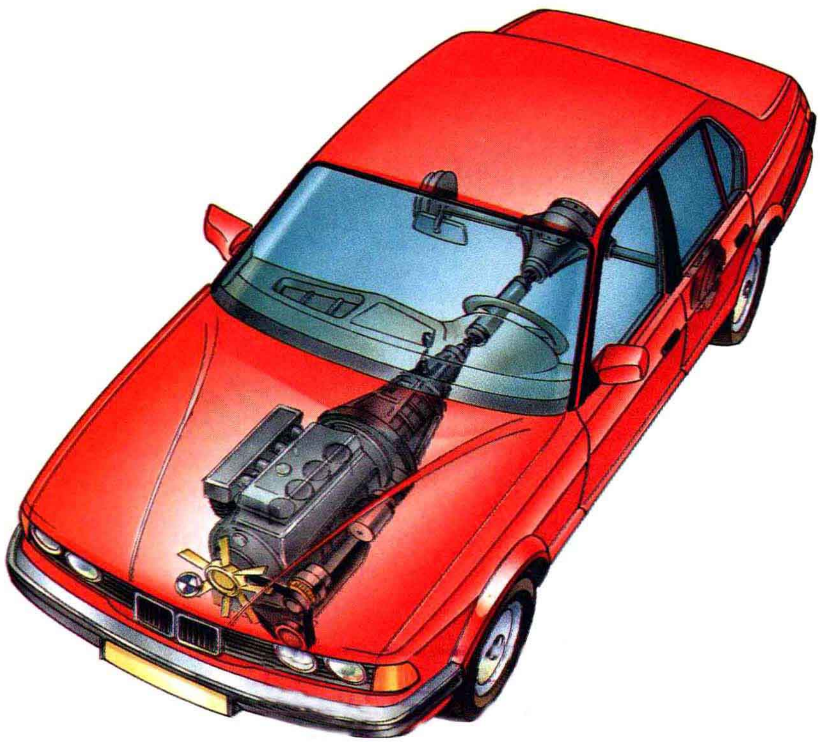

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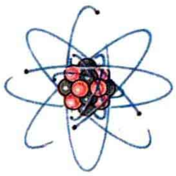
# CONTENTS







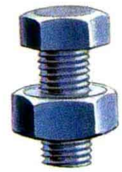






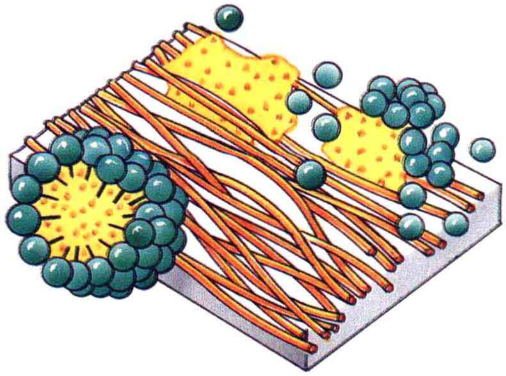






# About this Factfinder

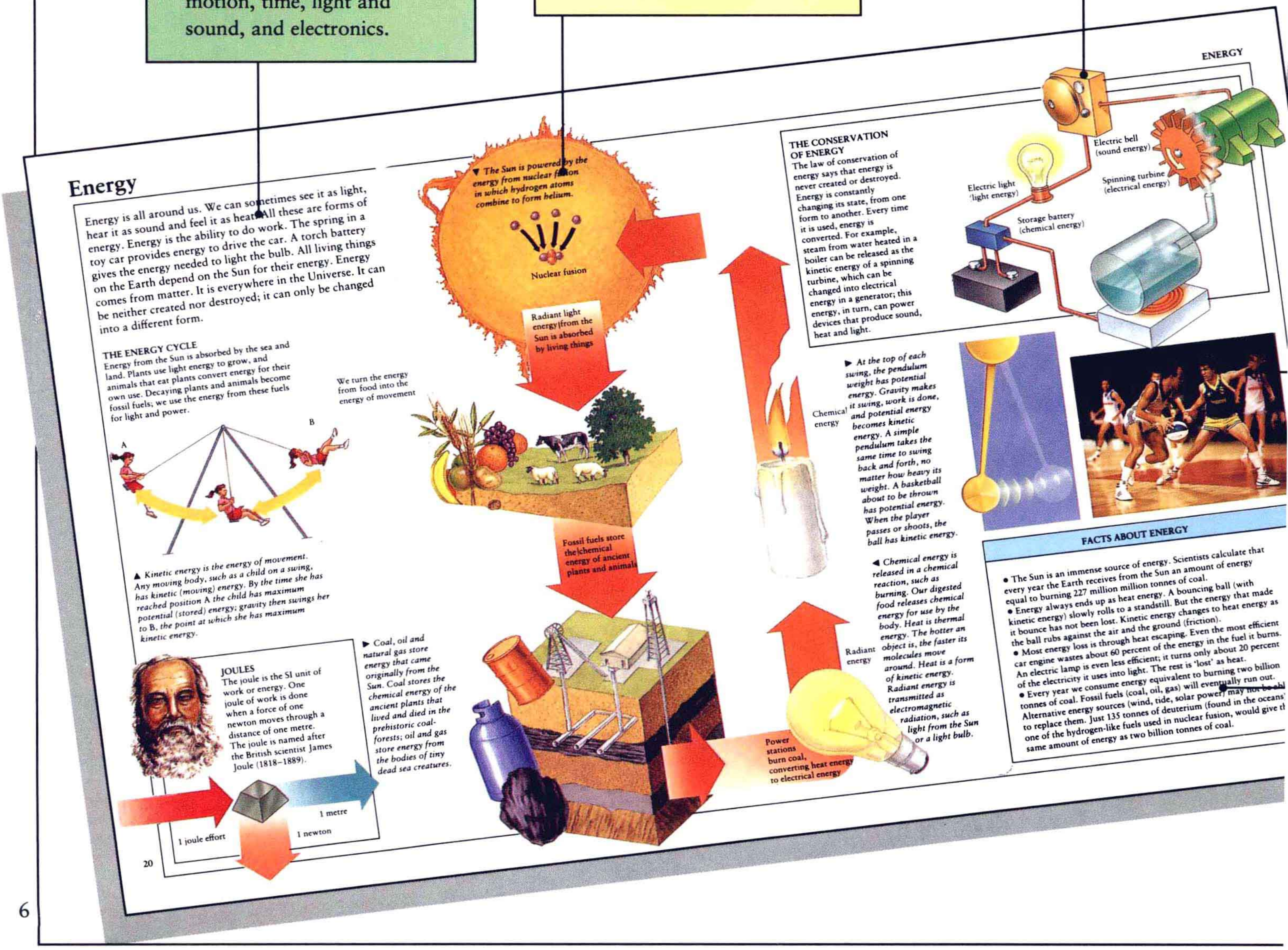
Through a dynamic combination of words and pictures, this encyclopedic reference book presents a wealth of facts and figures in an instantly accessible form. It describes the fascinating principles of the scientific workings of the world, as well as the progress of technology through the centuries.



Short text essays introduce each of the main scientific and technological areas, including energy, force and motion, time, light and sound, and electronics.

Captions give comprehensive in-depth information on subjects such as what things are made of, heat, colour, machines, transport computers and buildings.

Schematic artworks help to explain the secrets of science as well as the detailed mechanisms of both commonplace and unusual objects.



ENERGY

## Energy

Energy is all around us. We can sometimes see it as light, hear it as sound and feel it as heat. All these are forms of energy. Energy is the ability to do work. The spring in a toy car provides energy to drive the car. A torch battery gives the energy needed to light the bulb. All living things on the Earth depend on the Sun for their energy. Energy comes from matter. It is everywhere in the Universe. It can be neither created nor destroyed; it can only be changed into a different form.

THE ENERGY CYCLE
Energy from the Sun is absorbed by the sea and land. Plants use light energy to grow, and animals that eat plants convert energy for their own use. Decaying plants and animals become fossil fuels; we use the energy from these fuels for light and power.

▲ *Kinetic energy is the energy of movement. Any moving body, such as a child on a swing, has kinetic (moving) energy. By the time she has reached position A the child has maximum potential (stored) energy; gravity then swings her to B, the point at which she has maximum kinetic energy.*

JOULES
The joule is the SI unit of work or energy. One joule of work is done when a force of one newton moves through a distance of one metre. The joule is named after the British scientist James Joule (1818–1889).

▶ *Coal, oil and natural gas store energy that came originally from the Sun. Coal stores the chemical energy of the ancient plants that lived and died in the prehistoric coal-forests; oil and gas store energy from the bodies of tiny dead sea creatures.*



THE CONSERVATION OF ENERGY
The law of conservation of energy says that energy is never created or destroyed. Energy is constantly changing its state, from one form to another. Every time it is used, energy is converted. For example, steam from water heated in a boiler can be released as the kinetic energy of a spinning turbine, which can be changed into electrical energy in a generator; this energy, in turn, can power devices that produce sound, heat and light.

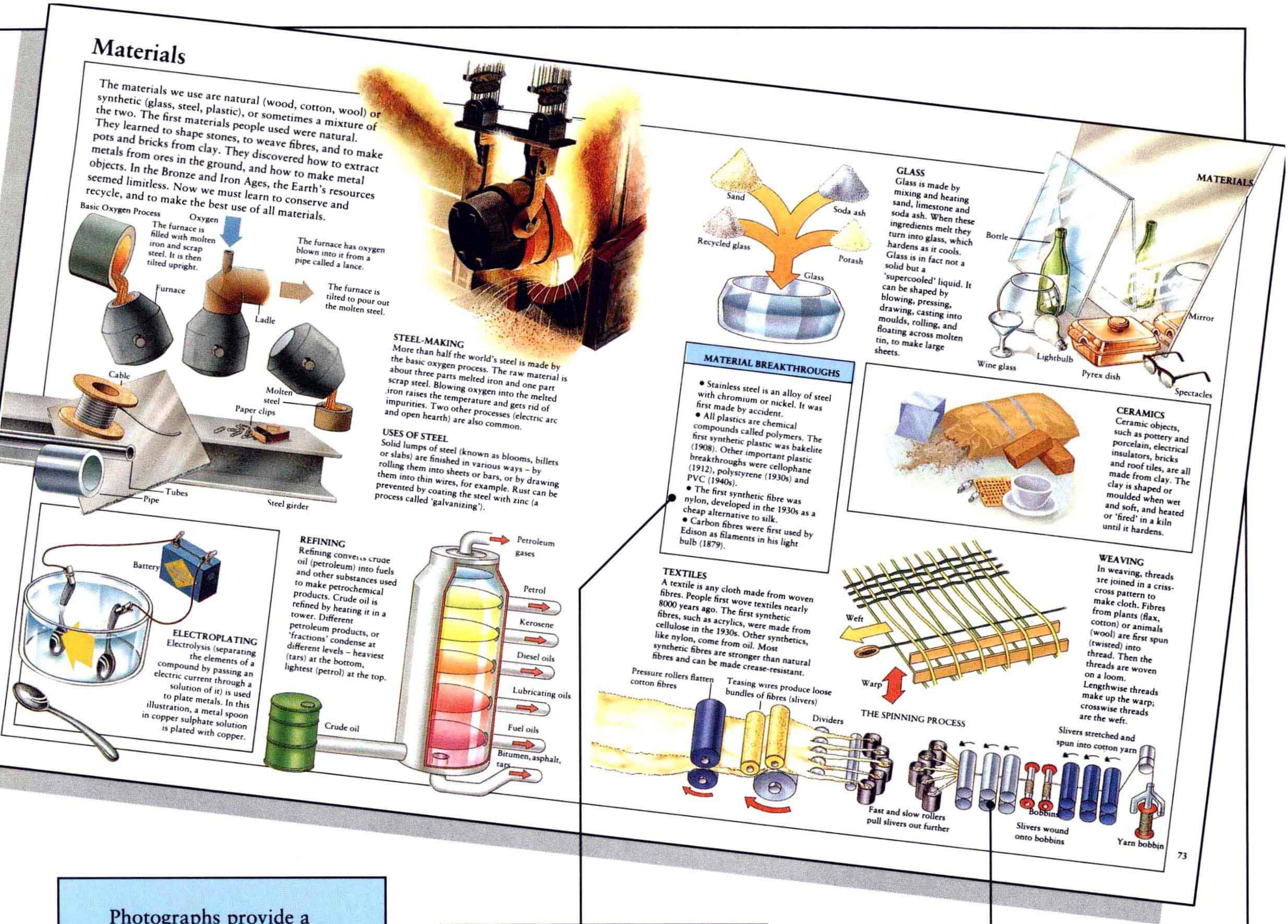
▶ *At the top of each swing, the pendulum weight has potential energy. Gravity makes it swing, work is done, and potential energy becomes kinetic energy. A simple pendulum takes the same time to swing back and forth, no matter how heavy its weight. A basketball about to be thrown has potential energy. When the player passes or shoots, the ball has kinetic energy.*

◀ *Chemical energy is released in a chemical reaction, such as burning. Our digested food releases chemical energy for use by the body. Heat is thermal energy. The hotter an object is, the faster its molecules move around. Heat is a form of kinetic energy. Radiant energy is transmitted as electromagnetic radiation, such as light from the Sun or a light bulb.*

FACTS ABOUT ENERGY

- The Sun is an immense source of energy. Scientists calculate that every year the Earth receives from the Sun an amount of energy equal to burning 227 million million tonnes of coal.
- Energy always ends up as heat energy. A bouncing ball (with kinetic energy) slowly rolls to a standstill. But the energy that made it bounce has not been lost. Kinetic energy changes to heat energy as the ball rubs against the air and the ground (friction).
- Most energy loss is through heat escaping. Even the most efficient car engine wastes about 60 percent of the energy in the fuel it burns. An electric lamp is even less efficient; it turns only about 20 percent of the electricity it uses into light. The rest is 'lost' as heat.
- Every year we consume energy equivalent to burning two billion tonnes of coal. Fossil fuels (coal, oil, gas) will eventually run out. Alternative energy sources (wind, tide, solar power) may not be abl to replace them. Just 135 tonnes of deuterium (found in the oceans) one of the hydrogen-like fuels used in nuclear fusion, would give th same amount of energy as two billion tonnes of coal.

20



# Materials

The materials we use are natural (wood, cotton, wool) or synthetic (glass, steel, plastic), or sometimes a mixture of the two. The first materials people used were natural. They learned to shape stones, to weave fibres, and to make pots and bricks from clay. They discovered how to extract metals from ores in the ground, and how to make metal objects. In the Bronze and Iron Ages, the Earth's resources seemed limitless. Now we must learn to conserve and recycle, and to make the best use of all materials.



STEEL-MAKING
More than half the world's steel is made by the basic oxygen process. The raw material is about three parts melted iron and one part scrap steel. Blowing oxygen into the melted iron raises the temperature and gets rid of impurities. Two other processes (electric arc and open hearth) are also common.

USES OF STEEL
Solid lumps of steel (known as blooms, billets or slabs) are finished in various ways – by rolling them into sheets or bars, or by drawing them into thin wires, for example. Rust can be prevented by coating the steel with zinc (a process called 'galvanizing').



ELECTROPLATING
Electrolysis (separating the elements of a compound by passing an electric current through a solution of it) is used to plate metals. In this illustration, a metal spoon in copper sulphate solution is plated with copper.

REFINING
Refining converts crude oil (petroleum) into fuels and other substances used to make petrochemical products. Crude oil is refined by heating it in a tower. Different petroleum products, or 'fractions' condense at different levels – heaviest (tars) at the bottom, lightest (petrol) at the top.







GLASS
Glass is made by mixing and heating sand, limestone and soda ash. When these ingredients melt they turn into glass, which hardens as it cools. Glass is in fact not a solid but a 'supercooled' liquid. It can be shaped by blowing, pressing, drawing, casting into moulds, rolling, and floating across molten tin, to make large sheets.



MATERIAL BREAKTHROUGHS
- Stainless steel is an alloy of steel with chromium or nickel. It was first made by accident.
- All plastics are chemical compounds called polymers. The first synthetic plastic was bakelite (1908). Other important plastic breakthroughs were cellophane (1912), polystyrene (1930s) and PVC (1940s).
- The first synthetic fibre was nylon, developed in the 1930s as a cheap alternative to silk.
- Carbon fibres were first used by Edison as filaments in his light bulb (1879).

CERAMICS
Ceramic objects, such as pottery and porcelain, electrical insulators, bricks and roof tiles, are all made from clay. The clay is shaped or moulded when wet and soft, and heated or 'fired' in a kiln until it hardens.

TEXTILES
A textile is any cloth made from woven fibres. People first wove textiles nearly 8000 years ago. The first synthetic fibres, such as acrylics, were made from cellulose in the 1930s. Other synthetics, like nylon, come from oil. Most synthetic fibres are stronger than natural fibres and can be made crease-resistant.

WEAVING
In weaving, threads are joined in a criss-cross pattern to make cloth. Fibres from plants (flax, cotton) or animals (wool) are first spun (twisted) into thread. Then the threads are woven on a loom. Lengthwise threads make up the warp; crosswise threads are the weft.



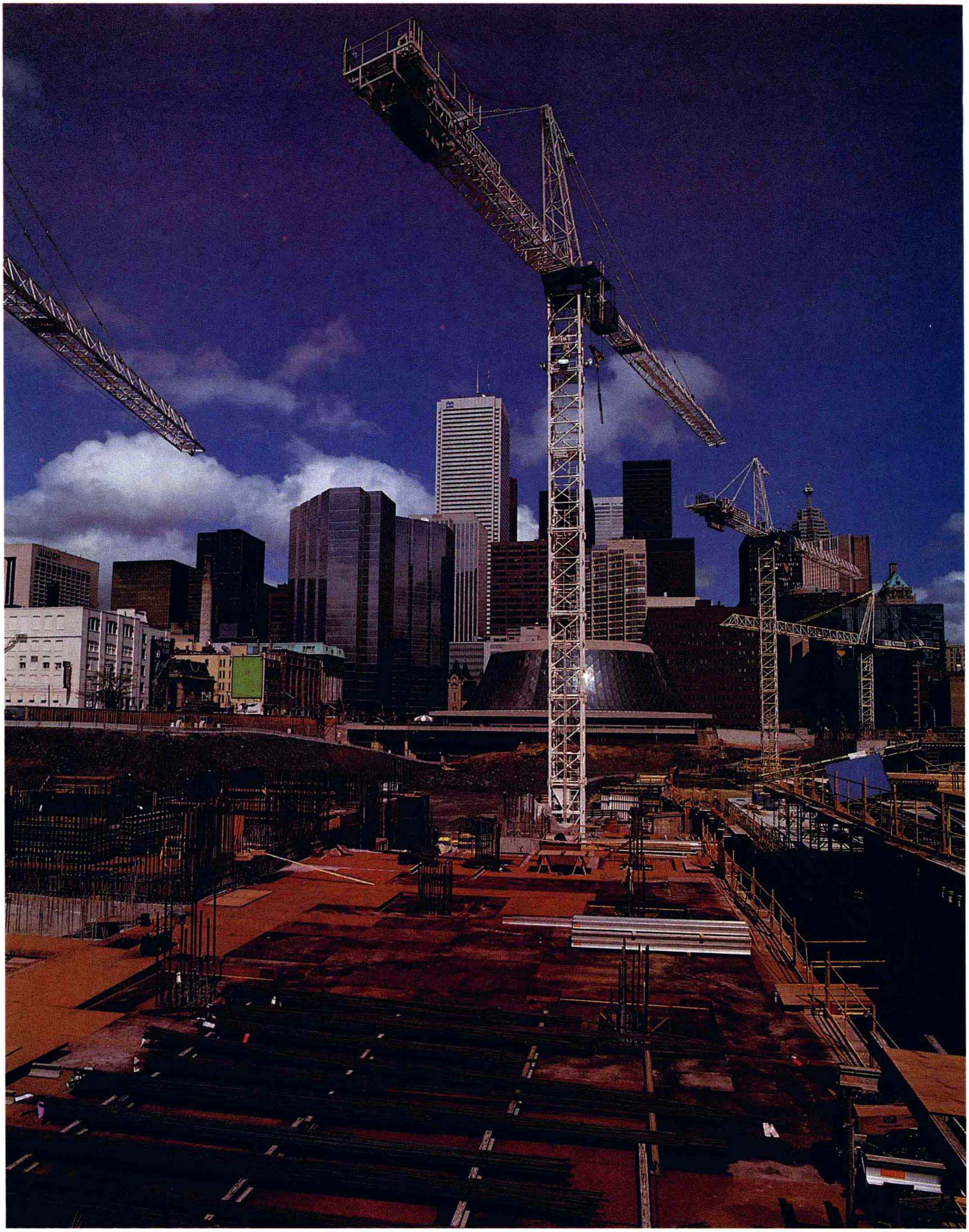
73

Photographs provide a further source of visual information on scientific areas such as energy, fuels, movement, flying, light, colour and electricity.

Quick-reference data files provide essential facts and figures on the world's most important discoveries and inventions in the history of science and technology.

Diagrams and charts make it easy to understand and compare both the details of scientific principles, and how everyday objects are made and work.

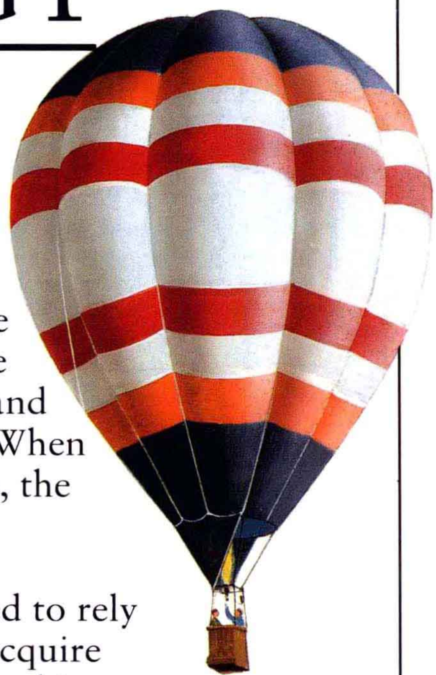
Key facts and statistics on the secrets of science, and the ways in which technological advances have changed our lives are highlighted in fact boxes.



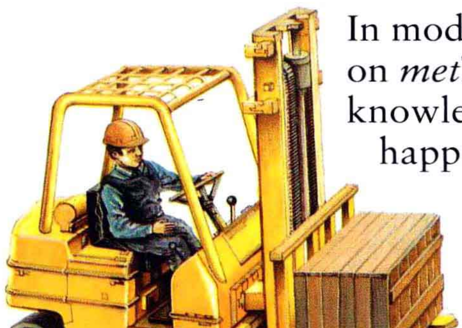


*A building site in the Canadian city of Toronto shows the materials and technology needed to build a skyscraper.*

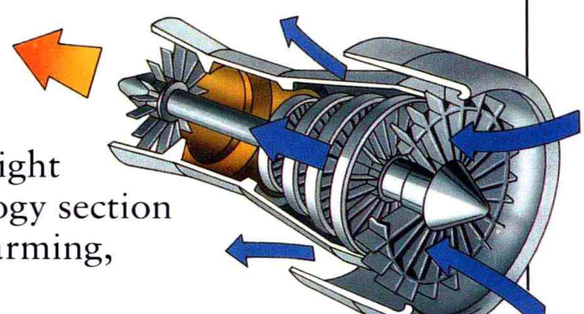
# SCIENCE
## AND
# TECHNOLOGY



Science makes discoveries; technology puts the discoveries to use. From earliest times, prehistoric people observed the weather, the behavior of animals, and the growth of plants; their observations marked the beginnings of science. The first sciences to develop were counting (mathematics), healing (medicine), the rising and setting of the Sun (astronomy), and tools (mechanics). When people first picked up stones to use as tools or weapons, the long march of technology had begun.



In modern times scientists have learned to rely on *method* as well as observation to acquire knowledge. They try and find out how things happen through a series of experiments. The scientists can then predict what ought to happen, given certain conditions. If the experiments show that his or her theory is correct, the scientist may be able to state a new principle or rule.



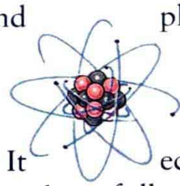
*Science and Technology* first deals with the different branches of science, including matter and energy, force and motion, space and time, light and sound, and electromagnetism. The technology section covers engineering, transportation, materials, farming, medicine, and modern communications.

*Brian Williams*

# DISCOVERING SCIENCE

## The Branches of Science

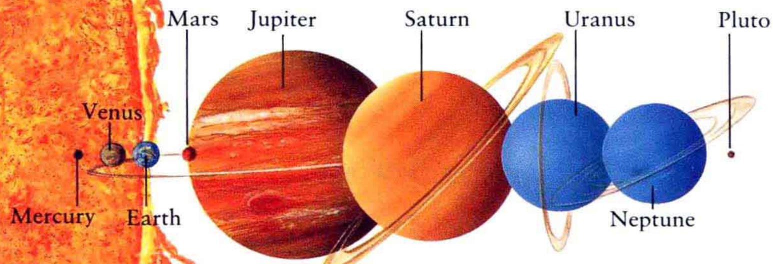
Science means knowledge (from the Latin word *scientia*), and therefore it covers every field of human inquiry. The desire to find out how and why things work is one of humankind's most distinctive qualities. Science has given people power, for example, to make their lives more comfortable and to change their environment. It has also given people technology – the ability to make tools, to build with materials, and to harness sources of energy. Science has various branches concerned with different areas of knowledge. They include the physical sciences, such as astronomy, chemistry, physics, and geology; mathematics; life sciences, such as biology, botany, and zoology; and social sciences, such as anthropology, economics, and psychology. The pages that follow concentrate on the ways in which science and technology have shaped the modern world.



◀ *Astronomy began thousands of years ago when people first peered at the stars. The study of the universe is called cosmology. Modern ideas about cosmology date from the 1500s, when Copernicus showed that the Earth and other planets orbit the Sun. The universe began about 15 billion years ago, almost certainly with the Big Bang.*

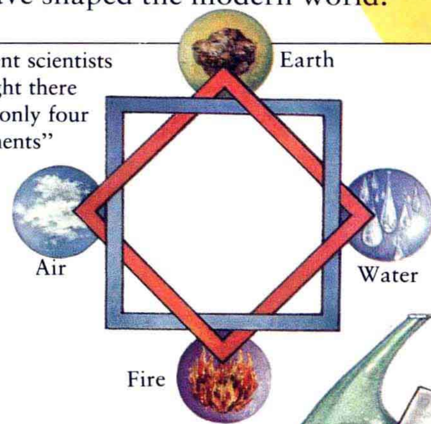
The Sun

The Solar System

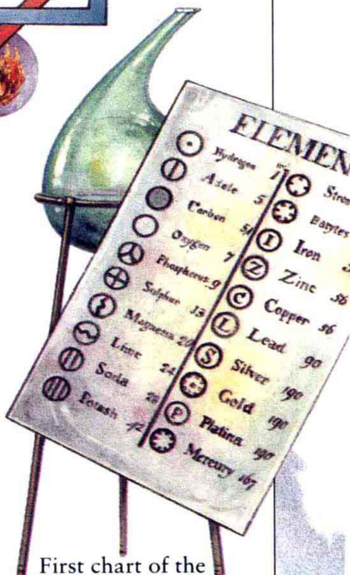



(Distances not shown to scale)

Ancient scientists thought there were only four "elements"

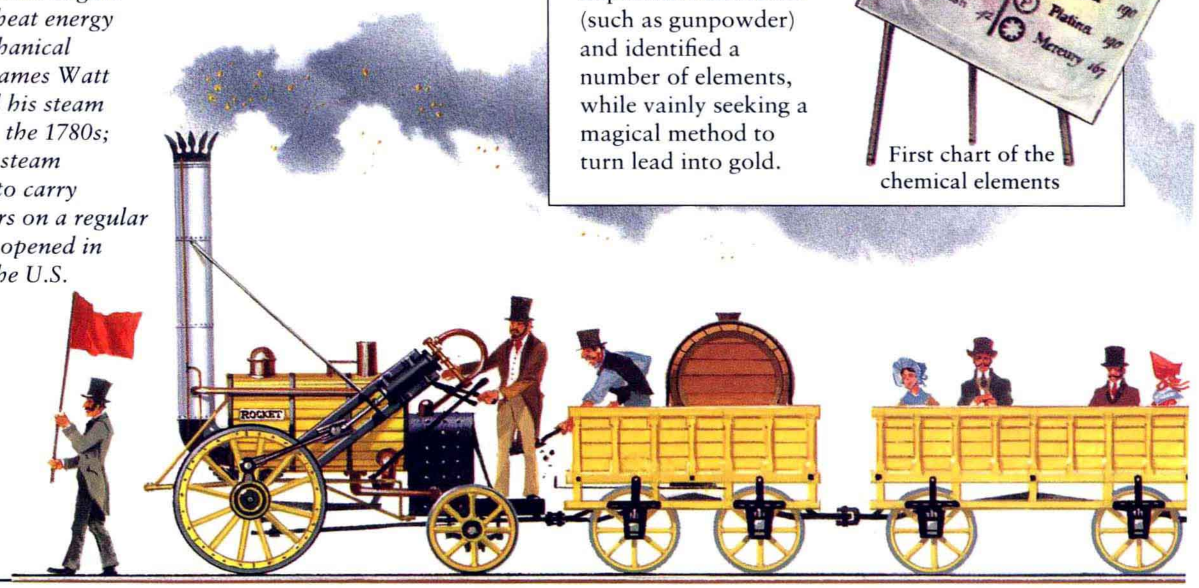


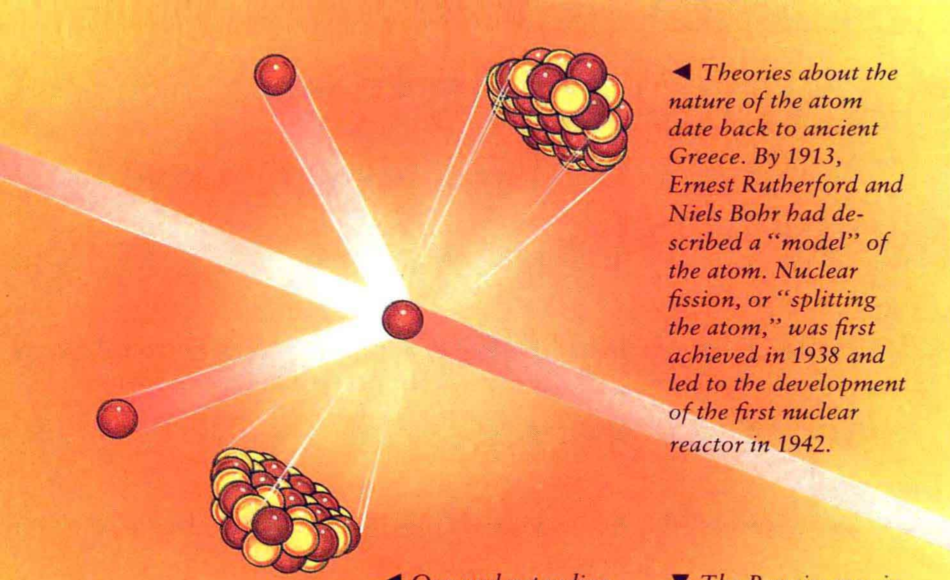

**CHEMISTRY**
Modern chemistry has its origins in alchemy, a mixture of science and superstition. The Egyptians, Chinese, and Arabs were masters of alchemy. Early chemists made important discoveries (such as gunpowder) and identified a number of elements, while vainly seeking a magical method to turn lead into gold.



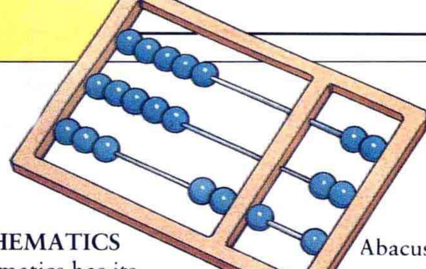

First chart of the chemical elements

▶ *The steam engine changes heat energy into mechanical energy. James Watt perfected his steam engine in the 1780s; The first steam railroad to carry passengers on a regular schedule opened in 1830 in the U.S.*



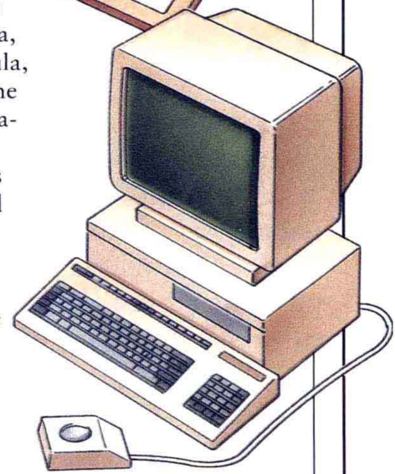


◄ *Theories about the nature of the atom date back to ancient Greece. By 1913, Ernest Rutherford and Niels Bohr had described a "model" of the atom. Nuclear fission, or "splitting the atom," was first achieved in 1938 and led to the development of the first nuclear reactor in 1942.*



Abacus

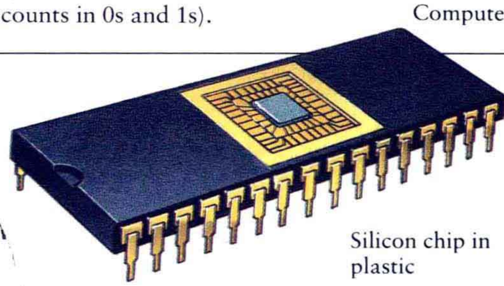
**MATHEMATICS**
Mathematics has its roots in India, China, the Arabian Peninsula, and Greece. From the abacus, a beads-on-a-frame calculator invented 5,000 years ago, we have moved to computers, with their microchip technology. Computers have the ability to process data at fantastic speeds using codes based on the binary system (which counts in 0s and 1s).



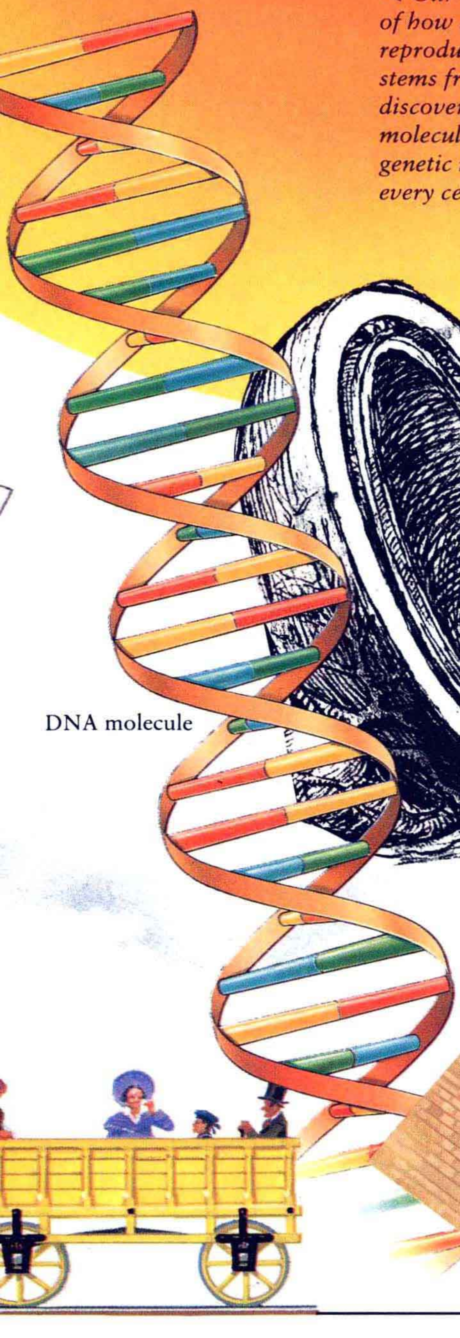
Computer

◄ *Our understanding of how living things reproduce themselves stems from the discovery of the DNA molecule which carries genetic information in every cell.*

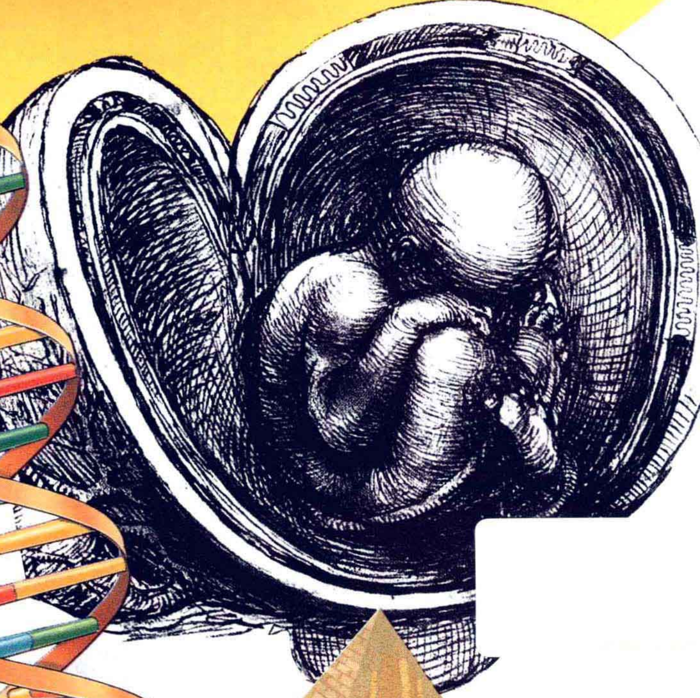
▼ *The Renaissance in Europe (1400s–1500s) was an age of discovery. Artists such as Leonardo da Vinci, who drew this anatomical drawing, were also scientists.*



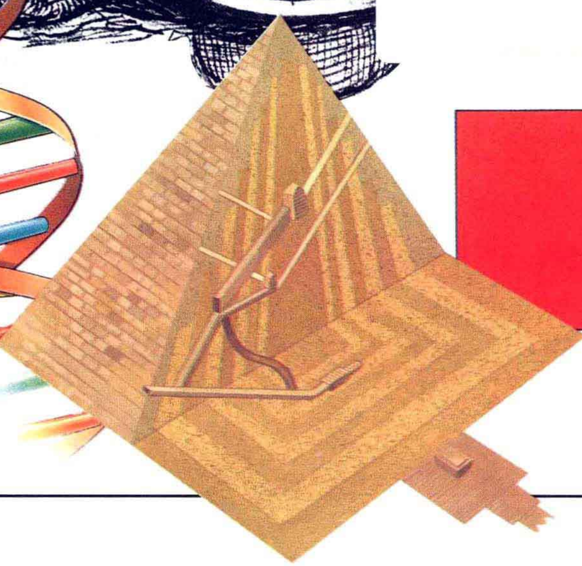
Silicon chip in plastic

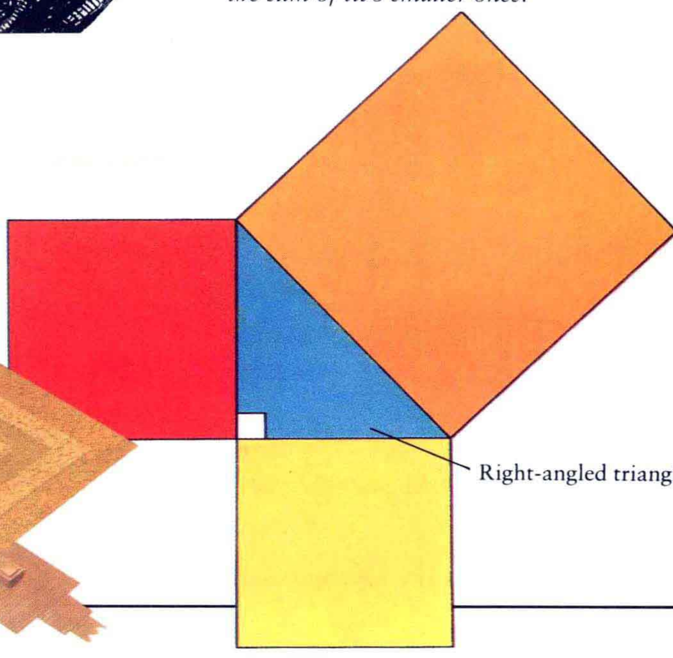


DNA molecule



▼ *The first people to use geometry were the Babylonians and Egyptian pyramid-builders (about 5,000 years ago). The Greek mathematician Pythagoras devised his right-angled triangle theorem in the 500s* B.C. *Pythagoras proved that in this kind of triangle* (shown below) *the larger square has the same area as the sum of two smaller ones.*





Right-angled triangle

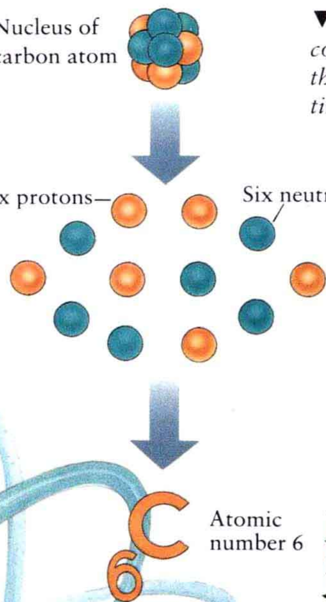
# MATTER AND ENERGY

## Atoms and Molecules

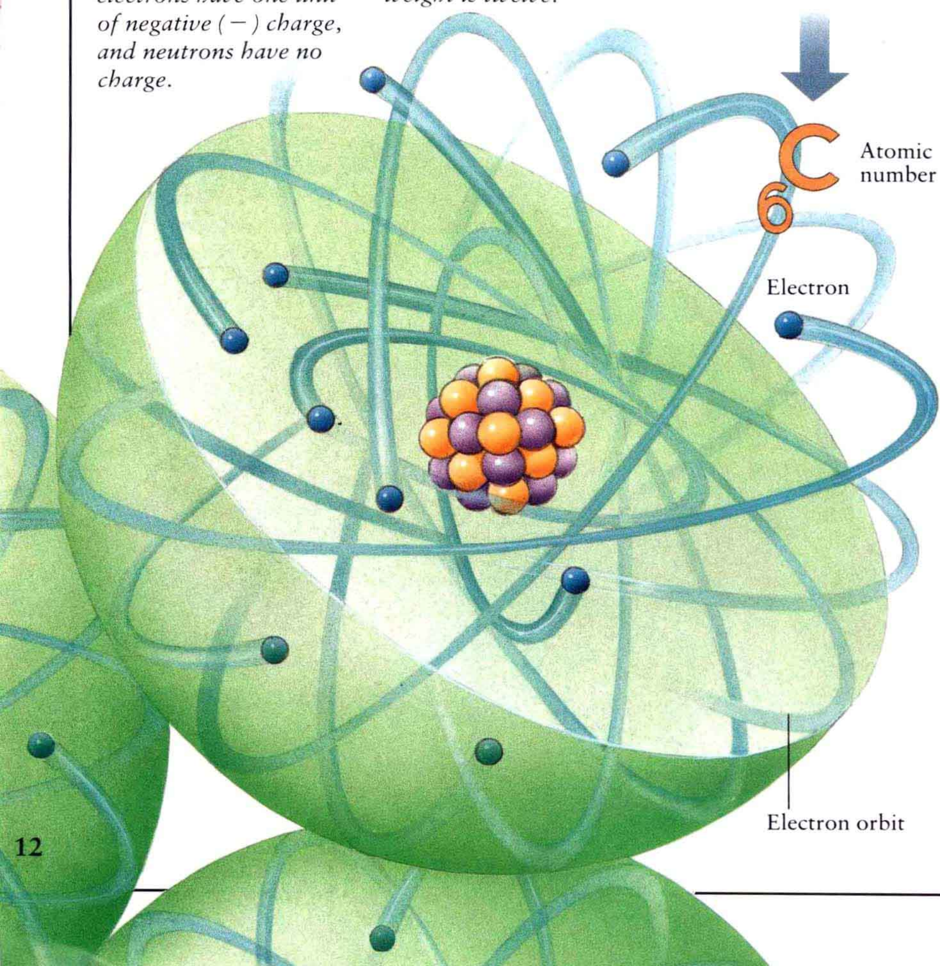
Matter is all the material in the universe—animals, plants, rocks, air, and water. Matter can exist in three familiar states—solid, liquid, and gas. A fourth state, plasma, is formed at very high temperatures—for example, within stars. In all its states, matter is made of the same basic units—atoms. The smallest piece of a substance that can exist on its own is called an atom. An element is a substance made up of only one kind of atom. Atoms are made of even smaller particles, called electrons, moving around a center called a nucleus made up of neutrons and protons, in much the same way as the planets orbit the Sun. Within the atom is immense energy, which can be released by splitting the atom to produce a chain reaction, called nuclear fission. Atoms can combine with other atoms to form molecules.

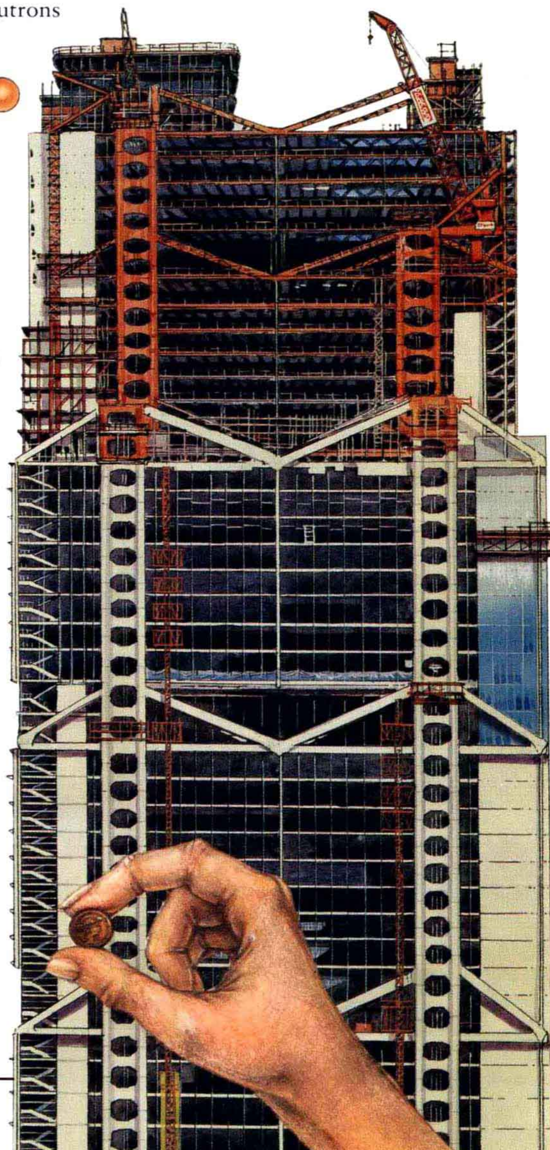
▼ *Every atom has a nucleus, a very small region at its center, which contains particles called protons and neutrons, except hydrogen which has no neutrons. Around the nucleus are electrons. Protons carry a positive (+) electric charge, electrons have one unit of negative (−) charge, and neutrons have no charge.*

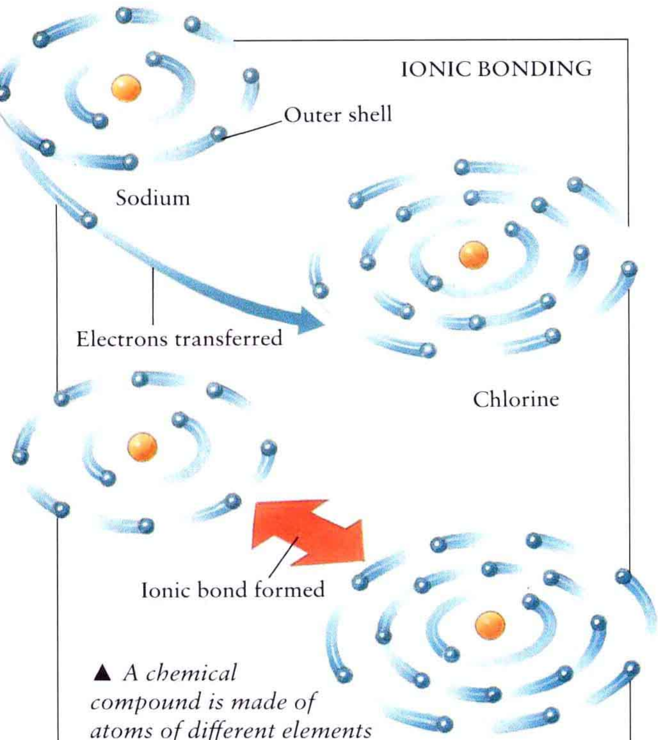
► *Every atom of an element has the same number of protons as electrons: its atomic number. Carbon has the atomic number six. An element's atomic weight (or mass number) is the number of protons and neutrons in the nucleus. Carbon's atomic weight is twelve.*




▼ *Atoms are incredibly tiny—a speck of dust contains a quadrillion atoms! If an atom were the size of a coin, you would be many, many times taller than the tallest skyscraper.*

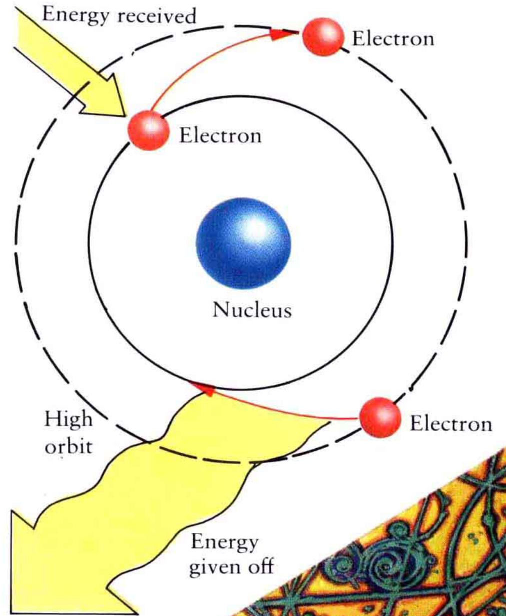


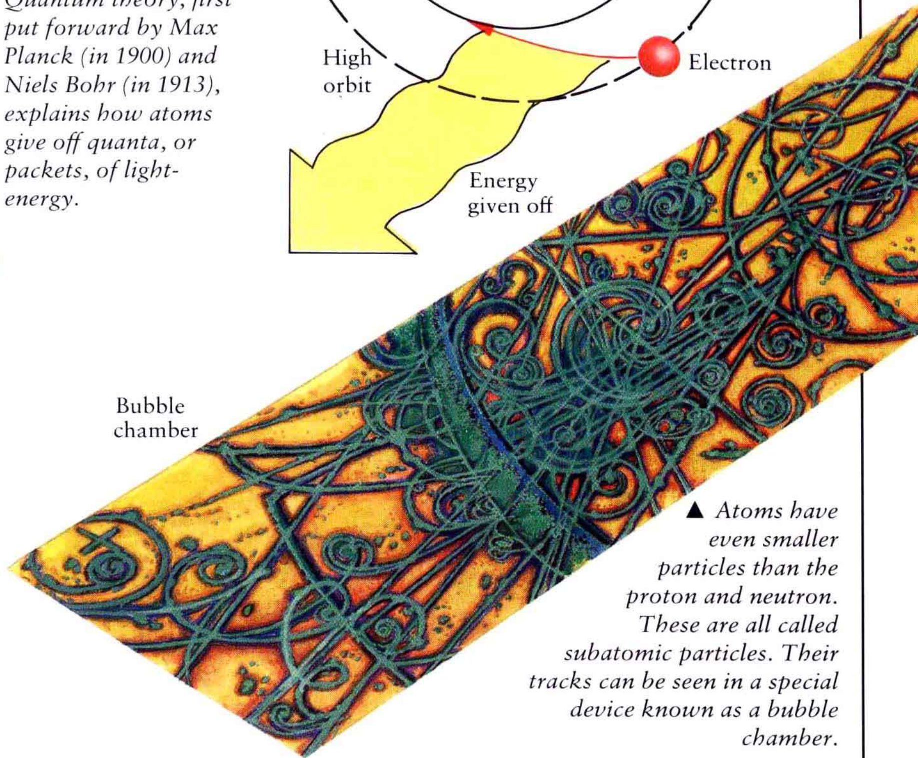





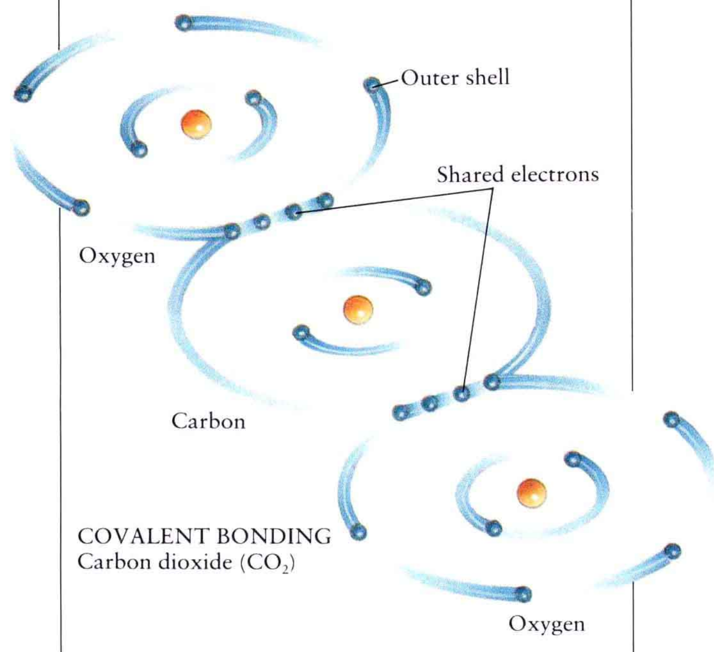

▲ *A chemical compound is made of atoms of different elements bonded together. Usually an atom has no electric charge: its positive nucleus and negative electrons cancel each other out. Sometimes one atom transfers electrons to another atom. The atoms then become positively or negatively charged ions. Ions of opposite charges attract each other to form a bond, called an ionic bond.*

► *An electron orbiting the nucleus of an atom can absorb energy (such as light) and move from its normal orbit to a higher one. If it moves back again it gives off energy. The amount of energy given off is measured in quanta. Quantum theory, first put forward by Max Planck (in 1900) and Niels Bohr (in 1913), explains how atoms give off quanta, or packets, of light-energy.*



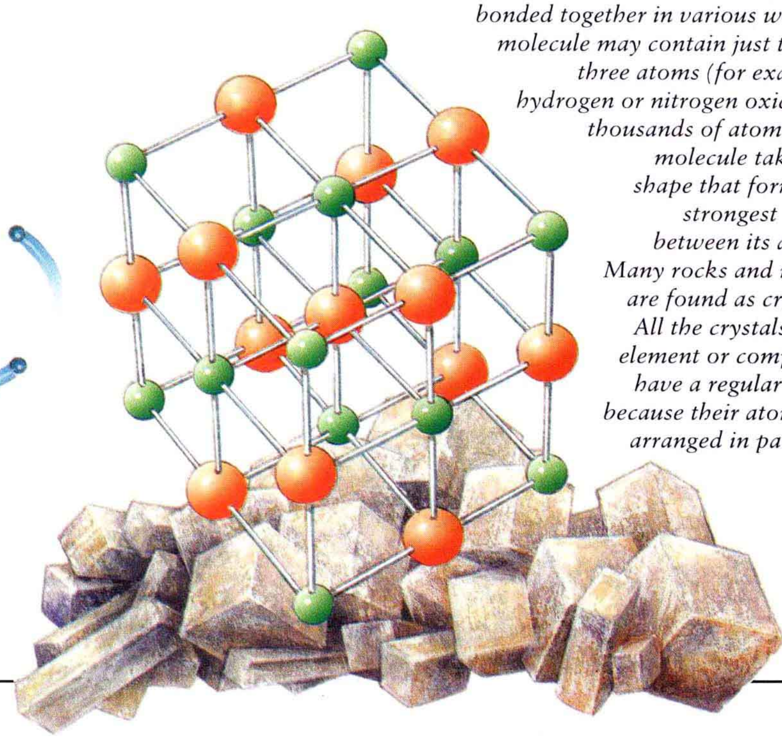




▲ *Atoms have even smaller particles than the proton and neutron. These are all called subatomic particles. Their tracks can be seen in a special device known as a bubble chamber.*




▲ *Covalent bonding is the other main type of chemical bonding. Here two or more atoms join by sharing pairs of electrons. Together they are more stable than they are apart.*

▼ *Molecules are made of atoms bonded together in various ways. A molecule may contain just two or three atoms (for example, hydrogen or nitrogen oxide), or thousands of atoms. The molecule takes the shape that forms the strongest bonds between its atoms. Many rocks and metals are found as crystals. All the crystals of an element or compound have a regular shape because their atoms are arranged in patterns.*

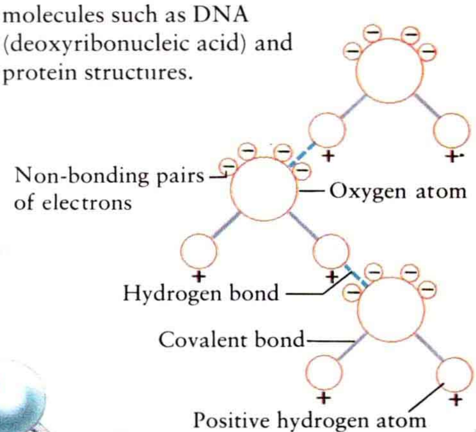


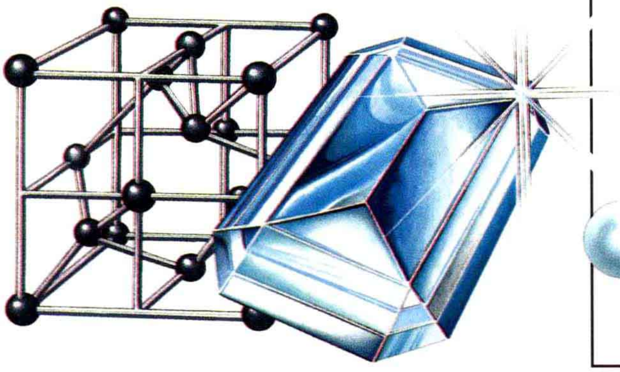
# What Are Things Made Of?

Every substance is either a chemical element or a combination of elements. The atoms in a substance are held together by chemical bonds that form molecules. Different elements can bond together to make compounds. As bonds form or break, a chemical reaction takes place. Carbon is found in all living things. It combines freely with hydrogen, nitrogen, and oxygen. Organic chemistry concentrates on substances that have carbon-to-carbon bonds: there are over one million organic compounds.

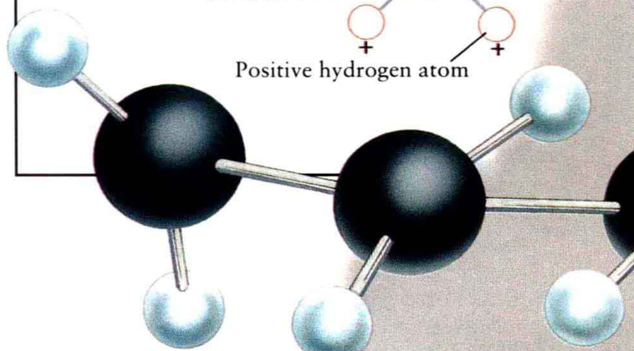
### HYDROGEN BONDS

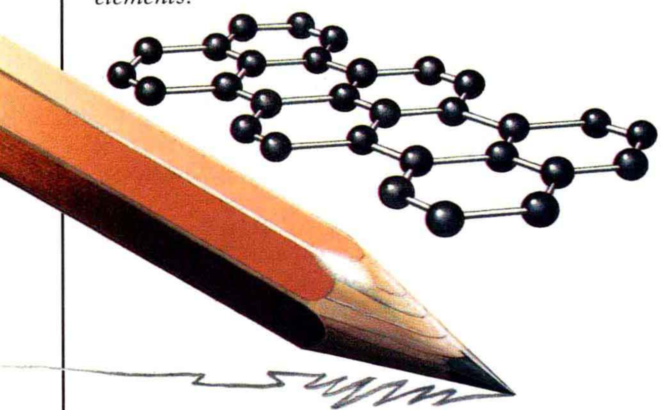
In water, hydrogen and oxygen atoms join by sharing pairs of electrons—an example of covalent bonding. Water molecules are also held together by hydrogen bonds. These weak bonds are important in building large molecules such as DNA (deoxyribonucleic acid) and protein structures.



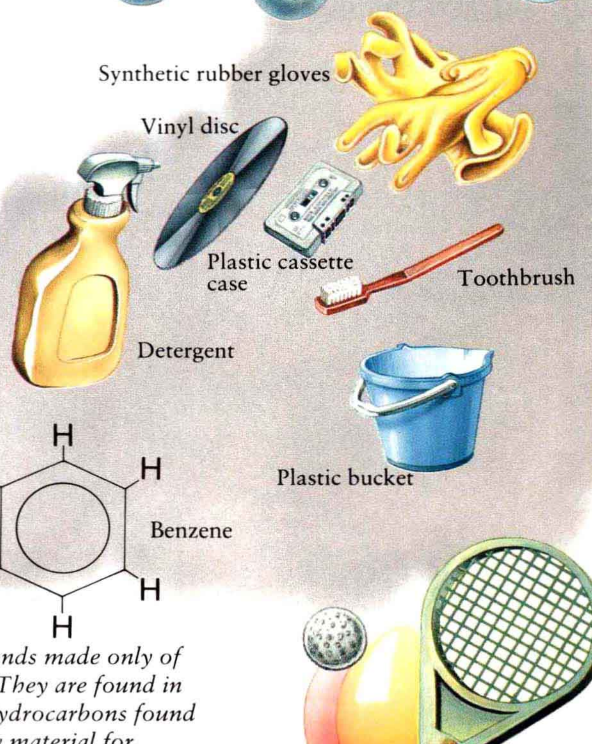



► *Diamond is a form of pure carbon. The atoms in diamond are arranged in a dense lattice framework. This is why diamond is so hard. Carbon makes up less than 0.03 percent of the Earth's crust. Most of this carbon is combined with other elements.*

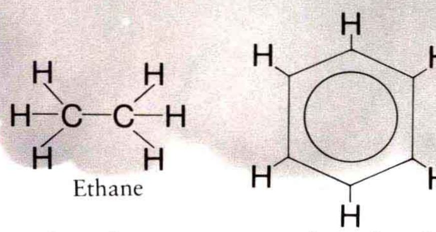




◄ *Graphite, once called plumbago, is another form of pure carbon. Its atoms are arranged in layers which slide easily over one another. Graphite is one of the softest solids. It is also greasy and makes a useful lubricant. The "lead" in a pencil is a mixture of graphite and clay.*



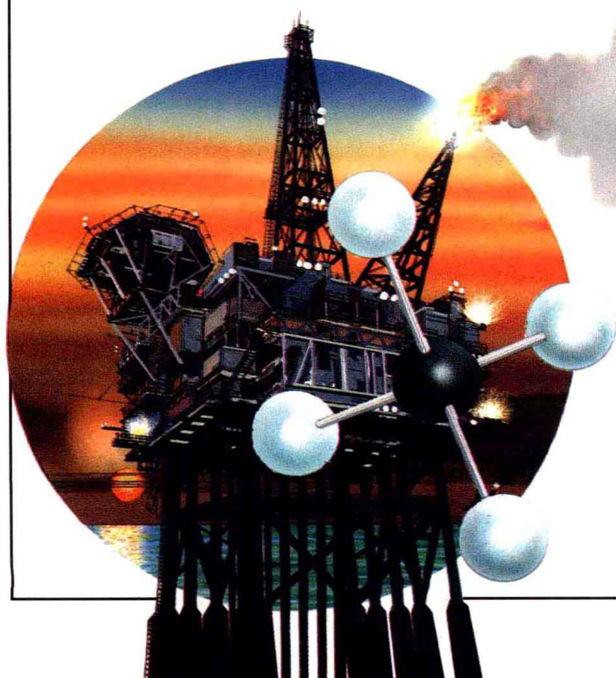

THE USES OF HYDROCARBONS

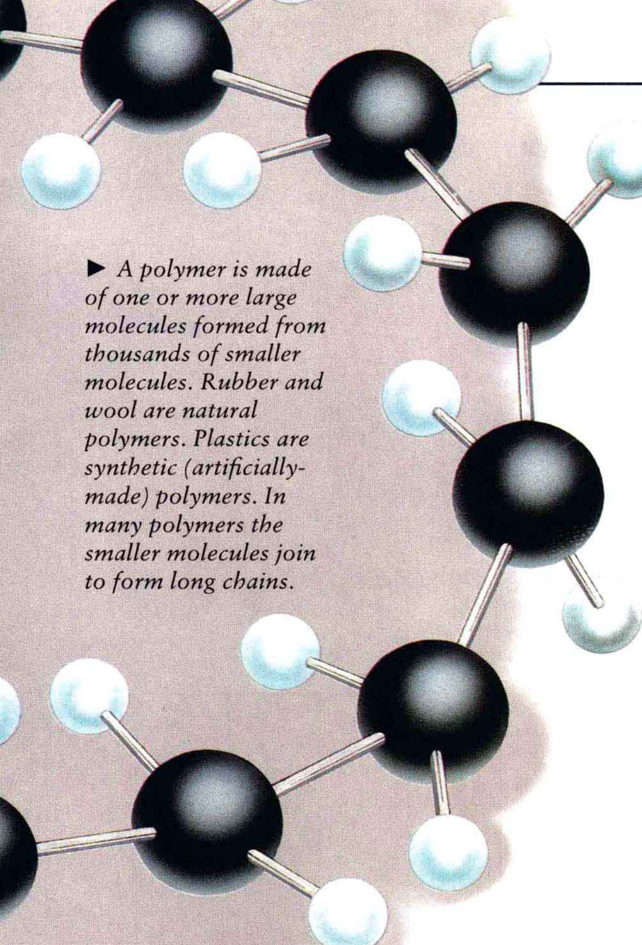


Ethane

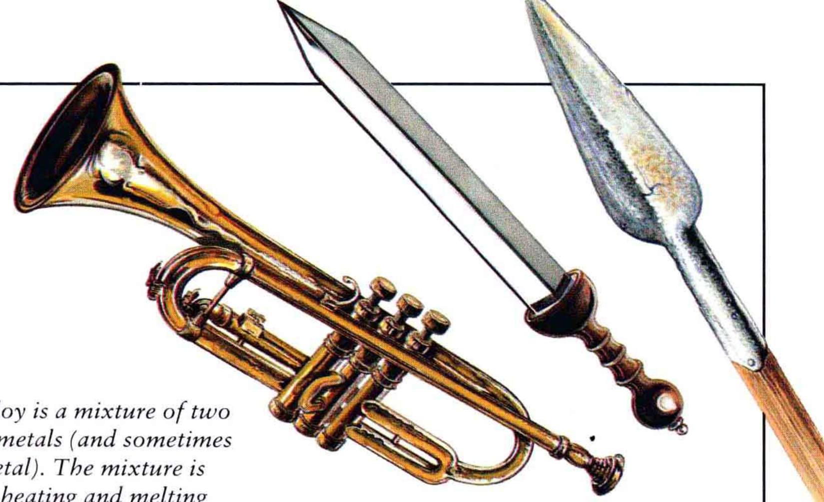
Benzene

▲ *Hydrocarbons are compounds made only of hydrogen and carbon atoms. They are found in petroleum and natural gas. Hydrocarbons found in nature also provide the raw material for making plastics, solvents, and other synthetic materials. In hydrocarbons, carbon atoms are arranged either in chains (as in ethane) or rings (as in benzene).*

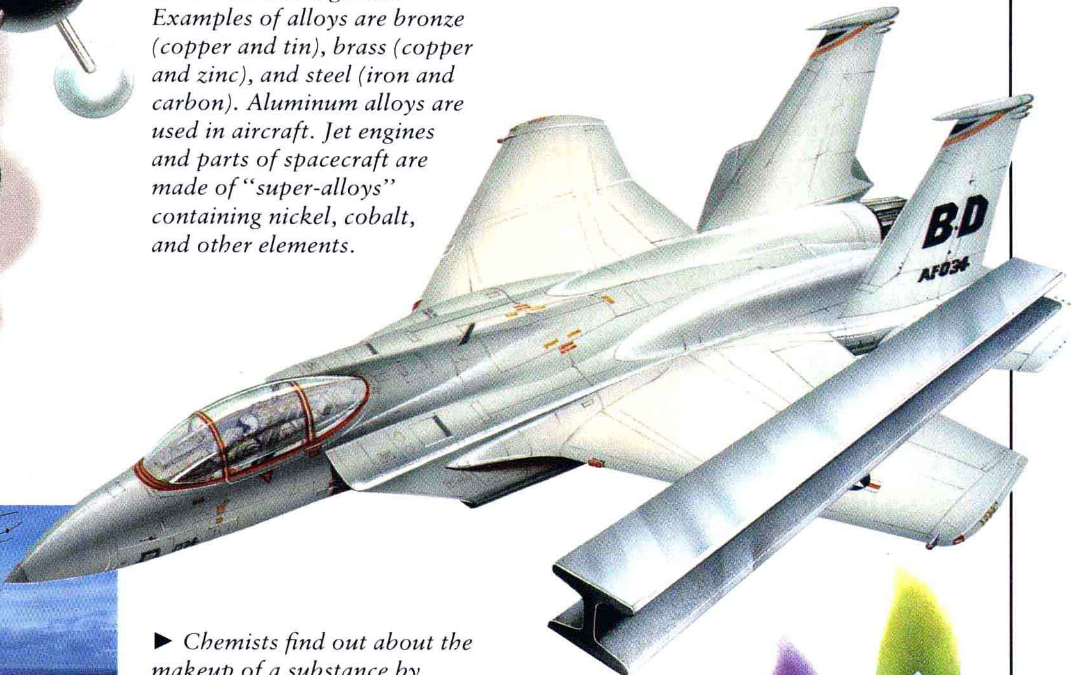


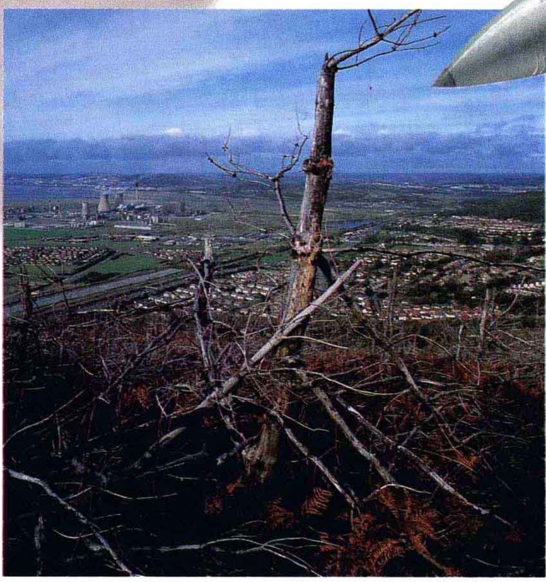


► *A polymer is made of one or more large molecules formed from thousands of smaller molecules. Rubber and wool are natural polymers. Plastics are synthetic (artificially-made) polymers. In many polymers the smaller molecules join to form long chains.*



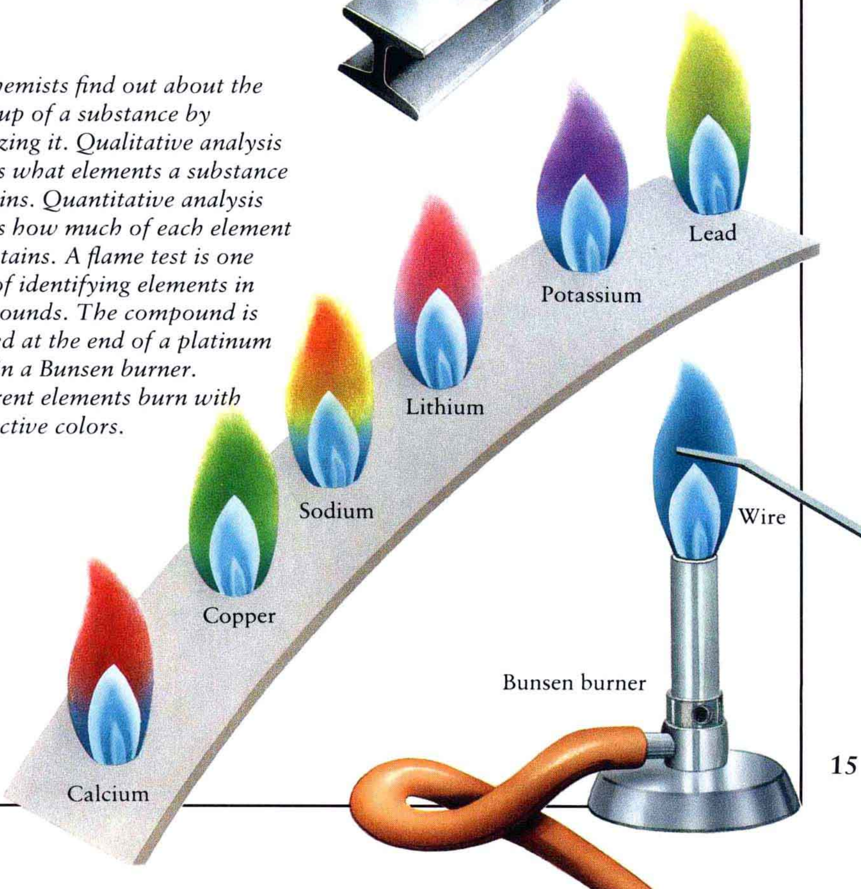
► *An alloy is a mixture of two or more metals (and sometimes a non-metal). The mixture is made by heating and melting the substances together. Examples of alloys are bronze (copper and tin), brass (copper and zinc), and steel (iron and carbon). Aluminum alloys are used in aircraft. Jet engines and parts of spacecraft are made of "super-alloys" containing nickel, cobalt, and other elements.*



▲ *An acid is a compound of hydrogen and at least one other element. Solutions of acid are usually sour-tasting and corrosive. Acids dissolve many metals and turn blue litmus paper red. Acid rain (rain polluted by acids in the atmosphere by the burning of industrial waste gases) has damaged trees and crops and polluted rivers and lakes in many countries.*

► *Chemists find out about the makeup of a substance by analyzing it. Qualitative analysis shows what elements a substance contains. Quantitative analysis shows how much of each element it contains. A flame test is one way of identifying elements in compounds. The compound is burned at the end of a platinum wire in a Bunsen burner. Different elements burn with distinctive colors.*



# The Periodic Table

In all, 103 elements have been officially named. Ninety-two elements occur naturally on the Earth and others have been made in laboratories. Scientists claim to have discovered a further six elements, known as 104 to 109. Twelve elements were known to the ancient world (before A.D. 1000). Seventy-six more were identified between the 1500s and 1920s. Each element from 1 (Hydrogen: H) to 103 (Lawrencium: Lr) has a symbol. Chemists use these symbols when writing formulas for compounds.

► *The periodic table presents information about the elements: their name, atomic number, and similarities with other elements. The elements are arranged in periods, or rows, in order of increasing atomic number. Groups of elements share certain characteristics because of the way the electrons in their atoms are arranged in shells. Elements with the same number of electrons in their outermost shells behave similarly. There are two main groups: the non-metals and the metals; certain similar elements fall into families, e.g. alkali metals, transition metals, and inner transition metals.*

| | |
|---|---|
| Alkali metals | Transition metals |
| Non-metals | Inner transition series |

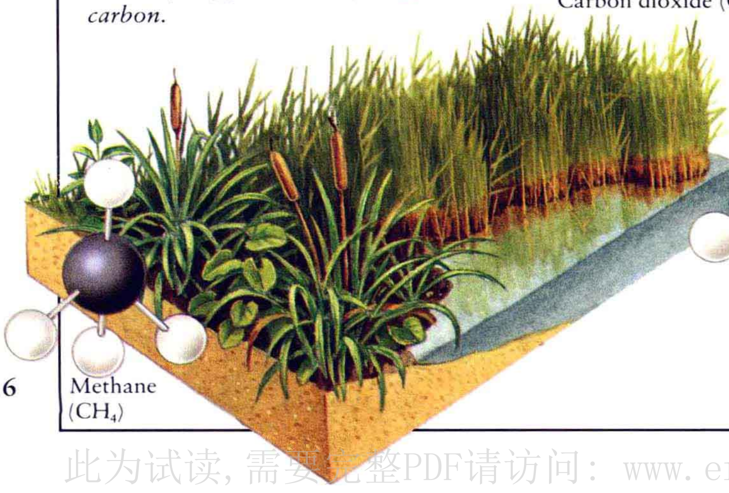
| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 3 Lithium Li | 4 Beryllium Be | | | | | | | | | |
| 11 Sodium Na | 12 Magnesium Mg | | | | | | | | | |
| 19 Potassium K | 20 Calcium Ca | 21 Scandium Sc | 22 Titanium Ti | 23 Vanadium V | 24 Chromium Cr | 25 Manganese Mn | 26 Iron Fe | 27 Cobalt Co | | |
| 37 Rubidium Rb | 38 Strontium Sr | 39 Yttrium Y | 40 Zirconium Zr | 41 Niobium Nb | 42 Molybdenum Mo | 43 Technetium Tc | 44 Ruthenium Ru | 45 Rhodium Rh | | |
| 55 Cesium Cs | 56 Barium Ba | 57–71 Lanthanide series | 72 Hafnium Hf | 73 Tantalum Ta | 74 Tungsten W | 75 Rhenium Re | 76 Osmium Os | 77 Iridium Ir | | |
| 87 Francium Fr | 88 Radium Ra | 89–103 Actinide series | Element 104 | 105 Element 105 | 106 Element 106 | 107 Element 107 | 108 Element 108 | 109 Element 109 | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 57 Lanthanum La | 58 Cerium Ce | 59 Praseodymium Pr | 60 Neodymium Nd | 61 Prometheum Pm | 62 Samarium Sm | 63 Europium Eu | 64 Gadolinium Gd | 65 Terbium Tb |
| 89 Actinium Ac | 90 Thorium Th | 91 Protactinium Pa | 92 Uranium U | 93 Neptunium Np | 94 Plutonium Pu | 95 Americium Am | 96 Curium Cm | 97 Berkelium Bk |

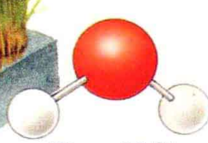
**DOWN**
Going down, the size of atoms increases; elements in the same group behave similarly.

▼ *Water is a molecule made of two atoms of hydrogen (H) and one atom of oxygen (O). Hydrogen is the simplest and most abundant element in the universe. Methane gas is a hydrocarbon made of one atom of carbon and four atoms of hydrogen. Carbon dioxide is made of two atoms of oxygen to one of carbon.*

Carbon dioxide ($CO_2$)



Methane ($CH_4$)



Water ($H_2O$)

**EVERYDAY USE OF ELEMENTS**

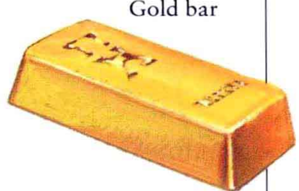
Neon-lit sign

◄ *Neon (used for artificial lighting) is a noble gas.*

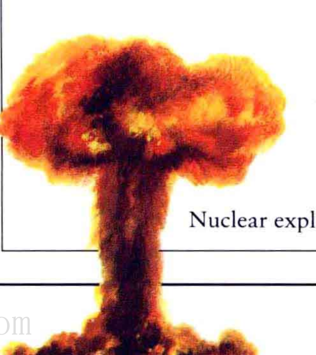
Phosphorus match

► *Phosphorus (used in matches) is another non-metal.*

► *Gold is a metallic element. It is soft, but heavy, and forms few compounds.*



Gold bar



Nuclear explosion

◄ *Uranium exists in several isotopes, or varieties. It is used as a nuclear fuel and in weapons.*