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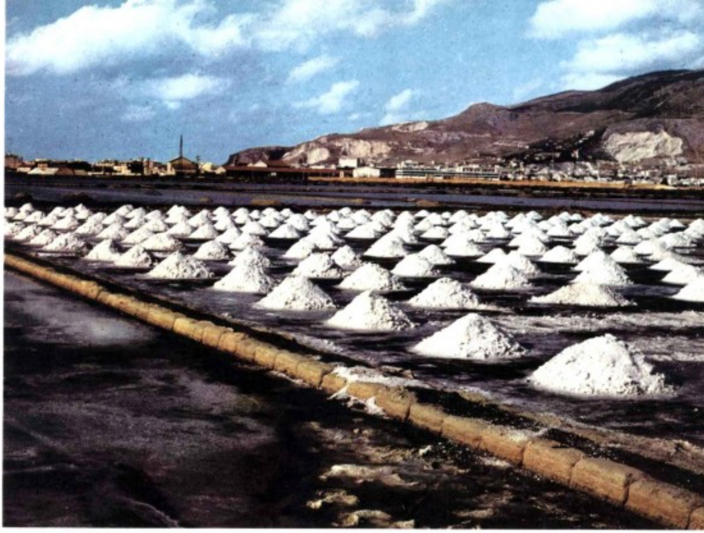
salt



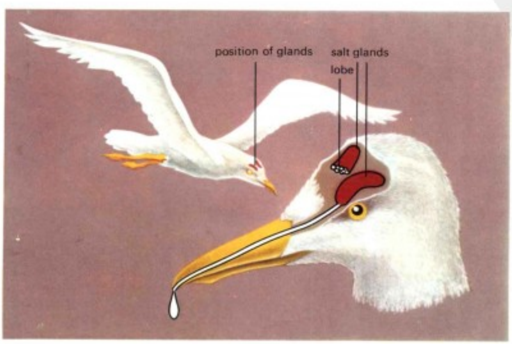
Salt can be produced by evaporating sea-water. These salt pans are at Trapani, Sicily. The salt crystallized from the sea is raked into heaps to drain before it is dried

The herring gull, which drinks only salt water, has special glands for removing excess salt from its blood. The glands, which are above the eyes, consist of two lobes made up of numerous tubules. Salt and water are drawn out of the surrounding blood vessels. This salt solution is chanelled along a duct and drips off the end of the beak

Salt is a precious chemical for man. It is essential to life. If our food does not contain salt, then we must take salt tablets or add salt to the food. We have several expressions in our language where salt is used as a symbol for value. We describe a person we value highly as 'the salt of the Earth'. We criticize people who are 'not worth their salt'.

The soldiers of the Roman army were given salt rations. Later the custom changed, and the soldiers were given money to buy their salt rations. The money for the salt was called the 'salarium argentum' – 'salt money'. It is from this Latin expression that our word 'salary' comes.

To a scientist, 'salt' may mean one of two things. The word is generally used to describe 'common', or table, salt. The chemical name for common salt is sodium chloride. It can be represented by chemical symbols in a formula. Na is the symbol for sodium, Cl is the symbol for chlorine, so NaCl is the formula for sodium chloride. Common salt contains equal numbers of sodium atoms and chlorine atoms. Sodium by itself is a very reactive metal. Chlorine by itself is a poisonous gas. But when they combine together they form a stable, harmless compound.



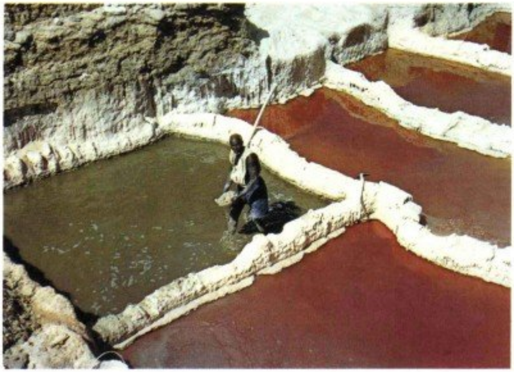
The word 'salt' is also used to describe certain chemical compounds, produced when an acid reacts with its chemical opposite, a base (see: *acids and bases*). Sodium chloride itself is a salt of this kind. It is produced when hydrochloric acid (HCl) reacts with the base sodium hydroxide (NaOH). The chemical equation for this reaction is expressed like this:

$$HCl + NaOH = NaCl + H_2O$$

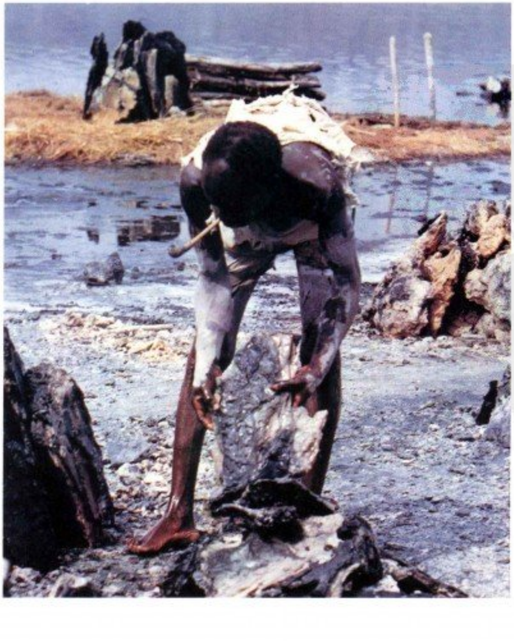
Or, in general: acid + base = salt + water. The acid always contains a hydrogen ion (H^+) and the base an hydroxyl ion (OH^-), the two of which combine together to form water. This process is called neutralization as both acidic and basic characteristics are eliminated.

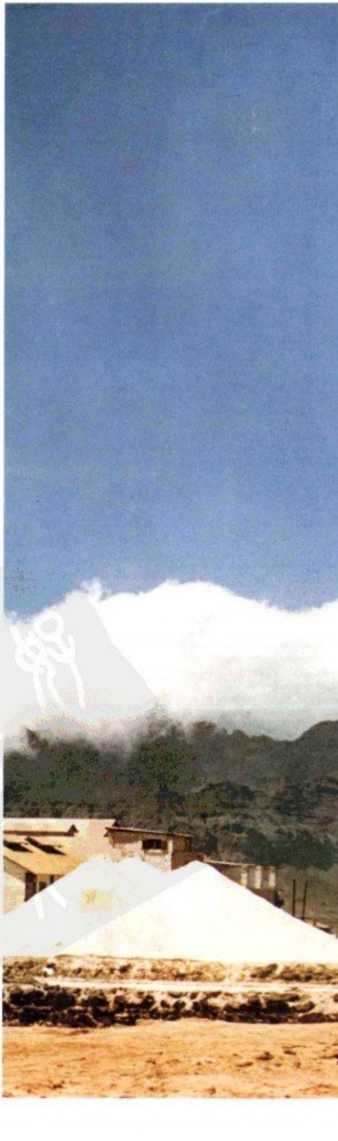
Sometimes, if the acid has more than one hydrogen ion a different type of salt is formed. For instance when sodium hydroxide (NaOH) reacts with carbonic acid (H_2CO_3), the sodium may replace only one of the two hydrogen ions. When this occurs an acid salt is made – sodium hydrogen carbonate or sodium bicarbonate ($NaHCO_3$). You will know this chemical better by its common name – baking soda.

Common salt is a white solid. It is composed of crystals – geometric arrangements of atoms.



Apart from salt water, the other source of salt is rock salt. Rock salt is salt that evaporated from sea water in the geologic past. It has to be mined. In some cases, as at Bilma oasis in the Sahara (*above*), mined salt is dissolved in water and allowed to evaporate, as with salt water deposits. Otherwise the lumps of mined salt, if the salt is pure, are ground on the spot. (*Right*) A windmill provides the power for crushing salt at a salt mine in Aden. (*Below*) Mining rock salt from a surface deposit in Uganda





△ This machine extracts salt from the water and sand dredged from this canal
▽ Animals need water to excrete salt in the form of urine. The horse can drink a lot of water and produces large amounts of urine with a low salt concentration. The camel, which lives in the desert, needs to save water. It produces small amounts of urine with a high salt concentration

The crystals of common salt are cube-shaped (see: *crystal*). In nature, salt is sometimes found in the form of solid rock. Rock salt is called halite.

Salt dissolves readily in water to form brine. When it is dissolved in water, salt lowers the freezing point of the solution. So brine will not freeze at the normal freezing point of water, which is 0°C (32°F). This is why salt is scattered over icy roads in winter. It lowers the temperature at which ice melts. If the weather is not too cold the ice therefore melts and the road is no longer slippery and dangerous.

Sources of salt

Salt is one of the most widely distributed chemical compounds in the Earth's crust. Crystals of salt are present in many different types of rock and soil. A small quantity of the salt in rocks is constantly being dissolved by rainwater. The dissolved salt is carried down to the coast by streams and rivers. Over the course of many millions of years, vast quantities of dissolved salt have accumulated in the oceans.

There was some salt present when the oceans were formed. But since then, some of the water of the oceans has been evaporated by the heat of the Sun. As a result of these processes the salt in the oceans is becoming more and more concentrated. (See: *ocean*.) The concentration of the salt in ocean water varies. It is greatest at the Equator. There are several kinds of salt in the ocean. But more than three quarters of it is common salt or sodium chloride.

In the course of Earth's history, the land and the oceans have been constantly changing (see: *Earth*). At one time much of our land was covered by the ocean. At various times in the past, areas of the ocean became enclosed by land, forming lakes and inland seas (see: *lagoons and lakes*). Sometimes evaporation of water from these enclosed areas was greater than the inflow of water from rivers. When water evaporates, the salt stays behind. As a result, the salt became more and more concentrated in the lake. Finally all the water disappeared, leaving large layers, or 'beds', of solid salt. These can still be seen in many parts of the world. Huge salt beds formed from an inland sea are found in Utah in North America. Salt is also mined out of the Earth in several parts of Eastern Europe.

Salt may be mined by cutting it out of the solid rock. A shaft is sunk through the earth until the salt bed is reached. Miners then dig into the wall of salt and use explosives to blast the salt loose. Another method is often used for beds of salt that are deep below the ground. Holes are drilled down through the Earth into the layer of salt. Water is pumped down into the salt layer. The water dissolves some of the salt, and the resulting brine is pumped up to the surface. The brine is heated. Water evaporates leaving solid salt.

In many parts of the world, salt is extracted from ocean water. Sea water flows into shallow evaporating ponds. The water gradually evaporates in the heat of the Sun. The salt is left as a deposit on the beds of the ponds.

A total of about 100,000,000 tonnes per year of salt is obtained from mines and from the ocean. About three quarters of this supply is used in industry. Much of this is used in the manufacture of chemicals such as sodium carbonate (washing soda), sodium bicarbonate (baking soda), sodium hydroxide (caustic soda), hydrochloric acid and chlorine. Chemicals made from salt are important in the manufacture of paper, soaps, detergents, man-made rubbers, leather, glass, fertilizers, and explosives. Liquid sodium made from salt plays an important part in nuclear power plants by acting as the cooling agent or heat exchanger. Relatively small quantities of salt are used in foods.

We add salt to our food to bring out the taste. Sometimes it is added to foods as a 'preservative'. Salted meat and fish last for a long time before decaying. Thirdly – and most important – our bodies require a regular intake of salt. The level of salt in the blood must be maintained. A serious lack of salt in the body means that the volume of blood drops. Low blood pressure, a rapid pulse and cramps may result, and eventually the person may die.

See: *chlorine*, *ice*, *kidney*, *sodium*, *water*.

To think about

Why do mountaineers, steel workers and desert workers swallow salt tablets? And why do farmers often provide blocks of salt for cattle to lick? (*Clue: sweat contains a lot of salt.*)

sand

Most seaside holiday resorts have sandy beaches. Sand is soft underfoot. If the sand is free from rubbish, you can walk and lie on a sandy beach without fear of hurting yourself. Some beaches have surfaces of pebbles. Pebbles can be very painful to walk on with bare feet. Other beaches are rocky.

Sand, pebbles and rocks differ in size. Rocks are large lumps. Pebbles and gravel are made up of smaller lumps. Sand particles are much smaller. Clay and silt are made up of even smaller particles. Rock, gravel, sand, and silt are defined according to the size of their particles. Grains of sand are 0.2 centimetres ($\frac{1}{12}$ inch) or less in diameter.

If you look across the broad stretch of a sandy beach, it appears to be a yellowish-grey or white. Take up some sand in your hand, and study it carefully. Within the sand there are particles of several different colours. When you look at a sandy beach the various colours of all the individual particles seem to blend together into one overall shade.

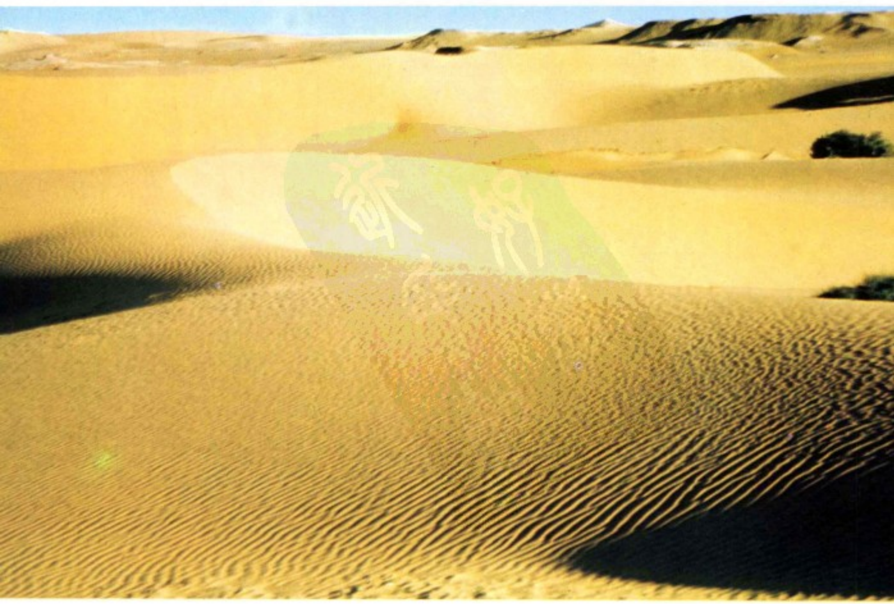
When you study the particles of sand from a beach, you may find some fragments that you recognize, such as a tiny piece of mussel shell, or a fragment of a snail shell. Already you have found a clue to how sand is formed (see: *shell*).

The pieces of shell that you find among the sand on the beach have been broken up by the action of the waves and wind. At one time the shells were occupied by living creatures called molluscs (see: *mollusc*). When they died the empty shells were pounded by the waves and beaten against the rocks. Soon the shells were broken into tiny fragments. Further action by the wind and waves caused the particles to rub against each other. By this means they were worn down into smaller fragments.

Apart from shells, a large proportion of the particles in sand are made from rock. The rock is worn down in the same way that the shells are broken into small fragments. The process of wearing down is called 'erosion' (see: *erosion*).

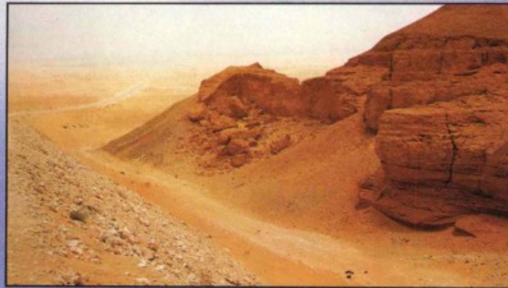
For millions of years the waves of the ocean have beaten against the shore. Even the hardest of rocks cannot withstand this pounding. First, large areas of rock are broken into boulders. The boulders are gradually broken down into pebbles and gravel. Pebbles are light enough to be carried away by the waves. Each wave crashes down upon the pebbles scattering them like marbles. As soon as each wave draws back, it pulls some of the pebbles with it. There is a loud grinding noise, as the pebbles move over each other. As they grind each other the pebbles become more and more eroded. Smaller and smaller particles are formed, until sand is created.

The waves of the ocean are not the only

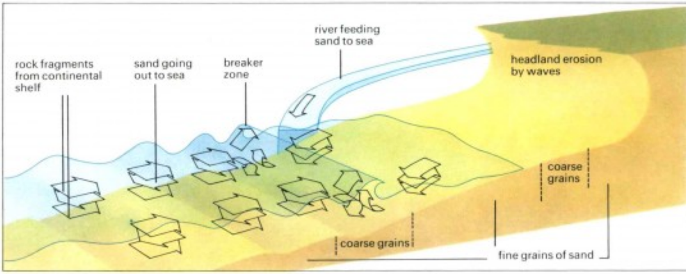


Sand dunes in the Arabian desert. Sand is formed as a result of rocks being broken down into tiny grains by erosion. Winds blow the grains into ridges and dunes which are constantly on the move. Desert sands are too dry to support plant growth which would anchor the sands down. Some sand dunes move as much as 30 metres in a year

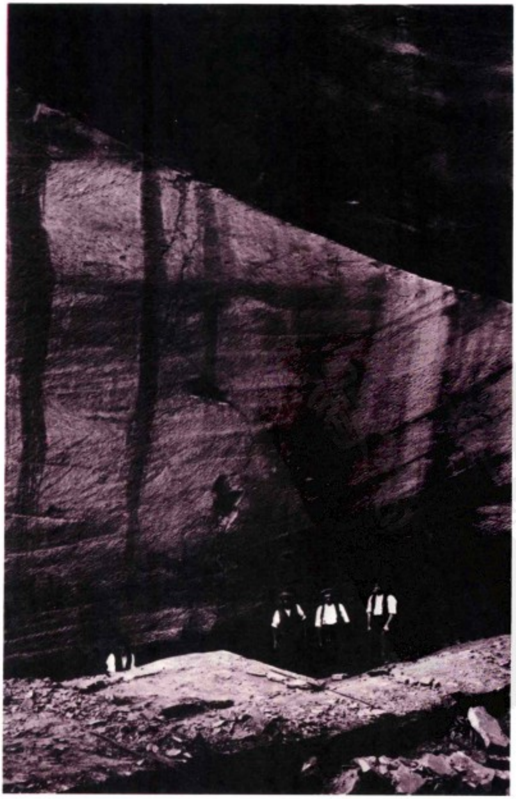
▷ Sand of a river delta, exposed at low tide. The sand that is being deposited here may one day become so packed down by layers above it that it forms rock — sandstone. The colourful sandstones of Bryce Canyon, Utah, are formed of sands that were laid down in the Tertiary period. Bryce Canyon's fantastic spires and arches are the result of wind and water erosion, wearing the sandstone down to sand again



▷Sands of the Sahara desert in Algeria. The rocky outcrop is sandstone which is gradually being broken down to smaller rocks *(at left)*, and finally to sand by temperature erosion. During the heat of the day the rock expands. At night the temperature drops sharply and the rock contracts. Eventually, the rock is weakened and splits. Windblown sand acts as an abrasive that further erodes the rock



▻ Sand forms on a beach as a result of rock fragments and particles being buffeted by the water. As they rub against each other and the sea bed, they are worn down by friction until they become grains of sand. Fine grains are deposited on the steep slopes of the beach. Coarse grains are heavy and settle on the less steep slopes and level parts



▽ The line running across the photograph outlines a sand dune that has become compressed into sandstone over thousands of years

forces of erosion that form sand. The rocks of the land are constantly being eroded by the action of rain, streams and rivers, and wind. They are also worn away by glaciers – huge masses of ice found today in high mountain areas and in the polar regions (see: *glacier, ice ages*). Not only do these forces wear down the land, but they also carry the particles some distance from where they were formed. Rivers collect the eroded particles from the land, and carry them toward the ocean (see: *river*). Moving glaciers tear fragments of rock from the land. When the glaciers melt, the fragments are deposited in ridges called 'moraines'. The wind carries particles over the land. In deserts and on the sea shore, the wind piles up hills of sand which are called 'dunes'.

Not all the substances that are present in rock break down into sand. Some of the naturally occurring substances, or 'minerals', dissolve in water. Common salt, for instance, is dissolved by rain and river water. Then it is carried to the sea. Softer substances are ground into the very small particles that make up clay and silt. The most common mineral in sand is 'quartz'. This is a hard substance made up of crystals often found in rocks.

Sand is an important material for glass-making (see: *glass*). When glass is made, sand is heated in a furnace until the quartz melts. It is allowed to cool slowly. Instead of forming quartz crystals again as in sand or rock, the melted quartz forms glass.

Sand is also used in the making of moulds in metal 'foundries'. In a foundry, molten metal is made into required shapes by pouring it into moulds. The inner surfaces of the moulds are sand. The building industry uses sand. Mortar consists of lime mixed with sand. Sand mixed with cement or plaster forms a more powerful bonding mixture than either cement or plaster on its own.

We have seen how sand itself is created by erosion. Sand is used by man to 'erode' other materials. Sandpaper is used by woodworkers. In industry, 'sandblasting' is often used for cleaning surfaces. Air under pressure is used to spray sand onto the surface to be worn down. See: *desert, erosion, glacier, rocks and minerals.*

Saprophytes are plant parasites. They cannot make their own food. Above are some examples. *(Left)* Earthstars grow in woodland areas. Light pressure (even raindrops) on the spore sac in the centre of each mushroom causes spores to be released. *(Centre)* Stinkhorn, which grows in open meadowland. The spores are contained in the slimy green covering of the cap. The smell of this covering attracts flies which help disperse the spores. *(Right)* Coral spot, a fungus which grows on rotting branches and tree trunks

saprophyte

All the time, living organisms are dying, and new organisms are growing up to take their place. What happens to all the remains of dead plants and animals? And what happens to all the waste material produced by living creatures?

In the autumn, there are piles of dead leaves. By the following spring, most of the dead leaves have disappeared. The leaves decay. The decay of dead matter is due to the action of plants and bacteria called saprophytes. The word saprophyte means 'waste feeder'. The saprophytes are the scavengers of the living world.

Most saprophytes are so small that they are invisible to the naked eye. Most fungi and many bacteria are saprophytes. Toadstools and mushrooms are saprophytic fungi. So are *Mucor*, the mould that grows on bread, and *Saccharomyces*, the fungus that we call yeast and use in making bread.

Living organisms are made up of complex 'organic' chemicals. There are three main ones, which are called carbohydrates, proteins and fats. A living thing makes the carbohydrates, proteins and fats that form its body from those in its food (see: *metabolism*). But before they can be used, the food substances must first be broken down into more simple forms. This breakdown is called digestion (see: *digestion*).

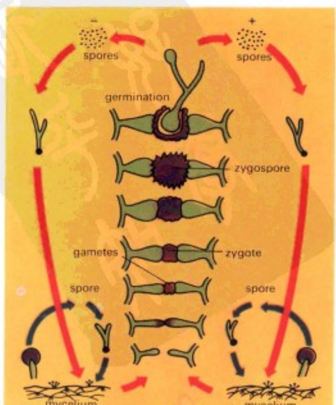
Saprophytes digest dead organic matter. They cannot use the ready-made carbohydrates, proteins and fats found in dead material. They must first break them down into simpler substances. This breakdown could not happen without the help of chemicals, called enzymes, made by the saprophytes (see: *enzyme*). The digestion process of a saprophyte takes place outside its body. The substances resulting from the breakdown can dissolve in water. The saprophyte then absorbs them into its body. This is done through the cell wall.

Many saprophytes can make only a few enzymes. So they can digest only a few types of food. A certain fungus, for instance, can attack only feathers. One kind of bacteria is able to break down only cellulose – the material plant cell walls are made of. On any decaying matter there may be many different saprophytes at work.

Saprophytes do not absorb all the substances that they make by the breakdown of organic matter. Some of the carbon in carbohydrates is set free into the air as carbon dioxide gas. Carbon dioxide is used by all green plants to make carbohydrates. This process is called photosynthesis (see: *photosynthesis*).

Some of the nitrogen in proteins is left in nitrogen compounds in the soil. Living plants, such as trees, can use these compounds to make their own carbohydrates and proteins. They, in turn, are the food of living animals. When animals and plants die and decay, their substances are freed by saprophytes in the soil, to be used again. So it goes on, generation after generation, like a circle. Without saprophytes the circle would not happen. Living things would run out of the substances they need, and would die out.

See: *bacteria, fungus, life, plant, soil.*



The life cycle of the bread mould *Rhizopus*. Reproduction can be asexual or sexual. In asexual reproduction, sporangia (singular, sporangium) develop on upright threads (hyphae) of the mycelium. A sporangium contains spores. When the spores are ripe, the sporangium bursts, thus releasing them. The spores germinate and give rise to more hyphae. Sexual reproduction takes place when two different strains of *Rhizopus* grow near each other. The two strains (marked + and –) act like male and female. Male and female hyphae meet and fuse to form a zygospore. This germinates and produces a sporangium which produces spores of both strains when it bursts

satellite

Man has long wanted to leave the Earth and travel in space. Scientists of our century have been eager to send devices into space, which could stay there and collect valuable information about, for example, radiation from the Sun. This dream began to come true a few years ago. Sputnik 1 the world's first man-made satellite went up on October 4, 1957. It was sent from Russia. With that bold experiment, the 'space age' was born.

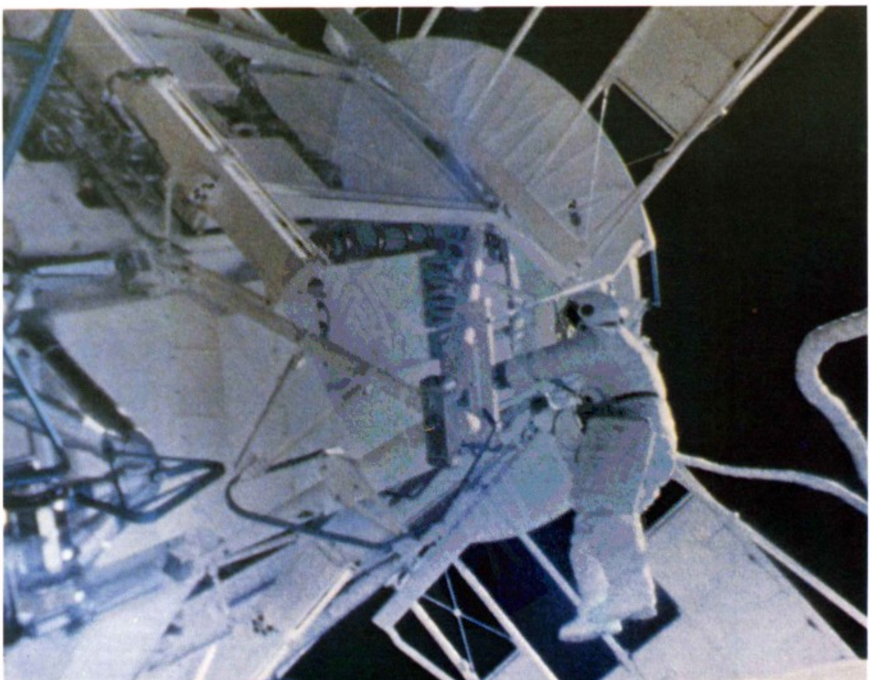
Since then, many satellites have gone into space. The United States first launched one on January 31, 1958, and France followed in 1965. Today, satellites are designed for all sorts of useful purposes. They can carry not only equipment, but animals and people as well. The Earth now has hundreds of satellites going around it.

The word 'satellite' comes from a Latin word for an attendant. The planets are called satellites of the Sun because they travel in paths around it. But the word usually is used by astronomers for the moons of the planets. Our Earth is one of nine planets that move around the Sun. It has a moon that goes around it. Most other planets have moons too.

The artificial satellites are usually sent up to go round the Earth. Spacecraft that travel far beyond the Earth are called 'space probes'. In 1966 a probe made the first soft landing on the Moon. Before that, several probes had been sent to crash-land on the Moon. The probe that made the soft landing was Luna 9 from Russia. It automatically relayed photographs of the Moon's surface back to Earth. Probes supplied information needed for planning the manned Moon expeditions.

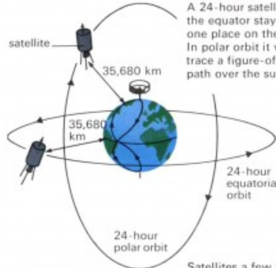
Some probes are now satellites of the Moon. They travel in a path around it. An example is Luna 10, sent up from Russia in 1966. All satellites travel in a path known as an orbit. An orbit always has the shape of an ellipse. An ellipse is a partly flattened circle.

A satellite takes a fixed amount of time to make each complete trip, or 'revolution',

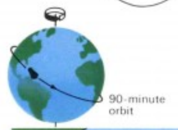


△ Two Soviet satellites on display at an aerospace exhibition. A craft of the *Proton 1* type dwarfs a *Cosmas* satellite. *Proton 1* weighed over 10 tonnes, was unmanned, and made measurements of cosmic rays. The four 'paddles' are solar panels, which turn the energy of sunlight into electrical energy. Many satellites were launched in the *Cosmos* series. They studied the electrical and magnetic fields of the Earth, cosmic rays and radiation from the Sun

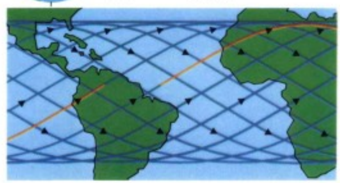
◁ Floating in space many kilometres above the Earth, an astronaut works on the outside of the huge *Skylab* satellite



A 24-hour satellite over the equator stays above one place on the surface. In polar orbit it would trace a figure-of-eight path over the surface



Satellites a few hundred kilometres up take about 90 minutes to go once around the Earth. During each orbit the Earth turns 22$\frac{1}{2}$ east. The craft traces out a path over the surface like that picked out in red here



around its central body. This time is the 'period'. A satellite near the Earth has a shorter period than one farther away. The nearer a satellite is to the Earth, the faster it must travel to stay in orbit. Also, the nearer it is the smaller its orbit will be. So, it will not have to travel so far to make one revolution. Its period, then, will be less than the period of a satellite farther away. An artificial satellite near the Earth may have a period less than 1$\frac{1}{2}$ hours. It may go as fast as 8 kilometres (5 miles) in one second.

A satellite is kept in orbit by the body, such as the Earth, that it goes around. The body pulls on the satellite with the force of gravity (see: *gravity*). The result is just as if you were whirling a stone on the end of a string. If the string broke, the stone would fly away. And without the similar pull of gravity, no satellite could stay in orbit.

A satellite will go on moving by itself. It needs no push, from a source such as an engine, to stay in orbit. But, of course, it is the rocket's engine that puts the satellite in orbit in the first place. The planets and moons continue in their orbits for many millions of years. This is because they move in space, which is almost empty. There is little friction or other slowing force.

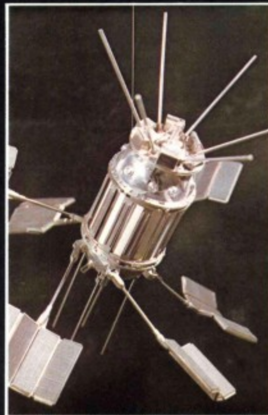
But the Earth's artificial satellites can quickly be slowed down. Some satellites pass through the atmosphere. They are slowed down by thin traces of air. Satellites whose orbits come within this distance are similarly slowed. These satellites may stay in orbit for just a few days. Some will stay for months, even years. But, eventually they fall toward the Earth. They are usually burned up, by the heat of friction, in the air near the Earth's surface (see: *air*). Above 480 kilometres (300 miles) the air is too thin to slow the satellites. They can orbit for years.

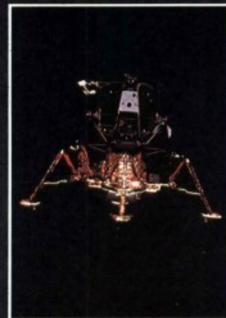
The movement of objects in orbit has been understood by scientists for three centuries. It was first studied to explain how natural satellites move in our solar system. Today the same knowledge is used to work out the orbits of artificial satellites. So we owe a great debt to earlier investigators, such as Newton, for their discoveries (see: *solar system*).

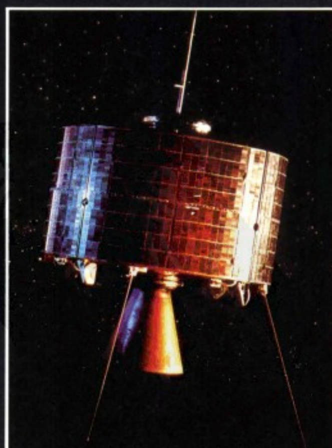
Launching a satellite

The shape of an artificial satellite's orbit depends on two things. One is the pull of gravity from the body it orbits, as we have seen. And it also depends on the way it is sent up. For the satellite must be pushed, or 'launched', into its orbit. This is done by powerful engines that we call rockets. A satellite in orbit can be given a new orbit. The change of orbit is made by small steering rockets attached to the satellite.

A launching rocket often has three stages. These are separate engines, one below the other. The satellite is carried at the very top, protected by a covering. Each stage has its own fuel tanks as well as engines. When the fuel in the first







(Opposite page) Two *Echo* satellites, undergoing inflation tests. *Echo 1* was the first artificial communications satellite to be launched, in 1960. Like these, it was a gas-filled, plastic balloon, 30 metres in diameter. It was a passive satellite, reflecting back to Earth signals beamed to it. Later communications satellites, amplified incoming messages before returning them to Earth. *Elektron 1 (above left)*, a Russian satellite launched in 1964, made measurements of the Van Allen belts, together with *Elektron 2*. *Early Bird, (left)*, the first commercial communications satellite, is covered with photo-electric cells to power the equipment it carries. *(Above right)* Exploration of our natural satellite, the Moon. The Lunar module used in the Apollo missions is seen from the Command Module orbiting the Moon