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water – index

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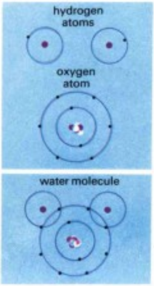
water



△ Water is made up of two kinds of atom, hydrogen and oxygen. There are two atoms of hydrogen to each oxygen atom. That is why water is represented by the formula, H_2O. The water molecule is the basic unit of water as a solid, a liquid and as a gas.

▷ An iceberg in the Antarctic Ocean. Icebergs are mountains of fresh-water ice floating in the ocean. They are formed when huge chunks are broken off glaciers. Unlike most other substances, water is lighter in the solid form than in the liquid form. When water is cooled to below 4°C it expands and gets lighter. This is the reason why an iceberg floats on top of the water

(*Overleaf*) A strong wind blowing through the narrow straits blows the tops off the waves so that the foam forms a streaky pattern on the water

How many times have you used water today? It was in the shower or bath that you took. It made up most of the food you have eaten too. Eggs, fruit, and even meat are mainly water. Beverages contain still more water. Water also forms ice, which you may have put in a cold drink. Water in the form of steam may run machines that produce electricity for your home and school.

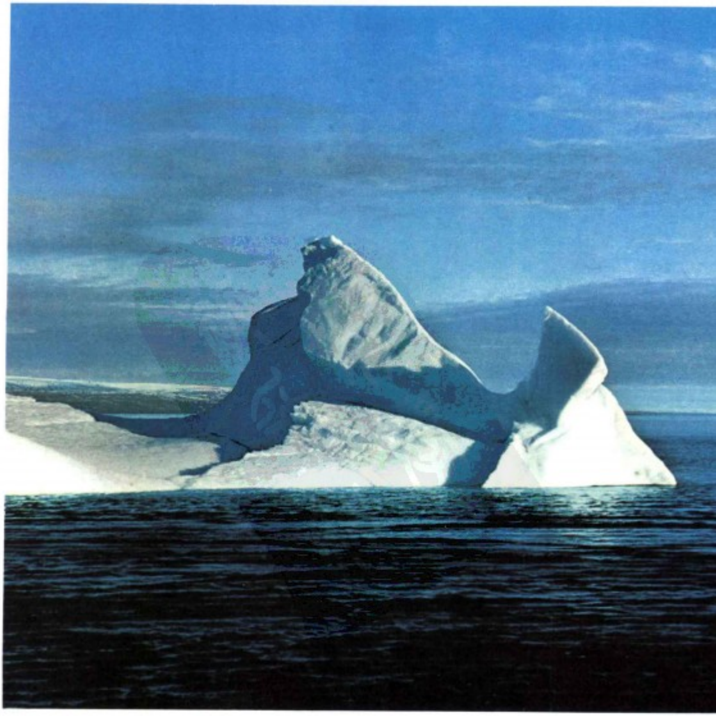
Water is the world's most useful material. We drink it, wash with it, and swim in it. So do many other living creatures. Their bodies, like yours, consist mainly of water. Without it, such life could not exist. And water is needed in order to make nearly all the products that we use every day.

Water is also one of the most abundant substances on Earth. It forms seas, lakes, rivers, snow on mountains, and ice at the North and South Poles. These areas cover about three fourths of the Earth's surface. They contain more than 1,250 million cu. km. of water. There is water beneath the ground and in the air as well.

Because of its familiarity and abundance, water may seem to be an ordinary substance. But it has some very unusual characteristics. And these are what make water useful to us. For example, at normal room temperatures, it is a liquid. This is why it can be used for drinking, washing, and swimming. But most other substances are in the form of solids or gases at room temperatures.

Hot and cold water

In the kitchen or bathroom of your house, there is a sink with hot and cold water taps. These taps provide liquid water at different temperatures. But liquid water can be made much hotter or colder than this. If cooled down to a certain temperature, normally 0°C (32°F), it 'freezes'. It changes into the solid form called ice. If it is heated up to another temperature, normally 100°C (212°F), it 'boils'. Then it changes into the form of a gas, known as steam or water vapour. Ice and steam are produced by the refrigerator and steam iron in your home.



Ice 'melts' into liquid water at the same temperature as that of freezing. Ice can be heated in order to melt it. And steam will 'condense' into liquid water at just the same temperature as that of boiling. Steam can be cooled in order to condense it. By these processes, water may be changed from any one of its three forms into any other.

Why does water need heating or cooling to change its form? Like all matter, water is made of tiny particles called molecules. In solid ice, the molecules are arranged in a rigid structure, and do not move around. But when the ice is heated, the molecules move fast, and the ice melts into a flowing liquid. The molecules move ever faster as the liquid is heated up to the temperature of boiling. Finally they can move apart, independent of each other, and the liquid boils into steam. However, when water is cooled, its molecules move ever more slowly and less independently of each other. Then its form changes from steam to a flowing liquid to solid ice.

The water particles do not always stay at the same distance from each other. In steam, they can fly apart in all directions, unless they are kept in a closed space. In liquid water, they stay much closer together. So the liquid has a certain 'density'. This is the amount of matter in a particular space or volume of a substance (see: *density*).

One cubic centimetre of water weighs one gram. In other words, it has a density of one gram per cubic centimetre. As the water cools down, its molecules come closer together, and the density increases slightly.

But when it is cooled below a temperature of about 4°C (39°F), water begins to expand. Then its particles get farther apart, and the density decreases. So each volume of the water loses weight as it freezes. For this reason, a volume of ice weighs less than the same volume of liquid water does. This is why ice floats on the top of liquid water. Most other substances behave in the opposite way. Their density continues to increase as they cool down and freeze.

Thus a layer of ice forms on the top of a pond in the winter. And this layer can keep the water below from freezing. The water does not cool as much, since its heat cannot escape easily through the ice. Then fish can continue to live all winter in the pond under the ice. They would die if ice did not float on liquid water, for ice would form on the pond's bottom, not as a layer on top. So the pond would freeze quickly and completely. If this happened, life could not have survived in the ocean during the Ice Ages long ago.

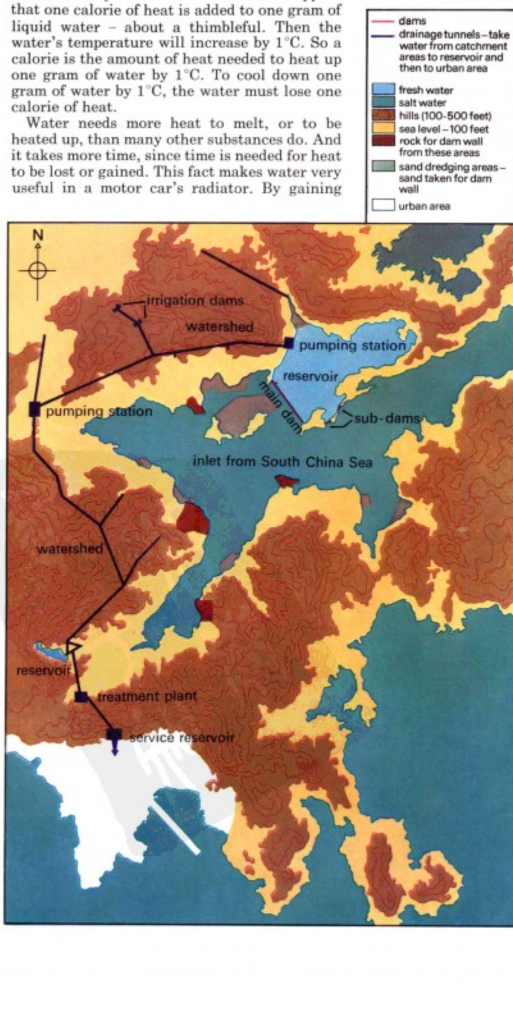
Water expands by about nine per cent as it freezes. This increase in its volume makes water push much harder against the sides of a container. The container may be broken by the harder push. Thus motor car radiators, or the water pipes in a house, may split during the winter if the water inside them freezes.

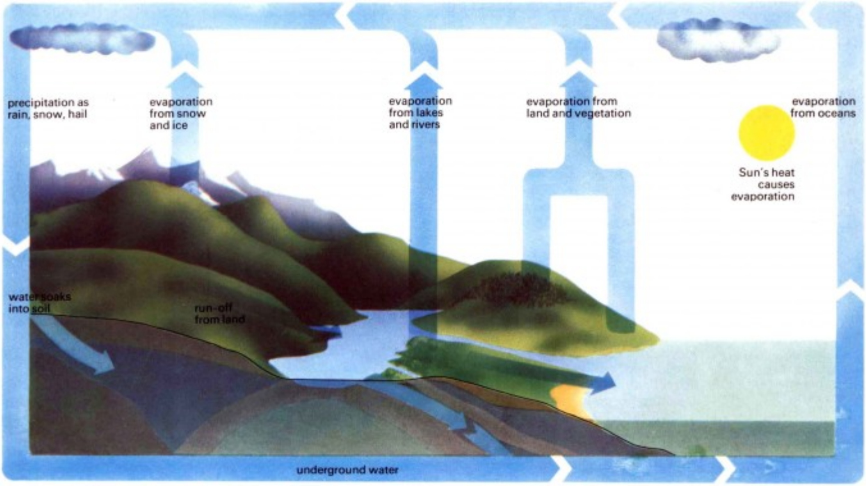
Water loses some heat as it is freezing. But while doing so, it does not change in temperature. It just stays at the freezing temperature of 0°C, and turns from a liquid into ice. The loss of heat changes its form, but does not make it any colder. Similarly, when ice melts into liquid water, it gains some heat without changing in temperature. The amount of heat that is lost in freezing equals the amount that is gained in melting. This amount is about 80 'calories' for each gram of water.

The calorie is an important unit of heat. And it is defined by the behaviour of water. Suppose that one calorie of heat is added to one gram of liquid water – about a thimbleful. Then the water's temperature will increase by 1°C. So a calorie is the amount of heat needed to heat up one gram of water by 1°C. To cool down one gram of water by 1°C, the water must lose one calorie of heat.

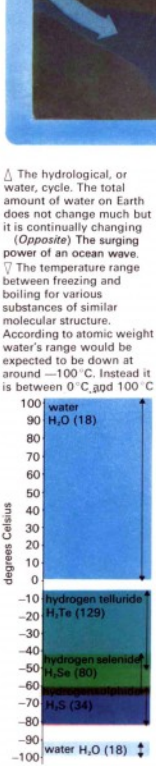
Water needs more heat to melt, or to be heated up, than many other substances do. And it takes more time, since time is needed for heat to be lost or gained. This fact makes water very useful in a motor car's radiator. By gaining

▽ A unique reservoir system in Hong Kong. Dams were built across the bay and neighboring islands. Seawater was pumped out and replaced by rain water which drained from the catchment area. Eventually enough fresh water built up in the reservoir to be pumped to urban areas





△ The hydrological, or water, cycle. The total amount of water on Earth does not change much but it is continually changing
(*Opposite*) The surging power of an ocean wave.
▽ The temperature range between freezing and boiling for various substances of similar molecular structure. According to atomic weight water's range would be expected to be down at around —100°C. Instead it is between 0°C and 100°C



heat from the engine, it can keep the engine cool, while its own temperature does not rise fast. Water is also used in hot-water bottles because it does not lose heat and cool down very fast. Such a bottle stays warm for quite a while. Hot iron cools much faster than the same weight of water at the same temperature.

Water gains a lot of heat when it boils. The liquid does not change in temperature while turning into steam. It only takes in heat that changes its form. The amount of heat is nearly 600 calories for each gram of water. Steam can be very useful since it contains so much heat (see: *steam engine*). And boiling water is often used to cook food or to heat other materials.

Water normally freezes at 0°C and boils at 100°C. These two temperatures are exactly 100°C apart. This difference is not accidental. It was arranged by defining 1°C as just one hundredth of that temperature difference. So water provides the basis of our temperature scale. And this difference is much greater than in other comparable substances. Scientists find that the freezing and boiling temperatures of substances similar to water are lower, and closer to each other. This surprising fact gives water useful characteristics.

You know that liquid water can dry up in a puddle, or can dry from wet clothes. This occurs by the process of 'evaporation'. It is very similar to boiling, but it takes place at lower temperatures. Particles of water are continually escaping from the surface of liquid water. They form water vapour, which rises in the air.

The process opposite to evaporation and boiling is 'condensation'. Here, particles of steam or water vapour are slowed down by cooling. Then they turn back into liquid water. This is how water vapour from the air forms drops of liquid water on a cold surface such as the outside of a glass of iced water.

Water may be 'distilled' to make it pure. This is done when water contains undesirable impurities, or materials such as dirt. First the water is boiled. It escapes as steam. But the impurities remain in the container. Then the steam is condensed to form liquid water with no impurities. Distilled water is used in motor car batteries and industrial processes that need pure water.

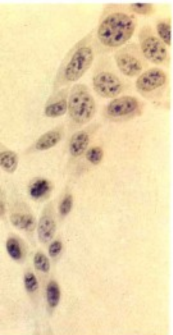
Most water contains many impurities. This is because water can easily 'dissolve' solid substances. Their particles break apart in the water and form a 'solution'. Thus water is said to be an excellent solvent. Ocean water contains dissolved substances such as salt. These are carried into the sea from the land, by waves and ocean currents and by water from rivers. Solutions of substances dissolved in water are useful in science and industry (see: *solutions and solvents*).

The amazing water molecule

What gives water its useful characteristics? They are caused by the tiny molecules that water is made of. Each molecule is a group of even smaller particles, known as atoms. Atoms form the basis of all kinds of matter. (See: *atom*.)

A water molecule contains three atoms. One atom of the element oxygen is joined to two atoms of the element hydrogen. This is shown by the chemical formula for water, H_2O.

In ordinary water, the atom of oxygen is eight times as heavy as the pair of hydrogen



△ Human cells grown in a special broth. Cells consist of protoplasm, which is about 80% water.

▽ A village water pump. In some countries villagers obtain their entire water supply from the communal pump

atoms. So it makes up about 8/9 of the full weight of the water molecule. And about 8/9 of the weight of all water consists of oxygen. But there is a kind of water called 'heavy water'. This contains hydrogen atoms that weigh more than ordinary ones. Very small amounts of heavy water are found in nature. But it is used today in some nuclear reactors. These produce electrical power. (See: *nuclear energy*.)

The atoms in a molecule are held together by electric forces. Their arrangement gives the molecule a certain shape. The shape of a water molecule is like a triangle. Its three atoms are at the triangle's corners.

Because of its shape, the molecule is electrically 'unbalanced'. It creates an electric force on other molecules around it. This strong force is the main reason why water acts as it does.

For example, water molecules are easily joined together by the forces between them. Thus they form solid ice. The molecules in ice are arranged in orderly patterns. You can see such a pattern in a snowflake. To melt ice, these forces must be removed. So a lot of heat must be added to melt ice.

The force between molecules in liquid water is weaker. But it is enough to prevent the molecules from moving independently of each other. So to make them move faster, and to raise the water's temperature, much heat is needed. And when water boils, the molecules must escape from each other completely to form steam. Their forces can only be broken by adding a great amount of heat.

Surface tension

You have probably seen a droplet of water coming out of a tap. A raindrop which falls through the air is similar. Such a drop has a rounded shape. It is held together by the forces between water molecules in the liquid form. They give the drop 'surface tension' which prevents it from coming apart.

In the same way, water molecules create forces on different kinds of molecule near them. This is how water dissolves a material like salt. It pulls the solid salt apart into separate molecules. Then it pulls the molecules apart into 'ions' (see: *ion*).

Water can climb upward in thin 'capillary' tubes, by pulling on the molecules in their sides. Water moves up a plant from its roots into its stem or trunk by such 'capillary action'.

The force caused by a water molecule is called a 'hydrogen bond'. The two hydrogen atoms on one side of the triangular molecule give it a positive electric charge there. This will attract negative electric charges on other molecules and form strong bonds. Such negative charges are on the oxygen-atom sides of water

The world's largest water wheel, the 'Lady Isabella' at Laxey in the Isle of Man. From 1854 it kept the local lead mines free of water until they closed in 1929. It could raise over 1100 litres (250 gal) per minute through more than 365 metres (1,100 ft)

△ A simple apparatus for raising water in monsoon areas such as India.

▽ Victoria Falls on the Zambezi river in Africa. The force of falling water is used to create hydroelectric power

molecules, for example. Thus, each water molecule can form several bonds, linking itself to its surroundings.

The world's water

There is so much water on Earth that every human being could have about 400,000 million litres of it. This amount has not changed much since the Earth was formed. There has only been a continued movement of water from place to place. This process of circulation of water is called the water cycle, or the hydrologic cycle, from the ancient Greek for water.

The hydrologic cycle begins in the ocean. That is where nearly all of the world's water is at all times. Much water is continually evaporating from the surface of the ocean. It evaporates from rivers, lakes, and soil on land too. The water vapour rises high into the atmosphere. Then it becomes colder and may condense. So water droplets are formed. They may even freeze into tiny ice crystals. These may be seen as clouds (see: *clouds*).

Rain and snow

If enough water condenses in this way, it 'precipitates' and falls as rain or snow. Thus water reaches the land. Some of it may stay in the soil or underground for years. Most of it flows into lakes and rivers where it may be used by man. But nearly all of it eventually returns to the ocean, completing the hydrologic cycle, which then begins again.

This process is kept going by the heat of the Sun. The heat is needed to evaporate water and make it rise in the air. And the movement of water has great effects on the Earth's surface. It creates the weather and climate, shapes the land, and makes all life possible. (See: *Sun*.)

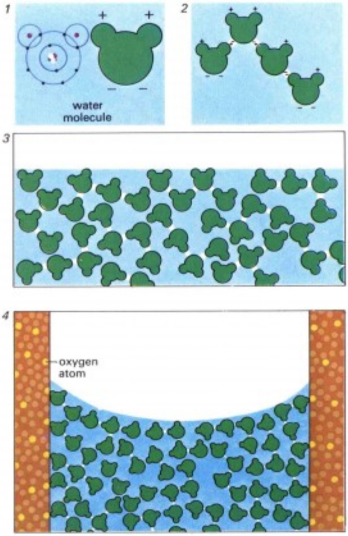
The hydrologic cycle can provide us with very pure water, for evaporation is similar to distillation. The water vapour leaves any impurities behind in the ocean or the soil. When this water falls as rain, it may still be almost pure. But it often picks up dust and other materials from the air as it falls. Gases, such as carbon dioxide, dissolve in it too.

More materials are dissolved in water as it moves across the land. It can dissolve rocks, such as limestone, chalk and gypsum, by carrying away their particles as it flows over them. Thus it slowly forms riverbeds and caves. And these substances may make water 'hard'. This means that it does not mix well with soap. Instead, the soap combines with the dissolved substances to form a scum. Until the scum has removed all the hardness, the soap will not make a useful lather in the water. Hard water wastes soap and is not good for washing. Hard water must be made 'soft' by chemicals in order to be used with soap and for other purposes.

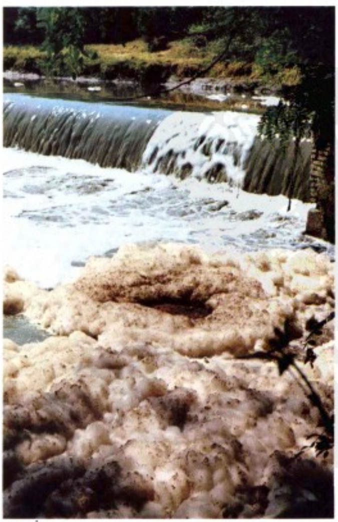
Water supplies

Water is supplied to man directly from rivers and lakes. It may be kept in a big reservoir near a city (see: *reservoir*). It is pumped out of the ground in wells on farms (see: *wells*). Some countries have abundant water all year round. But others have very little water at any time. In a drought, crops often fail and people die. To prevent this, new ways of getting water are being developed. Soon sea water may be purified of its salt on a large scale to get fresh water. Icebergs may be towed by ships from the polar regions and melted for water.

△ The pressure of a wire lowers the melting point of ice and makes it melt. So the wire cuts through the block of ice. But as the pressure returns to normal above the wire, the ice freezes again



(Top right) Two atoms of hydrogen combine with one of oxygen to form a water molecule *1)*, looking rather like Mickey Mouse in this diagram. The 'ears' have a positive charge and the 'chin' negative. *2)* These charges are the basis of molecular attraction. *3)* This holds liquid molecules together in a jar. *4)* In a glass tube, however, the positively charged 'ears' of the water molecules are attracted by the negative oxygen atoms in the glass. This causes the concave 'meniscus' on the surface of the water



▷ A river badly polluted with detergents. Polluted water cannot be drunk or used by industry, and is harmful to fish and wildlife. In the 1930s new man-made detergents called syndets were put on the market. Syndets were not affected by the processes used in treating water wastes, so they passed unchanged into surface waters. The result was foamy water in many streams. Often drinking water became foamy too. Today detergents are being made that can be broken down by sewage treatment processes

Water pollution

Still more materials are dissolved in water when it is used by man. By washing with it, we add dirt and soap and detergents to it. After we drink water, and eat food that contains it, water carries waste matter out of our bodies. And this 'sewage' is usually poured into large areas of water such as rivers. Water also takes away chemical substances from farms and factories that use it. (See: *sewage*.)

These impurities are dangerous to life. Water containing them is 'polluted'. It cannot be drunk safely by man or animals. It is harmful to most water-dwelling animals and to plants that need water. So it must be purified before it is used again. Life depends on a supply of relatively pure water. (See: *pollution*.)

Up until recently the Sun's action in the hydrological cycle has taken care of these impurities. Water evaporated by the heat of the Sun is pure, and when it falls as rain or snow it provides the pure supply needed for life. But now man's output of polluted waste is so great that the hydrologic cycle is not enough to cope.

Modern technology has been faced with the problem and has come up with various ways of reducing the amounts of polluted water industry produces and the extent to which the waste water is polluted.

Scientists have found some ways to purify such water. Thus sewage is normally treated before it is dumped. There are also tiny bacteria that live in polluted water and break up its impurities into less harmful substances (see: *bacteria*). Also, it is thinned out, or 'diluted', when added to a large river or lake or the sea.

Fatal nourishment

But today, huge amounts of polluted water are being produced. It often has surprising effects. For example, 'phosphate' chemicals may be in it. They come from fertilizers on farms and from detergents that we wash with (see: *fertilizer*, *phosphorus*). Phosphates actually nourish plants in polluted water. The plants may grow enough to cover up the water's surface, and use up all the oxygen in the water. Then other plants and fish in the water will die, making the water foul and useless. Life in water is also killed by 'heat pollution'. This occurs when the water is made too warm by factories and by power stations that use it for cooling.

Sea animals such as shellfish can become infected by sewage. Fish take in chemicals, such as mercury, from factories. These animals may not die, but store dangerous substances in their bodies. Then, other animals may die by eating them. Thus, people have been killed indirectly by water pollution.

The only certain way of preventing water pollution is to avoid polluting water at all. This is becoming increasingly difficult. But we must try to protect supplies of water, which is the most valuable substance on Earth.

See: *Earth*, *ice*, *lagoons and lakes*, *life*, *ocean*, *pollution*, *rain*, *river*.

◁ Riding along on the crest of a wave as it travels toward the seashore. The board is pushed forward by the water thrown up at the crest. Such a wave slows down on approaching a shore, since the water becomes ever shallower. But the crest grows ever higher, until the wave 'breaks' on the shore

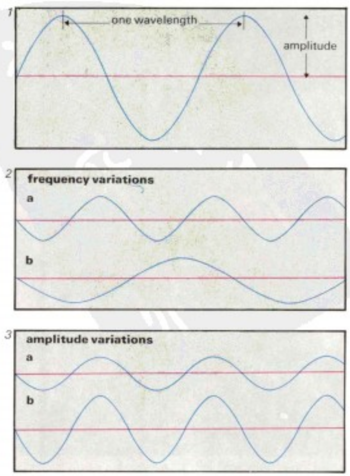
wave

You may have seen ocean waves at the seashore. They reach the shore one by one, all day and night long. There they may 'break' on the sand or rocks, throwing water high into the air. They have travelled to the shore from far away over the sea. And often they carry seaweed or driftwood onto the shore.

Such waves travel on the surface of the water. They are caused by a disturbance of the water. This is usually produced by the winds that blow across the sea's surface. The waves also disturb the water as they travel. They make each part of the surface move up and down as they pass it.

Smaller waves can be studied on a pond. Toss a stone into the water in the middle of the pond. The stone disturbs the water's surface. Then the disturbance travels away from the point where the stone hit the water. It becomes a wave that travels outward from there. The wave has the shape of an ever-widening circle. A number of waves may be produced one after the other. They all travel across the surface of the water toward the pond's edge.

These waves will disturb an object that is floating on the pond. At first the object is not moving. Then a wave reaches the part of the



◁ *1)* A series of waves, seen from the side while travelling either to the left or to the right. *2)* Waves of equal height or 'amplitude', in which the lower waves have a 'wavelength' about twice as long as the upper ones do. *3)* Waves of equal wavelength, in which the lower waves have twice as great an amplitude as the upper waves do. Amplitude and wavelength are very important quantities in the study of wave motion water that the object is floating on. As the wave passes, the object will move up and down. It is not carried forward by the wave, but it will continue to move up and down as other waves reach it. For the waves make the water beneath the object rise and fall.

The highest part of a wave is called the crest. The lowest part of a wave is known as the trough. The crest and trough of the wave travel together, one after the other. And they are followed by the crest and trough of another wave. Waves do not carry water along with them. They move across the surface.

Water is the material, or medium, through which such waves travel. It consists of tiny particles called molecules (see: *atom*). Each particle of the water's surface is disturbed by a passing wave. As the crest goes by, the particle rises. It also moves forward a little way in the direction of the wave's travel. As the trough goes by, the particle falls. Then it moves backward in the direction that is opposite to the wave's direction of travel. Thus it stays in about the same place, while the wave travels onward to other particles.

Waves of the most simple kind are equally spaced. The same space, or distance, exists between each wave and the next. This can be measured from the crest of one wave to the crest of the next. Or it can be measured between the troughs of the two waves. It is called the wavelength of the waves. Ocean waves may have a wavelength of many yards. The ripples on a pond may have a wavelength of only a few centimetres.

Waves have a certain 'frequency' too. In each second of time, a definite number of waves travel past a place on the surface of the water. The number might be two waves per second. Or five, or more, waves per second might pass that place. This number is the frequency.

Frequency is measured in cycles per second, or 'hertz'. A cycle is one complete wave, with one crest and one trough. You can find the frequency of water waves easily. Put a floating object like a cork in the water. Watch it bobbing up and down as the waves pass it. Count the number of times that it makes a complete up-and-down movement. You can do this during a time interval of, say, ten seconds on your watch. Then you divide ten seconds into the number of times that you counted. The result will be the frequency of the waves in cycles per second, or cps.

Waves travel at a particular speed. This speed may be measured in metres per second, or kilometres per hour. The speed always equals the frequency multiplied by the wavelength. For example, suppose the frequency is 2 cycles per second, and the wavelength is 3 metres. Then two whole waves travel past a certain place in each second. And the total length of the two waves is 6 metres. So the waves must be travelling at a speed of 6 metres per second.

Waves can be made on the surface of liquids other than water. They travel more slowly on a liquid such as oil. The speed of waves always depends on the medium that they are travelling through. For surface waves, the speed also depends on how deep the liquid is. The waves travel more slowly where the liquid is shallower. Ocean waves slow down as they approach a shore. For the water is shallower there.

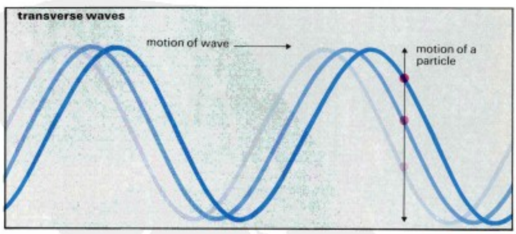
Waves can bounce off an object. This is called reflection. You can see it by making waves on water in a swimming pool. The waves approach one side of the pool. They hit the side and are reflected. The reflected waves are seen going away from the side. And these waves make a definite angle with the side of the pool. It is equal to the angle that the approaching waves made with the side. This equality is called the law of reflection.

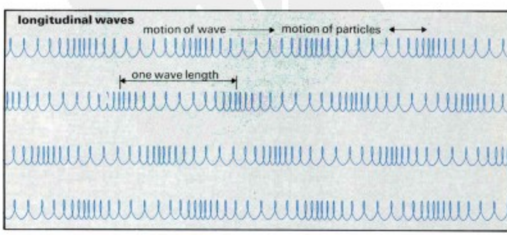
Waves can also be 'refracted'. That is, they change their direction of travel without hitting any object. This happens to ocean waves when the depth of the water changes. Suppose that the waves approach a shore at an angle. They go from deeper into shallower water. Their direction of travel changes so that they travel more directly toward the shore. The path of the waves bends. The amount of bending can be described by a law of refraction. This law shows how the amount of bending depends on the angle that the waves make with the shore.

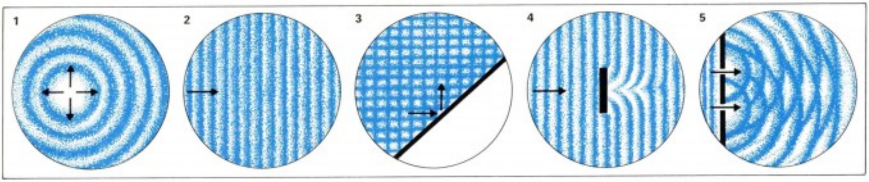
Waves on the surface of a liquid travel horizontally. But they make the tiny particles of the liquid move up and down, or vertically. So they are an example of 'transverse' waves. This means that the particles do not travel in the same direction as the waves. They travel at right angles to that direction.

There is another kind of wave called a 'longitudinal' wave. Longitudinal waves can exist deep inside a liquid. Such a wave makes the particles move back and forth in the same

Two basic types of waves, travelling to the right. A series of transverse waves is shown in three successive positions. As the waves travel past a particle, they make it move up and down, but it does not move in the same direction as the waves. Waves on the surface of water, or travelling along a rope that is shaken, and light or radio waves, are all transverse. A longitudinal wave series, travelling along a vibrating spring, is seen in four positions. The particles of the 'medium' (in this case the spring) move back and forth in the same direction that the waves travel. Sound also consists of longitudinal waves, in a medium such as air







△ Wave action in water as seen in a 'ripple tank'. **1** Circular waves from a 'point source' that moves the water at one place. **2** Plane waves from a flat source moving the water along a straight line. **3** Plane waves hitting a flat wall at an angle and reflecting off the wall. The reflected waves going away from the wall are also plane waves. They make the same angle with the wall as the waves hitting the wall do, and this fact is known as the Law of Reflection. **4** Plane waves travelling from left to right and passing a small object in the water. They are bent or 'diffracted' by the object as they go by it. **5** Circular waves from two point sources near each other. The waves combine to form an 'interference' pattern, with crests and troughs larger than those made by a single source.
▽ A ripple tank which is used to demonstrate wave patterns in water. It has an electrically-powered agitator that makes ripples in the water. Various obstacles can be put in the tray to show reflection and diffraction, and the agitator can be adapted to form interference patterns. The light above shines through the tray and projects the wave patterns onto a screen below. The patterns above were drawn from these projections.
Use a slit card and the diagram *(below left)* to demonstrate the pattern of longitudinal wave motion. (see: **Find out by doing**)

direction that the wave travels.

Both transverse and longitudinal waves can exist inside a solid material as well. This may be a metal object. If the object is suddenly hit or twisted, it vibrates. The vibrations are waves that go through it and along its surface. Earthquakes result from similar waves going through the solid rock of the Earth (see: *earthquake*). Such waves can travel at several kilometres per second. The denser, or thicker, the material is, the faster the waves travel (see: *density*).

Sound waves are the most important example of longitudinal waves. They can travel in a gas like air. They are caused by a vibrating object that disturbs the air. Then the waves travel away from the object to reach our ears. They make our eardrums vibrate, and we hear.

Electromagnetic waves are an important example of transverse waves. Light, radio signals, and X-rays such as those that a doctor uses, are all electromagnetic waves. They can travel even through empty space. For they do not need to travel in a medium of material with moving particles. Instead, they consist of changing electric and magnetic 'fields'. These fields have directions that are perpendicular to the waves' direction of travel. Such waves travel at the speed of light, which is 300,000 kilometres (186,282 miles) per second in empty space. (See: *electricity*, *magnetism*.)

A basic characteristic of all waves is that they carry energy. Energy is the ability to do work. The energy of waves comes from the source that produces them. Their energy can also be 'absorbed' into materials that the waves hit or travel through. Then the waves lose energy by doing work on those materials. For example, waves of sunlight have energy that comes from the Sun. Some of this energy is absorbed when the light travels through a material like glass. So the light looks less bright to your eyes if you are wearing a pair of dark sunglasses.

The energy of waves can be put to use by man. Thus sound waves, radio signals, and X-rays have many uses today. Wave energy may cause destruction as well. The sand on a seashore is created by the energy of ocean waves pounding the rock and soil of the land.
See: *lenses and mirrors*, *light*, *matter*, *ocean*, *radio*, *sound*, *supersonic flight*.

Find out by doing

You can 'see' longitudinal waves by looking at the dotted diagram. Cut a narrow slit in a piece of paper. Place the paper over the diagram so that the slit runs sideways across the page, at the top of the diagram. You should be able to see only the top row of ten dots through the slit. These may represent ten molecules of air. They are not equally spaced because they are being moved by sound waves travelling through the air. The crest of a wave is where dots are closest together. Now slide your slit down the page slowly to the second row of ten dots, and the third, and so on. You will be looking at the same ten molecules, but at different moments of time. And you will see the crest of a wave come in at the left, travel through the row, and go out at the right just as another wave crest comes in at the left. The wavelength, or distance between crests, is about 3·5 centimetres (1·5 inches). Notice that the molecules do not move far, but only vibrate back and forth.

wax

Wax is a substance that is produced by many plants and animals. Different kinds of wax have many uses in our lives. We use wax to make candles and gramophone records. Wax is used in cosmetics and in floor polishes. 'Sealing wax' is used to seal letters and parcels. Wax crayons are good to draw with. 'Waxworks' are exhibition galleries where wax models of famous people are displayed.

One of the best known kinds of wax is beeswax. Bees produce wax to make the walls of the 'combs' in which they store their honey. The wax is made inside the bees' bodies, from their food. They need about 10 kilos (20 pounds) of food to produce one kilo of wax. (See: *bee*.)

You will find an example of a plant wax on the skin of an apple. If you rub an apple against a cloth, the apple becomes shiny. The shininess comes from the thin coating of wax on the apple's surface.

Chemically, wax is related to fats and oils. Fats and oils are in the same family of chemicals. The difference between them is that fats are solid at normal room temperatures, whereas oils are liquid. Like fats, waxes are solid at normal room temperatures. But they do not have the greasy texture of fats.

Although it is normally a solid, wax can easily be 'melted' – or made liquid. You must have seen liquid wax running down a candle. The heat of the flame melts the wax. Beeswax melts at a temperature of about 62°C (144°F).

Its low melting point is one of a wax's most useful properties. To seal a parcel, red sealing wax only needs to be warmed in a flame to make it melt. Then it can be poured onto a string knot. As it cools and solidifies, the wax binds the knot together.

Many plants have a thin coating of wax to reduce water loss, or transpiration. (See: *transpiration*.) Water is lost from plants mainly through the leaves. It turns to vapour, or evaporates, and passes into the air. Many plants that live in hot climates have leaves that are coated with wax. This cuts down their water loss.

Carnauba wax, for instance, is from leaves of the carnauba palm tree which grows in Brazil in South America. Carnauba wax is used for floor and shoe polishes, because it forms a hard surface layer. Wax polishes give a protective coating to shoes, leatherwear, and furniture. Shoe-polish wax prevents water from penetrating the leather and rotting it. Also, the wax in polishes gives a pleasing shiny appearance. Carnauba wax is also used in making carbon paper.

Animal waxes include wool wax. This is on the surface of wool fibres from animals such as sheep and goats. Another name for wool wax is lanolin. This is a regular component of face-creams, ointments, and soaps. Spermaceti is another animal wax. It comes from the head of the sperm whale. It is used for making cosmetics. Beeswax is also used for cosmetics. Beeswax has been used for hundreds of years to make candles. Nowadays, candles are more commonly made of paraffin wax.

A large amount of wax is obtained from petroleum. Petroleum, or paraffin, wax is almost transparent. It is colourless and has hardly any smell. Some kinds of wax are synthetic, or man-made. These waxes are made from simple chemical ingredients in laboratories. Silicone wax is a synthetic wax made from silicon, a metal, and oxygen. Scientists can make waxes that have just the right properties for a particular purpose. Floor waxes, for instance, must be hard and shiny, but not slippery.

See: *fats and oils*.

▽ A bee's honeycomb is made of beeswax produced by the worker bees. To obtain the wax, a honeycomb is emptied, drained, of honey, and melted. The wax is used to make candles and polishes. *(Right)* A moulding frame for making candles. Each mould in the frame is threaded with wick. Then hot wax is poured in and left to harden. Dyes are added to colour candles. Candles may also be made by dipping wicks into hot wax. Household candles are made of paraffin wax. Beeswax candles are used for religious purposes