10,000 THINGS EVERY CHILD SHOULD KNOW

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The WORLD OF WONDER

EDITED BY
CHARLES RAY

Features in this Part include

HOW A PRINTING MACHINE WORKS

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WHY THINGS DO NOT FALL APART

We can hold up a slab of marble, but we cannot hold up a slab of sand. Directly we try to lift a piece of sand the grains all fall apart. Why is this? A force which men of science call Cohesion holds the particles of a substance together, but its power varies greatly in different materials. Even grains of sand can be made to cohere to some extent when they are wet. The word "cohesion" means "a sticking together." Here we read some facts about this remarkable force, which is of great value to mankind

HAVE you ever thought what a remarkable thing it is that when two teams of extremely powerful men are pulling the ends of a comparatively slender rope, the rope does not break?

You may also see a huge liner towed through the water by means of a slender steel hawser. The strain on this cable must be enormous, yet it does not break. On the other hand, sometimes when you are tying up a parcel and you pull the string tightly it breaks. Why is this?

Why is it that so rarely does a rope break, or cloth tear, or wire snap, or a wooden plank give way? Why is it that sometimes when you catch your umbrella in a crack or hole in the pavement the stick snaps, and why is it that a stout poker which when it is cold will not bend at all, can be bent quite easily when it is made red-hot in the fire? Why, too, if you drop a kettle on the stone floor of the scullery, does it dent but not break, and why if you drop an earthenware basin or china cup does it crack or break up into fragments?

A Clinging Force

All these facts are very commonplace, and yet there is a reason why the different objects and materials behave in the different ways described. There must be some force or power which holds the particles of a substance together, and that force is known to science as Cohesion.

The name comes from a Latin word which means "to cling together," and cohesion is the force which causes the molecules of a body to hold together.

The power of cohesion in different substances varies a great deal, and the strength of a material depends upon whether the force which holds its particles together is strong or weak. If we take a biscuit between our fingers we can break it quite easily, for the cohesion between its various particles is very weak indeed. But if we take a penny between our fingers we shall find we can make no impression, the reason being that the cohesion between the molecules is powerful.

Before the force of cohesion can come into play the molecules must be very close together. If we smash an earthenware or porcelain pot we may fit the fragments together so skilfully that the unaided eye can detect no cracks at all, but we have only to touch the vessel with our finger for it to fall to pieces again. The cohesion between the molecules has been destroyed, and though when the fragments are fitted together they appear to be very close, they are not close enough for cohesion to come into play.

There are some substances, however, which can be welded together by cohesion much more easily than others. If, for example, we take two slabs of lead with very smooth, level and clean surfaces, and press them tightly together with a screwing motion, they will cohere so that a good deal of force is required to pull them apart again.

Similarly, if two very smooth cast-iron plates are pressed together so as to exclude the air between them, they will adhere so firmly that they will support a considerable weight. This is in no sense due to atmospheric pressure, as in the case of a boy's sucker, for they will adhere just as firmly in a vacuum.

Powdered graphite, that is the material which forms the lead of lead pencils, when subjected to a very great pressure, becomes a solid mass. The pressure brings the mysterious force of cohesion into play, and the particles hold together. This force is also present in liquids, though there it is much weaker than in solids. If we take a perfectly clean glass rod and dip it into water, we shall find when we withdraw it that a film of water clings to the rod. If, on the other hand, we dip the glass rod into quicksilver, none of the metal adheres.

This is the famous Portland Vase, which was smashed into many fragments by a madman at the British Museum. The cohesion between the particles was overcome, but the many pieces were fastened together by cement and cohesion was once more restored by its means

Cohesion Lessened by Heat

This shows that the force of cohesion is stronger between the glass and the water than between the molecules of water themselves; and, on the other hand, there is no cohesion at all between the quicksilver and the glass. The tenacity of wire is due to the cohesion between its molecules, but the cohesion of solids is very much lessened by heat.

The older scientists used to make a distinction between the force which holds together the particles of one particular material or body and the force which holds together two different kinds of particles; they called the former cohesion and the latter adhesion. Thus, they said, the molecules of a plank of wood were held together by cohesion, while if the plank were glued to another plank the glue and the wood held together by adhesion.

In the same way the particles of a stick of chalk were, they said, held together by cohesion, while when writing was put upon the blackboard it was adhesion that held the chalk and the board together.

Modern scientists, however, make no such distinction, but speak of cohesion in all cases.

What exactly is the nature of this mysterious force, scientists are unable to say definitely. They think, however, that it is electro-magnetic in its origin.

If the force of cohesion were suddenly to cease, everything in the world would collapse. Houses would fall, furniture would become heaps of powder, and indeed all solids would be reduced to tiny particles. When in the engineer's shop metals are soldered, brazed or welded together, the strength of the joint depends entirely on the force of cohesion.

When engineers and builders speak of the strength of materials they are really only speaking of the force of cohesion which is operating among their particles. Many of the physical properties in which solid substances differ from one another depend on the differences in the cohesive forces which exist between their molecules. Hardness, brittleness, ductility (that is, the extent to which a substance can be drawn out into wire), malleability, or the extent to which it can be hammered into thin sheets, tenacity, or its power of resisting breakage, and elasticity, or the ability of a body after being drawn or pressed out of shape to return to its original condition, all depend on this force of cohesion.

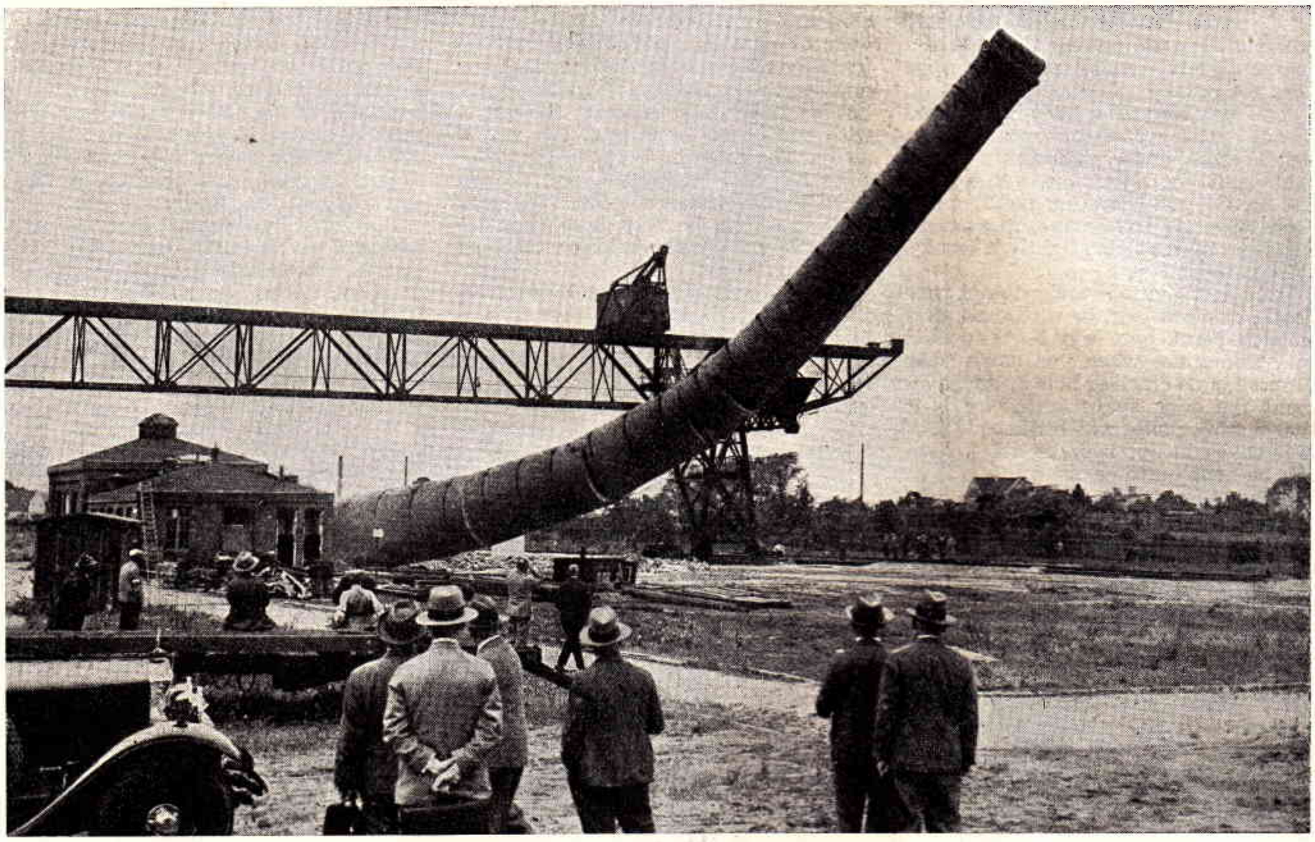
With regard to malleability, it is interesting to know that gold, which is the most malleable of all substances, has been hammered into sheets one-300,000th of an inch in thickness—that is, sheets so thin that it would take 300,000 piled one on top of another to make up an inch.

An interesting object-lesson in cohesion is afforded by the famous Portland Vase. This work of art, which is made of beautiful dark blue glass with figures of opaque white glass decorating its outside, and was found in the sixteenth century in a marble sarcophagus near Rome, is supposed to be about 2,000 years old.

For more than a century it was the glory of the Barberini palace in Rome, and was called the Barberini Vase. Then, after changing hands several times, it came into the possession of the Duke of Portland, since when it has been known as the Portland Vase.

While it was on loan in the British Museum a strange thing happened. On February 7th, 1845, just before closing-time, a loud crash was heard, and when attendants rushed to the spot they found the beautiful vase lying in fragments on the floor. A madman had hurled it to the ground. The shock of striking the floor had overcome the cohesion between the particles of the glass, and never again could the Portland Vase be as it had been.

But an employee of the Museum, with infinite patience and remarkable skill, stuck the pieces together again, so that the vase is able to stand up. At a distance it is almost impossible to see where the fragments are joined, and no doubt the cohesion between the glass and the cement which holds the pieces is probably as great as between the molecules of glass themselves. But the cement is necessary. No amount of pressing the fragments together without cement can produce the necessary cohesion to make the vase a unit.



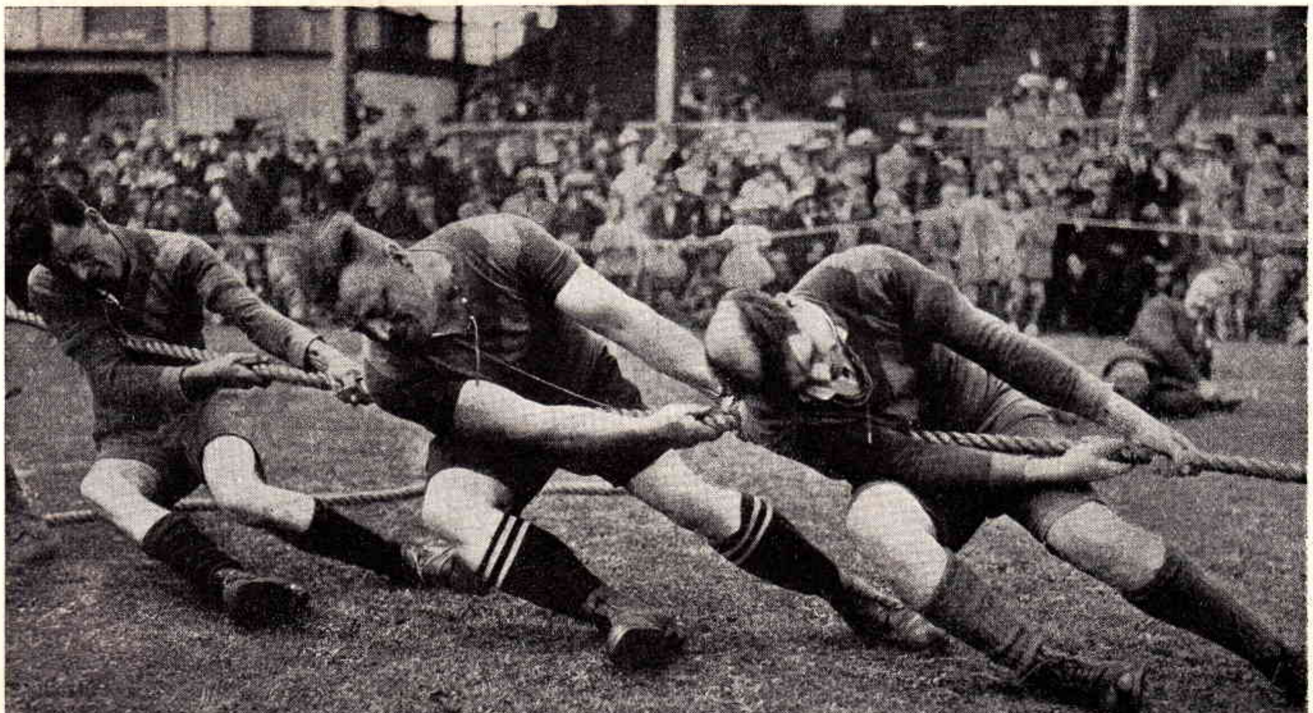
We often see examples of the force of cohesion being overcome by some other force, as when the pressure of our fingers breaks a biscuit in two, or when we drop a plate and break it. Here is a striking illustration of this. A chimney which has stood for half a century is seen being felled. One side was undermined, and the force of gravity caused it to begin to fall. Then the wrench given to the different parts of the chimney falling at different speeds overcame the cohesion between the bricks and mortar, and it broke up.

When a tall factory chimney that is no longer wanted is felled, it begins to fall as one structure till the wrench and the varying speeds at which the different parts of the chimney fall overcome the cohesion between the bricks and mortar and the chimney begins to break up into fragments, as can be seen in the picture on this page.

It has been said that heat weakens cohesion. That is why a red-hot poker can be bent so easily, and a piece of wire which when cold supports a certain weight, will break under the same weight if the wire be heated.

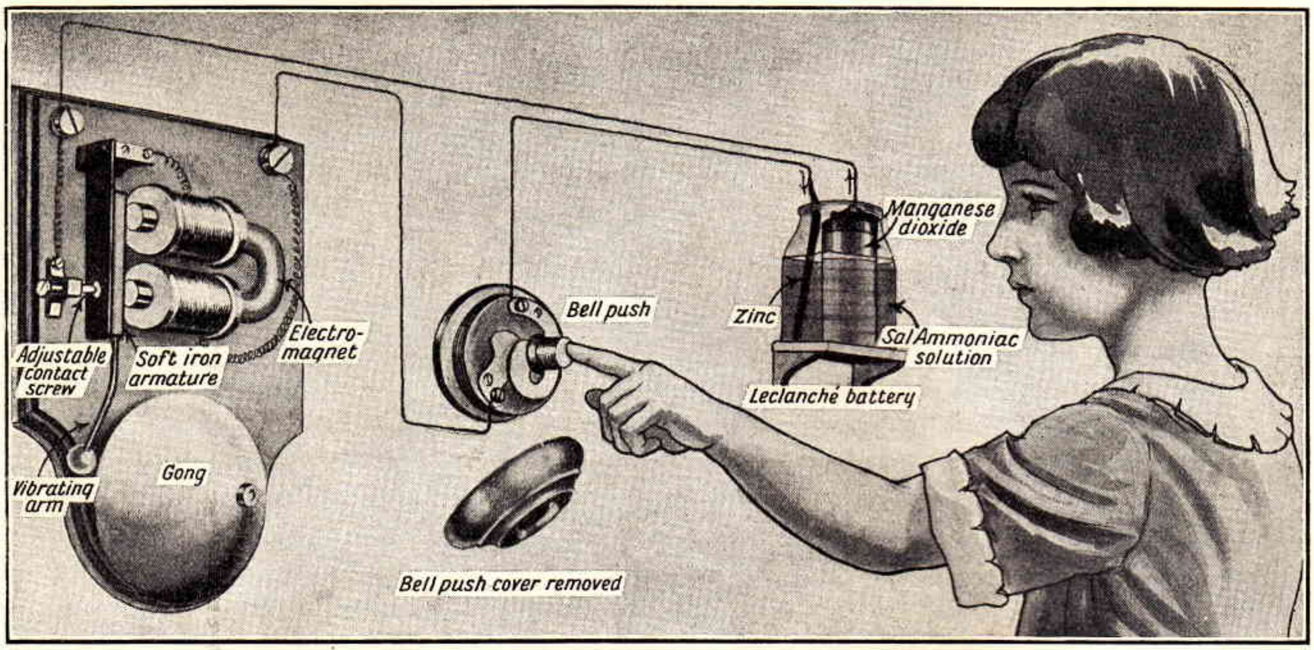
EXAMPLES OF THE FORCE OF COHESION

The force of cohesion, which holds things together, is the force which enables us to build houses and churches and chimneys by piling brick on brick. The power of cohesion between different materials varies a great deal. There is very little cohesion between the bricks themselves, but by using mortar we are able to build a wall that will stand for a hundred years or more. Indeed, some buildings put up by the Romans and others have stood for thousands of years.



Here is still a more striking example of cohesion. A rope is made up of short lengths of fibre twisted together, and it is the cohesion that makes the rope so strong that when a number of muscular men are pulling on the rope in opposite directions, as in a tug-of-war, the rope holds together without parting. Of course, if more and more force were used this might at last overcome the power of cohesion and the rope break. This sometimes happens with a ship's cable when wind and waves put an extra strain upon the rope. Friction between the various strands of the rope also has something to do with holding it together.

HOW AN ELECTRIC BELL IS MADE TO RING



The bell-push has a button fitted to a spring which, except when pressed, stands away from the other metal of the push. Wires connect up the battery with an electro-magnet and with the bell-push. As long as the push is untouched the electric circuit is broken, but as soon as the button is pressed the electric circuit is completed. A current now flows from the carbon or positive pole of the battery to a contact screw, passes up a steel spring to which a soft iron armature is attached, goes round the coils of the magnet, back to the bell-push, through the spring and the wire attached to it, and thence to the zinc or negative pole of the battery. The current going round the coils of the iron horseshoe turns that into a magnet, the armature is attracted and pulls the spring, vibrating a hammer and causing it to strike a gong. As soon as the armature and spring are drawn to the magnet away from the contact screw, the electric circuit is broken, whereupon the horseshoe ceases to be a magnet and the spring returns to the contact screw. At once the current is re-established, and the same thing happens again and again so long as the button is pushed.

WHY A WHIP CRACKS WHEN IT IS SLASHED

When a whip with a long lash is slashed right and left with a swing, we hear a loud crack. What causes this? Well, as the thong of the whip moves through the air at a rapid rate it compresses the air before it and then the compressed air, as soon as the lash has gone, expands back and resumes its normal pressure as suddenly as it was compressed.

Making an explosion with a whip-lash.

It is when the air is expanding to return to its place that it sets up a movement in the molecules of the atmopshere, causing them to strike upon our eardrums, and the auditory nerve then carries the message to the brain.

The crack of the whip is really a miniature explosion, the compressed air expanding suddenly making the same kind of sound as an explosion of, say, gunpowder.

A cracking sound is generally, if not always, the result of a small explosion. We get a familiar example of this in the crackling of a wood fire when it is lighted.

We know how, as soon as the paper has set light to the wood, there is a regular series of cracks. These are actually little explosions taking place in the wood.

The cavities are filled with air or liquid, and the heat causes this to expand suddenly with the result that there is an explosion setting up waves in the air which reach our ear-drums in the same way as in the case of the cracking of a whip-lash.

The sharp crack of thunder which is heard, when we are very near the lightning, is also caused in the same way. As the lightning, which is an electric spark on an enormously large scale, passes through the air its heat causes a sudden expansion of the air in its track, and this is succeeded almost immediately by a sudden compression of the air round the path of the lightning, with the result that there is a rapid inrush of air particles to fill the vacuum thus caused. In other words, there has been a kind of explosion giving the cracking sound which we know as a thunder clap.

STORED UP ENERGY CHANGED INTO MOTION

We can perform an interesting experiment by hanging an Indian club and a small weight from a beam. The strings must be of such a length that the two objects will swing in unison. Set both swinging, then stop the Indian club.

Now with a pencil give the club gentle taps near its centre of gravity, timing them by the swing of the small weight. There should be one tap for each double swing of the weight. Gradually the stored up energy received from the light pencil taps will set the club swinging once more.

How to tap the swinging club.

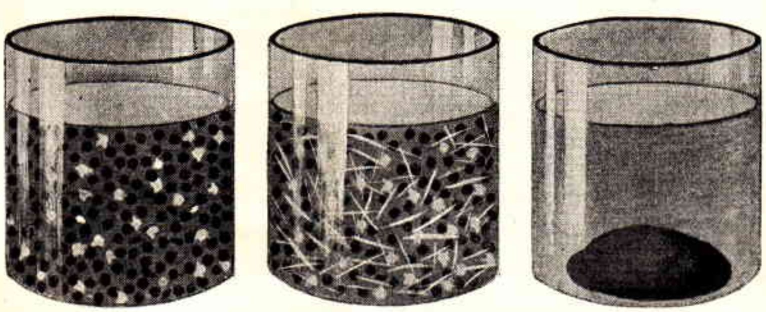
THE STREAM OF LIFE IN YOUR BODY

Except when we cut a finger or our nose bleeds, we rarely give a thought to the blood that courses through our bodies. Yet it is the most important substance in the world, and if we lose it, or it should stop travelling through our arteries and veins, we should die. It is indeed our very life-stream and in these pages we learn much about its nature and its importance to us

MEN of science have studied the blood for centuries, and have found out a great deal about it, but even now they have much to learn and there are many things about our blood which cannot be explained.

The blood does a vast amount of work in our bodies. It carries to the various tissues food-stuffs that have been properly prepared by our digestive organs; it also carries to the tissues oxygen gas which has been absorbed from the air in the lungs; and it carries off from the tissues various waste products which must be got rid of. It also helps to equalise the temperature and the water contents of different parts of the body. All this shows how important the blood must be to our life and health.

What is this wonderful fluid upon which we are so dependent? Well, when it is examined it is found to consist of various parts. There is, for instance, a liquid part called by men of science plasma, and this is nearly colourless, although as we know when we prick our finger the blood is red, sometimes bright red, and sometimes much darker. It is bright red if it is fairly pure and comes from an artery, and it is dark if it is impure and comes from a vein



These three pictures show in diagram form what happens to our blood if it is taken from our body. The fresh blood has just been placed in the first glass, and the red and white corpuscles are floating in the fluid. Almost directly, however, chemical changes take place, and small fibres form as in the second glass. After about ten minutes these, with the corpuscles, form a solid mass known as a clot, and the fluid part becomes a thin, watery liquid called serum

Tiny Discs

But what gives the blood its red colour if the liquid part of it is nearly colourless? Well, in the plasma there float a great number of tiny discs known as red corpuscles. They are not really red, but a kind of deep yellow. When, however, numbers of them are seen together they give the impression of redness. They are very small indeed. A red corpuscle is only one 3,200th of an inch in diameter, and in thickness about one-third of this. That is, if laid side by side it would take 3,200 red corpuscles to measure an inch, and if packed together like pennies piled up it would take nearly 10,000 to make an inch. If we laid red corpuscles side by side it would take about 10,000,000 of them to cover one square inch.

About half the weight of the total amount of blood in our bodies consists of red corpuscles, so knowing how small they are we can quite understand that there must be an enormous number. Indeed, in every cubic inch of blood in our bodies there are about 82,000 million red corpuscles, and in the whole of the body of a full-grown man weighing eleven stones, the number is about 25 million million. What a marvellous thought it is that we have in a thimbleful of our blood more than thirty times as many corpuscles as there are people in the world.

An Amazing Fact

Now it is these little bodies which absorb the oxygen from the air as they pass through our lungs, and as we need a great amount of oxygen it is a very good thing there are so many tiny red corpuscles, for the total number present a very large surface to the oxygen. The total area of all the red corpuscles in a man's body is nearly 35,000 square feet, or 1500 times the whole of the outside surface of his body. What an amazing fact this is.

If we go up a mountain our blood soon has an increasing number of red corpuscles, and at a height of 13,000 feet we should have nearly half as many again as when we are at sea level. This is a wonderful provision of nature in order that our bodies may receive sufficient oxygen.

As we know, at the top of a high mountain the air is much rarer than it is at sea-level, which means that it contains much less oxygen. Our blood, therefore, at such a height develops more and more red corpuscles, so that their area or surface may be greatly increased and thereby be enabled to take up as much as possible of the oxygen that gets into our lungs.

But the red corpuscles are not the only bodies which are found in the plasma or liquid of the blood. There are some other corpuscles which are white in colour and are, in consequence, known as white corpuscles.

They are larger than the red corpuscles, being one 2,500th of an inch in diameter. They also differ from the others in being not round like discs, but irregular in form. They are all sorts of shapes and, something like that little creature known as the amoeba, are constantly changing in shape. Men of science are not quite sure whether there are different kinds of white corpuscles or whether their apparent differences are due only to these constant changes in form.

Another way in which white corpuscles differ from the red is that there are far fewer of them in the blood; in fact, on an average there is only one white corpuscle to every 500 red. They are like the red corpuscles, however, in that the number varies at different times. It increases during digestion, and so, while at one time there may be one to every 300 red corpuscles, the proportion may be only one to every 600 at another time.

Disease Fighters

What is the work of these white corpuscles? Well, doctors are still studying them and they do not yet know everything the white corpuscles do to help our bodies, but they know that they are of enormous service in fighting disease.

If we get a wound and inflammation sets in, white corpuscles rush to the spot and begin devouring or absorbing the injured tissue, which is causing the harm, or the little bacteria that cause the trouble. In other words, they help us to resist infection. They are like a great and efficient army of defence in a country; directly an enemy invades the country the army of defence rushes to the spot to repel the invader.

So it is with the white corpuscles of our blood. They lose no time in assembling at the danger spot and generally they win the battle, though sometimes the invading army of bacteria is too strong for them.

They fight the enemy by eating him up. They also clear away dead tissue, whether it be due to injury or to any other cause, and in the case of the tadpole, when its tail becomes no longer necessary, it is by means of the white corpuscles in the blood that the tail is absorbed as the tadpole changes into a frog. By a wonderful provision of nature in certain acute diseases the number of white blood corpuscles is greatly increased. It is indeed like the mobilisation of a fighting army from the civilian population of a country when invasion threatens.

In addition to the red and white corpuscles there is a third class of bodies in the blood known as blood plates or platelets. They are so small—much smaller than the red corpuscles—that it is only in recent years that they have been discovered at all, and their minute size makes examination exceedingly difficult. Indeed, some scientists deny the existence of these plates altogether.

Hidden Wonders

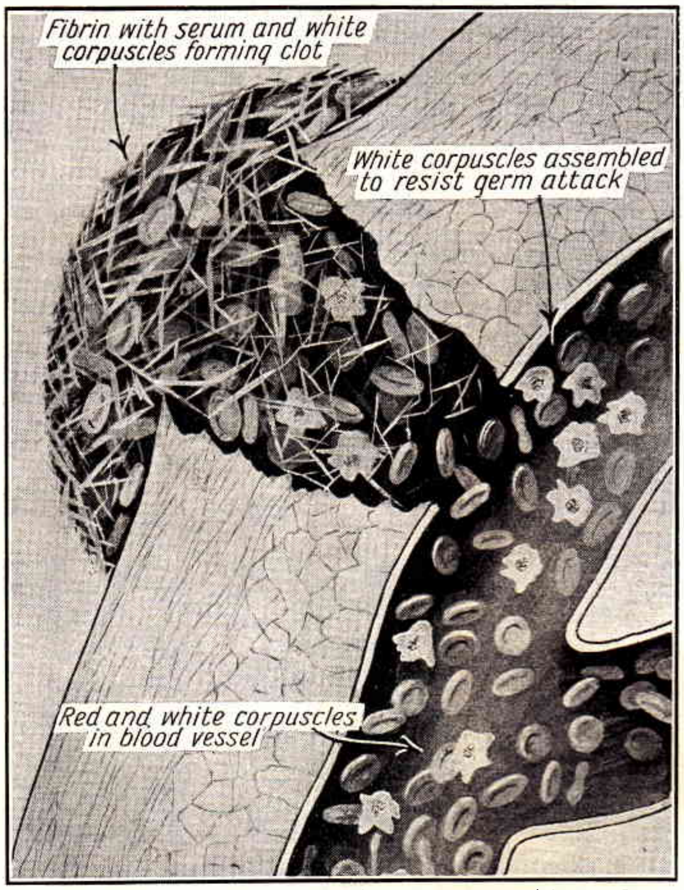
Their number has been variously estimated at from 3,000 million to over 13,000 million in every cubic inch of blood. Their shape is said to vary a good deal, some being doubly convex on both sides like a lens, and others flat like a gramophone record. They are believed to have something to do with forming clots of blood, as they always gather round any injured spot in the wall of a blood vessel and fuse together so as to form a clot over the injured place, thereby preventing the escape of blood from the blood vessels. They are believed to exist only in the blood of mammals.

To return to the red corpuscles, these are being constantly formed in the blood, and it is, therefore, assumed that they are also being constantly destroyed. They are soft, flexible, elastic bodies, so that they can readily squeeze their way through openings and canals narrower than themselves without undergoing any permanent change of shape.

When we lose blood, and we must remember that one-thirteenth of the weight of our body consists of blood, though the proportion in a new-born baby is only one-nineteenth, nature at once begins to make up for the loss. First of all the fluid parts of the blood are made up so that the total volume is restored to its normal, but then, of course, there is a shortage of red corpuscles. Gradually, however, their number is increased, until in a few weeks the blood is normal once more.

New red corpuscles are said to be formed in the marrow of our bones, where the blood capillaries and veins have very thin walls. It is there that the newly formed corpuscles are able to pass through the walls into the blood stream.

Each red corpuscle consists of a framework of protein, containing in its meshes a red colouring matter known as haemoglobin, and it is to this that the red colour of the blood is due.



This picture shows what happens when we cut or prick our finger. The blood would continue to pour out, but directly it reaches the air chemical changes take place, and fibres are formed which are known collectively as fibrin. These bind together the corpuscles and the fluid, which all hardens into a clot that stops up the opening and prevents further blood from escaping.

Haemoglobin has the power of uniting with considerable quantities of oxygen gas, and it thus gives the red corpuscles their useful power of acting as the carriers of oxygen from the lungs to the tissues in all parts of the body.

The haemoglobin or colouring matter of the red corpuscles forms crystals, and these vary in shape according to the animal from which the blood is taken. In man they have the shape of prisms. Haemoglobin from human blood crystallises less easily than that from the blood of other animals.

There is one property of blood which is of the very greatest value to us, and that is its power of clotting or becoming solid and jelly-like. We know how when we cut or prick our finger the wound bleeds for a short time, but soon the blood becomes solid round the cut, filling up the gap, and then the bleeding stops.

Let us see why the blood clots. It is certainly one of the most marvellous provisions of nature for saving us from bleeding to death. The plasma or liquid part of the blood in which the corpuscles move contains in solution various protein substances. One of these is known as fibrinogen. When the blood escapes from a blood vessel this fibrinogen undergoes certain chemical changes, and produces little threads or fibres which are called by men of science, fibrin. It is these which cause the clotting of the blood. In fact, the clots consist of these fibres massed together.

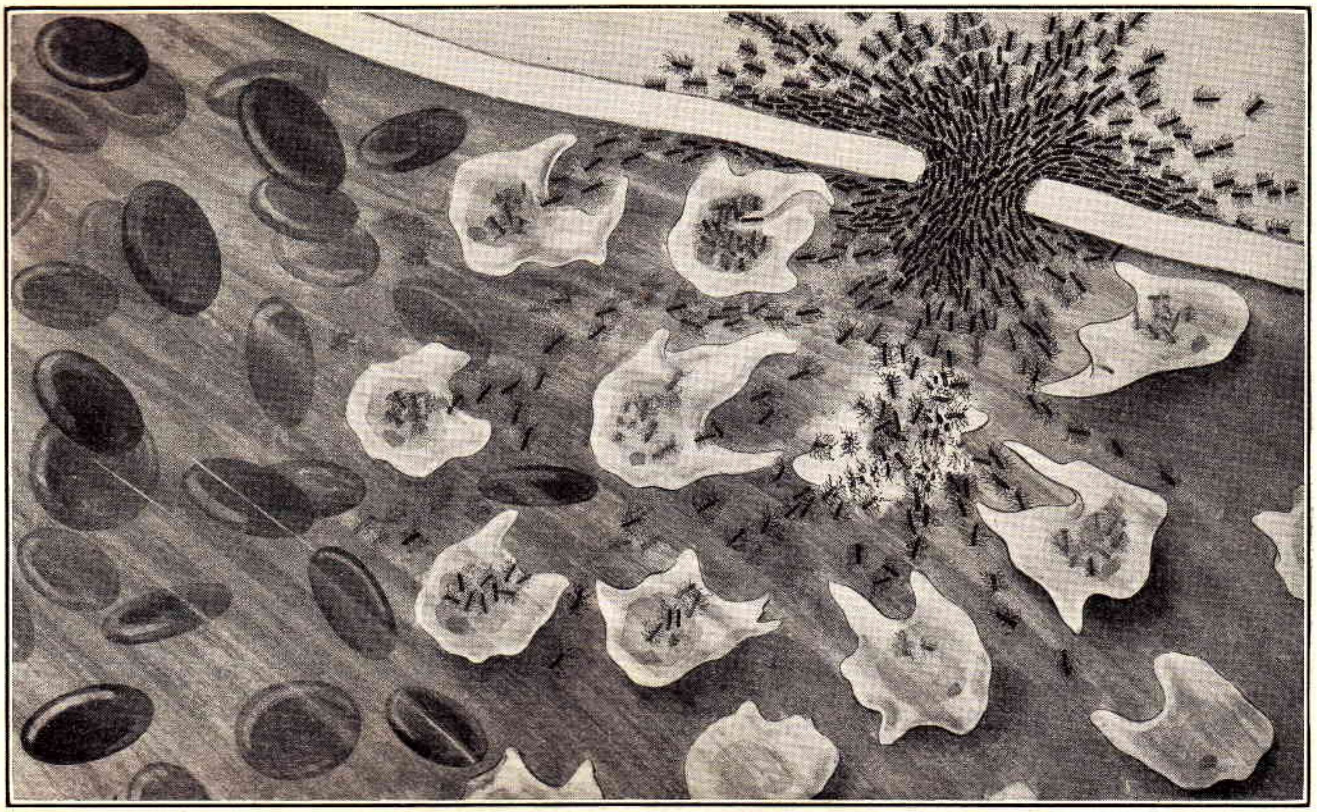
Of course, the wonderful thing is that the blood does not clot in the arteries and veins; if it did the stream would cease to flow, and we should die. But directly there is a wound in a blood vessel and the blood begins to pour out, the chemical changes take place, fibrin is produced, and the wound is stopped up so that no more blood can get away.

The Bundle of Fibres

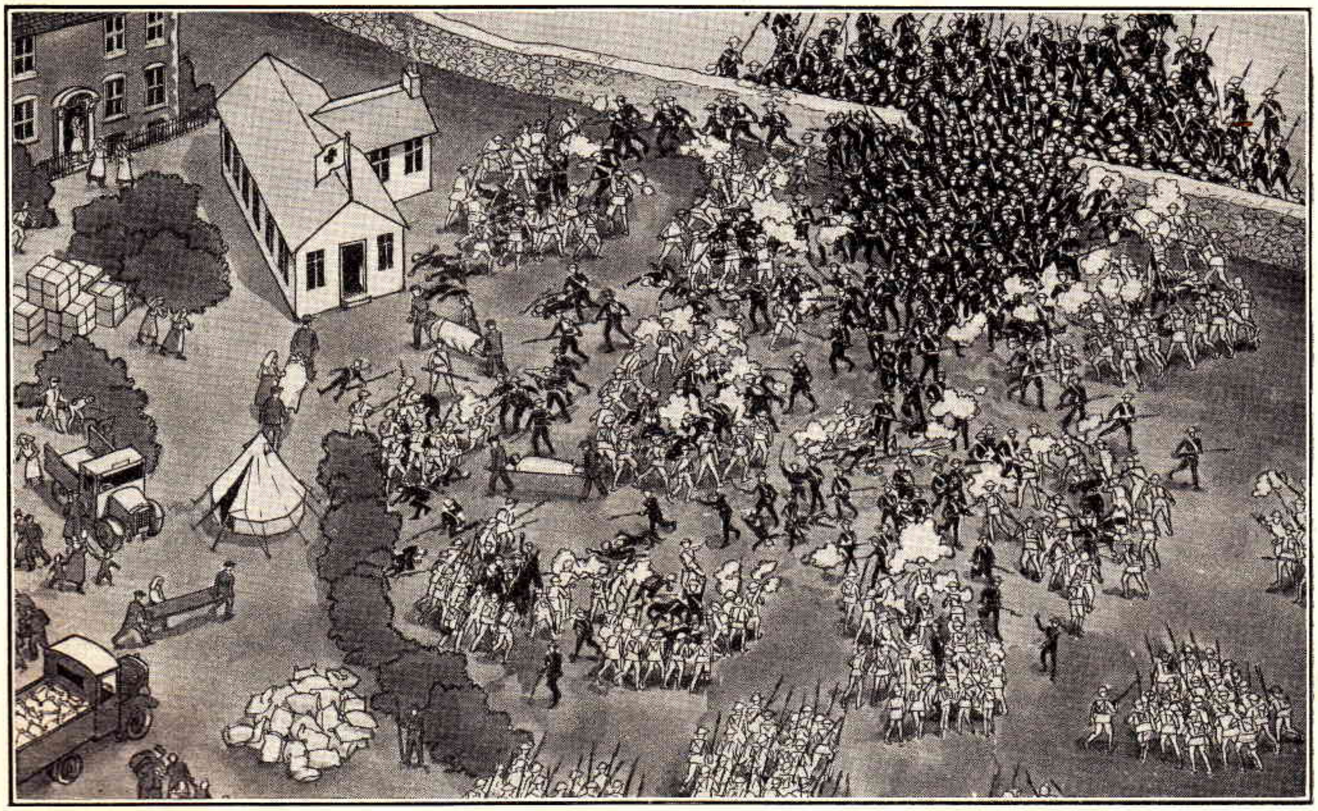
When the fibres are formed a yellowish, watery-looking fluid is left and appears on the surface of the clot. This is called serum. The clot of fibres has the corpuscles of the blood mixed with it. It is interesting to know that if blood freshly taken from the body is "whipped" in a vessel with twigs, just as we whip cream, the fibrin collects on the twigs, and a red fluid is left in the vessel consisting of serum with red and white corpuscles. The corpuscles in that case, do not get mixed up with the fibrin as they do in a clot. When the fibrin is washed in water it is found to consist of a white, stringy, elastic substance. Heat hastens clotting, and cold retards it.

Of the pumping of the blood through the body and the wonderful machinery that does this work we read in another part of this book, but next time we prick our finger and see the red blood, let us remember what a very marvellous substance it is and how our life and health and happiness all depend absolutely upon it.

A GREAT BATTLE IN THE BLOOD

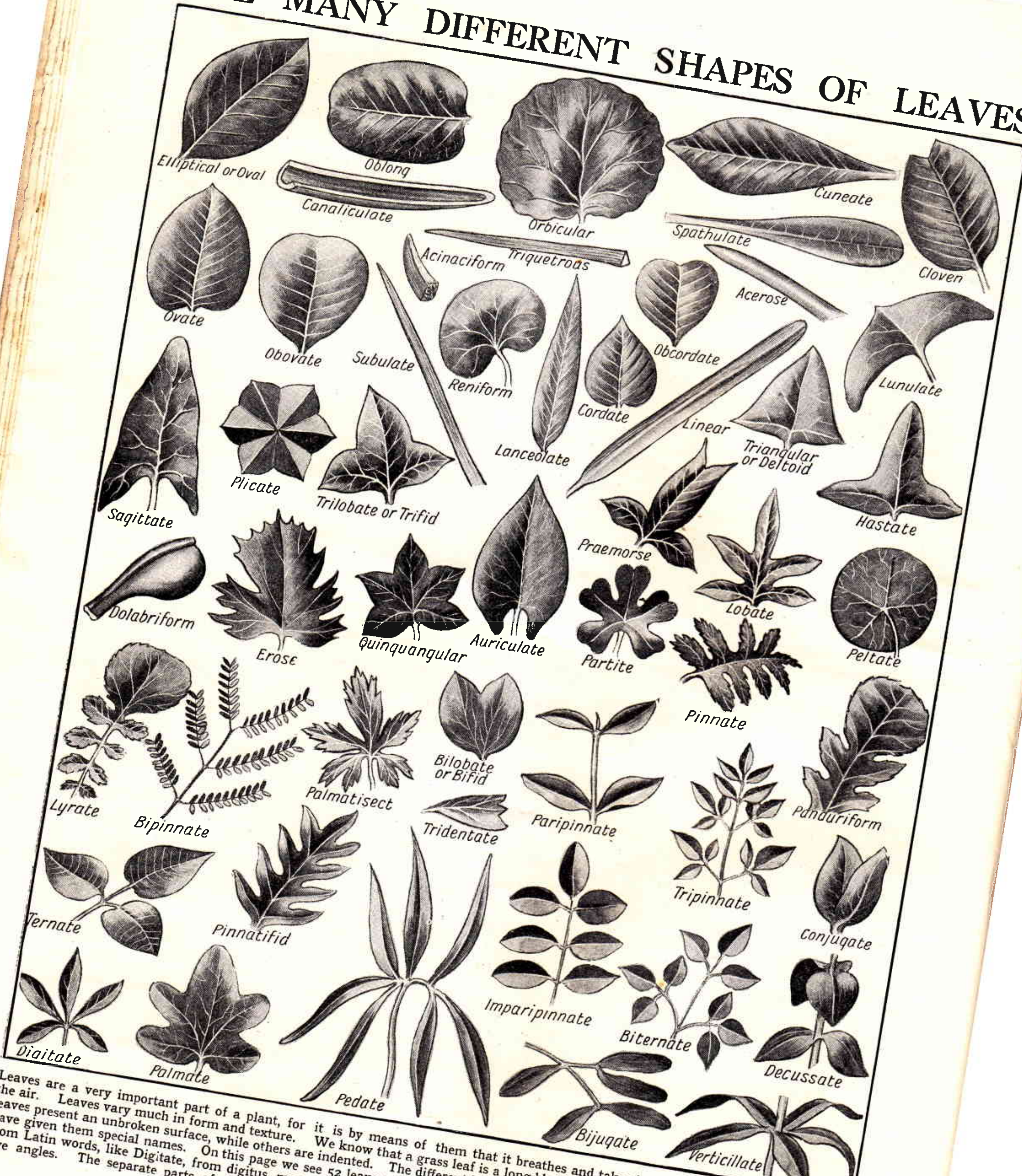


Sometimes when we have a wound, dangerous germs from outside try to enter our blood, and if they succeed we get ill. But if we are healthy we resist the germs. This picture shows the kind of thing that goes on when the germs try to enter. A great battle takes place. Little bodies in the blood, known as white corpuscles, rush to the opening to resist the germs. Generally they absorb and destroy them, but sometimes the germs get the upper hand, defeat the white corpuscles, and destroy them. Then they run riot in the blood.



The attack of the disease germs on our body is very much like the attack of troops on a city or fort. They try to rush the place as they are doing in this picture, but the defenders hurry up to keep them out, and sometimes one force may win and sometimes the other.

THE MANY DIFFERENT SHAPES OF LEAVES



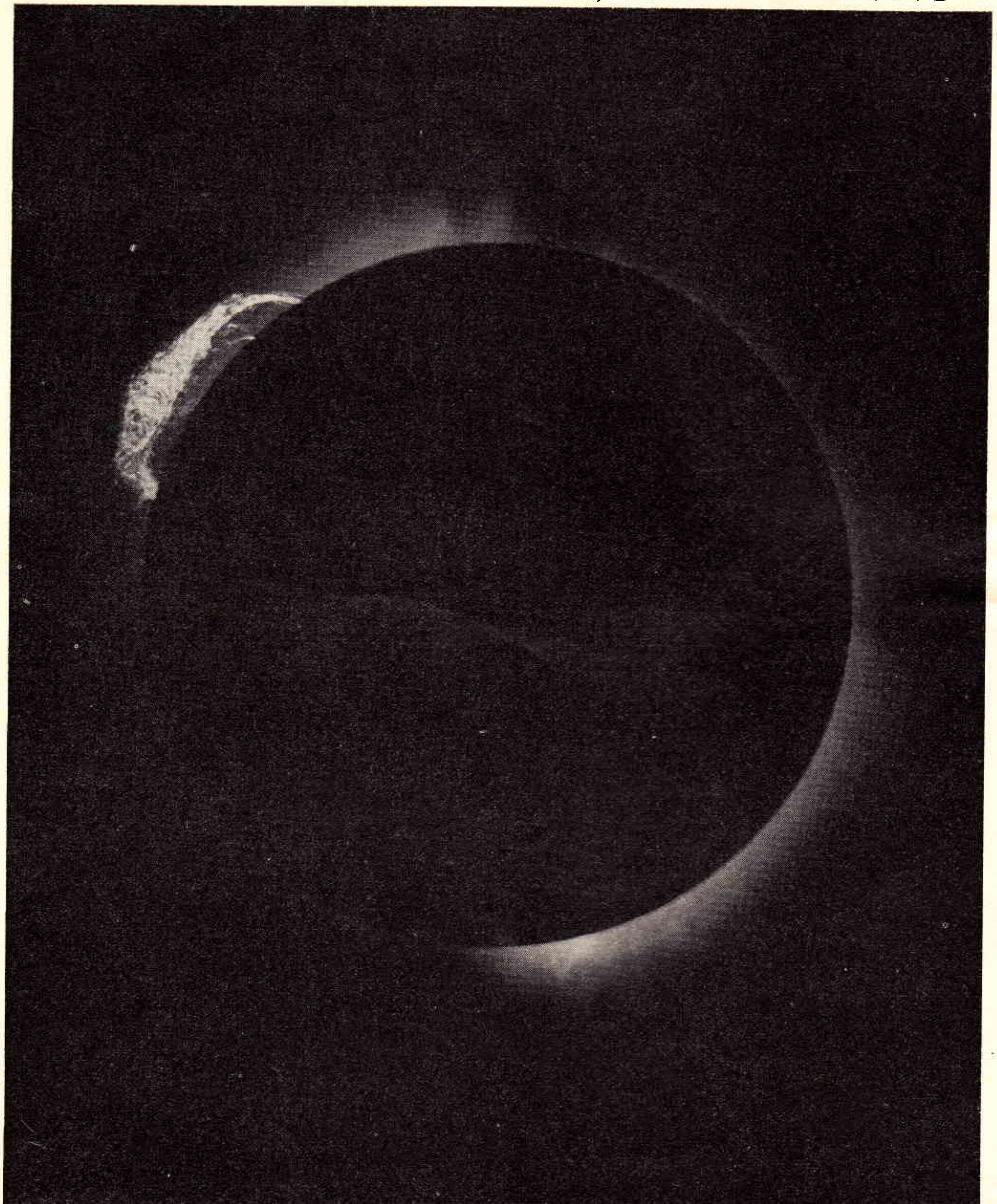
Leaves are a very important part of a plant, for it is by means of them that it breathes and takes in carbon dioxide and oxygen from the air. Leaves vary much in form and texture. We know that a grass leaf is a long blade and a nasturtium leaf almost round. Some leaves present an unbroken surface, while others are indented. The different kinds of leaves are grouped according to shape, and botanists have given them special names. On this page we see 52 leaves, with the correct names given to their particular forms. Some names are from Latin words, like Digitate, from digitus, meaning a finger. Others have formidable names like Quinquangular, which means having five angles. The separate parts of divided leaves, though looking like individual leaves, are only leaflets or parts of the one leaf

THE ZEBRA OF THE AFRICAN PLAINS

The zebra, of which there are several species, varying in their striping, is a South African animal, and though one species, known as the quagga, became extinct in 1875, other zebras are still quite plentiful. These animals, close relations of the horse and the ass, are dwellers in the open plains, and they are often found in large numbers associating at water holes with the gnu, as seen here

The zebra is a very striking animal, and men of science are not quite sure why nature has given it stripes, for, unlike the tiger, it does not live among the tall grasses where its stripes would look like shadows in the sun, and so conceal its presence. A few zebras have been broken to harness, but the animal has never been bred for domestic uses. Perhaps it might become as useful as the horse

AN AMAZING FLAME 350,000 MILES LONG



Here is one of the most wonderful photographs ever taken. It shows the Sun during a total eclipse, but the marvellous feature of it is the white object, something like an ant-eater in shape, at the top left-hand. Because of its shape astronomers call this the "Ant-eater Prominence." It is really an inconceivably enormous crimson flame shot up from the Sun's surface at a speed of thousands of miles a minute. The flame when first seen, as in this photograph, was 350,000 miles from end to end—an "ant-eater" which, as Sir James Jeans has said, could gulp down the whole Earth like a pill. The moment after this photograph was taken the flame made a great leap to a height of 475,000 miles. It is an amazing thought that astronomers watching gigantic flames of this kind sometimes see them travel at the rate of 8,000 miles a minute. The photograph is published by courtesy of the Royal Astronomical Society

WONDERS OF THE SKY

THE GLOWING BALL OF FIRE IN THE SKY

It is hardly surprising that in past ages, when knowledge was dim, men worshipped the Sun, believing it to be a god. They realised that they received light and warmth from its genial rays, and knew that in some way they depended for their lives and health upon its continued shining. In these days we know that the Sun is not a god, although we are dependent upon it for our existence. Let us see what the Sun really is.

HERE we read many surprising facts about the Sun. The Sun is a ball of fire, but not fire as we understand it, for there is no burning going on, that is, no chemical combination between oxygen and other elements. Everything in the Sun is too hot to burn in our familiar sense of the word. Men of science tell us that the temperature of the Sun at its surface is about 7,000 degrees Centigrade, or 12,000 degrees Fahrenheit. The highest temperature we can obtain artificially on the Earth is that of the electric arc, about 4,000 degrees Centigrade.

But this great temperature is only that of the Sun's surface. Deep down the temperature rises enormously, and Sir Arthur Eddington, the famous Cambridge scientist, believes that at the centre it is as high as 55 million degrees Centigrade.

Inconceivable Heat

Of course it is impossible for us to conceive any such heat, but Sir James Jeans tries to help us by explaining that to maintain a pinhead of matter at such a temperature would need all the energy generated by an engine of 3,000 million million horse-power, and then the pinhead would emit enough heat to kill anyone within a thousand miles of it.

With so much heat the state of matter in the Sun is very different from what it is on our Earth. It is all in a gaseous condition, although the enormous pressure towards the centre must cause it to be very dense. The heat is so terrific that chemical compounds cannot exist, and even the atoms of the elements are in many cases broken up.

The Sun does not keep its heat to itself, but pours it out in all directions. But of this heat the Earth receives only about one 2,200 millionth. Altogether in the solar system it is reckoned that about one hundred millionth of the heat radiated by the Sun is caught by the planets.

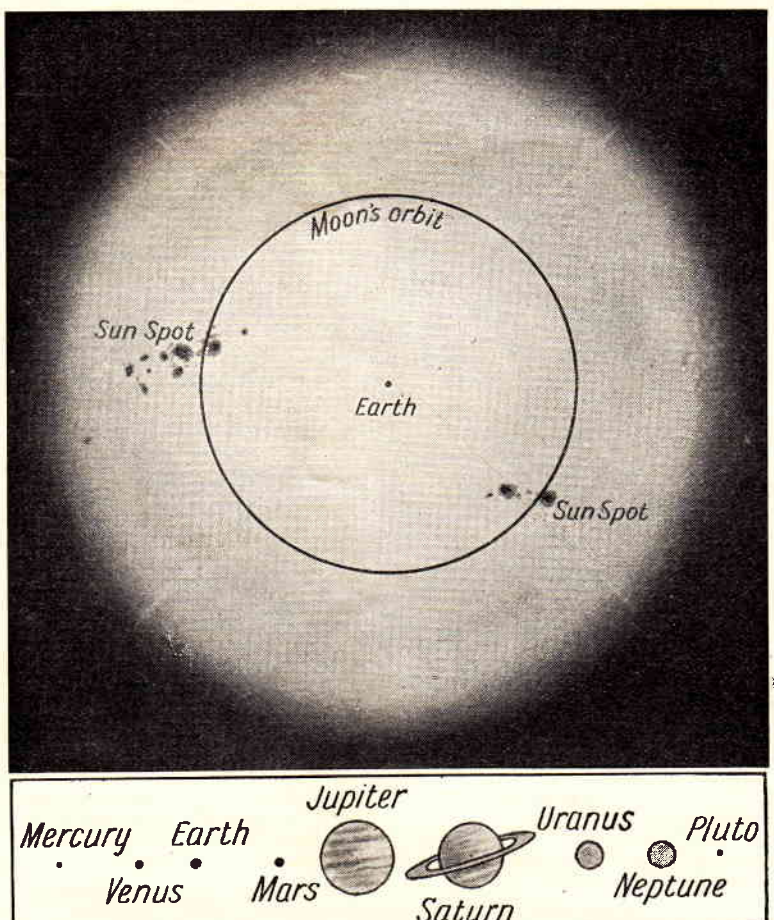
Let us see if we can get some idea of the enormous power of the Sun's heat. Supposing that the Sun's surface were frozen over to a depth of 45 feet, the heat it gives out would melt this frozen shell in one minute. If a bridge of ice whose section was just over two miles square could be formed reaching from the Earth to the Sun, and if all the Sun's radiated heat could be concentrated upon this, it would melt into water in a single second and in seven seconds would disappear as vapour.

The reason we are not burnt up by the Sun's terrific heat is that we are so far away, about 92,900,000 miles. The exact distance cannot be measured within about 100,000 miles. A train, running at 60 miles an hour without any stop, would take 175 years to reach the Sun, and the fare, at $1\frac{1}{2}$d. a mile, would be nearly £600,000. A cyclist travelling at the rate of 100 miles a day without a stop would take about 2,550 years to reach the Sun, so that if he had started in the first year of the Christian Era he would still have travelled only about three-quarters of the distance. The light from the Sun reaches us in 499 seconds.

A Giant Indeed

Compared with the Earth the Sun is indeed a giant. Its diameter is 865,000 miles, or nearly 110 times that of the Earth, and if the Earth were placed in the centre of the Sun the Moon would circle round in its orbit far inside the Sun's surface.

As to size, 1,300,000 Earths could be packed inside the Sun, and yet the Sun is only 333,000 times the weight or mass of the Earth. This is because, being so hot, its average density is much less than the Earth's. The Earth is about $5\frac{1}{2}$ times the weight of a ball of water of the same size, but the Sun is less than $1\frac{1}{2}$ times the weight of a sphere of water its size. That is, the Sun's density is less than $1\frac{1}{2}$ times that of water; the Earth's is $5\frac{1}{2}$ times.



A photograph of the Sun showing two series of sunspots. Each dark spot is a hurricane of fire big enough to swallow up the Earth several times over. The Moon's orbit, which is nearly half a million miles across, has been drawn on the Sun to the same scale. It will be noticed that the Sun's surface is less bright at the edges. This is because we see the edges through a greater depth of the Sun's fiery atmosphere, which, as a consequence, cuts off some of his brilliance. Below are the planets drawn to the same scale as the Sun's photograph. They could all be packed into the Sun many times over

But although its matter is less dense than the Earth's, its great size makes the Sun's gravitation very powerful. If a man could be suddenly transported to the Sun's surface and live, he would weigh about two tons, and his feet would be so heavy that he would be quite unable to lift them and walk.

A hundred years ago it would have seemed impossible that we could ever actually know what the Sun was made of. But a marvellous instrument called the spectroscope, of which we read in other parts of this book, has revealed to us that the Sun is made of the same materials as our Earth.

Elements found in Sun and Earth

About forty of the elements found on the Earth have been discovered in the Sun, nearly all of which are metals, including silver, iron, zinc, lead, tin, aluminium and calcium. The gas helium, which is so useful for filling airships because it is not inflammable like hydrogen, and is yet very light, was discovered in the Sun before it was found on the Earth.

The Sun turns round on its axis in rather more than 25 days, but, curiously enough, all its surface does not travel round at the same rate. The equator rotates in less time than the parts on either side of it. This is because the Sun is not a solid but a gaseous body. We know the Sun rotates, because we can see large dark spots on its surface travel right across, disappear, and then later on reappear on the other side. We read about the marvel of these spots in another part of this book.

Men of science, in describing the Sun as seen through a telescope, speak of its photosphere, which means "light sphere," its chromosphere, which means "colour sphere," and its corona, or crown.

The photosphere is the visible surface of the Sun, and when photographed by means of the light of certain elements, such as calcium, the surface appears mottled or granulated, as though made up of small luminous masses with darker openings between. Because of their appearance, they are often called the "rice grains."

Their nature is something of a puzzle to scientists, but it is generally believed that the photosphere is a sheet of clouds floating in a less luminous atmosphere, just as clouds of water vapour float in the Earth's atmosphere. Professor Young says the photosphere is intensely brilliant for the same reason that the mantle of a gas burner outshines the flame which heats it.

Part of the Sun's disc with the Earth and Moon all drawn to the same scale

The chromosphere is an outer layer of gas like an atmosphere, surrounding the Sun, and is 5,000 miles or more in depth. We can only see the chromosphere during a total eclipse of the Sun, or through a delicate spectroscope. This chromosphere is made up chiefly of the gases hydrogen, helium and calcium.

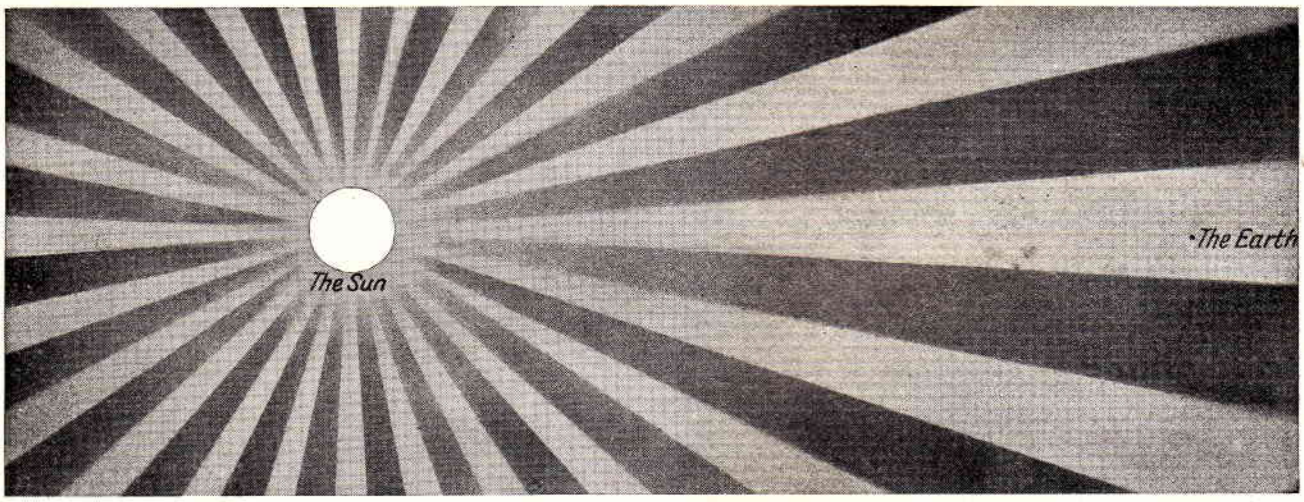
The corona is a beautiful halo of pearly-white colour which surrounds the Sun and is visible only during a total eclipse. It is not evenly distributed like an atmosphere, but has streamers reaching out at various parts to a distance of several million miles.

The spectroscope tells us that the corona is due partly to the presence of incandescent gases and partly to reflected sunlight. There is believed to be some kind of dust or fog mixed with the gas, which is possibly of meteoric origin. Very little, however, is known about the corona, for it can only be studied during a total eclipse, and such eclipses occur so rarely that the corona has been examined only for a few hours in the whole history of astronomy.

The Power of Sunlight

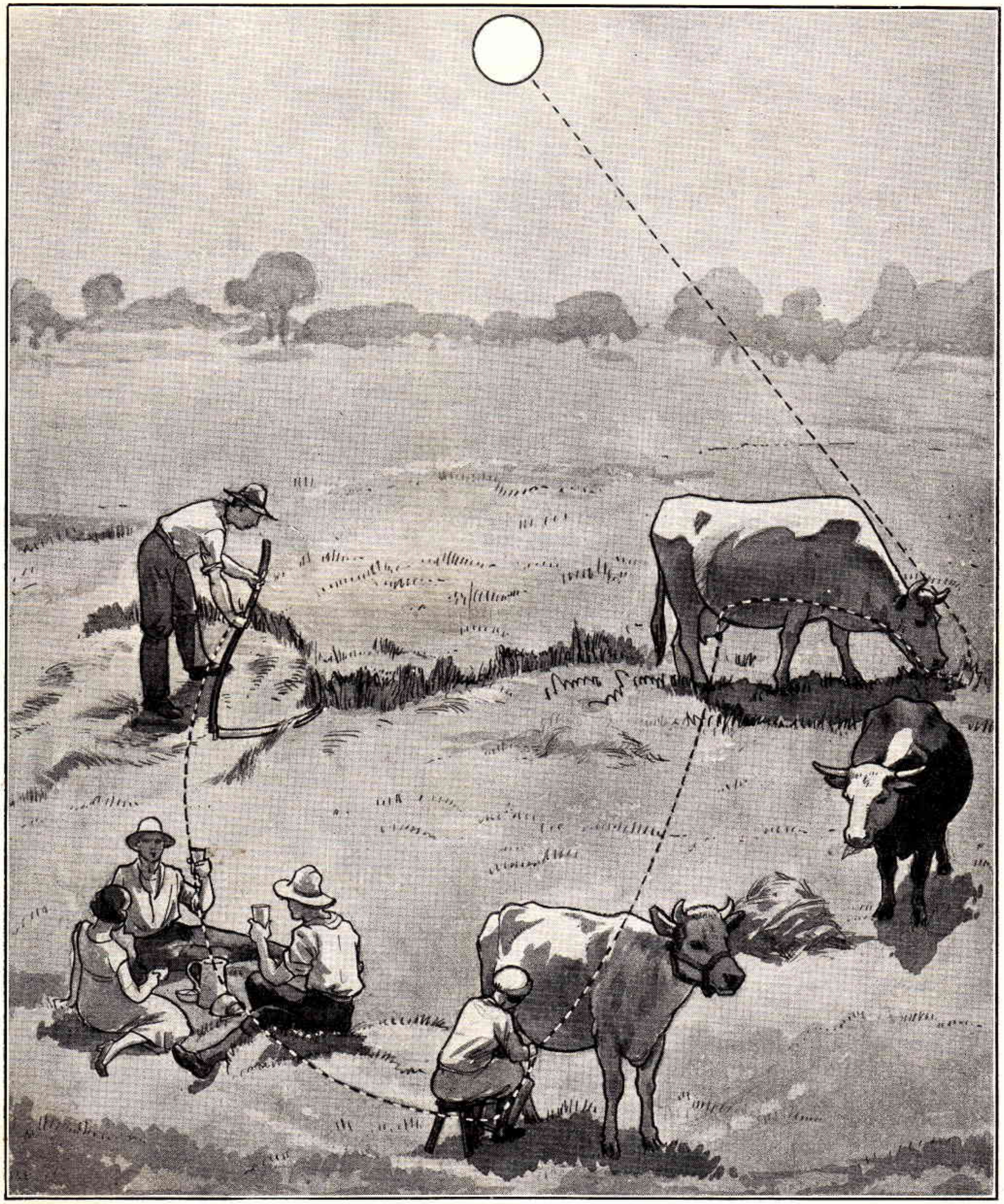
As to the light received by us from the Sun, it is about 600,000 times that received from the Moon and 7,000 million times that of Sirius, the brightest of the stars. A good deal of the Sun's light is absorbed by our atmosphere, but its light is said by scientists to be 60,000 times as bright as a standard candle placed at a distance of one yard. The brightest light on earth is the electric arc light, but this is only about one-third as bright as the Sun.

If all this radiant energy received by the Earth from the Sun were to be transformed into mechanical energy, it would amount to three horsepower for every square yard exposed perpendicularly to the Sun's rays. But only a very small part of it can be used directly for doing work. Indirectly, of course, all the work we and the animals and the plants do is due to the Sun. The coal we use to drive our ships and trains and work the machinery in our factories is only the stored-up energy of the Sun being used millions of years after it was received by the Earth. The amount of energy received from the Sun varies a good deal with weather conditions, as our atmosphere absorbs much of it.



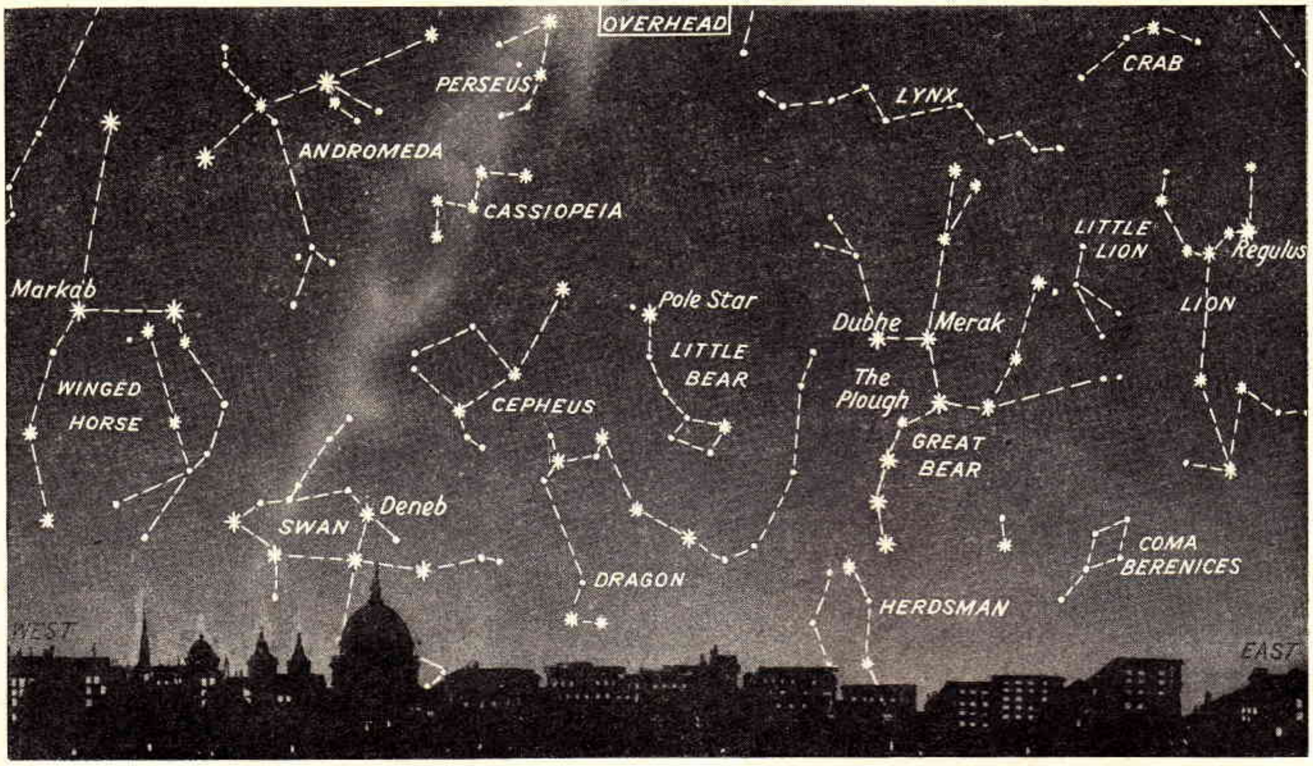
The Sun pours out vast quantities of heat in all directions, but only about one 2200 millionth of this reaches the Earth. Yet it is sufficient to bring life and health to man, animals and plants, and is directly or indirectly responsible for all the work done in the world. When we use coal in our fires and furnaces we are only using solar energy received millions of years ago

A RAY OF SUNSHINE AND ITS GOOD WORK

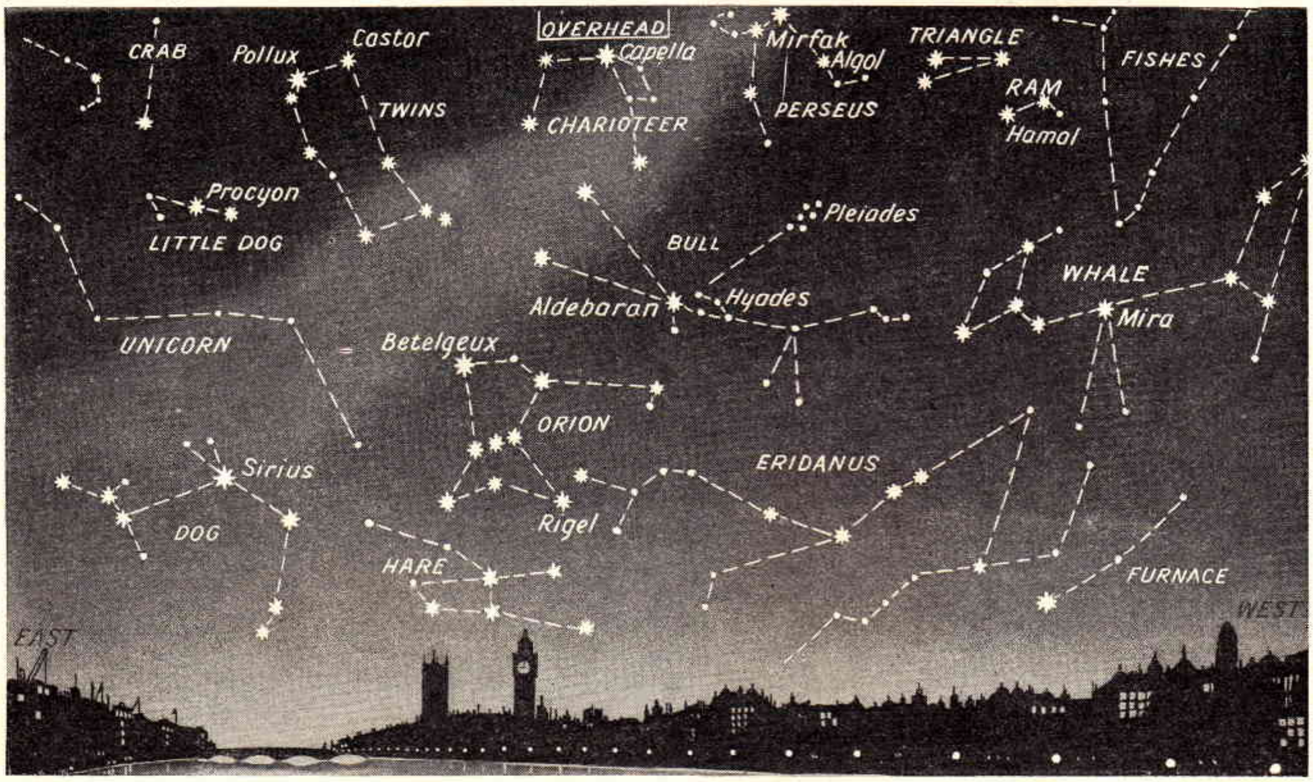


All living things are dependent upon the Sun, and this picture shows the work which a ray of sunshine does for plants and man and beast. The sunlight shines upon the soil in which the seeds are planted, and its radiant energy sets up chemical action so that the seeds sprout and the plants grow. The Sun continues to shine, and the chemical action which it causes produces the various substances that form the plant and build it up. Then the cow eats the grass, which has been produced by the ray of sunlight, and in the animal's body it is transformed into milk, which is drawn from the cow by the milkmaid, and supplies human beings with food. The milk helps to build up their bodies. The ray of sunlight is thus still doing its good work, and the food which it produces gives strength to the muscles so that a man can work and gather in the corn and grass which will form food for man and beast.

HOW YOU MAY RECOGNISE THE GROUPS OF STARS



Everyone should be able to recognise the chief constellations or groups of stars in the sky. For thousands of years men have looked up at the stars and seen them twinkling, and even before history came to be written, shepherds and others linked together certain stars and fancied they represented animals such as the bear, the goat, the lion, and the crab. It is difficult to see any resemblance to these creatures in the groups of stars to-day, but we still refer to the constellations by their old names, and each of us should be able to recognise these as we look up into the sky. Here we see the chief stars, visible to the naked eye looking directly north at midnight in the middle of January. The sky will have the same aspect as this in the middle of February at 10 o'clock and in the middle of March at 8 o'clock.



Here we are looking directly south at midnight in the middle of January. Perhaps the easiest constellation to recognise is Orion, with the belt of three stars in a line. Having located this, we shall be able to recognise the other groups. In both these pictures the names of the constellations are given in capital letters, and the names of special stars in small letters. The Pleiades are a cluster of stars in the constellation of the Bull. This picture serves also for the middle of February at 10 o'clock and the middle of March at 8 o'clock.

ROMANCE of BRITISH HISTORY

A MINSTREL FINDS A CAPTIVE KING

There is no more romantic story in all history than that of King Richard the Lion-hearted and his friend Blondel the minstrel. It was Blondel who found the King's secret prison away in a distant land and then hastened to England to tell the news, so that Richard might be ransomed. It is a thrilling tale of the stirring days of long ago, and is retold in these pages.

THERE is no doubt that Richard the Lion-Hearted was a very brave man, and the greatest warrior of his time. The old story that he obtained the name of "Lion's Heart" because, while on a Crusade, he had torn the heart out of a living lion is only a legend, but all his life Richard, although generally suffering from ill-health, was absolutely fearless and never hesitated to rush into the fight against overwhelming odds.

He was a soldier from his childhood. "Fighting was the breath of his life," an old chronicler tells us. "He was furious to rush to arms." When there were no wars—and such times were rare in Richard's days—he would go hunting the bear. When he was on his way to the Holy Land to win back Jerusalem from the Moslem, he called at Sicily and, having quarrelled with Tancred, the King of that island, seized a castle and calling to his men for those "whose hearts were not in their shoes" attacked the town and took it, "quicker than a priest would chant Màtins."

It is interesting to know that during his voyage to Palestine, Richard sank a Saracen vessel loaded with munitions by using what the old chronicler describes as "bottles of Greek fire and other dangerous machines of destruction."

A Fierce Swordsman

When he went to the rescue of Jaffa which was being attacked by Saladin, the Saracen leader, he leaped into the sea from his ship with his crossbow in his hand and only part of his armour on, and with a few daring followers routed the besiegers and seized their tents. The Saracen made a counter-attack at night but Richard beat it off with only ten mounted knights, some of whom were unarmed.

So fiercely did he slash with his sword when he went into battle that for years after he left Palestine Saracen mothers used to frighten their crying children by saying "Richard is coming," just as more than six centuries later English mothers scared their bad children by telling them that "Bony" was coming, meaning Napoleon Bonaparte.

An interesting incident happened at the time of the battle of Jaffa. Saladin asked where the King of England was. Some of his officers answered, "Sire, see him yonder on the ground on foot with his men."

"How," said Saladin, "is the King on foot among his men; is he not ashamed?"

Then Saladin sent Richard a horse and charged the messenger to say that such a one as he should not be on foot among his men in such danger. The Saracen messenger performed the commands of his lord. He came to King Richard and presented the horse sent by Saladin. Richard thanked him for it and ordered one of his own officers to mount it, and show its paces before him. After the officer had spurred the horse into a gallop and wished to return towards Richard, he found he could not do so for the horse, in spite of all his efforts, carried the Christian warrior away to the Saracen host. Saladin, we are told, "was much ashamed of this." It was truly an unfortunate end to a generous action.

Richard held up his shield to shut out the view of the Holy City, feeling he was not worthy to look upon it.

There are wonderful stories told of how Richard slashing with his sword cut off the heads of many Saracens, and once with one blow cut an Emir in two. Even when he was so ill that most commanders would have retired and gone to bed he had himself carried into battle on a silver litter, propped up on silken cushions, and not only directed the attacks of his crossbowmen, but used a crossbow himself with deadly effect.

But Richard was something more than a brave warrior, and a great commander. He was a poet. He loved to associate with the troubadours of the day, and songs have come down to us said to have been composed by Richard himself. He could not write, but he knew Latin quite well. He never learnt to speak English, his usual language being a French dialect. It is a strange thing that he was so popular among the English, for he had very little interest in England, rarely visited it, and indeed only looked upon the country and the people as useful for providing funds for his various enterprises.

Throughout his life of 42 years, Richard spent less than a twelve-month in his English dominions. He loved glory and finery, and when he was married to Berengaria of Navarre, after whom, by the way, the famous Atlantic liner is named, we are told that he wore a rose-coloured satin tunic with a cloak of striped silver tissue, a scarlet bonnet brocaded with gold, and that the hilt of his sword, and his baldrick or belt, were covered with jewels. When he led his fleet of 200 ships to the East, he had his own galley, The Trenchmer, painted red with a great lantern hung at the poop as a signal at night for the other ships.

A Two-Sided Character

Richard, however, had another side to his character, which we must not forget. He could be very cruel. When the city of Acre in Palestine was surrendered to him by the Saracens, he held a number of the enemy warriors as hostages for the payment of a large ransom, and when after a month, during which he repaired the walls and put the city in a fit condition to stand a siege, the ransom was not forthcoming, he beheaded 2,700 of the prisoners in sight of the enemy.

At Cyprus, which was ruled by a prince who called himself the Emperor Isaac, those of Richard's men who landed first were plundered and badly treated by the people of the island. Richard was furious, especially as the people had declared that the English had tails, so he landed his army, defeated the Greeks, and captured the Emperor. He had sworn that he would not put Isaac in irons, but the unfortunate Emperor was not much better off when Richard loaded him with silver chains.

Of course, the Italian historian who describes Richard as "a bad son, a bad brother, a bad husband, and a bad king" is exaggerating. There is some truth in what he says, but we must remember that the lion-hearted king lived in a half savage age, and we must never judge the people of those days by our standards of to-day On some occasions, as in his treatment of his brother John, who had proved disloyal and unfaithful, he could be generous, and he was often good in lending ships and money to his allies the French

London for Sale

He was enthusiastically religious in the queer way that religion was practised in the Middle Ages. He burned to become the champion of the Faith who should deliver the Holy Land from the infidel, as the Saracen was called, and in order to finance the necessary army and fleet he stopped at nothing to raise the funds required

Offices both spiritual and secular were sold to the highest bidder His half-brother, Geoffrey, for instance, paid him £3,000 for the Archbishopric of York, and it is said that Richard declared he would sell London itself if he could find a purchaser.

So pious was he as a Crusader that when he found he would not be able to capture Jerusalem he rode as far as Emmaus, and standing on a spot from whence the towers of Jerusalem could be seen, he held his shield before his eyes so as to shut out the view of the Holy City because, he said, he was unwilling to look on so sacred a city which he could not rescue. Then he went off and captured a caravan of rich merchandise coming from Egypt.

Richard performed many exploits of valour in the East, but the jealousies and failures of his allies prevented him bringing the campaign to a brilliant end, and with bad health and news from England that John was plotting against him, he decided to return home.

But he had made many enemies, and the journey from Palestine to England he knew would be perilous. One of his foes was Duke Leopold of Austria, and another was the Holy Roman Emperor, Henry the Sixth, who was very angry at Richard's behaviour in Sicily The Duke of Austria's banner he had thrown down at the taking of Acre on his way to the Holy Land, but, worse still, at Ascalon he had kicked the duke.

Richard had helped his men work on the repairing of the walls of that city, and he wanted the duke to assist also, but Leopold replied that he was not a carpenter or a mason, and this made Richard so angry that he gave the duke a good hard kick. No wonder, therefore, that Leopold, still smarting from the insult, was thirsting for revenge

Blondel began to play the air of the song

Embarking on a ship for the return journey, Richard was very unlucky, for the vessel encountered terrible storms, and it took him a month to reach Corfu. Then, knowing that he had enemies in Sicily and France, he changed his vessel and sailed up the Adriatic in disguise, intending to make the rest of the journey across Europe by land. But the ship was wrecked.

Richard, however, managed to reach land, and with a few servants started off He had let his hair and beard grow very long and was wearing the clothes of a peasant of the country, but he does not seem to have acted very wisely, for he spent so much money that rumours spread as to who he really was.

Eventually, with only a single page, William Marsh, he reached Vienna He was in great danger, for Duke Leopold, having heard that Richard was in his country, had spies looking out for him. At last, believing that he was discovered, Richard put on the dress of a scullion, and set to work in the kitchen of an inn, turning the capons that were roasting before the fire. A spy, however, recognised him, and went and told the duke, and thereupon Leopold sent many knights and soldiers to seize the King. He was captured and carried away to a fortress

Another account says that it was William Marsh who was suspected, and that he was seized and carried before the Duke of Austria who made him tell him where his master was, and that Richard was taken prisoner while he slept.

Poor Richard was now placed in the Castle of Durrenstein on the Danube, and a chronicler says, "Though his feet were not fettered, yet the filthy guards, their smell, dirt and conversation, were worse than a den of beasts."

Requiting a Kindness

The old records tell us that Richard's friends at home did not know where he was. It happened, however, that the King had been kind to a minstrel, a native of Artois, whose name was Blondel. This man, as soon as he heard that the King was missing, declared that he would seek him over the whole earth till he found him. He thereupon set out and wandered about day after day by land and water, until he had been hunting for a year and a half without hearing anything at all of the missing king.

At last he entered Austria, and chance led him straight to the castle where the king was confined. Near the building Blondel saw a widow woman who kept an inn, and asked to whom the castle—so fine and strong and well placed—belonged. The woman replied that it belonged to the Duke of Austria.

"Pretty hostess," said Blondel, "is there any prisoner confined in it?"

"Certainly," said the woman, "there is one who has been confined nearly four years, but we do not know who he is. They guard him very carefully, but we have no doubt that he is a gentleman and somebody of high quality."

When Blondel heard this he was delighted, and we are told that his heart whispered to him that at length he had found him whom he sought. He was careful, however, not to give any cause for suspicion to the hostess. That night Blondel slept soundly, for now his mind, which had been so long troubled, was at rest, and the next morning, when the cock's crow announced the coming of day, he arose and went to a church near by and prayed for assistance.

He then went to the castle and approached the keeper, telling him that he was a minstrel and played upon the lute, and that he would like to remain there for some time and play to him, if the keeper were agreeable. The keeper, who was a young and handsome knight, said he would be glad to engage Blondel as one of his retainers. The minstrel was delighted and went back to the inn to fetch his lute and his wallet.

During the next week or so he did all he possibly could to please the castle keeper, and became a great favourite in his household. He remained there all the winter, but was unable to discover who the notable prisoner was.

At last, near the festival of Easter, as he was one day walking in the garden which surrounded the castle, looking in all directions in the hope of seeing the prisoner, a strange thing happened. The King, who was confined in a tower, looking out of the small barred window, suddenly saw and recognised Blondel. Of course he wished to make himself known to the minstrel.

The King Sings

It was too risky to call out, but remembering a song which they had made together, and which, in those parts, no one but the King and Blondel knew, Richard began to sing the first verse of it in a loud and clear voice. Blondel's heart gave a leap. He knew that it was his friend, and he went straight from the garden to the chamber in which he had left his lute. Then he went back to the spot and began to play the air of the song. Each recognised the other, and it was now known where Richard was confined.

Blondel remained at the castle till Whitsun, and was so careful in his behaviour that no one suspected that he had discovered the great secret. Then, going to the keeper of the castle, the minstrel said:

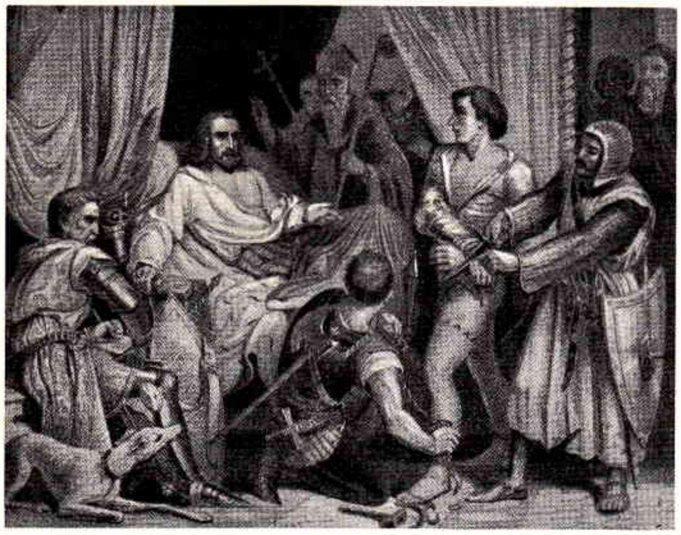
" Sir, if it is agreeable to you I should like to return to my own country, for it is a long time since I left it, and I long to see my friends."

" Blondel, my good brother," said the keeper, " if you take my advice you will not go away, but remain here and I will advance your fortunes."

" Oh, sir," said Blondel, " I cannot remain on any account." And when the keeper found he was unable to detain the minstrel he bade him farewell and presented him with a good horse so that he might travel quickly and comfortably.

Blondel, the story says, travelled so rapidly that before very long he reached England and informed the King's friends there where he was confined and how he had found him. Richard's friends were greatly delighted at this news, for they loved the King as a brave knight, and they determined among themselves that they would send to Austria to the duke and seek to obtain the deliverance of the King. Exactly how much of this story is true it is difficult to say now, but it is a very old one, and dates back to Richard's time.

The Emperor Henry, as soon as he had learned of the King's capture, had sent word to Philip of France, and he had forwarded the news to John in England. Richard and Philip, King of France, who had accompanied the English monarch to the Holy Land, were supposed to be very close friends, and as a proof of this the historian tells us that they ate from the same plate and slept in the same bed. Another historian, however, modifies this story of very close friendship by telling us that they merely ate at the same table and slept in the same room. But Philip had always been jealous of the King of England, and now he and the Emperor and John conspired to keep the secret of Richard's capture for some time. But when the news was known to Richard's friends they at once sent off two messengers to Germany. Some say these were knights, and others that they were abbots.


Richard generously ordered the brave youth to be released

Meanwhile, the Emperor bought the prisoner from Leopold of Austria, but Richard's mother wrote to the Pope, who threatened Henry with excommunication. It was regarded as a great outrage that the Holy Roman Emperor should hold as a prisoner the brave warrior who had done so much to win the Holy Land from the infidel.

The messengers from England found Richard, who was now confined near Speyer, and after some negotiations the Emperor fixed his ransom at £100,000. The messengers returned, and with a good deal of difficulty this huge sum, for those days, was raised in various parts of Richard's dominions, some in England, some in Normandy, some in Anjou, and some in Aquitaine. It is recorded that Caen gave more than London, and that Richard's brother John, who would have liked to have seen the English King remain a prisoner in Germany, stole the money collected on his own lands for Richard's ransom.

It was another year, however, before the King was set free, but at last, on March 20th, 1194, after he had been absent from his kingdom for over four years, he landed in England, and, going to London, was received at St. Paul's Cathedral with great joy and with solemn processions.

Richard lived for another five years, but he became more cruel as he got older, and he was very annoyed when he was given the nickname of " the fat man from Poictiers," he having put on a good deal of flesh.

His last act, however, is to his credit. He was besieging the castle of Chaluz, when he was struck by a poisoned arrow shot from the walls. Fever set in, and very soon it became clear that the King would die. When the castle was taken the archer who had shot the fatal arrow, a young man named De Gurdon, was brought before Richard.

A Generous Deed

" What was your grievance ? " asked the dying King.

" You have killed my father and brother," replied the archer, " and I hope that I have killed you."

Richard showed no resentment, but generously ordered the youth to be released. His followers, however, took the young man away and killed him.

It was a rough age in which Richard lived, and there were few, if any, men of power who were not cruel at times. As we have already said, we must not judge them by our own standards, and among those who lived at the same period Richard certainly holds a high place for bravery and even for generosity.

He was undoubtedly a great leader of men, and all the knights and soldiers who fought under him loved him, while, as we have seen, his enemies respected and feared him. He was quick to realise at a glance the moral qualities of a man, and it was said of him " that no one who was a coward or whose conscience accused him could bear to be with him." He made up his mind quickly when decisions had to be taken, but sometimes his love of money made him hesitate, and an old writer has, on this account, given him the name of Richard Yea-and-Nay.

THE ROUND EARTH ON A FLAT WALL

It is quite impossible to portray accurately on a flat surface an outline from a round globe, and therefore none of the maps in our atlases can possibly be correct. But we cannot carry about with us round globes representing the Earth, nor when we want a small part of the Earth's surface represented in large detail, as for example, an English county, can we conveniently use a globe large enough for our purpose. We therefore have to do the best we can and show the Earth or part of its surface as if it were flat, just as these boys have done by drawing the world on the wall of their playground. The making of maps is a great science, and all sorts of devices have been adopted to get as near accuracy as possible. We read about some of these on the opposite page and elsewhere in this book

WONDERS of LAND & WATER

WHY FLAT MAPS ARE NOT ACCURATE

The story of maps and how they have come to be made is a great romance. All kinds of scientific men have to get to work before we can have anything like a reasonably accurate map of a country, or even part of a country. Surveyors and mathematicians and physicists and opticians all get busy before the cartographer, as a map-maker is called, can draw a picture of the country on paper ready for our atlases. Here are some very interesting facts which we should know about maps and map-making

We have many atlases and many maps, some showing the world as a whole, some specific countries, and some smaller areas, and very useful these are. By looking at them we are able to see the relation of one place to another; to notice that a certain town is north-west of another town, and south-east of a third town; that one city stands on the right bank of a river and another on the left bank; that one river runs north and south and is fairly straight, while another runs east and west and curls about like a serpent. We can see, too, from the map, the outline of a coast, the position of the bays and gulfs and capes, and all this helps us to get an idea of what a country is like which would be impossible if we had no map.

We must remember, however, that all maps of the world, and even of countries and large areas must, of necessity, be incorrect. It is quite easy to see why this is. The Earth is in shape something like an orange, that is, a ball flattened slightly at the poles.

An Orange Experiment

Now it is quite impossible to see the whole surface of the orange at one time exactly as it is. We can, of course, look at the orange first on one side and then on the other side, and if we want to represent it on paper we can photograph the two sides and place them side by side as we have done in the picture on this page.

On the other hand, we can take a penknife and, dividing the whole of the orange peel into lozenge-shaped sections, spread this out as also shown on this page. The peel of the orange is soft and elastic, and so when we have removed it from the orange we can spread it out and press it down fairly flat.

Now the Earth is like the orange. If we could go away some thousands of miles into space, taking a camera with us, we could photograph one side of the Earth, and then, when it had turned round on its axis, we could photograph the other side. But while the pictures would give us a very good idea of what the Earth looked like from space, they would be of little use as maps, for we should see the sides of the globe in perspective, and so the shapes of the countries would be lost.

Something That is Impossible

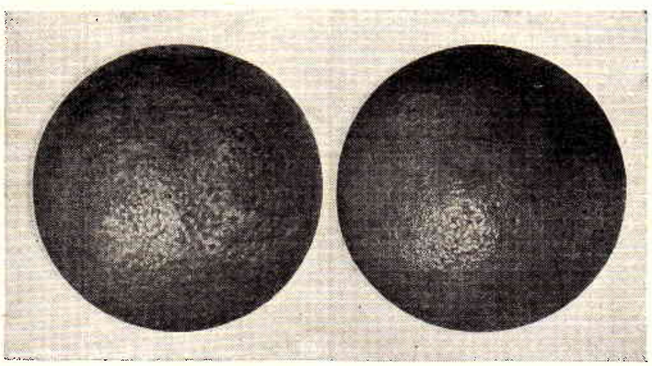
A representation of the Earth made in this way would give us an idea of the continents and seas only in that part which was immediately in front of the camera. All other features would recede and dwindle in perspective. A map of the world made in this way would be of very little use.

The difficulty in making maps is, of course, that it is absolutely impossible to represent exactly a curved surface on a flat sheet. The best map of the world is, of course, that found on a terrestrial globe. Such a globe can be obtained quite cheaply, and in all sizes, and no one who wants to get an idea of the Earth on which he lives should be without, at any rate, a small globe.

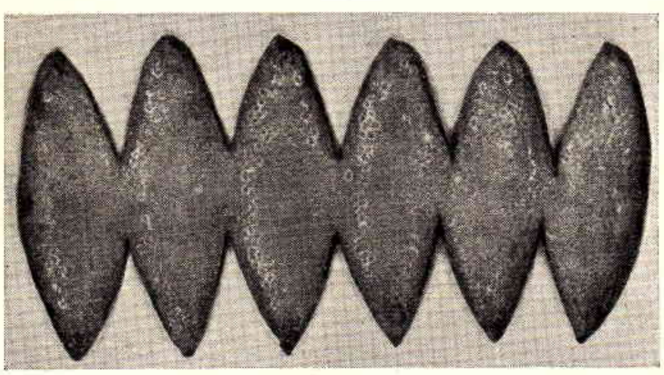
But the difficulty of having a map of the world in the form of a globe is that while it gives a good idea of the world as a whole, even the biggest countries on the largest globes are too small for us to study such details as rivers, lakes, mountains, cities, and so on

If we want to realise how difficult it is to make a flat map of any considerable part of our globe we can perform a little experiment. Get a cheap indiarubber ball, one of those plain ones without any paint or markings. On it draw any rough outline.

Now cut a good-sized square piece from the ball and lay it on a sheet of paper. It is, of course, humped up in the centre. But rubber, being elastic, can be pressed and stretched, and we can make the piece of the ball lie flat on the sheet of paper by stretching the edges. It is a good plan to pin each angle down with a drawing pin as we stretch it. In this way the round piece of ball is made into a flat surface.



One way of representing an orange on a flat sheet is to show the two sides in perspective as here



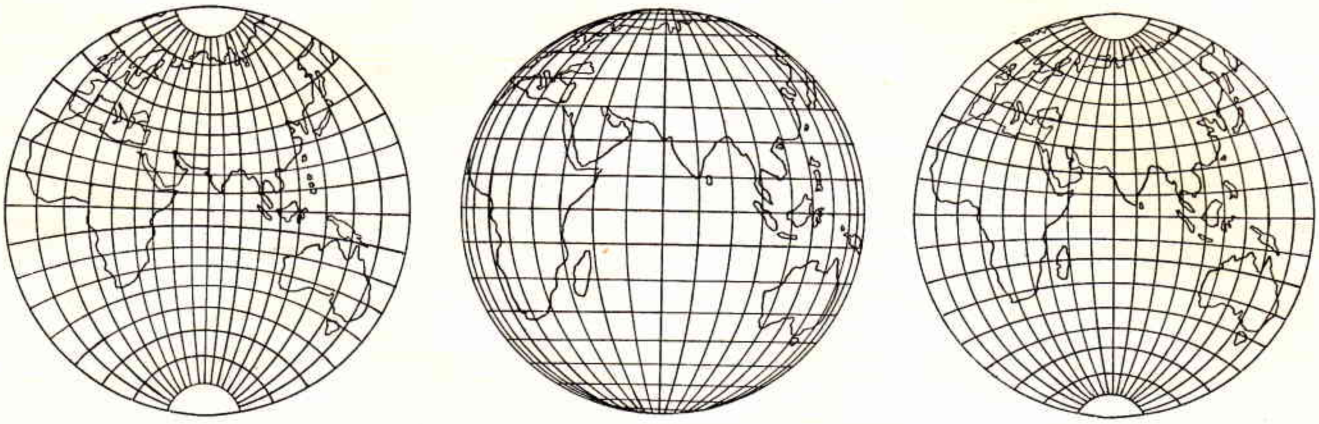
Another way of showing the round surface of an orange on a flat sheet is to cut the peel into many segments and lay them out flat

Distorting an Outline

But as we see when we look at the outline which we drew, this has become distorted. If before we press the skin out flat we mark two points on the side of the square, half an inch apart, we shall find that these points are now considerably more than half an inch apart; while another two points near the middle of the square would be almost in the same position as they were when on the ball.

Not only are the points marked on the side of the square farther apart from one another, but they are also farther apart from the centre of the square.

The whole outline which we drew has become distorted, and so, although we have a flat map in place of a curved one, scarcely anything is really in its true position in relation to the other parts.



The Eastern Hemisphere in three ways : on the left is the Stereographic Projection, in the centre the Orthographic, and on the right the Globular

We can see by this little experiment how difficult it is for those men who want to make maps of the Earth's surface to do so. We can spread out the piece of rubber ball flat by stretching its corners and sides, but of course the Earth is rigid, and in any case we cannot stretch out the Earth itself as we can the ball.

What, then, are we to do ? We must have maps, and we must have them as accurate as possible. Well, men have thought out all sorts of clever methods of portraying the surface of our round Earth on flat sheets, so that the maps could be hung on the walls or bound together in books.

But in all cases there are distortions of some kind. Some maps are fairly accurate for certain parts, and very inaccurate for others. For instance, in the beginning of our atlases we always find an oblong map of the world which is described as "On Mercator's Projection." It is so called because it is drawn on a plan invented by a sixteenth century Flemish map-maker named Mercator. This map is quite useful in giving us an idea of the shape of various parts of land and sea, and the middle part is fairly accurate as to proportion ; that is, India appears in the right proportion to Arabia and North Africa, and Cuba and Haiti are in the right proportions to Mexico.

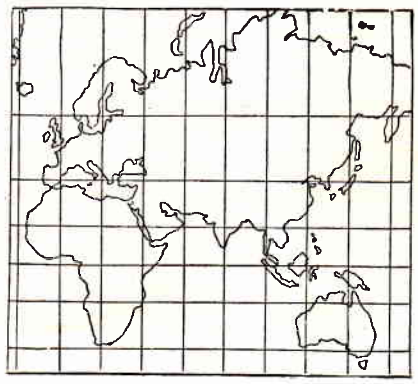
However, when we come to the north and south everything is much distorted and out of all proportion. For instance, Greenland is about 826,000 square miles in extent, while Africa is over eleven and a quarter million square miles ; yet on the map of the world, drawn according to Mercator's plan, Greenland appears as big as Africa, and Canada, which is not quite so big as the United States, appears more than twice the size of that country.

When we have a map of the world on Mercator's Projection, with the British Empire coloured red, we get an impression from this distortion of Canada that the British Empire is very much larger than it really is.

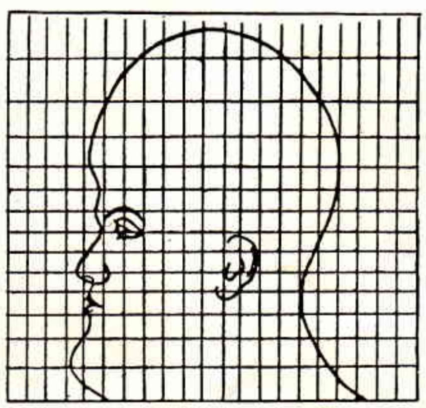
On the other hand, when we look at a map that shows the world on some other projection, as, for example, what is known as the Stereographic Projection, Greenland appears less than one-twentieth of the size of Africa, which is equally absurd, if we want to see them in anything like their true proportions.

It is interesting to take an atlas which shows the world on Mercator's Projection and also in hemispheres, and then to compare the various countries with these parts of the world as they appear on a terrestrial globe. We shall realise then the difficulties of map-making.

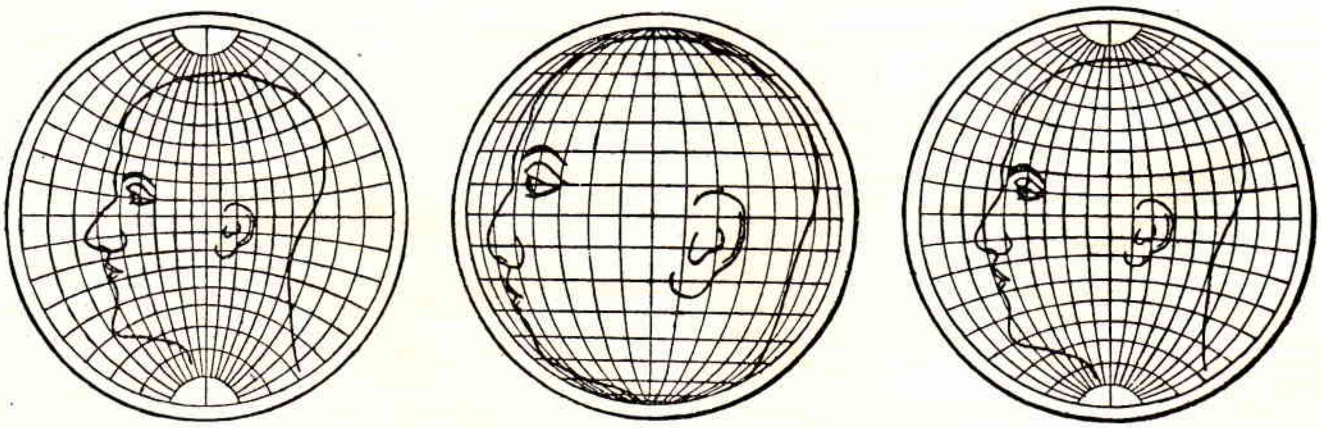
Of course, for small areas like the counties of England, there is not very



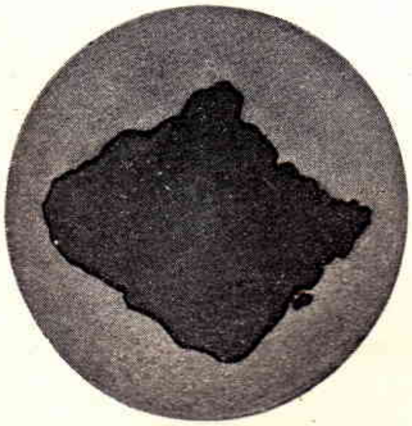
Eastern Hemisphere on Mercator's Projection



A head drawn on Mercator's Projection



The same head drawn according to the Stereographic Projection (left), the Orthographic (centre), and the Globular (right) much difficulty Here the area is so small in proportion to the world as a whole that the rotundity of the Earth's



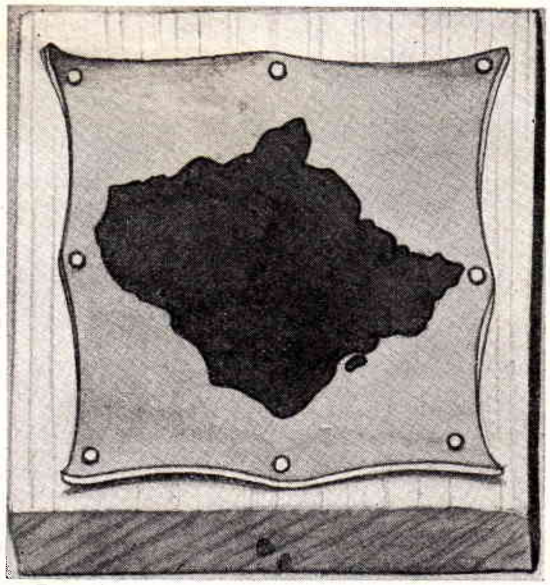
Photograph of a rubber ball with a drawing of an island

surface is very little, and so the county can be depicted with almost true accuracy on a flat sheet.

In another part of this book we read of some of the devices that men have invented in order to make flat maps.

The story of the atlas and how it has reached its present form is quite a romance. In the old days the men who drew maps made up for their lack of knowledge and lack of accuracy by making their maps look very interesting and artistic. They always put a great deal of decoration on the maps, with pictures of ships and animals and towns. The names of the countries and other places were printed in letters with plenty of scrolls and flourished. They also gave elaborate borders to their maps, and the colouring was very bright.

But considering the great difficulties under which the early geographers and map-makers laboured it is astonishing that they were able to be as accurate as they were. In some of the maps of the seventeenth century, and even of the century before, the outlines of the continents and countries are remarkably true. This applies to such parts as Africa, India and, of course, Europe, with the Mediterranean Sea.



Part of the rubber ball laid flat showing distortion

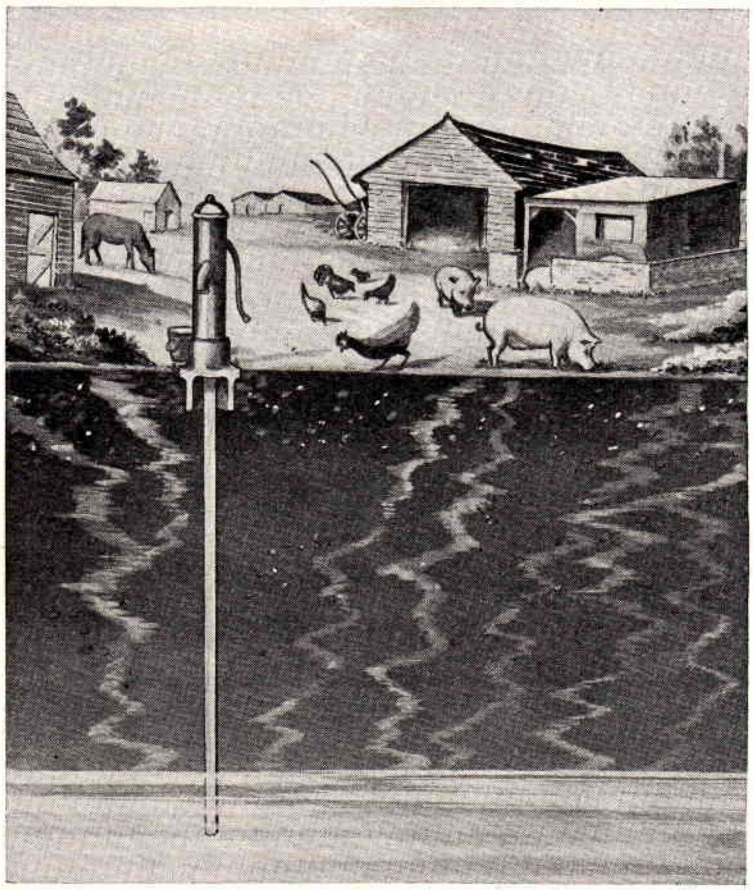
THE IMPORTANCE OF A PURE WATER SUPPLY

None of us can live without water. That is why, when professional fasters abstain, as they can do, from taking food for forty days, more or less, they invariably have to drink water every day. No one can live without water for more than a few days.

But quite as important as the water supply itself is the purity of it. There is little doubt that the great epidemics of plague in olden times were largely due to the contaminated water which was drunk by the people. No one understood about disease germs in those days or knew that water could easily become dangerous

The Need for Care

The water supply of large towns can now be relied upon, as it is regularly tested, filtered and, if necessary, chemically purified. But in isolated country districts, where people are dependent upon wells that do not go far down, great care should be taken to see that the water is pure. It may look pure and yet contain disease germs.



In this picture we see why it is often unsafe to drink water from surface wells with or without pumps. Impurities from the surface percolate through the soil to the water. Refuse should never be left near wells and pumps

The picture on this page shows how the water supply from surface wells is contaminated through impurities percolating through the soil to the underground supply. Domestic animals, poultry, manure heaps and all such sources of contamination should never be allowed near any well from which drinking water is drawn.

In the Old Days

Serious and sudden epidemics of disease in a district can usually be traced to pollution of the water supply. But even where there is no epidemic, ill-health may be caused to individuals through impure water.

In the old days there was an excuse, for people did not understand these matters, but now everyone should take care that no decaying matter or animal impurities are allowed to lie near a source of drinking water, such as a surface well.

Filtering alone does not remove disease germs from water.

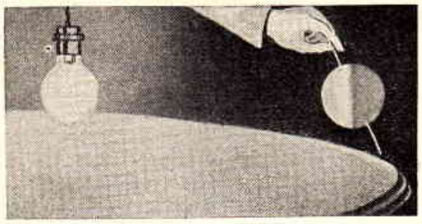
A GREAT STONE BRIDGE MADE BY WATER

There are in different parts of the world wonderful natural bridges of rock like this one to be seen in Utah, America. It is interesting to know how such bridges are formed. In some past age a river with a waterfall has flowed over rock containing deep open cracks Some of the water has descended through a crack, and after reaching a lower level worn a passage for itself through the rock to the river below the falls. Gradually the passage has been made bigger, until at last it has become large enough to take all the water of the river. The waterfall has thus been shifted back from its original position. Gradually more and more rock has been worn away, till at last the only part left was a natural bridge near the place where the fall originally went over the rocks. Indeed the fall in ancient times may have actually flowed over the top of this bridge. Another famous natural bridge is to be seen in Virginia.

HOW DAY AND NIGHT COME

Every 24 hours there are two varying periods of light and darkness, and these we call day and night. We owe these changes to the fact that the Earth whirls round and round on its axis,

How half the Earth has day and half night.



A simple experiment to explain day and night.

so that in turn every part of its surface is lighted up by the Sun. If the Earth kept still then the part turned toward the Sun would enjoy perpetual light, while the other side would be plunged in permanent darkness.

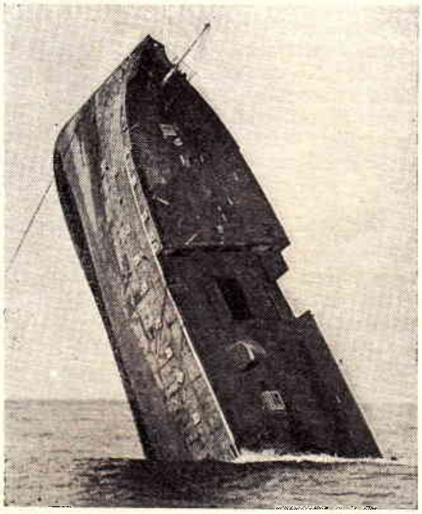
The Earth's axis tilts. If it did not do so day and night would always be equal in length. But since the axis is inclined the length of day and night varies from day to day. We can see this by a very simple experiment.

Stick a knitting-needle through an apple from top to bottom, then tilt it at an angle of rather more than 23 degrees and move it round the edge of a round table with a light hanging in the centre. Keep the knitting-needle as you go round always at the same angle and leaning towards the same side of the room. Then you will find that the North Pole of the apple is at one time leaning towards the light, and at another time leaning away from it. These positions represent summer and winter.

If you stick a pin into the apple so that the head represents England, you will see that this is in the light for a longer period of each turn when the knitting-needle is leaning towards the Sun, that is, in summer, than when the needle is leaning away from the Sun, that is, in winter. That is why there is more daylight for us every 24 hours in summer than in winter.

WHY A WRECK SINKS

When a ship sinks it goes to the bottom of the ocean for as it goes lower and lower its material gets more and more compressed, and is always denser and heavier than the water which, of course, is itself also compressed.



A ship going to the bottom of the sea.

THE ROMANCE OF THE PELTON WHEEL

Some discoveries and inventions have been the result of strange accidents, and in the whole realm of engineering there is nothing more romantic than the story of how the Pelton Wheel, an unusually efficient device that is of the greatest importance to-day, was invented. The strange story is told in detail on these pages.

WATER has been used as a source of power by man for thousands of years. We find that water-wheels were in use among the ancients, and in all sorts of lands, backward as well as advanced, the water-mill for grinding corn and doing other work is a regular institution.

There are various kinds of water-wheels, as we read in another part of this book, but the most efficient of all water-wheels is the modern type known as the Pelton wheel.

In this wheel a series of double buckets is attached to the circumference, and water, issuing from a nozzle at very great pressure, strikes the buckets in the middle, is deflected to both sides and drives the wheel round at great speed. This type of water-wheel has enormous advantages over the old-fashioned kinds, and as much as 87 per cent. of the power expended is harnessed for use.

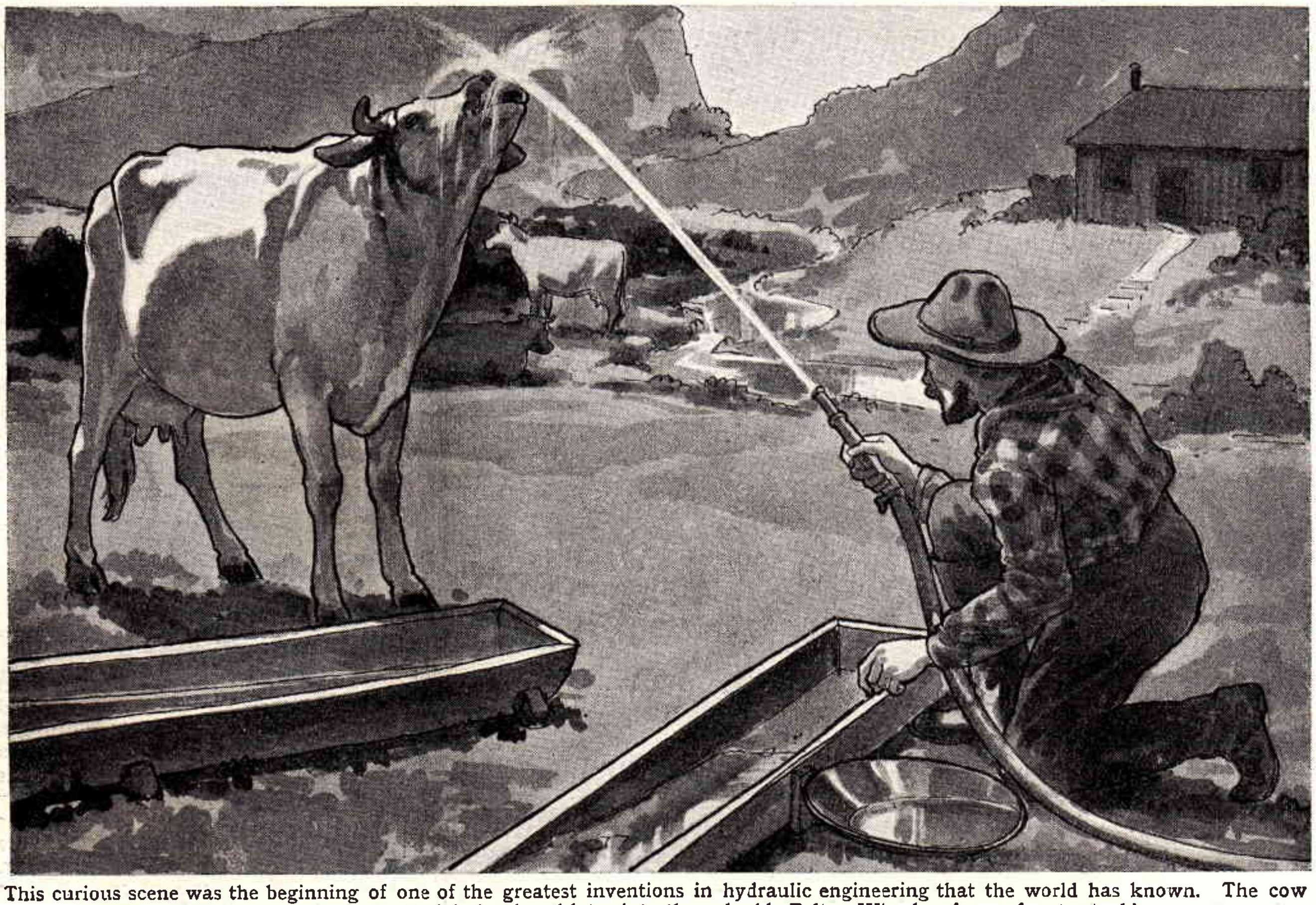
It is very serviceable where there is a limited supply of water, but provided that the water is falling from a height so as to get the necessary force. The nozzle from which the water is directed upon the buckets is of small diameter, generally ranging from a quarter to half an inch. The wheels vary very much in diameter, sometimes being as small as six inches and sometimes as great as ten feet.

Pelton wheels are often used for driving dynamos, and a wheel three feet in diameter with a fall of water of 520 feet, can develop 200 horse-power. This is very remarkable when one remembers that such a wheel would use only about 240 cubic feet of water per minute. In no other way could such an amount of water produce such great horse-power.

The invention of the Pelton wheel is one of the romances of engineering. We owe it to the foolishness or obstinacy of a cow. One hot summer day in 1860, a gold-miner was washing the gold-bearing gravel in Nevada in order to collect the grains of precious metal. He had rigged up a length of hose in order to provide a supply of water at sufficiently high pressure to do the work, and as the water supply was at a considerable height the stream came from the nozzle of the hose with considerable force.

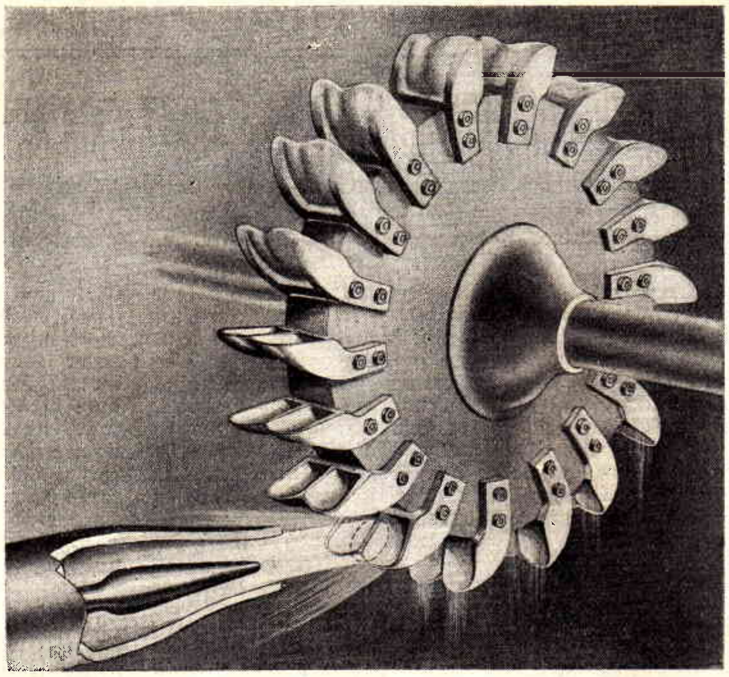
As the miner was engaged in this task, a cow belonging to him, which was kept for the use of her milk, went up to the workings to slake her thirst. She nearly upset some of the sluices which the miner had arranged, and so to drive off the cow the man turned his hose upon her. By chance the water struck the cow in her cup-like nostrils, and the force of the stream threw her head back sharply.

The miner noticed the effect of the water stream on his cow's nose, and



This curious scene was the beginning of one of the greatest inventions in hydraulic engineering that the world has known. The cow really contributed the idea which developed later into the valuable Pelton Wheel, a form of water turbine.

suddenly a brilliant idea came to him. He would make a water-wheel with receptacles formed like the cow's nostrils, and he felt sure that this would be much more efficient than any of the ordinary wheels then in use.



The Pelton Wheel as it is today. A powerful jet of water under pressure strikes a series of double buckets and whirls the wheel round at enormous speed. A needle inside the nozzle regulates the water-jet

A Great Idea

The man lost no time. He rigged up a waggon wheel on an axle so that it would turn freely, tied a number of empty cans to the rim of the wheel and when all was ready directed his hose stream upon the cans. The wheel went round with a whirl, and so long as he kept the stream directed in one position, that is directly at the openings of the cans, the wheel continued to rotate with great speed.

"Here," thought the miner, "is a great idea," and while he still went on with his gold-mining, he spent some time constructing a complete model of the new kind of water-wheel. It more than met his expectations, but here the matter rested for some years. No one seemed interested.

Then in 1885, the miner went to San Francisco and exhibited the wheel. He managed to convince a number of manufacturers of its great commercial possibilities. The Californian gold mines needed some form of cheap power, and here was the very idea. A plant was erected at the mines, a water stream was brought from a great height, and the new device was inaugurated in the presence of a large gathering of miners, who though interested, were somewhat sceptical. But the wheel justified itself at once.

Success Achieved

The demonstration proved a tremendous success, and from that time onwards Pelton wheels, as they were called, after the name of the miner inventor, Lester A. Pelton, were in great demand.

We are not told what happened to Pelton's cow, but certainly the inventor, whose name is now world-famous, must have felt grateful to the animal for giving him such a brilliant and useful idea.

In the modern Pelton wheel the inner surface of the buckets is highly polished to avoid friction, and when the stream of water is directed at the sharp edge of the wall between each pair of buckets it communicates as much as 98 per cent. of its energy to the buckets. When the water leaves the nozzle it is not so much a jet, as a solid bar of water. A three-inch jet of water at a pressure of 500 pounds to the square inch cannot be cut through or deflected by the blow of a massive crowbar.

Regulating the Water

The supply of water, and therefore its force, is regulated by means of a tapered needle inside the nozzle which can be moved to and fro so as to make the opening larger or smaller at will. The needle valve is worked by a governor and a motor, and as a reduction of the stream of water would increase pressure in the pipes delivering it, the governor also works an escape valve, automatically opening it when the needle valve closes, and closing it when the needle valve is opened. In this way the power of the wheel can be increased or lessened according to need, and as little water as possible is wasted.

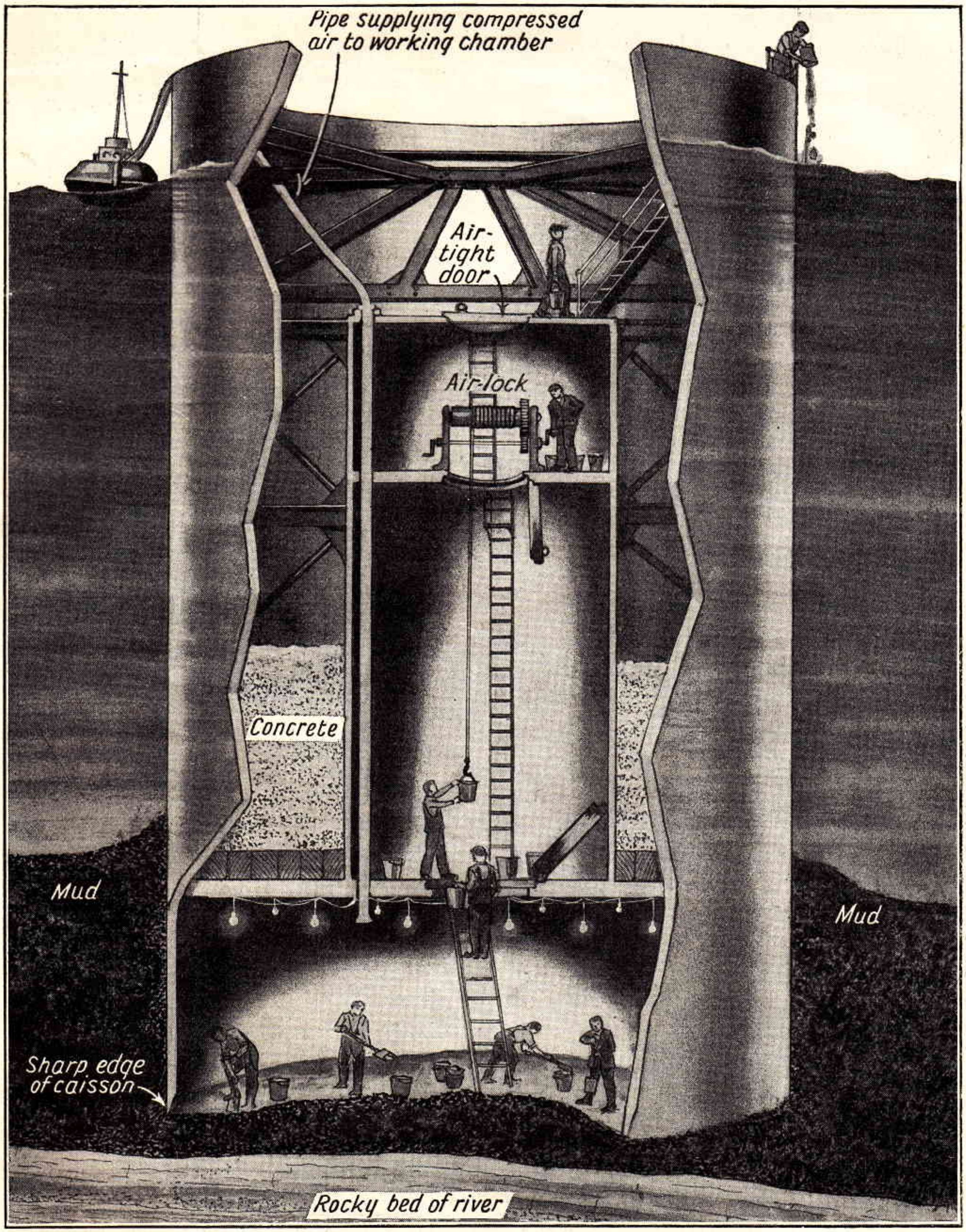
The very first Pelton Wheel made by tying old cans to a waggon wheel

Enormous Pressure

Pelton Wheels are made in all sizes, and they are designed to run at all speeds and to use water of varying pressures. In some the stream of water which leaves the nozzle has the enormous pressure of 935 pounds on every square inch.

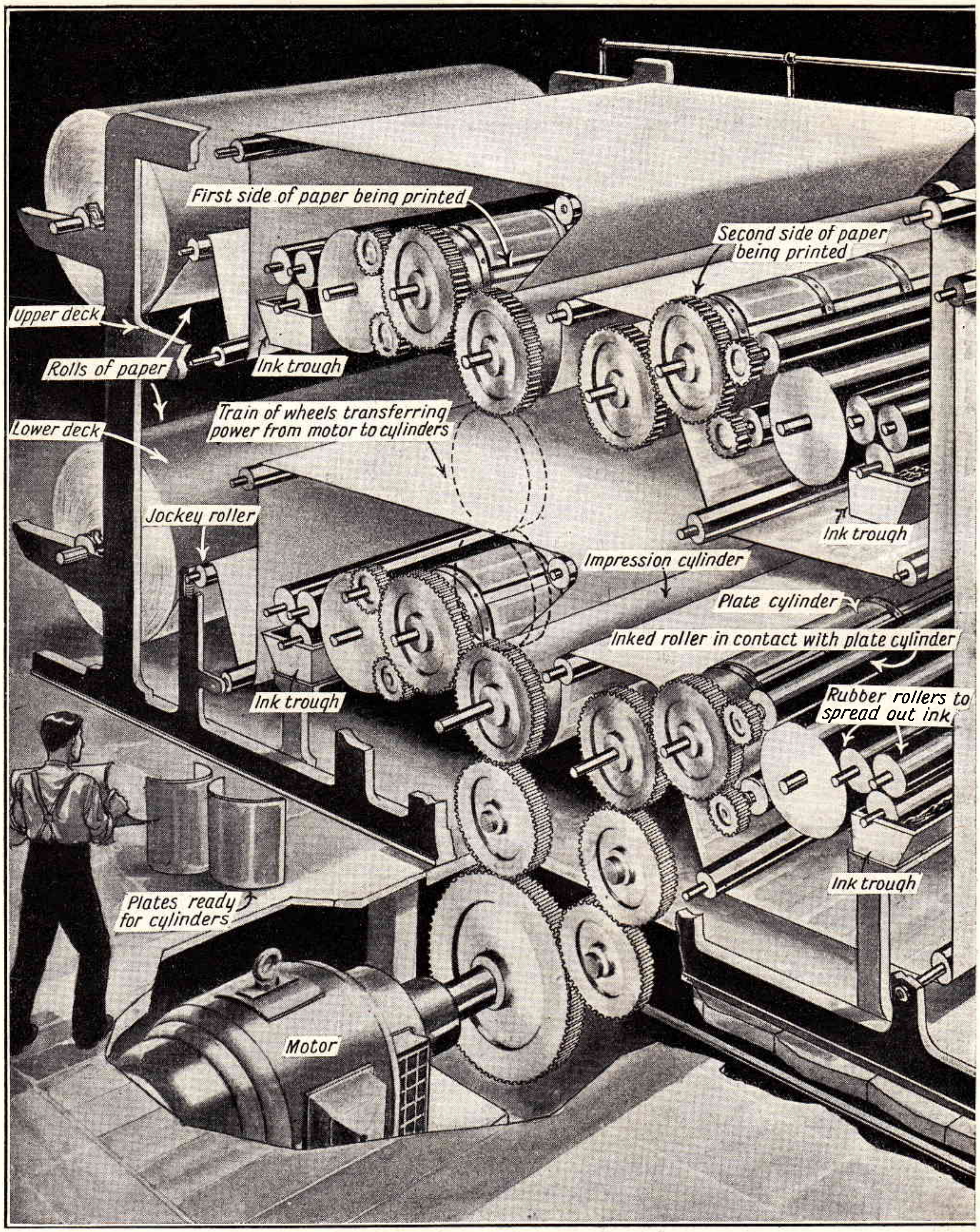
Think of what this means. Mark out on paper a little square with two-and-a-half inch sides. If the stream of a large Pelton Wheel were directed against this the pressure would be over a ton. No wonder the wheels have to be very strongly built of the best steel, and no wonder they whirl round at an enormous speed.

DIGGING A HOLE AT THE BOTTOM OF A RIVER



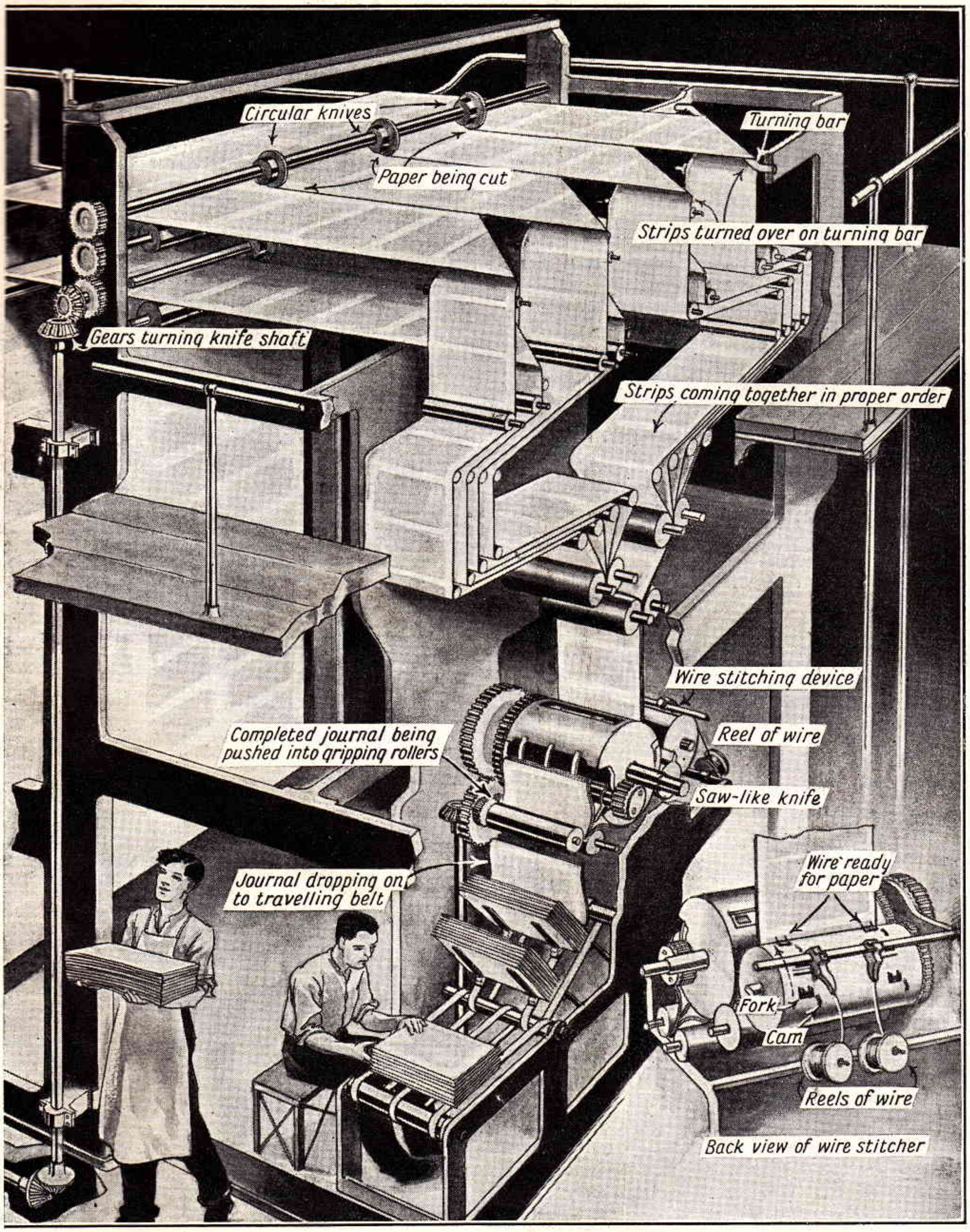
When a bridge is to be built across a wide river, concrete foundations have to be laid. A large circular iron chamber, called a caisson, is sunk in the river bed. Inside the caisson is a floor with concrete to give weight, and underneath is a working chamber into which compressed air is pumped, driving out the water. This is kept filled with compressed air and workmen enter through an air lock to get used to the pressure. They dig out the river bed, and the caisson is then filled with concrete and thus provides a good foundation for the bridge.

THE GREAT MACHINE THAT PRINTS



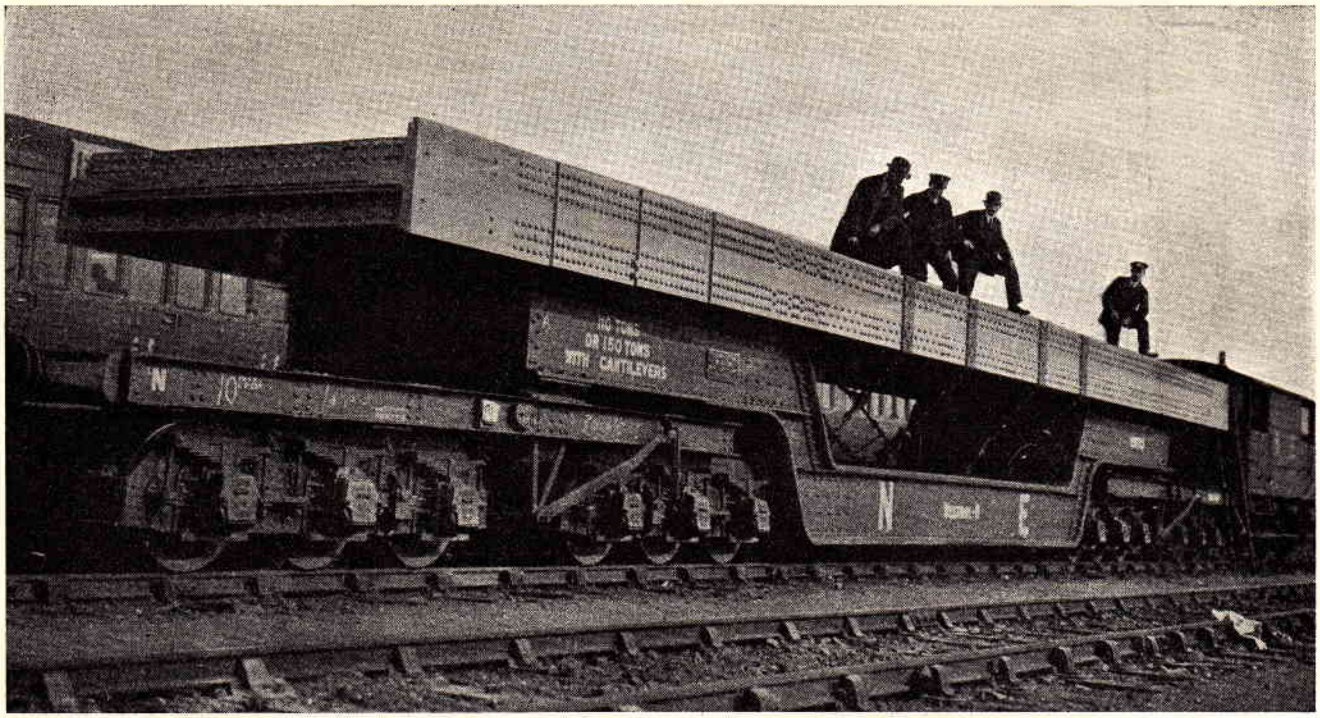
The machine that prints a newspaper or magazine is a marvel of ingenuity, and in these pages we see how it works. For clearness and simplicity part of the machinery on the far side has been brought to the front. The motor sets moving a whole series of huge rollers or cylinders. Some are to direct the paper, some are covered with ink, and some have bent round them metal plates cast from the type and arranged in pages. The plate cylinder is inked by a roller, and when the paper comes to this cylinder an impression of each page is left behind. There are two tiers to the machine, and both are printing parts of the paper or magazine. As the printed paper leaves the

AND BINDS A PAPER FOR YOUR USE



rollers it passes between a series of circular knives, which cut it into strips the depth of the pages. Then the strips pass over turning-bars and are drawn through rollers, where they are brought together with other strips from the lower tier of the machine. The whole of these pass through an apparatus which binds the pages by stitching them with wire, and cuts them off in separate magazines or journals. The journals then drop on to a travelling belt and are carried away for despatch to the newsagents or booksellers. In the bottom right-hand corner of this page the other side of the wire stitcher is shown, with the reels of wire.

A HUNDRED-TON GIRDER TRAVELS BY RAIL



In the ordinary way goods travel by rail quite easily, but now and again something has to be carried that is of such a large and awkward size that special arrangements have to be made. Not long ago this girder, weighing nearly a hundred tons, had to be brought by railway from Middlesbrough to London. The journey cost £4,000, for a special wagon with thirty wheels to distribute the weight, as shown in the picture, had to be constructed to bear the huge girder, which was 68 feet long. When it reached London it was a great task to get it off the rail on to a lorry and through the streets of London to the place where it was wanted

THE MEANING OF HORSE-POWER EXPLAINED

Before the development of machinery men did their work of digging or pulling or lifting as well as they could, merely comparing in a general way the work of a very strong man with that of a man less strong. As soon, however, as machinery was invented and developed it became necessary to find some way of comparing the work one machine was capable of doing with that of another.

James Watt, to whom we owe the steam engine, made experiments with strong dray horses and found that a good average amount of work done by one horse was equal to the lifting of 33,000 pounds to a height of one foot in one minute. Of course, a horse urged on could do more work than this, while over a full day the animal would work at a less rate. However, Watt took this useful average and called it a horse-power. Then he measured the work his engines could do by the amount of horse-power they could achieve. Ever since that time the work of engines has been reckoned in horse-power.

Sometimes we read of an engine having so much Indicated Horse-power. That means the amount of horse-power exerted by the piston. Of course, when we use the power in the engine some of this Indicated Horse-power is lost, and what we actually use in driving machinery is known as Effective or Brake Horse-power. Lifting a weight of 33,000 pounds to a height of one foot requires the same energy as lifting one pound 33,000 feet.

A striking example of horse-power which is the standard of work for all engines and machines

YOU CAN BIND
"THE WORLD OF WONDER" YOURSELF

Our Ingenious Self-Binder Makes This Simple

WHEN you take in a part publication like this, you naturally want to keep all the parts perfectly clean, but hitherto this has been difficult. While the earlier parts have been waiting for the completion of the work to go to the binder, they have been liable to get dog-eared or torn.

You need have none of this difficulty with THE WORLD OF WONDER. You can bind it yourself as the parts come out, and when the work is completed you will have a very handsome volume strongly bound and ready for use without calling in the bookbinder at all.

TO enable you to do this cheaply and well, the publishers have arranged for a special improved Self-Binder to be supplied to readers at a remarkably low cost. This Self-Binder is really a most ingenious device, and is so simple to work that a child can bind the parts as they come out with all the skill of a trained bookbinder.

Only by placing a large order in advance have the publishers of THE WORLD OF WONDER been able to buy the Self-Binder at a price which enables them to supply it to their readers for much less than they would have to pay if they purchased it in the ordinary way. At the same time remember that the Self-Binder is an extremely high-class article that will grace any bookshelf.

FULL INSTRUCTIONS FOR USING THE SELF-BINDER ARE GIVEN BELOW

THE supply is limited, and it is therefore highly advisable that you should order your Self-Binder at once before the stocks begin to run low, so that you may reap the full benefit of the extraordinarily low price.

REMEMBER that once you have acquired a Self-Binder you have no further expense. You become your own bookbinder without incurring any trouble at all. The Self-Binder is designed to take the entire contents of THE WORLD OF WONDER, and all you have to do week by week is to add the latest part. This is the work of a few moments only, and you are thus able to have an attractively bound volume from the very first part.

Loose parts are very often lost parts. By using the Self-Binder you can insure safety for the parts as they come out, and can be sure that they will be preserved in their original attractive state.

WITH the Self-Binder readers are given two stiff end-papers. One of these serves as an extra title page, while the other is taken out and replaced as each fresh part is put into the Binder. These end-papers form a valuable protection to the pages of the book.

A photograph of this Self-Binder will be found on the back page of the cover of this part, together with full particulars as to how you can obtain it. Send in your order at once.

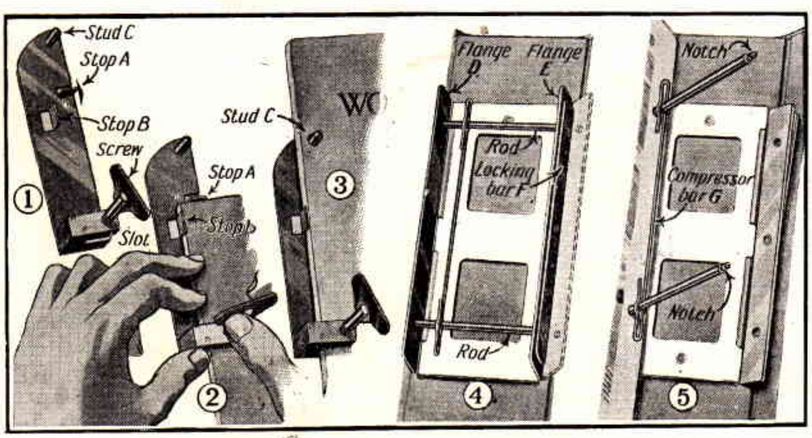
How to Use the Self-Binder

With the Self-Binder readers are supplied with a special combined piercer and gauge, Fig. 1. This very simple and easily worked implement pierces two holes through each part of THE WORLD OF WONDER, enabling the part to be placed in the Self-Binder and held tight.

At one end of the gauge is a screw and beneath the screw a slot. First remove the cover from the part you wish to bind. Then, holding the part face upward, slip the back edge of it into the slot. Before doing this you should, of course, turn up the screw till the slot is quite clear to receive the part.

The back edge of the part should then be pressed against the end of the slot and also against the stop B. The top edge of the part should touch stop A (see Fig. 2). Now turn the screw till you feel it "bite" on the paper, and continue till all the pages of the part are pierced right through. Then stop turning, so that the screw may not become blunted.

Having pierced the top hole, remove the part from the slot and fit the hole over the stud C. Put the back edge into the slot as before, keeping it close up against stop B. Keep the pages taut with a slight pressure of the forefinger. Now turn the screw and make the lower hole, Fig. 3.



The part has now two holes pierced right through it. Next take the binding case. In the centre are two metal flanges or strips locked together by two metal rods, Fig. 4. The ends of these rods are notched and fitted into flange E, and are locked there by a pivoted locking bar F. Press down the near end of bar F and push flange E outwards. The rods will then disengage themselves (Fig. 5). The two rods are joined by a compressor bar G. Slip this up and off the rods. Place the part face downwards with the holes over the rods and press it down firmly. Then replace the compressor bar. Now press the rods into the holes in flange E, and raise the end of locking bar F.

The compressor bar is merely for temporary use before the work is complete, to keep the loose parts pressed together. It can be discarded when the last part is put in the Self-Binder and the whole work is bound.

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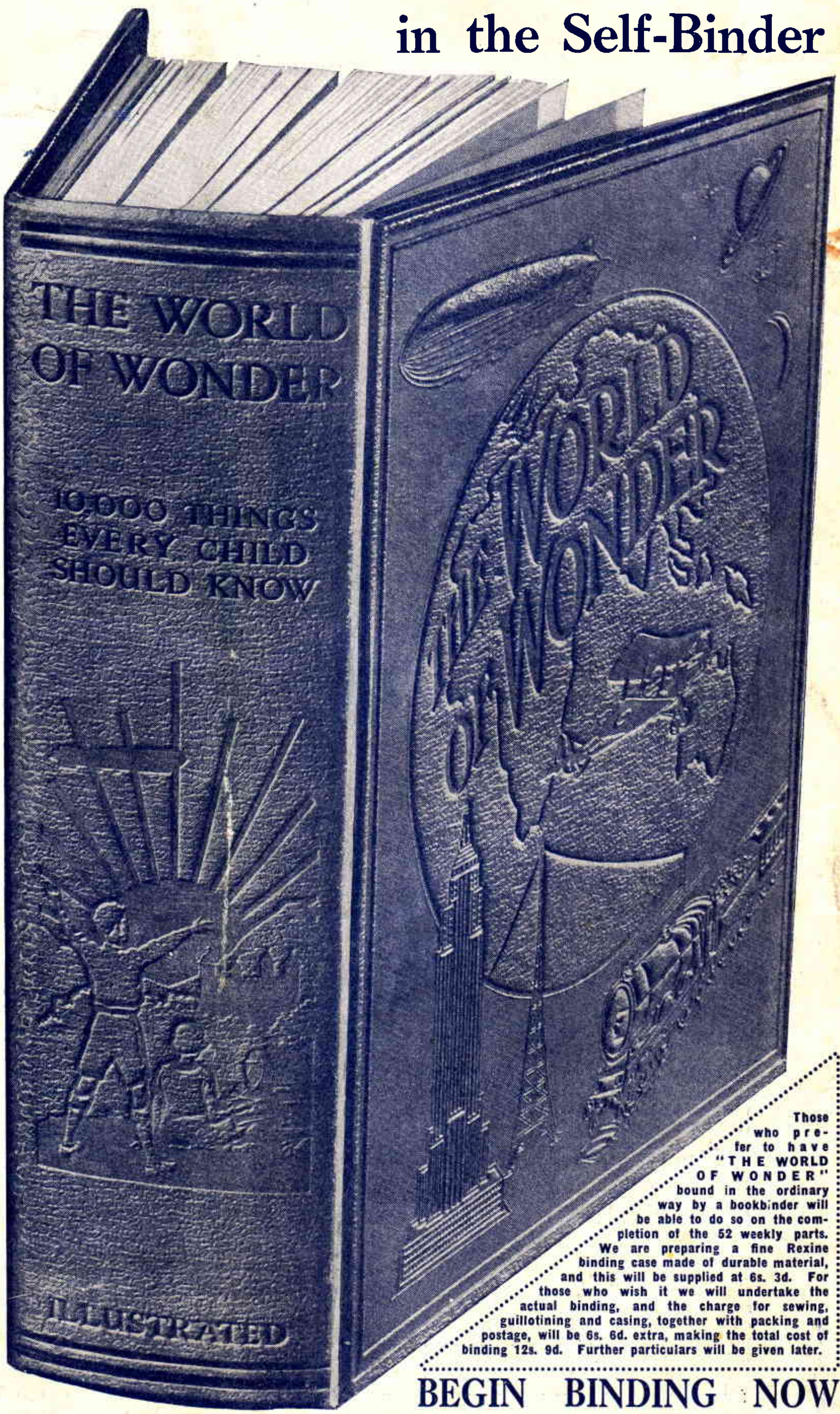

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